UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 NE Lloyd Boulevard, Suite 1100
PORTLAND, OREGON 97232-1274

June 16, 2017

Refer to NMFS No: WCR-2016-5506

Mr. David Murillo
Regional Director – Mid-Pacific Region
U.S. Bureau of Reclamation
2800 Cottage Way, MP-3700
Sacramento, California 95825-1898

Mr. William Croyle
Acting Director
California Department of Water Resources
1416 Ninth Street
Sacramento, California 95814

Re: Endangered Species Act Section 7(a)(2) Biological Opinion, Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response, and Fish and Wildlife Coordination Act Recommendations for the California WaterFix Project in Central Valley, California

Dear Mr. Murillo and Mr. Croyle:

Thank you for your letter, received August 2, 2016, requesting initiation of consultation with NOAA's National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 *et seq.*) for the proposed California WaterFix Project (Project).

Based on the best available scientific and commercial information, the Biological Opinion (Opinion) concludes that the Project is not likely to jeopardize the continued existence of federally listed:

- Endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*),
- Threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*),
- Threatened Central Valley steelhead (*O. mykiss*),
- Threatened Southern Distinct Population Segment (DPS) of North American green sturgeon (*Acipenser medirostris*), and
- Endangered Southern Resident killer whales (*Orcinus orca*).

NMFS concludes that the Project is not likely to destroy or adversely modify the designated critical habitats of:

- Sacramento River winter-run Chinook salmon,
- Central Valley spring-run Chinook salmon,
- Central Valley steelhead, and
- Southern DPS of North American green sturgeon.

Southern Resident killer whales critical habitat is outside of the action area.

As required by section 7 of the ESA, for the above species, NMFS has included an incidental take statement for activities within the proposed Project that do not require further analysis. The incidental take statement describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize the impact of incidental take associated with these activities. The take statement also sets forth nondiscretionary terms and conditions, including monitoring and reporting requirements, that the U.S. Bureau of Reclamation (Reclamation) as the Federal action agency, must comply with to carry out the reasonable and prudent measures. Incidental take from activities that meet these terms and conditions will be exempt from the ESA's prohibition against the take of listed species.

The Project for this consultation is a "mixed programmatic action" because it approves some actions that are not subject to further section 7 consultation as well as provides programmatic review of future actions that would be authorized, at a later time. For actions that are expected to be developed in the future (mitigation/restoration, monitoring, adaptive management), take of listed species would not occur until those future actions were authorized. For other actions (construction and operations), NMFS is providing an incidental take statement with this Opinion. The enclosed Opinion is based on information provided in the Reclamation's transmittal letter and biological assessment, correspondence and discussions between NMFS, Reclamation, and California Department of Water Resources staff, and consultants; a final proposed action issued on June 2, 2017; comments received from Reclamation; peer review reports from the Delta Stewardship Council's Delta Science Program; and an extensive literature review completed by NMFS staff. A complete administrative record of this consultation is on file at the NMFS California Central Valley Office.

NMFS also concurs with Reclamation's conclusion that the proposed action is not likely to adversely affect threatened Central California Coast steelhead (*O. mykiss*), endangered Central California Coast coho salmon (*O. kisutch*), or the designated critical habitat for Central California Coast steelhead. Designated critical habitat for Central California Coast coho salmon is not included in the action area.

NMFS reviewed the likely effects of the proposed action on essential fish habitat (EFH), pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1855(b)), and concluded that the Project would adversely affect the EFH of Pacific Coast salmon, Coastal Pelagic species, and Pacific Coast Groundfish in the action area. We have included these EFH consultation results in Section 3 of this document. The EFH consultation itself includes Conservation Recommendations specific to the adverse effects to EFH identified during our review.

Reclamation has a statutory requirement under section 305(b)(4)(B) of the MSA to submit a detailed written response to NMFS within 30 days of receipt of these EFH conservation recommendations, and 10 days in advance of any final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations. The written response must include a description of measures adopted by Reclamation for avoiding, minimizing, or mitigating the impact of the Project on EFH (50 CFR § 600.920(k)). If unable to complete a final response within 30 days, Reclamation should provide an interim written response within 30 days before submitting its final response. In the case of a response that is inconsistent with our recommendations, Reclamation must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the Project and the measures needed to avoid, minimize, or mitigate (also referred to by NMFS as measures that "offset") such effects.

Please contact Cathy Marcinkevage at the NMFS California Central Valley Office at (916) 930-5648, or by email at cathy.marcinkevage@noaa.gov, should you have any questions concerning this consultation, or if you require additional information.

Sincerely,

Barry A. Thom
Regional Administrator

Enclosure

cc: Copy to File ARN 151422-WCR2016-SA00204

Via electronic media to the following:

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Endangered Species Act Section 7(a)(2) Biological Opinion, Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response, and Fish and Wildlife Coordination Act Recommendations

California WaterFix Project
NMFS Consultation Number: WCR-2016-5506

Action Agencies: U.S. Bureau of Reclamation; U.S. Army Corps of Engineers

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	Is Action Likely To Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	Is Action Likely To Destroy or Adversely Modify Critical Habitat?
Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*)	Endangered	Yes	No	Yes	No
Central Valley spring-run Chinook salmon (*O. tshawytscha*)	Threatened	Yes	No	Yes	No
California Central Valley steelhead (*Oncorhynchus mykiss*)	Threatened	Yes	No	Yes	No
Southern Distinct Population Segment of North American Green Sturgeon (*Acipenser medirostris*)	Threatened	Yes	No	Yes	No
Southern Resident killer whale (*Orcinus orca*)	Endangered	Yes	No	N/A	N/A

Central California Coast steelhead (*O. mykiss*)	Threatened	No	N/A	No	N/A
Central California Coast Coho salmon *(O. kisutch)*	Endangered	No	N/A	N/A	N/A

Affected EFH and NMFS' Determinations:

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast salmon	Yes	Yes
Coastal Pelagic species	Yes	Yes
Pacific Coast Groundfish	Yes	Yes

Consultation Conducted By: National Marine Fisheries Service, West Coast Region

Issued By:

Barry A. Thom
Regional Administrator

Date: June 16, 2017

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H Model Description for the Sacramento River Winter-run Chinook Salmon Life Cycle Model

1 INTRODUCTION

This Introduction section provides information relevant to the other sections of this Biological Opinion (Opinion) and is incorporated by reference into Sections 2 and 3.

1.1 Background

The National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS) prepared the Opinion and Incidental Take Statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 United States Code [U.S.C.] 1531 *et seq.*), and implementing regulations at 50 Code of Federal Regulations (CFR) 402.

NMFS also completed an Essential Fish Habitat (EFH) consultation on the Proposed Action (PA), in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 *et seq.*) and implementing regulations at 50 CFR 600.

Because the PA would modify a stream or other body of water, NMFS also provides recommendations and comments for the purpose of conserving fish and wildlife resources and enabling the Federal agency to give equal consideration with other project purposes, as required under the Fish and Wildlife Coordination Act (16 U.S.C. 661 *et seq.*).

NMFS completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available through NMFS' Public Consultation Tracking System [https://pcts.nmfs.noaa.gov/pcts-web/homepage.pcts]. A complete record of this consultation is on file at the NMFS California Central Valley Office.

The Central Valley Project (CVP) and State Water Project (SWP) are two major inter-basin water storage and delivery systems that divert and re-direct water from the southern portion of the Delta—these systems have a complex history of consultation under the ESA. One part of this long and complex consultation history has been for a proposed north Delta diversion facility (i.e., for a dual-conveyance system), which has been under various stages of development since 2006. The first stage was the development of a conservation strategy in the Bay Delta Conservation Plan (BDCP) and this first stage evolved into a standalone project, the PA, referred to as the "California WaterFix" (CWF).

In July 2006, several state and private parties entered into a memorandum of agreement that established the financial commitments of the parties to carry out actions to satisfy existing regulatory requirements related to operation of the CVP and SWP and develop a conservation plan for the Delta that would support new regulatory authorizations under state and Federal endangered species laws for current and future activities related to the CVP and SWP. This plan was named the BDCP.

Coordination between state and Federal agencies has continued since 2006, including the U.S. Bureau of Reclamation (Reclamation), California Department of Water Resources (DWR), California Department of Fish and Wildlife (CDFW), NMFS, and U.S. Fish and Wildlife Service (USFWS).

In December 2013, DWR issued a draft habitat conservation plan (i.e., the BDCP) and filed an application for an incidental take permit under section 10 of the ESA (DWR 2013), and, together with Reclamation, NMFS, and USFWS, issued a Draft Environmental Impact Report (DEIR)/Environmental Impact Statement (DEIS) evaluating the BDCP and 12 other alternatives (DWR et al. 2013).

In February 2015, Reclamation and DWR decided to pursue an ESA section 7 consultation (instead of an incidental take permit under ESA section 10) for the construction and operation of water facilities formerly proposed under the BDCP—specifically, those included in BDCP Conservation Measure 1. The majority of other BDCP conservation measures are not included in the ESA section 7 consultation effort.

Reclamation is the lead Federal agency for this consultation and has been designated by the U.S. Army Corps of Engineers (Corps) to act on their behalf for the purposes of this consultation (Jewell 2015). DWR is the applicant for authorizations for and the entity undertaking all construction-related activities of the proposed CWF project. The Corps will be issuing Reclamation or DWR a permit (or permits) for the PA activities. This Opinion will therefore satisfy the requirements for the Corps to consult with NMFS under section 7 of the ESA of 1973, as amended (16 U.S.C 1531 et seq.).

Reclamation is responsible for operation and maintenance of the CVP. DWR is responsible for the operation and maintenance of the SWP. DWR's operation of the proposed facilities would modify operation of the SWP, which is operated in coordination with the CVP according to the Coordinated Operations Agreement (COA) between the United States of America and DWR. As the lead Federal agency for the ESA section 7 consultation on the PA and Federal action agency for coordinated operation of the CVP and SWP, Reclamation proposes to coordinate CVP operations of the new and existing facilities with DWR.

1.1.1 Central Valley Project

The CVP is the largest Federal Reclamation project. The CVP was originally authorized by the Rivers and Harbors Act of 1935 and reauthorized by the Rivers and Harbors Act of 1937, which provided that the dams and reservoirs of the CVP "shall be used, first, for river regulation, improvement of navigation and flood control; second, for irrigation and domestic uses; and, third, for power" (Pub. L. No. 75-392, 50 Stat. 844, 850). The CVP was reauthorized in 1992 through the Central Valley Project Improvement Act (CVPIA) (Pub. L. No. 102-575, 106 Stat. 4600, Title 34). The CVPIA 3406(a) amended the CVP authorizations to provide that the dams and reservoirs of the CVP should now be used "first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses and fish and wildlife mitigation, protection and restoration purposes; and, third, for power and fish and wildlife enhancement."

The CVPIA includes authorization for actions to benefit fish and wildlife intended to implement the purposes of Title 34. Specifically, CVPIA section 3406(b)(1), which is implemented through the Anadromous Fish Restoration Program (AFRP), provides for modification of the CVP operations to meet the fishery restoration goals of the CVPIA, so long as the operations are not in conflict with the fulfillment of the Secretary of the Interior's contractual obligations to provide CVP water for other authorized purposes. Furthermore, CVPIA section 3604(b) provides, "The Secretary [of the Interior], immediately upon the enactment of this title, shall operate the Central

Valley Project to meet all obligations under State and Federal law, including but not limited to the Federal Endangered Species Act, 16 U.S.C. 1531, *et seq.*, and all decisions of the California State Water Resources Control Board (SWRCB) establishing conditions on applicable licenses and permits for the project."

1.1.2 State Water Project

DWR was established in 1956 as the successor to the Department of Public Works for authority over water resources and dams within California. DWR also succeeded to the Department of Finance's powers with respect to state application for the appropriation of water (Stats. 1956, First Ex. Sess., Ch. 52; see also Wat. Code Sec. 123) and has permits for appropriation from the SWRCB for use by the SWP. DWR's authority to construct state water facilities or projects is derived from the Central Valley Project Act (CVPA) (Wat. Code Sec. 11100 *et seq.*), the Burns-Porter Act (California Water Resources Development Bond Act) (Wat. Code Sec. 12930-12944), the State Contract Act (Pub. Contract Code Sec. 10100 *et seq.*), the Davis-Dolwig Act (Wat. Code Sec. 11900-11925), and special acts of the state legislature. The Davis-Dolwig Act (Wat. Code Sec. 11900-11925) establishes the policy that preservation of fish and wildlife is part of state costs to be paid by water supply contractors, and recreation and enhancement of fish and wildlife are to be provided by appropriations from the general fund.

1.1.3 Coordinated Operations Agreement

The COA between the United States of America and DWR to operate the CVP and SWP was signed in November 1986. Public Law 99-546 (100 Stat. 3050 (1986)) authorized and directed the Secretary of the Interior to execute and implement the COA. The COA defines the rights and responsibilities of the CVP and SWP with respect to in-basin water needs and project exports and provides a mechanism to account for those rights and responsibilities.

Under the COA, Reclamation and DWR agree to operate the CVP and SWP under balanced conditions in a manner that meets Sacramento Valley and Delta needs while maintaining their respective annual water supplies as identified in the COA. Balanced conditions are defined as periods when the two projects agree that releases from upstream reservoirs, plus unregulated flow, approximately equal water supply needed to meet Sacramento Valley in-basin uses and project exports. Coordination between the CVP and the SWP is facilitated by implementing an accounting procedure based on the sharing principles outlined in the COA.

1.2 Consultation History

During 2015, NMFS provided technical assistance to Reclamation and DWR during the development of the components of the revised proposed CWF project. This included review of a draft Biological Assessment (BA) produced by Reclamation and DWR in October 2015 (Reclamation 2015).

In January 2016, Reclamation and DWR released a revised working draft BA for technical assistance review by the U.S Fish and Wildlife Service and NMFS (Reclamation 2016a). NMFS provided technical assistance on this draft between January and the end of July 2016.

On August 2, 2016, NMFS received a request for formal consultation on the PA from Reclamation, the lead Federal action agency for the ESA section 7 consultation on the PA, and DWR, the applicant (Reclamation 2016b). The accompanying BA identified the Corps as the

Federal action agency for construction under the PA (Reclamation 2016c). Reclamation determined that the project may affect and is likely to adversely affect Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) and its critical habitat, Central Valley (CV) spring-run Chinook salmon (*O. tshawytscha*) and its critical habitat, California Central Valley (CCV) steelhead (*O. mykiss*) and its critical habitat, and the Southern Distinct Population Segment (DPS) of North American green sturgeon (*Acipenser medirostris*) and its critical habitat. Reclamation determined that the project may affect but is not likely to adversely affect the Southern Resident killer whale (*Orcinus orca*) DPS and is not likely to adversely affect its critical habitat. The project may also adversely affect EFH, pursuant to the MSA.

On September 2, 2016, NMFS initiated formal consultation, which was confirmed by transmission of a letter of sufficiency to Reclamation on September 6, 2016 (Stelle 2016).

On September 6, 2016, NMFS sent additional information and clarification requests to Reclamation in its letter of sufficiency; communication exchange occurred throughout September.

On November 7, 2016, Reclamation requested two additional components be added to the PA:(1) new spring outflow criteria that were contained in their application for issuance of an incidental take permit under section 2081(b) of the California Endangered Species Act (CESA), and (2) the construction and operation of new facilities as a result of DWR's settlement agreement with Contra Costa Water District (CCWD) (Reclamation 2016d).

On December 20, 2016, Reclamation transmitted a log of responses to all information and clarification requests submitted by NMFS on September 6, 2016, including all changes to the project description that have occurred since submission of the BA (Reclamation 2016e).

On January 19, 2017, NMFS issued an Initial Draft Biological Opinion to Reclamation and DWR (Thom 2017).

On February 21, 2017, NMFS received via email from Mary Lee Knect, Reclamation, informal comments from Reclamation and DWR on the Initial Draft Biological Opinion.

On February 24, 2017, NMFS received a technical request letter from the state water contractors with specific questions regarding the modeling tools used in the Initial Draft Biological Opinion (State Water Contractors 2017).

On March 8, 2017, NMFS received the *Independent Review Panel Report for the 2016-2017 California WaterFix Aquatic Science Peer Review Phase 2B* (Simenstad et al. 2017).

During March and April 2017, NMFS met with Reclamation and DWR several times to discuss changes to the project description needed to reduce the level of species impacts from the PA. These discussions resulted in changes to the PA. NMFS also worked with Reclamation, DWR, and CDFW to finalize the funding needs of an Adaptive Management Program that would maintain existing study programs and augment them to support the program. On May 1, 2017, the list of needs was transmitted to agency representatives (Wilcox 2017).

On May 8, 2017, Reclamation transmitted an initial package of changes to the project description that have occurred since submission of the BA (Reclamation 2017a).

On May 24, 2017, DWR transmitted a final package of changes to the project description and reconciliation with other sections of the BA (DWR 2017). This package includes, among other components, a revised adaptive management program, implementation agreement, and implementation schedule; revisions to timing of some construction activities; revisions to operations of the proposed action; and commitment to habitat restoration.

On June 2, 2017, Reclamation provided correspondence identifying the May 24, 2017, package of changes to the project description as the final proposed action for consultation (Reclamation 2017b).

1.3 Proposed Federal Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR §402.02).

For EFH consultation, a Federal action means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a Federal agency (50 CFR 600.910).

Under the FWCA, except for circumstances that are not applicable under the PA, consultation is required "whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including navigation and drainage, by any department or agency of the United States, or by any public or private agency under Federal permit or license" (16 U.S.C. 662(a)).

The PA is described in detail in Chapter 3 of the BA, which contains the complete final PA (Appendix A2 of this Opinion) as transmitted on June 2, 2017.

In summary, the PA consists of the following:

- Construction and operation of new water conveyance facilities in the Delta, including three intakes, two tunnels, associated facilities, a permanent head of Old River (HOR) gate and an expanded Clifton Court Forebay (CCF)
- Coordinated operation of existing SWP and CVP Delta facilities and the new facilities, once construction is complete
- Maintenance of the newly constructed and existing SWP and CVP Delta facilities
- Implementation of new and existing conservation measures
- Implementation of an ongoing monitoring and adaptive management program

Reclamation, as the lead agency for the ESA section 7 consultation, proposes to coordinate CVP operations with DWR, the applicant, using the new and existing facilities in the Delta. The Corps proposes to issue permits to DWR pursuant to Rivers and Harbors Act section 10, Clean Water Act section 404, and 33 U.S.C. 408.

DWR's operation of the proposed facilities would modify operation of SWP, which is operated in coordination with the CVP. Reclamation is responsible for operation and maintenance of the CVP, and DWR is responsible for the operation and maintenance of the SWP. The proposed new facilities would operate in coordination with the existing Delta facilities, including the CCF, located in San Joaquin County, California. The three proposed intakes, comprising the new proposed north Delta diversions, would be located on the east bank of the Sacramento River near Clarksburg, in Sacramento County, California, and connected to the CCF by two underground tunnels and a new pumping plant, which would be sited at the CCF. SWP facilities draw water from the CCF and provide it to the Banks Pumping Station (BPP) and the South Bay Pumping Plant. This is described in more detail in chapter 3 of the BA, which contains the complete PA.

DWR is the entity undertaking all construction-related activities, including those related to the intakes, the associated tunnels, and their associated structures. The in-water construction activities associated with the intakes, tunnels, and associated structures, as well as the change in Delta operations, require a combination of approvals from the Corps. DWR and/or its designees will operate and maintain the facilities, and Reclamation will adjust operation of the CVP to utilize the dual conveyance.

The PA entails construction and operation of facilities for the movement of water entering the Delta from the Sacramento Valley watershed to the existing CVP and SWP pumping plants located in the southern Delta. The PA also entails operation of the existing and proposed new CVP and SWP Delta facilities in a manner that minimizes or avoids adverse effects on listed species and that protects and enhances aquatic, riparian, and associated natural communities and ecosystems. The PA includes activities that would occur in both aquatic and terrestrial environments with potential effects to both aquatic and terrestrial species.

The PA includes the following general categories of activities that may affect listed aquatic species under NMFS' jurisdiction and critical habitat for those species, as described below:

- Water conveyance facility construction
    - Geotechnical exploration: Sampling under the PA is expected to occur at locations along the water conveyance alignment and at proposed project facility sites to provide data to support the development of an appropriate geologic model, characterize ground conditions, and reduce the geologic risks associated with the construction of proposed facilities. The proposed duration of work is 24 months.
    - Tunneled conveyance: The PA includes construction of two conveyance tunnels that are expected to extend from the proposed north Delta diversion facilities to a proposed intermediate forebay and to CCF; the total length of the tunneled conveyance, most of which is proposed as 40-foot-diameter dual-bore, is approximately 40 miles. Sites will remain active throughout the construction period of 2018 to 2030, but peak activity will be from October 2020 to April 2025 (4.5 years).
    - NDD: The PA includes proposed construction of three 3,000-cubic feet per second (cfs)-capacity, on-bank, screened water intakes and associated land-based facilities on the east bank of the Sacramento River between Clarksburg and Courtland in Sacramento County, California. The total proposed duration of work is approximately 8 years.
    - HOR gate: The PA includes construction of an operable gate at the head of Old River to minimize the movement of out migrating salmonids into the south Delta via Old River and to improve water quality in the San Joaquin River during certain seasons; this would replace the temporary rock barrier that has been seasonally installed and removed. The proposed duration of work is approximately 1.5 years.
    - CCF: The PA includes a proposal to divide the existing CCF into two pieces. The North CCF will receive screened water from the north Delta diversions as primarily controlled by a proposed pump station at the North CCF, while the South CCF will be expanded and will continue to receive flows from the existing intake gate on Old River. The proposed duration of work is approximately 7 years.
    - Connections to Banks PP and C.W. 'Bill' Jones Pumping Plant (Jones PP): The PA includes a collection of control structures, canals, and siphons with radial gates and

stop logs to configure a system that allows both the Federal and state pumping plants to draw water from existing sources and/or from the North CCF. No changes are proposed to either the Federal or state fish facilities. The proposed duration of work is approximately 3 years.

- Interconnection Facility: The PA includes a new Interconnection Facility between the CWF water conveyance facilities and existing CCWD facilities. This would occur either at Victoria Island or at CCF. Construction of the new facility would take 24 to 30 months.

- Operation of new water conveyance facilities and existing Delta facilities
  - Site-specific operational criteria for new facilities: The PA includes operational criteria specific to the proposed new facilities applicable to:
    - NDD
    - HOR gate and its associated appurtenances
  - Operational criteria for existing Delta facilities: The PA also includes operational criteria that relate to operation of existing Delta facilities, which will apply when the new water conveyance facilities become operational. The operational criteria include:
    - Old and Middle River (OMR) Flows
    - Seasonal Outflow, Including Spring Outflow
    - Delta Cross Channel (DCC) gates
    - Suisun Marsh facilities
    - North Bay Aqueduct (NBA) Intake
  - Real-time operations (RTOs): The PA includes RTOs, which will apply when the new water conveyance facilities become operational, that will be needed at various times of the year for:
    - NDD
    - South Delta export facilities
    - HOR gate and its associated appurtenances
- Maintenance of new and existing water conveyance facilities: The PA includes the assumed maintenance of the NDD facilities (intakes, conveyance facilities, and appurtenance structures), the DCC, the HOR gate, and the south Delta facilities
- Implementation of conservation measures: The PA includes conservation measures intended to avoid, minimize, and offset effects on listed species, and to provide for their conservation and management, including:
  - Purchasing available credits at existing conservation banks
  - Permanent non-physical barrier at Georgiana Slough
  - Tidal perennial, floodplain, and riparian habitat restoration
  - A framework for collaborative science and adaptive management
  - A monitoring and research program
  - A secured endowment or other NMFS approved financial assurance that will be sufficient to fund any monitoring, operations, maintenance, and adaptive management of mitigation or restoration sites. Further, the endowment or other NMFS-approved financial assurance will designate the party or entity that will be responsible for the

long-term management of these lands and associated waterways as applicable. NMFS will be provided with written documentation that funding and management of mitigation lands will be provided in perpetuity

As described in Section 1.3.1.6 Operational Uncertainties and the Collaborative Science Process of this Opinion, the operational criteria for Delta facilities that are described in the CWF BA and in this Opinion are likely to change between the issuance of this Opinion and when the CWF becomes operational. Reclamation, as the lead Federal agency for the ESA section 7 consultation, has included the operational criteria in the PA in the CWF BA, and NMFS is analyzing the effects of operations according to those criteria based on the current definition in the PA.

As described in Section 1.2 Consultation History, with its request for initiation of formal consultation on August 2, 2016, Reclamation submitted a BA, which described the proposed action. In addition, Reclamation requested two additional components be added to the proposed action on November 7, 2016, and Reclamation transmitted a log of responses to NMFS' request for information and clarification on December 20, 2016. NMFS prepared an Initial Draft Biological Opinion for the CWF (dated January 21, 2017, NMFS 2017) based on the proposed action as described in the BA and revisions to the proposed action in these additional submissions. After release of preliminary draft sections of the CWF project analysis for the Delta Science Program's Independent Science Panel review (dated December 23, 2016, NMFS 2016), and the Initial Draft Biological Opinion for the CWF, Reclamation submitted additional revisions to the PA (dated June 2, 2017, Reclamation 2017b). The final revised PA is identified in Appendix A2 of this Opinion.

The PA for this consultation is a "mixed programmatic" action as defined by 50 CFR §402.02 because it approves some actions that are not subject to further section 7 consultation as well as a framework for the development of future actions that would be authorized at a later time. For the actions authorized at a later time, take of listed species would not occur until that subsequent authorization. For the non-framework actions, including construction activities and operational activities, this Opinion will serve as the final ESA consultation and, as required by section 7 of the ESA, with respect to those actions NMFS is providing an incidental take statement with this Opinion. For the activities that lack sufficient detail to analyze to the level of take, a framework programmatic level of analysis is completed; therefore, those activities are not expected to occur until further authorization and section 7 analysis is completed (see Section 2.5.1.4 Programmatic Activities).

1.3.1 Key Consultation Considerations

There are currently numerous regulatory constraints in place that relate to the operational aspects of the PA. Key constraints and relationships are highlighted briefly below.

1.3.1.1 Existing Biological Opinions on the Long-term Operations of the CVP and SWP

Implementation of the PA will include operations of both new and existing water conveyance facilities once the new NDD facilities are completed and become operational. Until the new NDD facilities are completed and become operational, the CVP and SWP are expected to continue to operate consistent with the currently applicable USFWS (2008) and NMFS (2009, 2011) biological opinions or as amended through successor biological opinions. However, operational limits included in this PA for south Delta export facilities will replace the south Delta operational limits currently implemented as described in the USFWS (2008) and NMFS (2009) biological opinions when the proposed NDD becomes operational. The PA also includes criteria for spring outflow that will apply when the proposed NDD becomes operational. The NDD and the HOR gate are new facilities for the SWP and will be operated consistent with the criteria presented in the PA for these facilities. See Appendix A2 for a more detailed explanation of the PA in this Opinion compared to the USFWS (2008) and NMFS (2009) biological opinions. The USFWS (2008) and NMFS (2009) biological opinions for CVP and SWP operations will continue to apply for CVP and SWP activities not described as part of the PA in this Opinion.

On August 2, 2016, Reclamation sent a letter to NMFS (Murillo 2016) requesting the use of the adaptive management provision outlined in the Reasonable and Prudent Alternative (RPA) Section 11.2.1.2 of the NMFS (2009) biological opinion relating to Shasta Reservoir operations. On August 18, 2016, NMFS sent a letter to Reclamation concurring that recent multiple years of drought conditions, new science and modeling, and data demonstrating low population abundance levels of Sacramento River winter-run Chinook salmon and Sacramento River spring-run Chinook salmon warrant modifications to the Shasta RPA actions (RPA Action Suite I.2) in the NMFS (2009) biological opinion. NMFS is targeting late 2017 for completion of the Shasta RPA adjustment, following the 2017 summer/fall pilot approach period. The proposed CWF operating criteria are not intended to change Shasta operations; thus, the Shasta RPA adjustment will control if there are any unforeseen conflicts in Shasta operations and the proposed CWF operating criteria.

On August 2, 2016, Reclamation sent a letter to NMFS (Cowin and Murillo 2016) requesting reinitiation of consultation on the Coordinated LTO of the CVP and SWP. On August 18, 2016, NMFS sent a letter to Reclamation concurring that reinitiation is required under the terms of the NMFS (2009) biological opinion and ESA regulations (50 CFR 402.16). Reasons for the reinitiation include new information related to the effects of multiple years of drought, recent data demonstrating extremely low abundance levels for endangered Sacramento River winter-run Chinook salmon and threatened CV spring-run Chinook salmon, and new information resulting from ongoing scientific collaboration.

1.3.1.2 Consultation on the Relicensing of the Oroville Facilities

NMFS issued the biological opinion for the Federal Energy Regulatory Commission’s (FERC) proposed relicensing of the Oroville Facilities Hydroelectric Project (Oroville Facilities) on December 5, 2016. Under the PA analyzed in that biological opinion, FERC will issue a license to DWR to operate the Oroville Facilities for the next 30 to 50 years. That biological opinion analyzes the effects of the proposed relicensing of the Oroville Facilities in the Feather River and the effects of Feather River Fish Hatchery salmonid strays in the Sacramento River watershed. Effects of the coordinated operations of the CVP and SWP, including the Oroville Facilities, downstream of the confluence of the Feather River and the Sacramento River were analyzed in the 2009 CVP and SWP biological opinion (as amended in 2011). However, because the final biological opinion for relicensing the Oroville Facilities was not completed before the hydrology/operational modeling scenarios were run for the CWF, Oroville Facilities operations were accounted for in the hydrology/operational modeling scenarios analyzed in this Opinion based on the information available at the time as described further in Section 4.4 of the CWF BA.

1.3.1.3 California Endangered Species Act

DWR's application for issuance of an incidental take permit for CWF under section 2081(b) of the CESA, which was submitted in October 2016, includes spring outflow criteria that are slightly different than the spring outflow criteria presented in the BA. Consistent with the discussion in Section 3.3.1, page 3-83 of the BA, the different spring outflow criteria are proposed to meet the mitigation requirements for longfin smelt, a species listed under the CESA. As these spring outflow criteria are included in DWR's section 2081(b) application and essentially revise the description of the PA, Reclamation has requested that this information be considered as part of the PA analyzed in this Opinion (Reclamation 2016b).

1.3.1.4 Decision 1641 and Revised D1641

On December 29, 1999, the SWRCB adopted and subsequently revised (on March 15, 2000) Decision (D)-1641, amending certain terms and conditions of the water rights of the CVP and SWP under SWRCB D1485. D-1641 substituted certain objectives adopted in the 1995 Bay Delta Water Quality Control Plan (WQCP) (SWRCB 1995) for water quality objectives that had to be met under the water rights of the CVP and SWP. The requirements in D-1641 address the standards for fish and wildlife protection, municipal and industrial water quality, agricultural water quality, and Suisun Marsh salinity. SWRCB D-1641 also authorizes the CVP and SWP to jointly use each other's points of diversion in the southern Delta, with conditional limitations and required response coordination plans. SWRCB D-1641 modified the Vernalis salinity standard under SWRCB Decision 1422 to the corresponding Vernalis salinity objective in the WQCP. The PA includes ongoing compliance with D-1641 when the proposed north Delta diversion becomes operational.

1.3.1.5 Real-time Operations

The PA does not propose changing any of the existing RTO processes in place for CVP and SWP operations. However, an additional RTO process would be implemented under the PA when the proposed NDD becomes operational. To complement the existing RTO process, DWR and Reclamation can convene a separate RTO coordination team (RTOCT) that includes representatives of USFWS, NMFS, CDFW, DWR, and Reclamation. DWR and Reclamation also will designate one representative of the SWP contractors and one representative of the CVP contractors as participants on the RTOCT in an advisory capacity. This RTOCT effort will assist DWR and Reclamation in fulfilling their responsibility to inform the SWP and CVP contractor participants regarding available information and real-time decisions. This may result in recommendations being made through the Delta Conditions Team (DCT). Decision-making will still happen as it currently does under the USFWS (2008) and NMFS (2009) biological opinions, as outlined in Section 3.3.3 of the BA.

For the PA, RTO are expected to be needed during at least some part of the year at the north and south Delta diversions and the HOR gate. Operational adjustments will be consistent with the criteria, and within any ranges, established in the PA. Any modifications to the criteria and/or ranges set out in the operating criteria will occur through the adaptive management program, and the effects of any such modifications will be analyzed by Reclamation and DWR, in consultation with NMFS and USFWS, to determine if Reclamation should reinitiate consultation prior to implementation.

1.3.1.6 Operational Uncertainties and the Collaborative Scientific Process

With respect to operations, Reclamation and DWR have described and analyzed in the BA one scenario for the CWF, which presents operational criteria. The criteria were largely formed, in coordination with USFWS, NMFS, and the CDFW, at the time in the development of the PA when the NDD were proposed at a capacity of 15,000 cfs and when the PA included a 50-year Habitat Conservation Plan and Natural Communities Conservation Plan covering both listed and non-listed species. Thus, the operational criteria required to satisfy regulatory requirements for the CWF at the time operations commence are likely to be different from those presented in the BA.

Additionally, some of the criteria and some of the outcomes in the effects analysis are based upon precautionary assumptions, whereas other outcomes are based upon a greater degree of certainty. The analysis of the effects of the PA on fish and aquatic resources is influenced by numerous factors related to the complexity of the ecosystem, changes within the system (e.g., climate change and species population trends), and the imprecision of operational controls and resolution in modeling tools. These factors are further complicated by the scientific uncertainty about some fundamental aspects of the life histories of the listed fish species and how these species respond to changes in the system, as well as sometimes competing points of view on the interpretation of biological and physical data within the scientific community. Some of the criteria of the PA have been conservatively estimated based on professional judgment. In this context, uncertainty in some of the criteria was resolved in a manner to provide greater protection of species and these criteria may be in excess of what may be required to avoid jeopardy or adverse modification of critical habitat.

As noted above, the operational criteria described in the BA are likely to change not only for the reasons described but also based on other processes. Future CVP and SWP operations with CWF and species needs will be informed by these other processes, including the State Water Board process to update the Bay Delta WQCP, reinitiation of consultation on the USFWS (2008) biological opinion, reinitiation of consultation on the NMFS (2009) biological opinion, the Collaborative Science and Adaptive Management Program (CSAMP), implementation of the CWF Adaptive Management Program (AMP), California EcoRestore, implementation of the Delta Smelt Resiliency Strategy, implementation of the Salmonid Resiliency Strategy, the Delta Smelt Recovery Plan update, and other actions that are likely to cause physical, chemical and biological changes within the watershed.

The outcomes of the processes described above, as well as consideration of Delta conditions and relevant regulatory obligations existing at the time, will be considered in determining how CWF will be operated. Some of the criteria identified in the PA may have substantial water supply effects while providing limited ability to minimize effects to species. As a result, operational criteria identified in the CWF PA may be modified, relaxed or removed and may no longer apply to an operation with CWF, while other operational criteria, not currently identified in this CWF consultation or those already identified may be included or modified. Therefore, the operational criteria that are described in the CWF BA and in this Opinion are likely to change between now and when CWF becomes operational.

NMFS is committed to working with other agencies and stakeholders through the CWF AMP, CSAMP, and other processes to undertake additional focused research and analyses to improve scientific understanding concerning the tools used to analyze species and critical habitat effects and the impact of the facilities' operations on listed species and their habitat as well as the scientific understanding concerning the benefits of other actions (e.g., habitat restoration) on listed species and their habitats.

The CWF includes a robust AMP that incorporates a collaborative science process to further refine, during subsequent consultations, what ultimately will be used as the initial operating criteria for the CWF project. The AMP will continue to refine CWF operations over time. The CWF AMP described in Appendix A2 will collect and analyze data for the purpose of evaluating the propriety of the anticipated operations in light of the evolving science and changing circumstances in the Delta, in the context of the consultation provisions set out in section 7 of the ESA.

Operating criteria applicable to CWF that are in addition to the criteria that govern CVP and SWP operations without CWF will only take effect once the NDD facilities become operational. Reclamation will propose CWF operational criteria through a subsequent consultation before the NDD facilities become operational. NMFS will use the best scientific and commercial data available at that time, including data collected and analysis conducted through the CWF AMP, to assist Reclamation in determining specific criteria required to comply with ESA section 7 when the NDD becomes operational.

1.3.2 Interrelated and Interdependent Actions

"Interrelated actions" are those that are part of a larger action and depend on the larger action for their justification. "Interdependent actions" are those that have no independent utility apart from the action under consideration (50 CFR §402.02).

There are no Interrelated or Interdependent Actions for this project.

2 ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provides an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes non-discretionary reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

2.1 Analytical Approach

2.1.1 Introduction

This section describes the analytical approach used by NMFS to evaluate the likely effects of the PA on listed species under NMFS jurisdiction and critical habitat designated for those species. The approach is intended to ensure that NMFS comports with the requirements of the statute and regulations when conducting and presenting the analysis. This includes using the best scientific and commercial data available in formulating the Opinion.

ESA section 7(a)(2) requires that the action agency "insure" that a PA "is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [designated critical] habitat…." This Opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "to jeopardize the continued existence of" a listed species, which is "to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR §402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This Opinion also relies on the regulatory definition of "destruction or adverse modification," which means "a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214; February 11, 2016).

The designations of critical habitat for CV spring-run Chinook salmon, CCV steelhead, and sDPS of North American green sturgeon use the term "primary constituent elements" (PCE) or "essential features." The recently revised critical habitat regulations (81 FR 7414; February 11, 2016) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a "destruction or adverse modification" analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this Opinion, NMFS uses the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

NMFS uses the following approach to determine whether a PA is likely to jeopardize listed species or destroy, or adversely modify, critical habitat:

- Identify the rangewide status of the species and critical habitat likely to be adversely affected by the PA.
- Describe the environmental baseline in the action area.
- Analyze the effects of the PA on both species and their habitat using an “exposure-response-risk” approach.
- Describe any cumulative effects in the action area.
- Integrate and synthesize the above factors as follows: (1) review the status of the species and critical habitat; and (2) add the effects of the action, the environmental baseline, and cumulative effects to assess the risk that the PA poses to species and critical habitat.
- Reach a conclusion about whether species are jeopardized or critical habitat is destroyed or adversely modified.
- If necessary, suggest a reasonable and prudent alternative to the PA.

The subsections of Section 2.1 outline the specific conceptual framework, key steps, and assumptions NMFS used to assess listed species’ jeopardy risk and critical habitat destruction or adverse modification risks. Wherever possible, these subsections apply to all seven listed species and associated designated critical habitats occurring in the action area. They include the following:

- Endangered Sacramento River winter-run Chinook salmon evolutionarily significant unit (ESU) (*Oncorhynchus tshawytscha*)
- Threatened CV spring-run Chinook salmon ESU (*O. tshawytscha*)
- Threatened CCV steelhead DPS (*O. mykiss*)
- Threatened sDPS of North American green sturgeon (*Acipenser medirostris*)
- Endangered Southern Resident killer whale DPS (*Orcinus orca*)
- Endangered Central California Coast coho ESU (*Oncorhynchus kisutch*)
- Threatened Central California Coast steelhead DPS (*O. mykiss*)
- Designated critical habitats for each of these listed species

The subsections of the analytical approach are as follows:

- Section 2.1.2 describes the legal and policy framework provided by the ESA, implementing regulations, case law, and policy guidance related to section 7 consultations.
- Section 2.1.3 gives a general overview of how NMFS conducts its section 7 analysis. It includes various conceptual models of the overall approach and specific features of the approach. It also includes information on tools that NMFS used in the analysis specific to this consultation. The section first describes the listed species analysis as it pertains to individual fish species and the physical, chemical, and biotic changes to the ecosystem caused by the PA. It then describes the critical habitat analysis.
- Section 2.1.4 discusses the evidence available for the analysis and related uncertainties. Also described are the assumptions made to bridge data gaps which enabled the analyses.
- Section 2.1.5 diagrams the overall conceptual approach in the assessment to address integration of all available information and decision frameworks to support the assessment of the effects of the PA.

- Section 2.1.6 discusses the presentation of all analyses within this Opinion as a guide to locating results of specific analytical steps.

2.1.2 Legal and Policy Framework

The statutory requirement to use the best scientific and commercial data available to ensure that a PA is not likely to jeopardize the continued existence of a listed species or destroy or adversely modify its critical habitat is a demanding one. In reviewing whether a consulting agency used the best scientific and commercial data available and adequately assessed whether a PA is not likely to jeopardize the continued existence of a listed species or destroy or adversely modify its critical habitat, courts have cited Congress' intent in the ESA to give the benefit of the doubt to the species.[1] The U.S. Supreme Court has called this principle "institutionalized caution."[2]

As will become clear in this Opinion, determining the effects of the PA in this manner requires a highly complex analytical process. The many analytical steps generate a range of possible results and a range of confidence levels that yield the most probable results. The results of each step are aptly inserted into further analyses. The final determination of whether or not the PA is likely to jeopardize the species' continued existence or destroy or adversely modify its critical habitat will be the product of this multi-layered analytical approach in which many of the intermediate results have associated degrees of uncertainty. Consequently, to comply with the requirements of ESA section 7 and Congress' intent, NMFS will apply the general principle of institutionalized caution, or giving the benefit of the doubt to the species, when considering the uncertainty of the data, analytical methods, and results. In addition, as described below in this section, adaptive management will apply to the PA in order to address uncertainties in effects.

Consultations designed to allow Federal agencies to fulfill the requirements of section 7 of the ESA conclude with issuing a biological opinion or a concurrence letter. For biological opinions, section 7 of the ESA, implementing regulations (50 CFR 402.14), and associated guidance documents (e.g., USFWS and NMFS 1998) require biological opinions to present the following:

- A description of the proposed Federal action
- A summary of the status of the affected species and its critical habitat
- A summary of the environmental baseline within the action area
- A detailed analysis of the effects of the PA on the affected species and critical habitat
- A description of cumulative effects
- A conclusion as to whether it is reasonable to expect that the PA is not likely to appreciably reduce the species' likelihood of both surviving and recovering in the wild by reducing its reproduction, numbers, or distribution or result in the destruction or adverse modification of the species' designated critical habitat

The purpose of the jeopardy analysis is to determine whether appreciable reductions of both the survival and recovery of the species in the wild are reasonably expected, but not to precisely quantify the amount of those reductions. As a result, this assessment often focuses on whether an

[1] Conner v. Burford, 848 F.2d 1441, 1454 (9th Cir. 1988), referencing H.R. Conf. Rep. No. 96-697, 96th Cong., 1st Sess. 12, reprinted in 1979 U.S. Code Cong. & Admin. News 2572, 2576. See also National Conservation Training Center, Advanced Interagency Consultation Training: Study Guide for the Analytical Framework, p. 10 (available at https://training.fws.gov/courses/csp/csp3116/resources/Study_Guides/07_overview.pdf). The Study Guide discusses the importance of avoiding what is called a "Type II error" in analyzing the likely effects of an action, in which scientists conclude that an action will not have an effect on a listed species when, in fact, there is an effect.

[2] Tennessee Valley Authority v. Hill, 437 U.S. 153, 194 (1978).

appreciable reduction is expected or not; it does not focus on detailed analyses designed to quantify the absolute amount of reduction or the resulting population characteristics (absolute abundance, for example) that could occur as a result of PA implementation.

For this analysis, NMFS equates a listed species' probability (or risk) of extinction with the likelihood of both the survival and recovery of the species in the wild. In the case of listed salmonids, NMFS uses the Viable Salmonid Population (VSP) framework (McElhany et al. 2000) as a bridge to the jeopardy standard. A designation of "a high risk of extinction" or "low likelihood of becoming viable" indicates that the species faces significant risks from internal and external processes that can drive it to extinction. The status assessment considers and diagnoses both internal and external processes affecting a species' extinction risk.

For salmonids, the four VSP parameters are important to consider because they are predictors of extinction risk. The parameters reflect general biological and ecological processes that are critical to the survival and recovery of the listed salmonid species (McElhany et al. 2000). The VSP parameters of productivity, abundance, and population spatial structure are consistent with the "reproduction, numbers, or distribution" criteria found within the regulatory definition of jeopardy (50 CFR §402.02) and are used as surrogates for "reproduction, numbers, or distribution." The VSP parameter of diversity relates to all three jeopardy criteria. For example, reproduction, numbers, and distribution are all affected when genetic or life history variability is lost or constrained, resulting in reduced population resilience to environmental variation at local or landscape levels. McElhany et al. (2000) highlight that the VSP framework will include "a degree of uncertainty in much of the relevant information," and that "because of this uncertainty, management applications of VSP should employ both a precautionary approach and adaptive management."

With respect to adaptive management, the Adaptive Management Program (Appendix 3.H of the Revised BA) that will apply to the PA subject to this Opinion describes the adaptive management program that will address uncertainties associated with the effectiveness of management actions taken to avoid jeopardy to federally listed species and destruction or adverse modification of critical habitat and meet other regulatory standards applicable to state listed species for: (1) ongoing operations of the SWP and CVP; (2) habitat restoration actions that are part of the PA and/or the CVP and SWP Opinions and CESA authorizations: and (3) construction and operation of the CWF. Due to the long period (over 10 years) before CWF will be operational, the adaptive management component will focus heavily during that timeframe on filling critical data and information gaps, enhancing the existing monitoring network, and improving quantitative modeling capability. The proposed adaptive management approach incorporates aspects that are both "active" (where managers and operations work through a process of experimentation to explore the benefits, limits, and response to management actions) and "passive" (which lacks explicit experimentation and is rather an assessment of existing and future conditions and circumstances). The adaptive management approach identifies a preliminary set of objectives that will be used to develop final objectives for this adaptive management program.

NMFS notes the inclusion of recovery in the regulations implementing ESA section 7(a)(2) (50 CFR §402.02) (i.e., to "'jeopardize the continued existence of' means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild…"). In 2014, NMFS finalized a recovery plan for the listed Central Valley salmon and steelhead species (NMFS 2014). The information from the NMFS 2014 recovery plan represents the best scientific and commercial data available and was therefore incorporated into this Opinion. A technical recovery team (TRT) that assisted in the recovery planning effort produced a “Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin” (Lindley et al. 2007). Along with assessing the current viability of the listed Central Valley salmon and steelhead species, Lindley et al. (2007) make recommendations for recovering those species. The framework was used to establish the current status of the listed Central Valley salmon and steelhead species within this Opinion, and both Lindley et al. (2007) and the recovery plan (NMFS 2014) were used to evaluate whether the PA reasonably would be expected to “reduce appreciably the likelihood of both the survival and recovery of a listed species…”.

Additional requirements for the analysis of the effects of an action are described in regulations (50 CFR §402). The conclusions related to “jeopardize the continued existence of” and “destruction or adverse modification” require an expansive evaluation of direct and indirect consequences of the PA, related actions, and the overall context of the impacts to the species and habitat from past, present, and future actions as well as the condition of the affected species and critical habitat (for example, see the definitions of “cumulative effects” and “effects of the action” in 50 CFR §402.02 and the requirements of 50 CFR §402.14(g)).

Recent court cases have reinforced the requirements provided in the ESA section 7 implementing regulations that NMFS must evaluate the effects of a PA within the context of the current condition of the species and critical habitat, including other factors affecting the survival and recovery of the species and the functions and value of critical habitat. In addition, the courts have directed that our risk assessments consider the effects of climate change on the species and critical habitat and our analysis of the future impacts of a PA. NMFS acknowledges that the effects of climate change could have notable impacts on listed species while also recognizing the challenge in quantifying the effects. Conservation of protected resources becomes more difficult when considering a changing climate, especially when accounting for the relative uncertainty of the rate and magnitude of climate-related changes and the response of organisms to those changes. Accordingly, NMFS recently issued general policy guidance for treatment of climate change in ESA decisions (Sobeck 2016). This guidance aligns with case law, noting the need to consider climate change in determinations and decisions despite the challenges of climate change uncertainty, and it provides policy considerations related to climate change that NMFS should use in ESA decision making, including ESA section 7 consultations.

Climate change is incorporated into this analysis implicitly by the modeling results provided in the BA. The modeling of the PA characterizes a 2030 scenario of climate conditions, water demands, and build-out. In doing so, the PA uses a multi-model ensemble-informed approach to identify a best estimate of the consensus of climate projections from the third phase of the Coupled Model Intercomparison Project (CMIP3), which informed the Intergovernmental Panel on Climate Change’s (IPCC) Fourth Assessment Report (AR4). Additionally, the PA characterizes sea level rise using an estimate for 2030. NMFS assumes that these projections will remain accurate through that period; any indication that the projections are not applicable may trigger reinitiation of consultation. Based on previous climate change modeling for the Central Valley (DWR 2013), NMFS expects that climate conditions will follow a similar trajectory of higher temperatures and shifted precipitation type timing beyond 2030.

In addition to Sobeck (2016), NMFS regional guidance (Thom 2016) further recommends use of the Representative Concentration Pathway (RCP) 8.5 scenario from the Fifth Assessment Report

(AR5), which is an updated climate characterization compared to what was used for the PA modeling. However, this guidance was provided after receipt of the BA and initiation of formal consultation on CWF. Sobeck (2016) notes that “when data specific to (the RCP 8.5) pathway are not available, (NMFS) will use the best available science that is as consistent as possible with RCP 8.5.” Because the RCP 8.5 data were not available, NMFS used the data provided in the BA as the best available science, though NMFS allows for evaluation of the projection and potential for reinitiation of consultation if the projection is found to not be applicable.

As climate change also contributes to uncertainty related to the factors affecting native species, water project operations, and ecological responses, climate change projections will be incorporated into adaptive management and science plans by including monitoring of climate change effects and projections; taking management actions; and adjusting water operations, research, and monitoring in response as needed. Such adaptive management responses may include, for instance, identifying alternative locations for implementing restoration or habitat protection actions to increase habitat availability and suitability, increasing productivity of the food web, better managing predators and invasive species, or allowing species movement across environmental gradients. Adjustments to water operations associated with inflow, outflow, and exports are another example of potential adaptive responses.

The proposed action for this consultation is a mixed programmatic action as defined by 50 CFR 402.02. A mixed programmatic action approves actions that are reasonably certain to cause take, and which will not be subject to further section 7 consultation, and also approves a framework for the development of future actions that are authorized, funded, or carried out at a later time. Take of a listed species would not occur unless and until those future actions are authorized, funded, or carried out and subject to further section 7 consultation. This PA includes construction activities and operational activities that are reasonably certain to cause take, and therefore will not be the subject of future individual consultations. We provide an incidental take exemption and associated reasonable and prudent measures and terms conditions for take resulting from these activities in the incidental take statement in this document. The reminder of the activities included in the proposed action will be addressed by individual or programmatic consultations if those actions may affect listed species or critical habitat. To complete our jeopardy and adverse modification analysis, we analyze effects of these activities considering how the action agency’s proposed management objectives and direction influence the nature of those effects. We then consider the action agency’s projected level of activity to predict, to the degree we can, the scale of any impact on listed species and critical habitat. For the activities that will be the subject of future consultations, we do not try to predict exactly what will happen at a particular action site in the future. Rather, our jeopardy and adverse modification analysis focuses on whether the management objectives and direction set sideboards that achieve an adequate level of conservation for listed species and critical habitat. We reserve the ability to conclude that any future site-specific action that appreciably reduces the likelihood of both the survival and recovery of a listed species would jeopardize the continued existence of listed species. Likewise, any future site-specific action that appreciably diminishes the value of critical habitat for the conservation of a listed species would adversely modify critical habitat. Any take we determine will not jeopardize the continued existence of listed species resulting from activities that will be the subject of future consultations will be exempted in future incidental take statements.

2.1.3 Overview of the Approach and Models Used

NMFS uses a series of sequential activities and analyses to assess the effects of Federal actions on endangered and threatened species and designated critical habitat. These sequential activities and analyses are illustrated in Figure 2-1 for listed species and Figure 2-2 for critical habitat. The first analysis uses the identified action components and interrelated and interdependent actions that result from the action deconstruction to identify environmental stressors—the physical, chemical, or biotic aspects of the PA that are likely to have individual, interactive, or additive direct and indirect effects on the environment. As part of this step, NMFS identifies the spatial extent of both the action components and any potential stressors, recognizing that the spatial extent of the stressors may change with time. NMFS notes that the spatial extent of potential stressors may extend beyond the geographic area included in the project description (i.e., a project description of in-Delta operations may have effects that extend upstream; the spatial extent of those effects is traced as part of this analysis).

The next step in the series of analyses starts by identifying the threatened or endangered species or designated critical habitat that are likely to occur in the same space and at the same time as the potential stressors and their spatial extent. Then we estimate the nature of that co-occurrence to represent the individual exposure assessment. In this step, we identify the proportion of a population (or number of individuals when available) and age (or life stage) that are likely to be exposed to an action's effects, and the specific areas and PBFs of critical habitat that are likely to be affected. When estimates of numbers of individuals affected are not available, the relative proportion of a population or populations is used to quantify adverse effects. Three general categories of proportion are assigned based on expected exposure and expected response. Those proportion categories are "small" (exposure not expected to exceed 2 percent), "medium" (a wider range of proportion, more than 2 percent, but less than 70 percent exposed), and "large" (70 percent or more exposed). In some cases, the term "very small" is used when the likelihood of exposure is so low that individuals are not expected to be exposed in some years, or only in very small numbers.

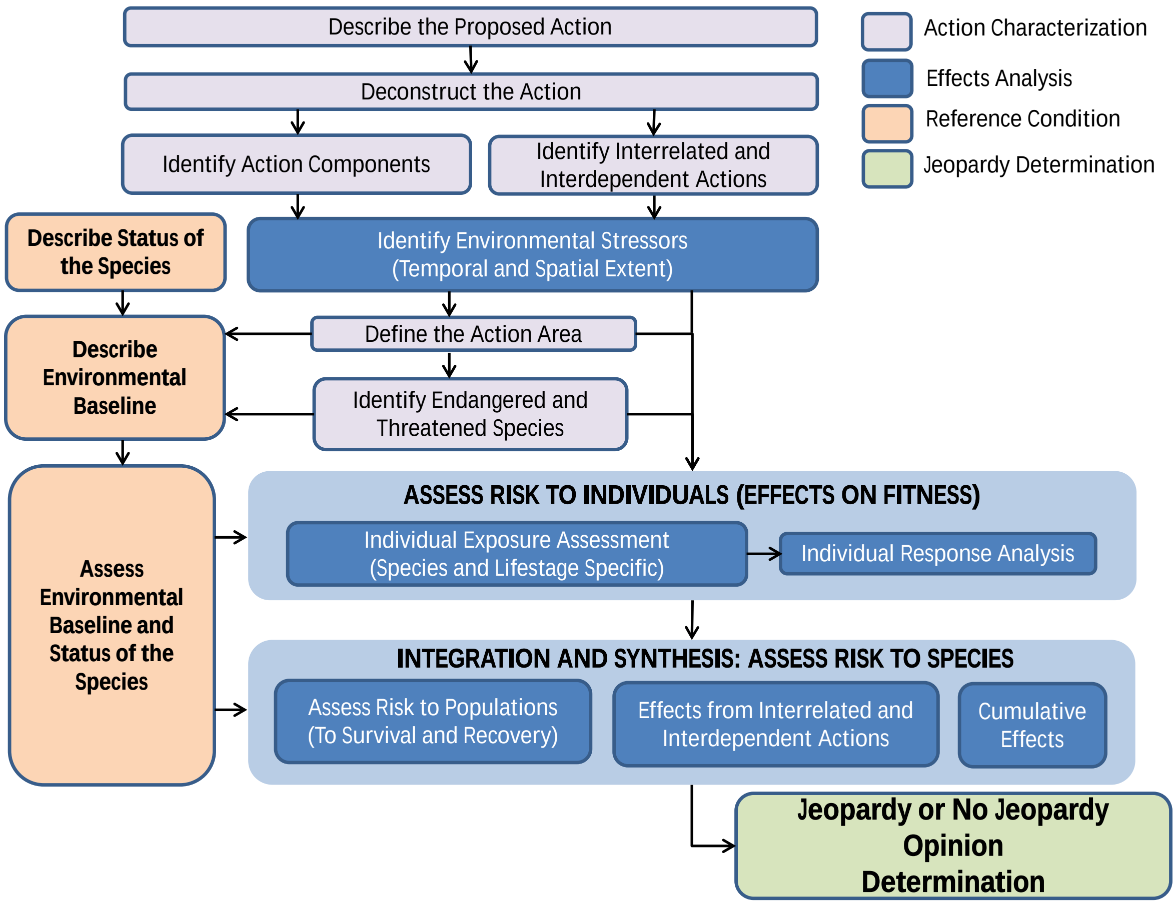


Figure 2-1. General Conceptual Model for Conducting Section 7 Analyses as Applied to Listed Species.

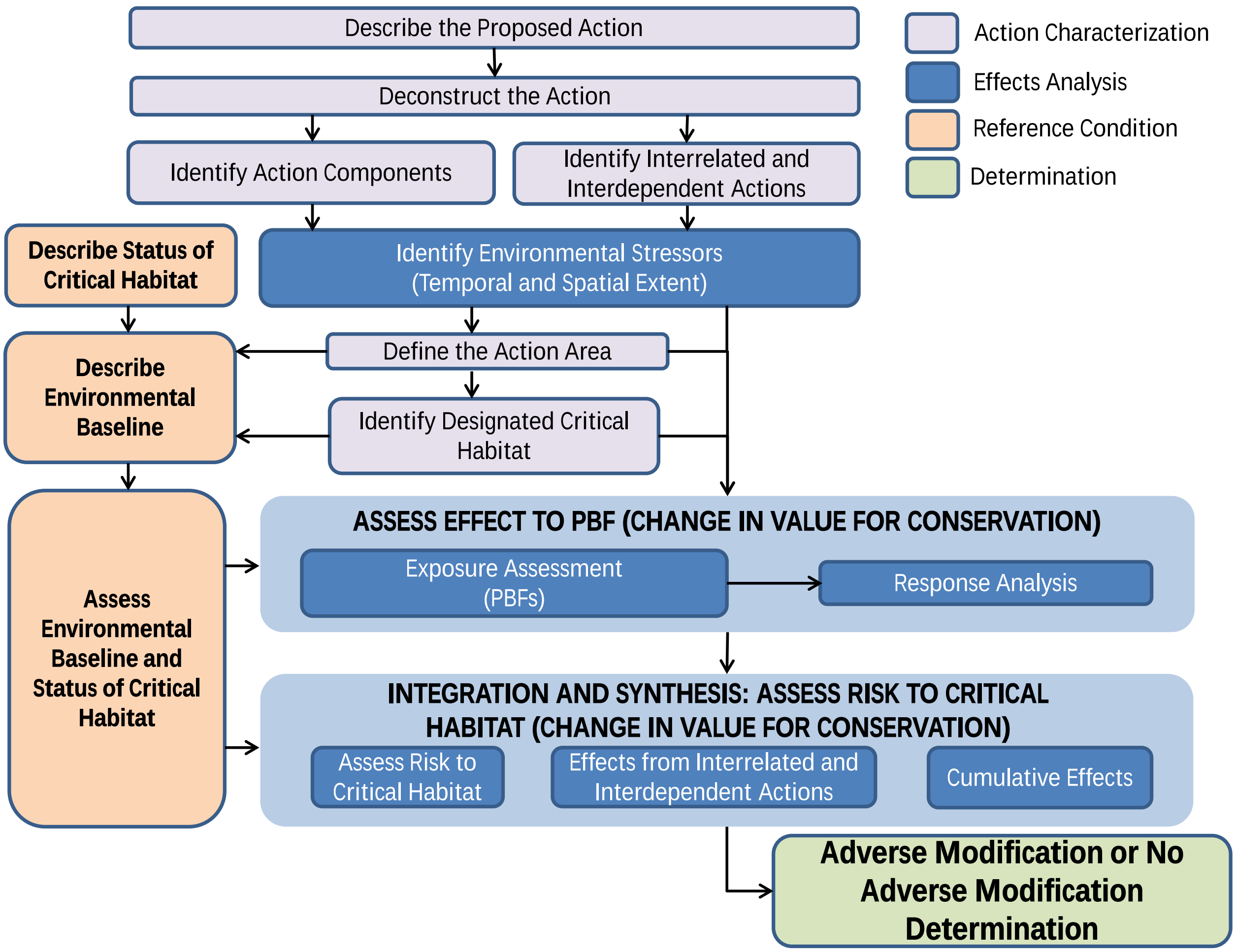


Figure 2-2. General Conceptual Model for Conducting Section 7 Analyses as Applied to Critical Habitat.

Once we identify which listed resources (i.e., endangered and threatened species and designated critical habitat) are likely to be exposed to potential stressors associated with an action and the nature of the exposure, we examine the scientific and commercial data available to determine whether and how those listed resources are likely to respond given their exposure. This represents the individual response analysis. The final steps of our series of analyses establish the risks those responses pose to listed resources. These steps represent our risk analysis. They are different for listed species and designated critical habitat and are discussed in the following sections.

2.1.3.1 Application of the Approach to Listed Species Analyses

Our jeopardy determinations must be based on an action's effects on the continued existence of threatened or endangered species and how those "species" have been listed (e.g., as true biological species, subspecies, or distinct population segments of vertebrate species). Because the continued existence of listed species depends on the fate of the populations that comprise them, the probability of extinction or probability of persistence of listed species depends on the probabilities of extinction and persistence of the populations that comprise the species. Similarly, the continued existence of a population is determined by the fate of the individuals that comprise it; populations grow or decline as the individuals that comprise the population live, die, grow, mature, migrate, and reproduce (or fail to do so).

Our analyses reflect these relationships. We identify the probable risks that actions pose to listed individuals that are likely to be exposed to effects of the actions. Our analyses then integrate the individuals' risks to identify consequences to the proportion of populations represented by the individuals (Figure 2-1). Our analyses conclude by determining the consequences of those population-level risks to the species that the populations comprise.

To measure risks to listed individuals, we use changes in the individual's "fitness" as a metric. "Fitness" can be characterized as an individual's growth rate, survival probability, annual reproductive success, or lifetime reproductive success. In particular, during the individual response analysis, we examine the scientific and commercial data available to determine if an individual's probable response to the effect of an action on the environment is likely to have consequences for the individual's fitness.

When individuals are expected to experience reduced fitness, we expect those reductions to also reduce the population abundance or rates of reproduction or growth rates (or to increase the variance in these rates) (Stearns 1992). Reduction in one or more of these variables is a necessary condition for increases in a population's probability of extinction, which is a necessary condition for increases in a species' probability of extinction.

If we conclude listed individuals are likely to experience reductions in their fitness, we evaluate whether those fitness reductions are likely to increase the probability of extinction of the populations those individuals represent. This can be measured using changes in population abundance, reproduction rate, diversity, spatial structure and connectivity, growth rate, or variances in these metrics. In this step of our analysis, we use the population's reference condition (established in the Status of the Species section of this Opinion) as our point of reference. Generally, this reference condition is a measure of how close a species is to extinction or recovery.

An important tool in this step of the assessment is a consideration of the life cycle of the species. The consequences on a population's probability of extinction as a result of impacts to different life stages are assessed within the framework of this life cycle and our current knowledge of the transition rates between life stages, the sensitivity of population growth to changes in those rates, and the uncertainty in the available estimates or information. An example of a Pacific salmonid life cycle is provided in Figure 2-3, which shows the cycle of the upstream freshwater spawning, juvenile smoltification and outmigration, ocean residence, and upstream spawning migration. Though not identical, the life history of green sturgeon is similar (i.e., spawning in upstream freshwater locations, juvenile outmigration through the riverine and estuarine areas, long ocean residence before returning to upstream spawning areas), and we take a similar approach in analyzing effects to both salmonids and sturgeon.

Various sets of data and modeling efforts are useful to consider when evaluating the transition rates between life stages and consequences on population growth as a result of variations in those rates. These data are not available for all species considered in this Opinion; however, data from surrogate species may be available for inference. Where available, information on transition rates, sensitivity of population growth rate to changes in these rates, and the relative importance of impacts to different life stages is used to inform the translation of individual effects to population-level effects.

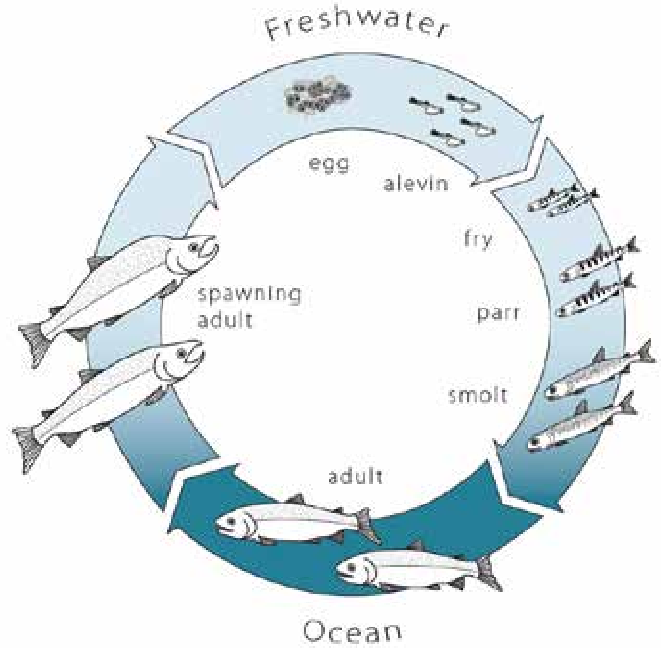


Figure 2-3. Conceptual Diagram of the Life Cycle of a Pacific Salmonid (NMFS 2016).

In addition, we recognize that populations may be vulnerable to small changes in life stage transition rates. Small reductions across multiple life stages can be sufficient to cause the extirpation of a population. This is hypothetically illustrated in Figure 2-4 for two scenarios with different transition rates. For two adult salmon (a spawning pair) that produce 2,000 eggs that then experience a 20 percent survival rate to the juvenile stage, a 10 percent survival to smoltification, and a 5 percent survival over several years at sea, two adult salmon will return to spawn again. However, if the survivorship is reduced to 18 percent at the juvenile stage, 8 percent at the smolt stage, and 4 percent at the sea stage, then only one adult salmon will return, leading to eventual extirpation if the trend continues.

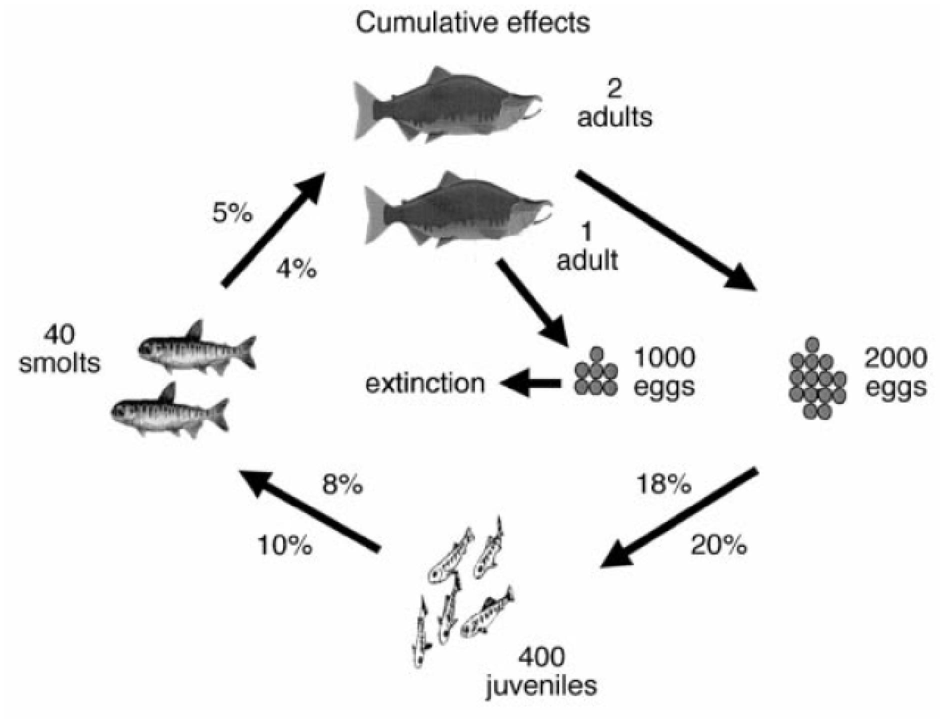


Figure 2-4. Illustration of Population Vulnerability to Small Changes in Transition Rates (Naiman and Turner 2000).

The section 7 consultation process requires assessment of the effects of several stressors to the species. The effects of these stressors require conceptual understanding of both the species' use of the area and the effects of the stressors on the species. NMFS closely considered the conceptual models of the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) (Williams 2010) for Chinook salmon and the recent sDPS green sturgeon report (Heublein et al. in review) when identifying and evaluating the effects of activities associated with the PA. These models identify the effects of stressors such as increased temperature, toxins, changes in flow, minor and major diversions, the site of action, and the life stage affected. These stressors and their effects are reflected in the structure and evaluations of the effects analysis.

Our assessment next determines if changes in population viability are likely to be sufficient to reduce the viability of the species the population comprises. In this assessment, we use the species' status (established in the Status of the Species section of this Opinion) as our point of reference. We also use our knowledge of the population structure of the species to assess the consequences of the increase in extinction risk to one or more of those populations. Our Status of the Species section discusses the available information on the structure and diversity of the populations that comprise the listed species and any available guidance on the role of those populations in the recovery of the species, noting that an action that is helping to implement recovery actions or strategies is less likely to jeopardize the species. An example of structure and diversity information used in this assessment is provided in Figure 2-5 for CV spring-run Chinook salmon. This figure illustrates the historic distribution and structure of the species and notes those populations that have been extirpated. This information provides a sense of existing and lost diversity and structure within the species, which are important considerations when evaluating the recovery consequences of extinction risk or effects to current or potential habitat.

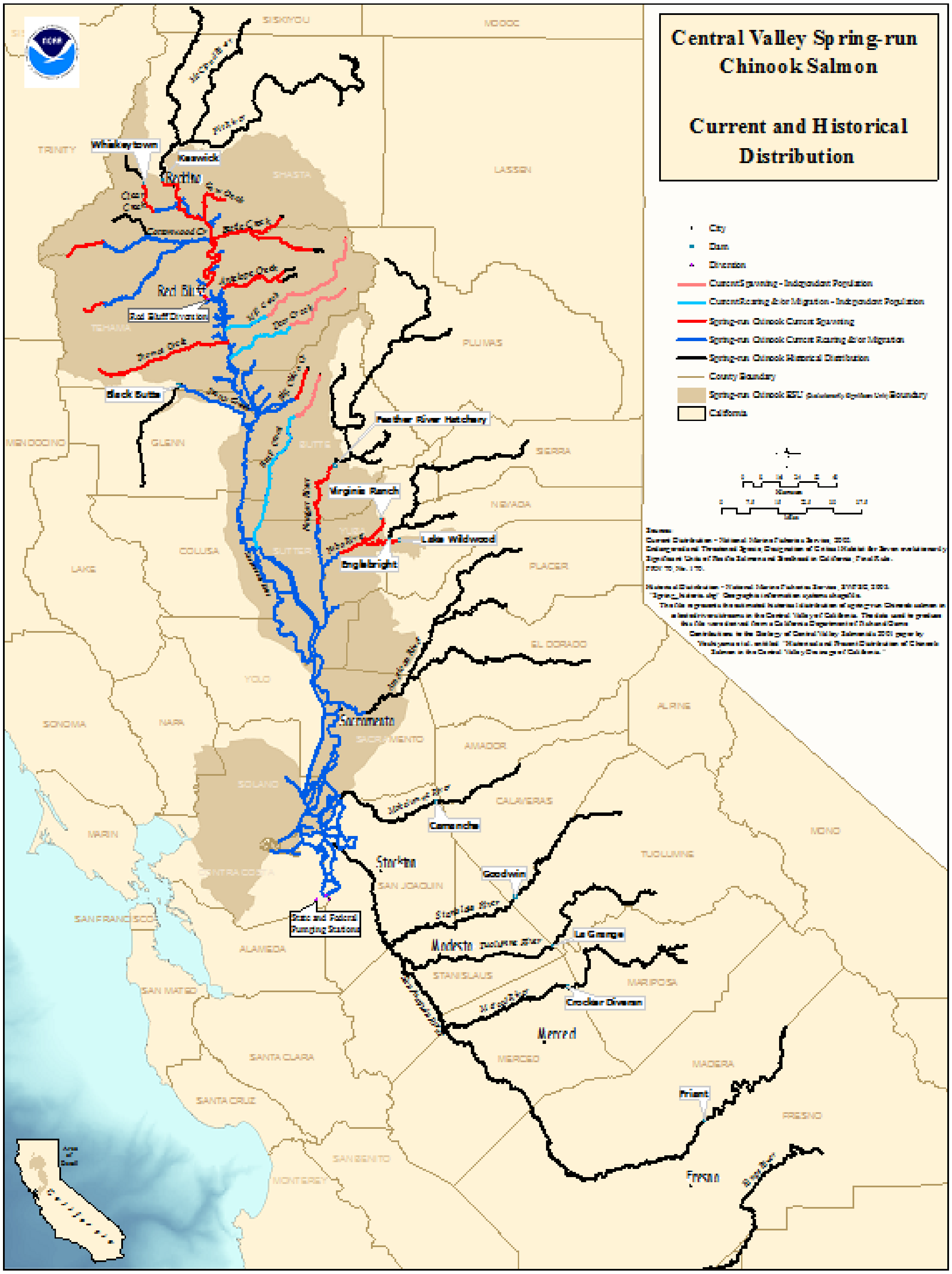


Figure 2-5. Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit and Current and Historical Distribution.

We used a set of tables to collect and evaluate the available information on the expected effects of each component action of the PA. These tables identify the stressor effect mechanism and the exposure, response, and risk posed to individuals and proportion of the species. Table 2-1 outlines the basic set of information we evaluated, and an example of the conceptual thought behind the information in the table is included in Box 1. We rank the effects to individuals on the basis of the severity of the predicted response and resulting fitness consequence within life stages.

Box 1: An example of the determination of effects to individuals of the species.

The first steps in evaluating the potential impacts a project may have on an individual fish would entail: (1) identifying the seasonal periodicity and life history traits and biological requirements of listed salmonids and sturgeon within the action area. Understanding the spatial and temporal occurrence of these fish is a key step in evaluating how they are affected by current human activities and natural phenomena; (2) identifying the main variables that define riverine or estuarine characteristics that may change as the result of project implementation; (3) determining the extent of change in each variable in terms of time, space, magnitude, duration, and frequency; (4) determining if individual listed species will be exposed to potential changes in these variables; (5) evaluating how the changed characteristic would affect the individual fish in terms of the fish's growth, survival, and/or reproductive success; (6) and determining the proportion of a population affected.

As an example, riverine characteristics may include flow, water quality, vegetation, channel morphology, hydrology, neighboring channel hydrodynamics, and connectivity among upstream and downstream processes. Each of these main habitat characteristics is defined by several attributes (e.g., water quality includes water temperature, dissolved oxygen, ammonia concentrations, turbidity). The degree to which the proposed project may change attributes of each habitat characteristic will be evaluated quantitatively and/or qualitatively in the context of its spatial and temporal relevance. Not all of the riverine characteristics and associated attributes identified above may be affected by project implementation to a degree where meaningful qualitative or quantitative evaluations can be conducted. That is, if differences in flow with and without the proposed project implementation are not sufficient to influence neighboring channel hydrodynamics, then these hydrodynamics will not be evaluated in detail either quantitatively or qualitatively. The changed nature of each attribute will then be compared to the attribute's known or estimated habitat requirements for each fish species and life stage. For example, if water temperature modeling results demonstrate that water temperatures during the winter-run Chinook salmon spawning season (mid-April through mid-August) would be warmer with implementation of the proposed project, then the extent of warming and associated impact would be assessed in consideration of the water temperature ranges required for successful winter-run Chinook salmon spawning.

NMFS will then evaluate how the proposed project's effects on riverine characteristics may affect the growth, survival, and reproductive success of individual fish. For example, all of these metrics may be affected if the proposed project results in increased water temperatures during multiple life stages. Individual fish growth also may be affected by reduced availability, quantity, and quality of habitats (e.g., floodplains, channel margins, intertidal marshes). Survival of an individual fish may be affected by suboptimal water quality, increased predation risk associated with non-native predatory habitats and physical structures, impeded passage, and susceptibility to disease. Reproductive success of individual fish may be affected by impeded or delayed passage to natal streams; suboptimal water quality (e.g., temperature), which can increase susceptibility to disease; and reduced quantity and quality of spawning habitats. Instream flow studies (e.g., instream flow incremental methodology studies) available in the literature, which describe the relationship between spawning habitat availability and flow, will be used to assess proposed project-related effects on reproductive success. All factors associated with the proposed project that affect individual fish growth, survival, or reproductive success will be identified during the exposure analyses.

Table 2-1. Example of Information Used to Identify Effects of the Components of the Proposed Action to Listed Species.

Stressor	Life Stage (Location)	Life Stage Timing (Work Window Intersection)	Individual Response and Rationale of Effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of Overall Effect (PA + Baseline + Cumulative Effects (CE))

As Table 2-1 shows, for each response to an action, we assign a relative magnitude of effect (high, medium, or low). This is a qualitative assessment of the likelihood of a fitness consequence occurring that allows for incorporation of some aspects of uncertainty (for instance, an infrequent but documented presence of a small number of individuals at a particular time). The categories to assign magnitude of effect mirror those from NMFS (2009) and are defined as follows:

- High: Lethal effect due to stressor that has a broad effect on the population at significant frequency
- Medium: Effect between high and low definitions
- Low: Generally sublethal effect, or lethal effect on a very small percentage of one population at a very infrequent interval

The weight of evidence identified in Table 2-1 is based on the best available scientific information. The stressor effect, as identified by a particular analytical method, is categorized based on the characteristics of the analytical method, as outlined in NMFS (2009), with modifications to include statistical power of analytical methods. Weights are defined as follows:

- High: Supported by multiple scientific and technical publications, especially if conducted on the species within the area of effect, quantitative data, and/or modeled results; high power in interpretation of analytical results
- Medium: Evidence between high and low definitions
- Low: One study, or unpublished data, or scientific hypotheses that have been articulated but not tested; low power in interpretation of analytical results

A key consideration in this assessment is the strategy of the NMFS recovery plan that “every extant population be viewed as necessary for the recovery of the ESUs and DPS,” and that “wherever possible, the status of extant populations should be improved” (NMFS 2014). Noted recovery actions include (but are not limited to) reintroduction of populations into key watersheds, completion of landscape-scale restoration throughout the Delta, restoring flows throughout the Sacramento and San Joaquin river basins and the Delta, reducing the biological impacts of exporting water through the CVP and SWP facilities, and meeting established water quality criteria. Several of these actions could be affected by the PA and therefore could contribute to either recovery or jeopardy. In following the recommendations of the recovery plan to also advocate that uncertainty be resolved in favor of the species, it was assumed that expected appreciable reductions in any population’s viability due to implementation of the PA would also appreciably reduce the likelihood of survival and recovery of the population’s diversity group and the ESU/DPS. Therefore, this assumption in our analysis of effects is consistent with the precautionary principle of institutionalized caution.

Table 2-2 presents the basic set of outcomes associated with acceptance or rejection of the propositions used when evaluating effects of the PA. These follow a logical path and hierarchical structure that is used to organize the jeopardy risk assessment. This table is populated using results from

Table 2-1 as completed for all stressors. For each step in Table 2-2, the stressor result that supports the true or false determination will be identified, with documentation of the magnitude of effect and weight of evidence, to allow clear disclosure of potential for uncertainty. While the approach cannot remove the uncertainty, it can allow a determination to be made based on a methodological approach of the magnitude of effect and weight of evidence.

Table 2-2. Reasoning and Decision-making Steps for Analyzing the Effects of the Proposed Action on Listed Species.

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse effects on the environment	True	End
		False	Go to B
B	Listed individuals are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action	True	NLAA
		False	Go to C
C	Listed individuals are not likely to respond upon being exposed to one or more of the stressors produced by the proposed action	True	NLAA
		False	Go to D
D	Any responses are not likely to constitute “take” or reduce the fitness of the individuals that have been exposed	True	NLAA
		False	Go to E
E	Any reductions in individual fitness are not likely to reduce the viability of the populations those individuals represent	True	NLJ
		False	Go to F
F	Any reductions in the viability of the exposed populations are not likely to reduce the viability of the species	True	NLJ
		False	LJ

Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and not likely/likely to jeopardize (NLJ/LJ).

2.1.3.1.1 The Viable Salmonid Populations Framework in Listed Salmonid Analyses

In order to assess the survival and recovery of any species, a guiding framework that includes the most appropriate biological and demographic parameters is required. This has been generally defined above. For Pacific salmonids, McElhany et al. (2000) defines a VSP as an independent population that has a negligible probability of extinction over a 100-year timeframe. The VSP concept provides specific guidance for estimating the viability of populations and larger-scale groupings of Pacific salmonids such as ESU or DPS.

Four VSP parameters form the key to evaluating population and ESU/DPS viability: (1) abundance; (2) productivity (i.e., population growth rate); (3) population spatial structure; and (4) diversity (McElhany et al. 2000). These four parameters and their associated attributes are presented in Figure 2-6.

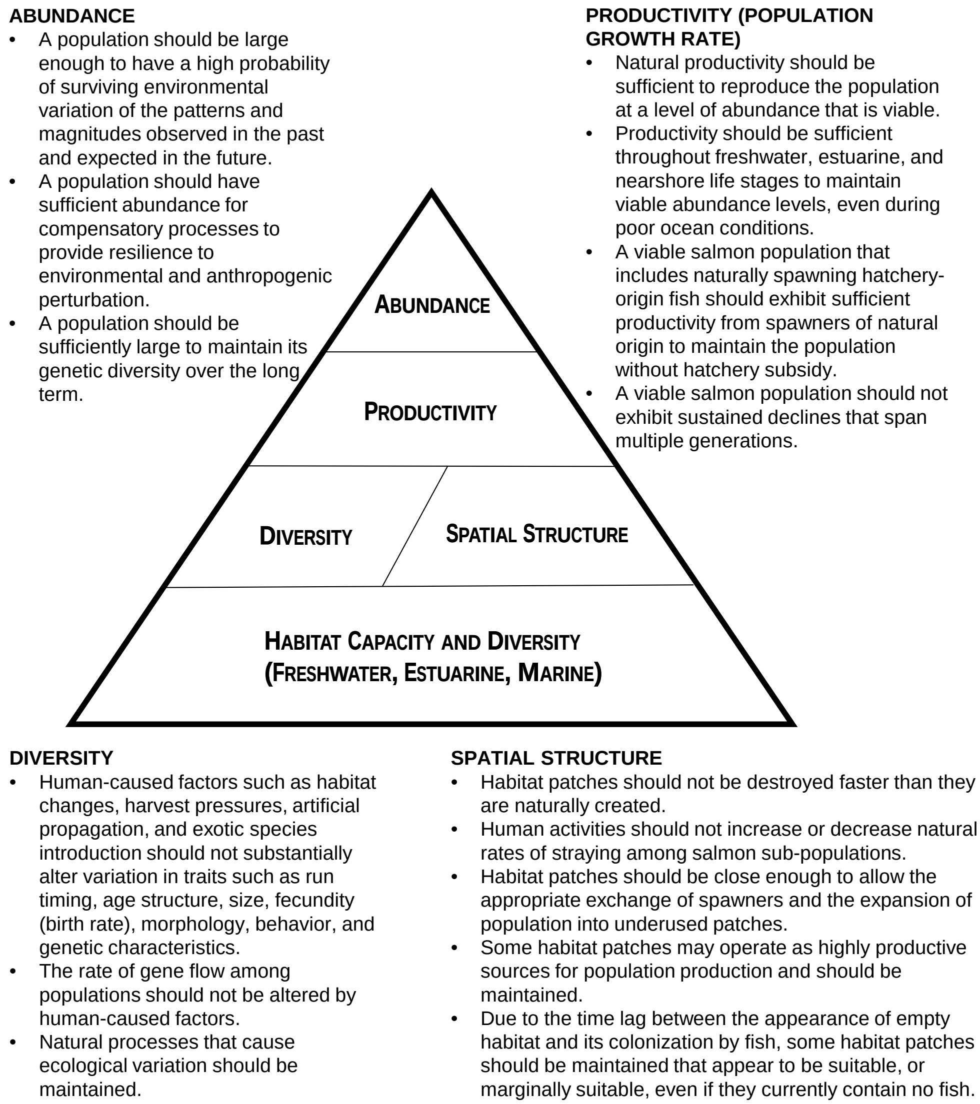


Figure 2-6. Viable Salmonid Population Parameters and Their Attributes.

In addition to the four key parameters, the quality, quantity, and diversity of the habitat (habitat capacity and diversity) available to the species in each of its three main habitat types (freshwater, estuarine, and marine environments) is a foundation to VSP. Salmon cannot persist in the wild and withstand natural environmental variations in limited or degraded habitats. Therefore, the condition and capacity of the ecosystem upon which the population (and species) depends play a critical role in the viability of the population or species. Without sufficient space, including accessible and diverse areas the species can utilize to weather variation in their environment, the population and species cannot be resilient to chance environmental variations and localized catastrophes. Salmonids have evolved a wide variety of life history strategies designed to take advantage of varying environmental conditions. Loss or impairment of the species' ability to use these adaptations increases their risk of extinction.

Recent research shows that a diversity of life histories among populations contributes to the maintenance of multiple and diverse salmon stocks fluctuating independently of each other, which in turn reduces species extinction risk and long-term variation in regional abundances (Hilborn et al. 2003; Schindler et al. 2010; Yates et al. 2012; Satterthwaite and Carlson 2015). Such variance buffering of complex ecological systems has been described as a portfolio effect (Schindler et al. 2010), borrowing on concepts from financial portfolio theory (Markowitz 1952; Koellner and Schmitz 2006; Satterthwaite and Carlson 2015).

The foundation for this “portfolio effect” of spreading risk across populations can be found at the within-population scale (Greene 2009; Bolnick et al. 2011). For example, juvenile Chinook salmon leave their natal rivers at different sizes, ages, and times of the year, and this life history variation is believed to contribute to population resilience (Beechie et al. 2006; Lindley et al. 2009; Miller et al. 2010; Satterthwaite et al. 2014; Sturrock et al. 2015). Life history diversity promotes salmonid population resiliency thereby reducing a species’ extinction risk. Thus, preserving and restoring life history diversity is an integral goal of many salmonid conservation programs (Ruckelshaus et al. 2002). It is increasingly recognized that strengthening a salmon population’s resilience to environmental variability (including climate change) will require expanding habitat opportunities to allow a population to express and maintain its full suite of life history strategies (Bottom et al. 2011).

As presented in NMFS (2014), criteria for VSP are based upon measures of the VSP parameters that reasonably predict extinction risk and reflect processes important to populations. Abundance is critical because small populations are generally at greater risk of extinction than large populations. Stage-specific or lifetime productivity (i.e., population growth rate) provides information on important demographic processes. Genotypic and phenotypic diversity are important because they allow species to use a wide array of environments, respond to short-term changes in the environment, and adapt to long-term environmental change. Spatial structure reflects how abundance is distributed among available or potentially available habitats and can affect overall extinction risk and evolutionary processes that may alter a population’s ability to respond to environmental change. However, each of these parameters, and the criteria that can be developed from them, must be sensitive to the uncertainty of estimates, levels, and processes (McElhany et al. 2000).

The VSP concept also identifies guidelines describing a viable ESU/DPS. The viability of an ESU or DPS depends on the number of populations within the ESU or DPS, their individual status, their spatial arrangement with respect to each other and to sources of potential catastrophes, and diversity of the populations and their habitat (Lindley et al. 2007). Guidelines describing what constitutes a viable ESU are presented in detail in McElhany et al. (2000). More specific recommendations of the characteristics describing a viable Central Valley salmon population are found in Table 1 of Lindley et al. (2007). The effects of the PA are analyzed with consideration for the diversity and spatial structure of the salmonid populations. Because the effects of the project are experienced at locations where individual populations (e.g., Mill Creek spring-run Chinook salmon and Butte Creek spring-run Chinook salmon) come together, the effects to individual populations are not differentiated in the effects analysis. For spring-run Chinook salmon, all Sacramento River basin populations are analyzed as a single unit, and effects are separately analyzed for San Joaquin River basin spring-run (regardless of experimental population designation, because individuals of the experimental population are not recognized as such while in an area of overlap with individuals that are not part of the experimental population (50 CFR 222.501(a)) and spring-running fish, with available information of their presence and timing. Steelhead populations are similarly analyzed in the effects analysis based on basin of origin. However, the impacts to the diversity and spatial structure provided by the individual populations will be evaluated when the VSP approach is applied in the integration and synthesis.

We nest the VSP concept within the hierarchy of the individual-population-diversity group-ESU/DPS relationships to evaluate the potential impact of the PA. For the species, the conceptual model is based on a bottom-up hierarchical organization of individual fish at the life stage scale, population, diversity group, and ESU/DPS (Figure 2-7). The viability of a species (e.g., ESU) is dependent on the viability of the diversity groups that compose that species and the spatial distribution of those groups; the viability of a diversity group is dependent on the viability of the populations that compose that group and the spatial distribution of those populations; and the viability of the population is dependent on the four VSP parameters and on the fitness and survival of individuals at the life stage scale. The anadromous salmonid life cycle (see Figure 2-3) includes the following life stages and behaviors, which are evaluated for potential effects resulting from the PA:

- Adult immigration and holding
- Spawning, embryo incubation
- Juvenile rearing and downstream movement[3]
- Smolt outmigration

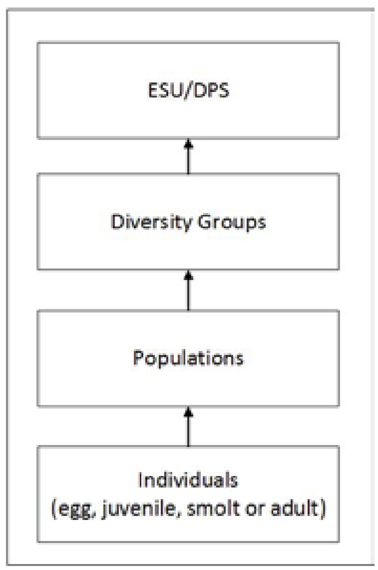


Figure 2-7. Conceptual Model of the Hierarchical Structure that is Used to Organize the Jeopardy Risk Assessment for Anadromous Salmonids.

2.1.3.1.2 Approach to Southern Distinct Population Segment of Green Sturgeon

Although McElhany et al. (2000) specifically addresses viable populations of salmonids, NMFS believes that the concepts and viability parameters in McElhany et al. (2000) can also be applied to the SDPS of green sturgeon due to the general similarity in life cycle and freshwater/ocean

[3] The juvenile rearing and downstream movement life stage is intended to include fry emergence and fry and fingerling rearing, which occurs both in natal streams and as these fish are moving downstream through migratory corridors at a pre-smolt stage. The distinction between juveniles and smolts is made because smolts have colder thermal requirements than juveniles that are not undergoing osmoregulatory physiological transformations.

use. Therefore, in this Opinion, NMFS applies McElhany et al. (2000) and the viability parameters in its characterization of the status of the species, environmental baseline, and analysis of effects of the action to the Southern DPS of green sturgeon.

2.1.3.1.3 Approach Specific to Southern Resident Killer Whales

The Overview of the Approach and Models Used (Section 2.1.3) and Application of the Approach to Listed Species Analysis (Section 2.1.3.1) described above also apply to NMFS' approach for Southern Resident killer whales (Southern Residents). The Southern Resident DPS is a single population. The population is composed of three pods, or groups of related matrilines, that belong to one clan of a common but older maternal heritage (NMFS 2008). The Southern Resident population is sufficiently small that the relative fitness of all individuals from each pod can influence the survival and recovery of the DPS. Southern Residents are known to prefer Chinook salmon as their primary prey (Ford and Ellis 2006; Hanson et al. 2010), and Southern Resident population dynamics have been shown to be well-correlated with the abundance of Chinook populations over a broad scale throughout their range (Ward et al. 2013). Prior sections have discussed the analytical approach to assessing impacts to ESA-listed Chinook salmon. Similarly, an accompanying analysis of impacts to non-ESA-listed Chinook salmon will be performed as part of the MSA EFH consultation provisions. This analysis of effects to Southern Residents relies on the expected impacts of the PA on the abundance and availability of Chinook salmon for prey and how any expected changes in prey availability will affect the fitness, and ultimately the abundance, reproduction, and distribution, of the Southern Resident DPS.

2.1.3.2 Application of the Approach to Critical Habitat Analyses

The basis of the destruction or adverse modification analysis is to evaluate whether the PA affects the quantity or quality of the PBFs in the designated critical habitat for a listed species and, especially in the case of unoccupied habitat, whether the PA has any impacts to the critical habitat itself. Specifically, NMFS will generally conclude that a PA is likely to destroy or adversely modify designated critical habitat if the action results in an alteration of the quantity or quality of the essential PBFs of designated critical habitat, or that precludes or significantly delays the capacity of that habitat to develop those features over time, and if the effect of the alteration is to appreciably diminish the value of critical habitat for the conservation of the species (81 FR 7214; 7216; February 11, 2016) (Note that the concept of primary constituent elements has been replaced by the statutory term "physical or biological features" as of February 2016 (81 FR 7414; February 11, 2016). NMFS bases critical habitat analysis on the affected areas and functions of critical habitat essential for the conservation of the species, and not on how individuals of the species will respond to changes in habitat quantity and quality. If an area encompassed in a critical habitat designation is likely to be exposed to the direct or indirect consequences of the PA on the natural environment, NMFS asks if PBFs included in the designation that give the designated critical habitat value for the conservation of the species are likely to respond to that exposure. In particular, NMFS is concerned about responses that are sufficient to reduce the quantity or quality of those PBFs or capacity of that habitat to develop those features over time.

To conduct this analysis, NMFS follows the basic exposure-response-risk analytical steps described in Figure 2-2 and applies a set of reasoning and decision-making questions designed to aid in this determination. These questions follow a similar logic path and hierarchical approach to the elements and areas within a critical habitat designation.

Table 2-3 outlines the reasoning and decision-making steps in the determination of effects of the PA on designated critical habitat. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and destruction or adverse modification of critical habitat (D/AD MOD). Table 2-4 includes the collection of information used to evaluate the effects of components of the PA on critical habitat.

Table 2-3. Reasoning and Decision-making Steps for Analyzing the Effects of the Proposed Action on Designated Critical Habitat.

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse effects on the environment	True	End
		False	Go to B
B	Areas of designated critical habitat are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect effects of the proposed action	True	NLAA
		False	Go to C
C	The quantity or quality of any physical or biological features of critical habitat or capacity of that habitat to develop those features over time are not likely to be reduced upon being exposed to one or more of the stressors produced by the proposed action	True	NLAA
		False	Go to D
D	Any reductions in the quantity or quality of one or more physical or biological features of critical habitat or capacity of that habitat to develop those features over time are not likely to reduce the value of critical habitat for the conservation of the species in the exposed area	True	NLAA
		False	Go to E
E	Any reductions in the value of critical habitat for the conservation of the species in the exposed area of critical habitat are not likely to appreciably diminish the overall value of critical habitat for the conservation of the species	True	No D/AD MOD
		False	D/AD MOD

Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and destruction or adverse modification of critical habitat (D/AD MOD).

Table 2-4. Example of Information Used to Identify Effects of the Components of the Proposed Action to Critical Habitat.

Action Component	Location of Effect	Physical and Biological Features Affected	Response and Rationale of Effect	Magnitude	Weight of Evidence	Probable Change in PBF Supporting the Life History Needs of the Species

These tables allow us to determine the expected consequences of the action on physical and biological features, sort or rank the magnitude of those consequences, and determine whether areas of critical habitat are exposed to additive effects of the PA and the environmental baseline. We recognize that the value of critical habitat for the conservation of the species is a dynamic property that changes over time in response to changes in land use patterns, climate (at several spatial scales), ecological processes, changes in the dynamics of biotic components of the habitat, etc. For these reasons, some areas of critical habitat might respond to an exposure when others do not. We also consider how the physical and biological features of designated critical habitat are likely to respond to any interactions with and synergisms between cumulative effects of pre-existing stressors and proposed stressors.

At the heart of the analysis is the basic premise that the value of an overall critical habitat designation for the conservation of the species is the sum of the values of the components that comprise the habitat. For example, the value of listed salmonid critical habitat for the conservation of the species is determined by the value of the watersheds or other areas that make up the designated area. In turn, the value of the watersheds or other areas is based on the quantity or quality of PBFs of critical habitat or capacity of that habitat to develop those features over time in that area. Specifically, NMFS will generally conclude that a Federal action is likely to "destroy or adversely modify" designated critical habitat if the action results in an alteration of the quantity or quality of the essential PBFs of designated critical habitat, or that precludes or significantly delays the capacity of that habitat to develop those features over time, and if the effect of the alteration is to appreciably diminish the value of critical habitat for the conservation of the species. NMFS may consider other kinds of impacts to designated critical habitat. For example, some areas that are currently in a degraded condition may have been designated as critical habitat for their potential to develop or improve and eventually provide the needed ecological functions to support species' recovery. Under these circumstances, NMFS generally conclude that an action is likely to "destroy or adversely modify" the designated critical habitat if the action alters it to prevent it from improving over time relative to its pre-action condition.

Therefore, reductions in the quantity or quality of any PBFs of critical habitat or capacity of that habitat to develop those features over time may reduce the value of the exposed area (e.g., watersheds) for the conservation of the species, which in turn may reduce the value of the overall critical habitat designation for the conservation of the species. In the strictest interpretation, reductions to any one PBF could equate to a reduction in the value of the whole.

There are, however, other considerations. We look to various factors to determine if the reduction in the quantity or quality of any PBFs of critical habitat or capacity of that habitat to develop those features over time would affect the value of the critical habitat for the conservation of the species. Examples of these factors include the following:

- The timing, duration, and magnitude of the reduction
- The permanent or temporary nature of the reduction

We use the value for the conservation of the species of those areas of designated critical habitat that occur in the action area as our point of reference for our assessment of effects of the PA on designated critical habitat. For example, if the critical habitat in the action area has limited current value or potential value for the conservation of listed species, then that limited value is our point of reference for our assessment of the consequences of the effects of the PA on the value of the overall critical habitat designation for the conservation of the species. In addition, we must determine whether reductions in the value of critical habitat for the conservation of the species in the exposed area of critical habitat are likely to appreciably diminish the overall value of critical habitat for the conservation of the species. A PA may adversely affect critical habitat in an action area without appreciably diminishing the value of critical habitat for the conservation of the species.

2.1.3.3 Characterization of the Environmental Baseline

ESA regulations define the environmental baseline as "the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process" (50 CFR §402.02). The "effects of the action" include the direct and indirect effects of the PA and of interrelated or interdependent activities "that will be added to the environmental baseline" (50 CFR §402.02). Consistent with these definitions, in *National Wildlife Federation v. National Marine Fisheries Service,* 524 F.3d 917, 929 (9th Cir. 2008), regarding NMFS' consultation on the effects of operating hydropower dams on the Columbia River, the Ninth Circuit Court of Appeals noted, "The 2004 BiOp initially evaluated the effects of the PA as compared to the reference operation, rather than focusing its analysis on whether the action effects, when added to the underlying baseline conditions, would tip the species into jeopardy." The court concluded that NMFS needed to consider the effects of the action in the context of the degraded baseline conditions when NMFS determined whether the PA would not jeopardize the continued existence of listed species. *Id*. at 929-31.

In the Environmental Baseline section (Section 2.4), we summarize the past and present impacts leading to the current status of the species in the action area, including the effects of CVP and SWP operations to date. The Environmental Baseline section also describes the future non-project stressors to which listed species and their critical habitats will be exposed. Therefore, as illustrated in Figure 2-8, the pre-consultation environmental baseline characterizes the effects of the combination of natural environmental variation, human impacts not associated with CWF or operations of the CVP and SWP, and impacts of the CVP and SWP as regulated by the 2008 USFWS and 2009 NMFS biological opinions on the CVP and SWP operations. Note that the figure blocks are illustrative of general categories of components of aggregation of effects in the analysis. The figure does not denote relative intensity of effect or whether impacts are positive or negative; temporal variability of effect/impact is not depicted.

Implicit in both these definitions of environmental baseline and effects of the action is a need to anticipate future effects, including the future component of the environmental baseline. Future effects of Federal projects that have undergone consultation and of contemporaneous State and private actions, as well as future changes due to environmental variations, are part of the future baseline, to which effects of the proposed project are added. In accordance with NMFS guidance (Sobeck 2016), climate change is included along with environmental variations in order to best characterize the future condition that the species will encounter.

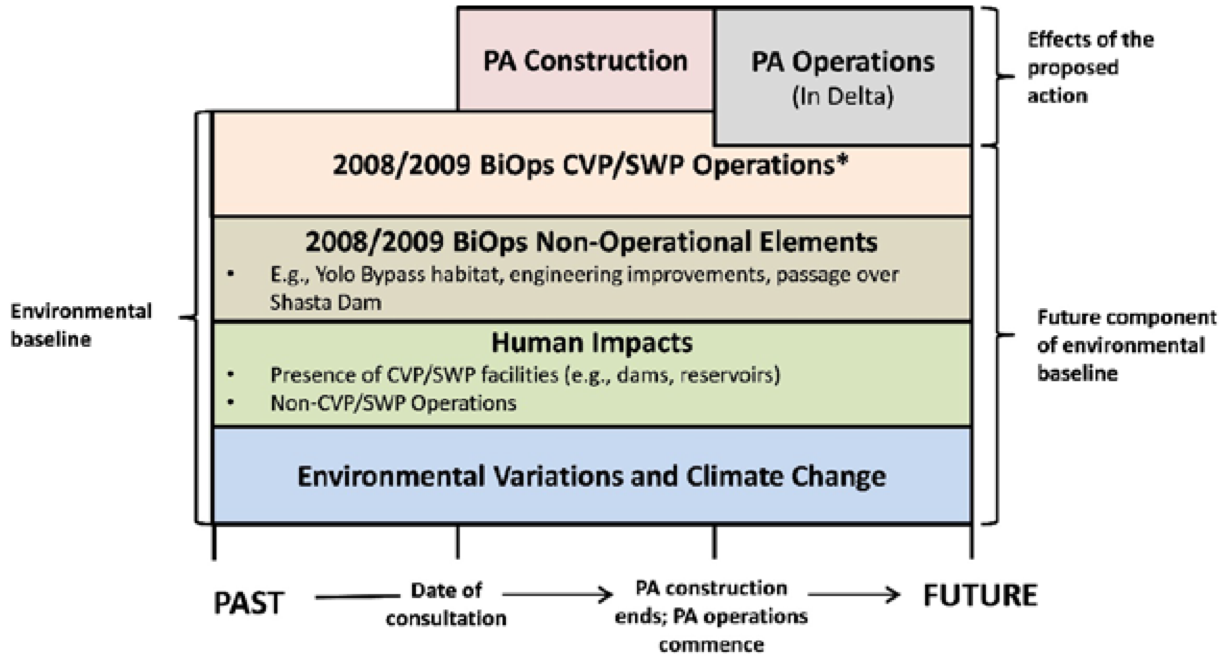


Figure 2-8. A Conceptual Model of the Effects of the Proposed Action Added on Top of the Future Component of the Environmental Baseline.

Note:
Asterisk (*) denotes that after PA operations commence, the 2008/2009 biological opinions on Central Valley Project and State Water Project operations will govern all upstream operations and any Delta operations not included in the proposed action operations.

To consider the effects of the action in the context of environmental baseline conditions, the analysis considers future effects of Federal projects that have undergone consultation and of contemporaneous State and private actions, as well as future changes due to natural processes, along with the effects of the proposed project. Given the timeline of the PA and because it includes an ongoing action (i.e., the future ongoing delivery of water), we analyze the entire suite of project effects (both construction- and operations-related) along with environmental baseline conditions in the future, which captures anticipated effects of non-project processes and activities. As presented in the project description of the BA, the PA includes Delta operations of the CVP and SWP in the future after construction of the new north Delta intakes. These future operations include modifications to some operations outlined in the 2008 USFWS and 2009 NMFS biological opinions on the CVP and SWP (i.e., CVP and SWP operations in the Delta); however, not all CVP and SWP operations are included in the CWF PA (i.e., CVP and SWP operations outside of the Delta). The facilities and operations included and not included in the PA are identified in Section 1. Specifically, upstream operational criteria of CVP and SWP facilities at Trinity, Shasta/Keswick, Folsom, Oroville, New Melones, and Friant reservoirs are not included in the PA, and effects of operations of these facilities are considered part of the environmental baseline for this analysis to the extent those effects occur in the action area. Therefore, Figure 2-8 illustrates that the integrated analysis of effects of the PA in the future will include effects of operations governed by a combination of components of the 2009 NMFS biological opinion and the biological opinions issued by NMFS for this PA.

2.1.4 Evidence Available for the Analysis

The primary source of initial project-related information was the CWF BA. However, to conduct the consultation analyses, NMFS considered current literature and published information to provide a foundation for the analysis and represent evidence or absence of adverse consequences. In addition to a thorough review of up-to-date literature and publications, the following provides a list of resources that we considered in the development of our analyses:

- Final rules listing the species in this Opinion as threatened or endangered
- Final rules designating critical habitat for the CV salmon and steelhead species, sDPS of green sturgeon, and Southern Resident killer whale DPS
- Final rule describing the use of surrogates in ITSs (80 FR 26832; May 11, 2015)
- Final rule defining destruction or adverse modification of critical habitat (81 FR 7214; February 11, 2016)
- 5-year Status Review: Summary and Evaluation of Sacramento River Winter-run Chinook Salmon ESU
- 5-year Status Review: Summary and Evaluation of CV Spring-run Chinook Salmon ESU
- 5-year Status Review: Summary and Evaluation of CCV DPS Steelhead
- 5-year Status Review: Summary and Evaluation of sDPS Green Sturgeon
- CWF BA
- NMFS 2009 biological opinions on CVP and SWP operations and 2011 amendments to the reasonable and prudent alternative
- NMFS recovery plan for CV salmonids
- NMFS co-manager review draft recovery plan for the sDPS of green sturgeon
- Past independent peer reviews (i.e., of project operations, CVP and SWP biological opinions, and draft BDCP products)
- Independent Delta Science Panel Review (January 2017)
- Scientific submissions related to SWRCB processes
- Information included in CSAMP and Collaborative Adaptive Management Team (CAMT) process

2.1.4.1 Primary Analytical Models

The CWF BA includes a suite of models used in the analysis of the effects of the operations of the CWF PA. NMFS used these model results along with results from additional analytical methods. Figure 2-9 provides a schematic of information and results flow between the models; models specific to the Opinion are denoted with an asterisk (*). Fundamental models used in the BA and/or Opinion include the following:

- CalSimII: A hydrological planning scenario tool that provides monthly average flows for the entire SWP and CVP system based on an 82-year record.
- DSM2-HYDRO: One-dimensional hydraulic model used to predict flow rate, stage, and water velocity in the Delta and Suisun Marsh.
- DSM2-PTM: Simulates fate and transport of neutrally buoyant particles through space and time in the Delta and Suisun Marsh.
- HEC-5Q: Water quality simulation tool used to provide water temperatures for the Sacramento and American rivers.

- DSM2-QUAL: Used to predict water temperature, dissolved oxygen, and salinity in the Delta and Suisun Marsh.
- Reclamation Egg Mortality Model: Uses CalSimII flow and climatic model output to predict monthly water temperature on the Trinity, Feather, American, and Stanislaus River basins and upstream reservoirs.
- SALMOD: Predicts effects of flows on habitat suitability and quantity for all races of Chinook salmon in the Sacramento River.
- SALSIM: Total life history population simulation model for fall-run Chinook salmon originating from the San Joaquin River.
- OBAN: Statistical modeling approach to evaluating scenarios effects to Sacramento Valley Chinook salmon populations.
- DPM: Simulates migration and mortality of Chinook salmon smolts entering the Delta from the Sacramento, Mokelumne, and San Joaquin rivers through a simplified Delta channel network, and provides quantitative estimates of relative Chinook salmon smolt survival through the Delta to Chipps Island.
- IOS: A stochastic life cycle model for winter-run Chinook salmon the Sacramento River.
- Salvage-density Analysis: A model of entrainment into the south Delta facilities as a function of flow based on historical salvage data.
- U.S. Geological Survey (USGS) Flow-survival Model*: A model that combines equations from statistical models estimating the relationship of Sacramento River inflows on reach-specific travel time, survival, and routing of salmonids to allow assessment of travel time and survival for different operational scenarios.
- USGS Entrainment Model*: A statistical model of probability of entrainment into the central Delta as a function of hydrodynamic variables in the Sacramento River.
- NMFS-Southwest Fisheries Science Center Temperature Dependent Egg Mortality Model (Martin et al. 2017)*: A temperature-dependent mortality model for Chinook salmon embryos that accounts for the effect of flow and dissolved oxygen on the thermal tolerance of developing eggs.
- Sacramento River Winter-run Chinook Salmon Life Cycle Model*: A state-space and spatially explicit life cycle model of eggs, fry, smolts, juveniles in the ocean, and mature adults that includes density-dependent movement among habitats.

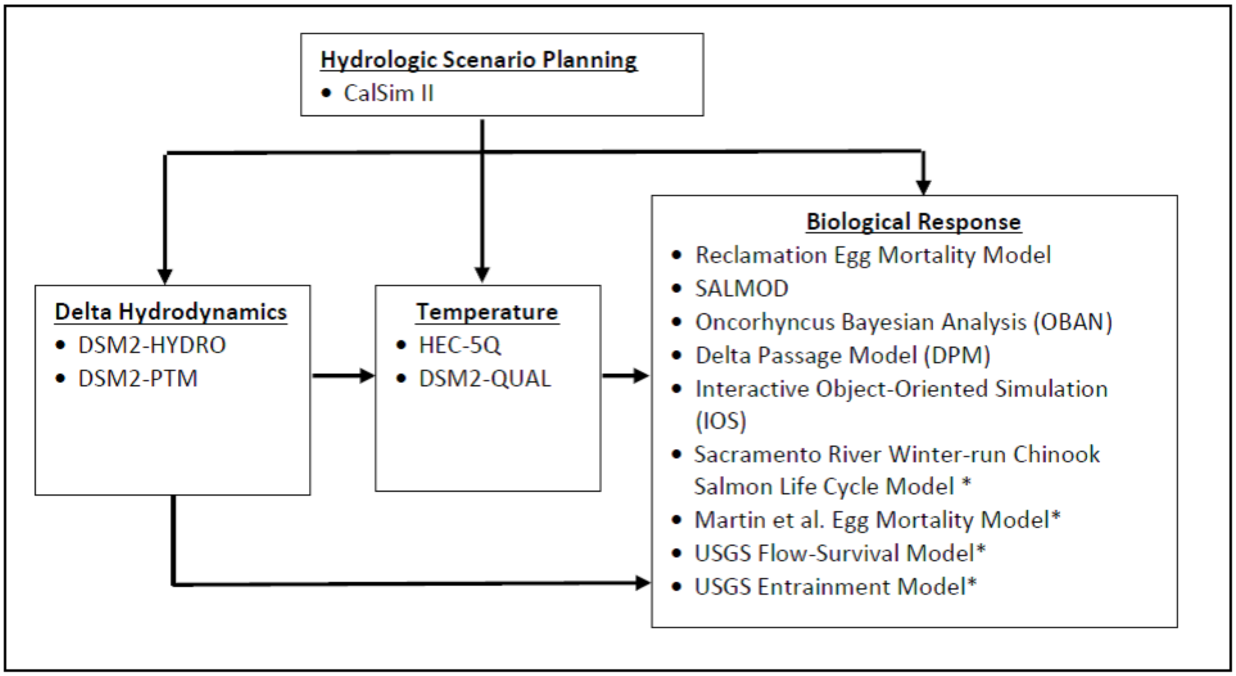


Figure 2-9. Main Models Used in the Analysis of Operations in the California WaterFix Biological Assessment and Biological Opinion and Their Information Flow with Respect to Each Other.

Though salmon life cycle modeling was not used in previous biological opinions on water project operations in the Central Valley (i.e., NMFS 2009), NMFS has recognized the need to better integrate life cycle models into their assessments of the effects of water operations on the listed anadromous fish species. Peer reviews (Cummins et al. 2008; Anderson et al. 2009; National Research Council 2010) recommended increased use of life cycle modeling as part of the consultation analyses and provided general recommendations on how NMFS should proceed with further incorporating life cycle modeling into ongoing analyses (Rose et al. 2011).

In response, NMFS has developed a life cycle modeling framework for CV Chinook salmon that is used in this Opinion to allow better evaluation of how complex and interacting management actions affect salmon populations. Specifically, the analyses include results from a model framework developed by the NMFS Southwest Fisheries Science Center to describe salmon population dynamics given water management, habitat restoration, and climate change scenarios (Hendrix et al. 2014; Hendrix et al. 2016). The framework relies upon standard Central Valley physical (i.e., CalSimII, DSM2, HEC-RAS) and chemical (i.e., temperature models, DSM2-QUAL) models to provide a characterization of abiotic conditions for a given scenario. A stage-structured population dynamics model of Chinook salmon links the habitat information to density-dependent stage transitions. These transitions describe the movement, survival, and reproduction that drive the dynamics of salmon populations.

The physical models applied in the BA and relied upon for the Opinion are generalized and simplified representations of a complex water resources system. The models are not predictive models of actual operations, and therefore the results cannot be considered as absolute and within a quantifiable confidence interval. For instance, CalSim II is a monthly planning model; it is not calibrated and cannot be used in a real-time predictive manner. CalSim II results are intended to be used in a comparative manner, which allows for assessing the changes in the CVP and SWP system operations and resulting incremental effects between two scenarios. This and any subsequent models that use CalSimII results require caution when used to characterize absolute conditions or conditions on a sub-monthly time step.

Though the results of the analytical tools require a more comparative analysis, the analysis for section 7 consultation requires that the effects of the project be evaluated in the aggregate. Therefore, NMFS used the results of the analysis in the exposure-risk-response framework along with knowledge of the species status and environmental baseline to evaluate the overall conditions that fish experience. The quantitative results of the analytical methods are used to inform this evaluation as much as possible, though, given the limitations of the model to comparative analyses, this assessment does rely on a qualitative analysis and application of results.

2.1.4.2 Critical Assumptions in the Analysis

To address the uncertainties identified above related to the PA and the analysis provided in the CWF BA, NMFS established a set of key assumptions required to address existing data gaps in the CWF BA that are critical to our analysis of effects. General assumptions that were made in filling those data gaps include the following:

- All components of the RPAs included in NMFS (2009) and USFWS (2008) biological opinions (and amendments) on the coordinated operations of the CVP and SWP will be completed before construction on the CWF PA begins.
- Species presence data are an accurate description of when and where a proportion of a particular species can be expected to occur in a particular area. While real-time monitoring in any given year may provide an opportunity to fine-tune short-term presence information, the available data that characterize both the bulk of presence and the tails (that is, smaller proportional) of presence are considered the best information for informing exposure and risk.
- Operational criteria outside of the operations described in the PA remain unchanged. The PA does not include specific changes to several operational criteria of the CVP and SWP that are operated in conjunction with the facilities of the PA.
- The characterization of future conditions incorporated into the PA is applicable throughout the construction period and at the onset of initial operations until a subsequent consultation on the CVP and SWP, including CWF operations, is completed. The PA characterizes climate conditions, water demands, and build-out as predicted for approximately 2030.
- Real-time operations and adaptive management will be designed to incorporate uncertainty and allow action within reasonable timeframes for those activities given opportunities or scenarios to address uncertainties.
- The project, as characterized in the modeling provided by the BA, does not simulate short-term real-time operations, especially those that are dependent on biological triggers. Because the modeling analysis is based on comparative long-term scenario planning tools, it is not able to emulate the daily operations that would be implemented to manage to biological, water quality, and other constraints. NMFS has analyzed the effects of the project as characterized by an initial approach to operations as identified by the operational criteria of the PA and completed auxiliary analyses when possible to evaluate

the effects of real-time operations that are within the operational criteria identified in the PA.

- Current assumptions regarding hydrodynamics, loss, predator density, and predation risk within CCF are applicable throughout the construction period and into the operational period of the PA. Because the BA does not provide alternative assumptions to characterize the stresses associated with CCF configuration and operation, NMFS has completed analysis given the current assumptions. NMFS assumes that the commitment to continued monitoring and evaluation of these assumptions will be addressed by the technical team identified in the PA.
- Results that include confidence intervals to characterize uncertainty are viewed in totality, considering the range of results over the intervals and not simply mean or median values.
- Exposure of a few individuals, as indicated by the species presence, to a stressor does not result in no adverse effect. Exposure of a small number of individuals may still result in take of those individuals, however few, and this take should not be ignored. If the level of harm to those individuals is insignificant, it will be stated as such.

Many of the methods described above focus the analyses on particular aspects of the action or affected species. Key to the overall assessment, however, is an integration of the effects of the PA with each other and with the baseline set of stressors to which the species and critical habitat are also exposed. In addition, the final steps of the analysis require a consideration of the effects of the action within the context of the reference condition of the species and critical habitat. That is, following the hierarchical approaches outlined above, NMFS combines the effects of the action to determine if the action is not likely to appreciably reduce the likelihood of both the survival and recovery of the species and not likely to result in the destruction or adverse modification of critical habitat.

2.1.5 Integrating the Effects

The preceding discussions describe the various quantitative and qualitative models, decision frameworks, and ecological foundations for the analyses presented in this Opinion. The purpose of these various methods and tools is to provide a transparent and repeatable mechanism for conducting analyses to determine whether the PA is likely to jeopardize the continued existence of the listed species or result in the destruction or adverse modification of designated critical habitat.

Many methods described above focus the analyses on particular aspects of the action or affected species. Key to the overall assessment, however, is an integration of the effects of the PA with each other and with the baseline set of stressors to which the species and critical habitat are also exposed (Figure 2-1 and Figure 2-2). In addition, final steps of the analysis require considering the effects of the action within the context of the reference (or without action) condition of the species and critical habitat as identified in the environmental baseline and status of species or critical habitat. That is, following the hierarchical approaches outlined above, NMFS integrates the effects of the action with the reference condition as the foundation to determine whether the action is reasonably expected to appreciably reduce the likelihood of both the survival and recovery of listed species in the wild and whether the action is likely to result in the destruction or adverse modification of critical habitat.

2.1.6 Presentation of the Analysis in this Opinion

Biological opinions are constructed around several basic sections that represent specific requirements placed on the analysis by the ESA and implementing regulations. These sections contain different portions of the overall analytical approach described here. This section is intended as a basic guide to the other sections of this Opinion and the analyses that can be found in each section. Every step of the analytical approach described above is presented in this Opinion in either detail or summary form.

Description of the Proposed Action—This section summarizes the proposed Federal action and any interrelated or interdependent actions. This description is the first step in the analysis where we consider the various elements of the action and determine the stressors expected to result from those elements. The nature, timing, duration, and location of those stressors define the action area and provide the basis for our exposure analyses.

Rangewide Status of the Species and Critical Habitat—This section provides the reference condition for the species and critical habitat at the listing and designation scale. For example, NMFS evaluates the current viability of each salmonid ESU/DPS given its exposure to human activities and natural phenomena such as variations in climate and ocean conditions, throughout its geographic distribution. These reference conditions form the basis for determining whether the PA is likely to jeopardize the continued existence of the species or result in the destruction or adverse modification of critical habitat. Other key analyses presented in this section include critical information on the biological and ecological requirements of the species and critical habitat and the impacts to species and critical habitat from existing stressors.

Environmental Baseline—This section provides the reference condition for the species and critical habitat within the action area. By regulation, the environmental baseline includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area; the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation (except the effects of the PA); and the impact of state or private actions, which are contemporaneous with the consultation in process on the species and critical habitat. This section will also include anticipated effects of climate change on the species and critical habitat within the action area. In this Opinion, some analysis may be contained within the Status of the Species and Critical Habitat section, due to the large size of the action area (which entirely or almost entirely encompasses the freshwater geographic ranges of some listed fish species). This section also summarizes the impacts from stressors that will be ongoing in the same areas and times as the effects of the PA. This information forms part of the foundation of our exposure, response, and risk analyses.

Effects of the Proposed Action—This section details the results of the exposure, response, and risk analyses NMFS conducted for effects of the PA on individuals and proportion of the listed species population and PBFs and value for the conservation of the species of critical habitat within the action area. This will include the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR §402.02). Indirect effects are those that are caused by the PA and are later in time, but still are reasonably certain to occur. Discussion of results will include identification of uncertainties associated with analytical methods or interpretation and will highlight instances of application of the precautionary principle to give the benefit of the doubt to the species. In the case of the CWF

PA, climate change effects as modeled for a 2030 climate scenario will be incorporated into the analysis by explicit modeling of that condition for the PA. Based on previous climate change modeling for the Central Valley (DWR 2013), NMFS expects that climate conditions will follow a similar trajectory of higher temperatures and shifted precipitation type timing beyond 2030.

Cumulative Effects—This section summarizes the impacts of future non-Federal actions reasonably certain to occur within the action area, as required by regulation. Similar to the rest of the analysis, if cumulative effects are expected, NMFS determines the exposure, response, and risk posed to individuals of the species and features of critical habitat. Future Federal actions that are unrelated to the PA are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Integration and Synthesis of Effects—Section 2.7, Integration and Synthesis, is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the PA. In this section, we add the effects of the action to the environmental baseline and the cumulative effects, taking into account the status of the species and critical habitat, to formulate NMFS' Opinion as to whether the PA is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its reproduction, numbers, or distribution; or (2) appreciably diminish the value of designated critical habitat for the conservation of the species. Discussion will include identification of uncertainties associated with the integration of effects and will highlight instances of application of the precautionary principle to give the benefit of the doubt to the species.

2.2 Rangewide Status of the Species and Critical Habitat

This Opinion examines the status of each species that would be adversely affected by the PA. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' current "reproduction, numbers, or distribution" as described in 50 CFR §402.02. The Opinion also examines the condition of critical habitat throughout the designated area, including the various watersheds and coastal and marine environments that make up the designated area, and discusses the current function of the essential physical and biological features.

The designations of critical habitat for some species use the term "primary constituent elements" (PCEs) or "essential features." The recently revised critical habitat regulations (81 FR 7414; February 11, 2016) replace this term with PBFs. The shift in terminology does not change the approach used in conducting a ''destruction or adverse modification'' analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this Opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

2.2.1 Sacramento River Winter-run Chinook Salmon

- First listed as threatened (54 FR 32085; August 4, 1989)
- Reclassified as endangered (59 FR 440; January 4, 1994); reaffirmed as endangered (70 FR 37160; June 28, 2005)

- Designated critical habitat (58 FR 33212; June 16, 1993)

The federally listed evolutionary significant unit (ESU) of Sacramento River winter-run Chinook salmon and designated critical habitat for this ESU occur in the action area and may be affected by the proposed action. Detailed information regarding ESU listing and critical habitat designation history, designated critical habitat, ESU life history, and viable salmonid population (VSP) parameters can be found in Appendix B: Rangewide Status of the Species and Critical Habitat.

Historically, Sacramento River winter-run Chinook salmon population estimates were as high as 120,000 fish in the 1960s, but declined to less than 200 fish by the 1990s (NMFS 2011a). In recent years, since carcass surveys began in 2001, the highest adult escapement occurred in 2005 and 2006 with 15,839 and 17,296, respectively (CDFG 2012). However, from 2007 to 2013, the population has shown a precipitous decline, averaging 2,486 during this period, with a low of 827 adults in 2011 (CDFG 2012). This recent declining trend is likely due to a combination of factors such as poor ocean productivity (Lindley et al. 2009), drought conditions from 2007 to 2009, and low in-river survival rates (NMFS 2011c). In 2014 and 2015, the population was approximately 3,000 adults, slightly above the 2007 to 2012 average, but below the high (17,296) for the last 10 years (CDFW 2016).

The year 2014 was the third year of a drought that increased water temperatures in the upper Sacramento River, and egg-to-fry survival to the Red Bluff Diversion Dam (RBDD) was approximately 5 percent (NMFS 2016d). Due to the anticipated lower than average survival in 2014, hatchery production from Livingston Stone National Fish Hatchery (LSNFH) was tripled (i.e., 612,056 released) to offset the impact of the drought (CVP and SWP Drought Contingency Plan 2014). In 2014, hatchery production represented 83 percent of the total in-river juvenile production. In 2015, egg-to-fry survival was the lowest on record (approximately 4 percent) due to the inability to release cold water from Shasta Dam in the fourth year of a drought. As expected, winter-run Chinook salmon returns in 2016 were a low, as they show the impact of 1,546 (CDFW 2017), due to drought impacts on juveniles from brood year 2013 (NMFS 2016d).

Although impacts from hatchery fish (i.e., reduced fitness, weaker genetics, smaller size, less ability to avoid predators) are often cited as having deleterious impacts on natural in-river populations (Matala et al. 2012), the winter-run Chinook salmon conservation program at LSNFH is strictly controlled by the USFWS to reduce such impacts. The average annual hatchery production at LSNFH is approximately 176,348 per year (2001 to 2010 average) compared to the estimated natural production that passes RBDD, which is 4.7 million per year based on the 2002 to 2010 average (Poytress and Carrillo 2011). Therefore, hatchery production typically represents approximately 3 to 4 percent of the total in-river juvenile winter-run production in any given year. However, the average over the last 12 years (about four generations) is 13 percent, with the most recent generation at 20 percent hatchery influence, making the population at a moderate risk of extinction.

The distribution of winter-run spawning and initial rearing historically was limited to the upper Sacramento River (upstream of Shasta Dam), McCloud River, Pitt River, and Battle Creek, where springs provided cold water throughout the summer, allowing for spawning, egg incubation, and rearing during the mid-summer period (Yoshiyama et al. 1998). The construction of Shasta Dam in 1943 blocked access to all of these waters except Battle Creek, which currently has its own impediments to upstream migration (i.e., a number of small hydroelectric dams situated upstream of the Coleman National Fish Hatchery (CNFH) weir). The Battle Creek Salmon and Steelhead Restoration Project (BCSSRP) is currently removing these impediments, restoring spawning and rearing habitat suitable for winter-run Chinook salmon in Battle Creek, which will be reintroduced to establish an additional population. Approximately 299 miles of former tributary spawning habitat above Shasta Dam are inaccessible to winter-run Chinook salmon. Yoshiyama et al. (2001) estimated that in 1938, the upper Sacramento River had a "potential spawning capacity" of approximately 14,000 redds equal to 28,000 spawners. Since 2001, the majority of winter-run chinook salmon redds have occurred in the first 10 miles downstream of Keswick Dam. Most components of the winter-run Chinook salmon life history (e.g., spawning, incubation, freshwater rearing) have been compromised by the construction of Shasta Dam.

The greatest risk factor for winter-run Chinook salmon lies within its spatial structure (NMFS 2011a). The winter-run Chinook salmon ESU is comprised of only one population that spawns below Keswick Dam. The remnant and remaining population cannot access 95 percent of their historical spawning habitat and must therefore be artificially maintained in the upper Sacramento River by spawning gravel augmentation, hatchery supplementation, and regulation of the finite cold water pool behind Shasta Dam to reduce water temperatures.

Winter-run Chinook salmon require cold water temperatures in the summer that simulate their upper basin habitat, and they are more likely to be exposed to the impacts of drought in a lower basin environment. Battle Creek is currently the most feasible opportunity for the ESU to expand its spatial structure, but restoration is not scheduled to be completed until 2020. The Central Valley Salmon and Steelhead Recovery Plan (Recovery Plan) includes criteria for recovering the winter-run Chinook salmon ESU, including re-establishing a population into historical habitats in Battle Creek as well as upstream of Shasta Dam (NMFS 2014).

Winter-run Chinook salmon embryonic and larval life stages that are most vulnerable to warmer water temperatures occur during the summer, which makes the species particularly at risk from climate warming. The only remaining population of winter-run Chinook salmon relies on the cold water pool in Shasta Reservoir, which buffers the effects of warm temperatures in most years. The exception occurs during drought years, which are predicted to occur more often with climate change (Yates et al. 2008). The long-term projection of how the CVP and SWP will operate incorporates the effects of climate change in three possible forms: less total precipitation; a shift to more precipitation in the form of rain rather than snow; or, earlier spring snow melt (Reclamation 2008). Additionally, air temperature appears to be increasing at a greater rate than what was previously analyzed (Lindley 2008, Beechie et al. 2012, Dimacali 2013). These factors will compromise the quantity and/or quality of winter-run Chinook salmon habitat available downstream of Keswick Dam. It is imperative for additional populations of winter-run Chinook salmon to be re-established into historical habitat in Battle Creek and above Shasta Dam for long-term viability of the ESU (NMFS 2014a).

2.2.1.1 Summary of the Sacramento River Winter-run Chinook Salmon Evolutionarily Significant Unit Viability

There are several criteria that would qualify the winter-run Chinook salmon population at moderate risk of extinction (continued low abundance, a negative growth rate over two complete generations, significant rate of decline since 2006, increased hatchery influence on the population, and increased risk of catastrophe), and because there is still only one population that spawns below Keswick Dam, the Sacramento River winter-run Chinook salmon ESU is at a high risk of extinction in the long term. The extinction risk for the winter-run Chinook salmon ESU has increased from moderate risk to high risk of extinction since 2005, and several listing factors have contributed to the recent decline, including drought, poor ocean conditions, and hatchery influence (NMFS 2016a). Thus, large-scale fish passage and habitat restoration actions are necessary for improving the winter-run Chinook salmon ESU viability (NMFS 2016a).

2.2.1.2 Critical Habitat and Physical or Biological Features for Sacramento River Winter-run Chinook Salmon

The critical habitat designation for Sacramento River winter-run Chinook salmon lists the PBFs (58 FR 33212, 33216-33217; June 16, 1993), which are described in Appendix B. This designation includes the following waterways, bottom and water of the waterways, and adjacent riparian zones: the Sacramento River from Keswick Dam (river mile (RM) 302) to Chipps Island (RM 0) at the westward margin of the Delta; all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge from San Pablo Bay to the Golden Gate Bridge (58 FR 33212; June 16, 1993). NMFS clarified that “adjacent riparian zones” are limited to only those areas above a stream bank that provide cover and shade to the nearshore aquatic areas (58 FR 33212, 33214; June 16, 1993). Although the bypasses (e.g., Yolo, Sutter, and Colusa) are not currently designated critical habitat for winter-run Chinook salmon, NMFS recognizes that they may be utilized when inundated with Sacramento River flood flows and are important rearing habitats for juvenile winter-run. Also, juvenile winter-run Chinook salmon may use tributaries of the Sacramento River for non-natal rearing (Maslin et al. 1997, Pacific States Marine Fisheries Commission 2014).

2.2.1.3 Summary of Sacramento River Winter-run Chinook Salmon Critical Habitat

Currently, many of the PBFs of winter-run Chinook salmon critical habitat are degraded and provide limited high quality habitat. Factors that lessen the quality of migratory corridors for juveniles include unscreened diversions, altered flows in the Delta, and the lack of floodplain habitat. In addition, water operations that limit the extent of cold water below Shasta Dam have reduced the available spawning habitat (based on water temperature). Although the current conditions of winter-run Chinook salmon critical habitat are significantly degraded, the spawning habitat, migratory corridors, and rearing habitat that remain are considered to have high intrinsic value for the conservation of the species.

2.2.2 Central Valley Spring-run Chinook Salmon

- Listed as threatened (64 FR 50394; September 16, 1999); reaffirmed (70 FR 37160; June 28, 2005)
- Designated critical habitat (70 FR 52488; September 2, 2005)

The federally listed ESU of CV spring-run Chinook salmon and designated critical habitat for this ESU occur in the action area and may be affected by the PA. Detailed information regarding ESU listing and critical habitat designation history, designated critical habitat, ESU life history, and VSP parameters can be found in Appendix B.

Historically, CV spring-run Chinook salmon were the second most abundant salmon run in the Central Valley and one of the largest on the west coast (CDFG 1990). These fish occupied the upper and middle elevation reaches (1,000 to 6,000 feet) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud and Pit rivers, with smaller populations in most tributaries with sufficient habitat for over-summering adults (Stone 1872, Rutter 1904, Clark 1929). The Central Valley drainage as a whole is estimated to have supported CV spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998). The San Joaquin River historically supported a large run of CV spring-run Chinook salmon, suggested to be one of the largest runs of any Chinook salmon on the West Coast, with estimates averaging 200,000 to 500,000 adults returning annually (CDFG 1990).

Monitoring of the Sacramento River mainstem during CV spring-run Chinook salmon spawning timing indicates some spawning occurs in the river (CDFW 2014). Genetic introgression has likely occurred here due to lack of physical separation between spring-run and fall-run Chinook salmon populations (CDFG 1998). Battle Creek and the upper Sacramento River represent persisting populations of CV spring-run Chinook salmon in the basalt and porous lava diversity group, though numbers remain low. Other Sacramento River tributary populations in Mill, Deer, and Butte creeks are likely the best trend indicators for the CV spring-run Chinook salmon ESU. Generally, these streams showed a positive escapement trend between 1991 and 2006, displaying broad fluctuations in adult abundance (Table A-3 in Appendix B). The Feather River Fish Hatchery (FRFH) CV spring-run Chinook salmon population represents an evolutionary legacy of populations that once spawned above Oroville Dam. The FRFH population is included in the ESU based on its genetic linkage to the natural spawning population and the potential for development of a conservation strategy (70 FR 37160; June 28, 2005).

The Central Valley Technical Review Team (TRT) estimated that historically there were 18 or 19 independent populations of CV spring-run Chinook salmon, along with a number of dependent populations, all within four distinct geographic regions (i.e., diversity groups) (Lindley et al. 2004). Of these populations, only three independent populations currently exist (Mill, Deer, and Butte creeks tributary to the upper Sacramento River), and they represent only the northern Sierra Nevada diversity group. Additionally, smaller populations are currently persisting in Antelope and Big Chico creeks and the Feather and Yuba rivers in the northern Sierra Nevada diversity group (CDFG 1998). The northwestern California diversity group has two low abundance persisting populations of spring-run in Clear and Beegum creeks. In the San Joaquin River basin, the southern Sierra Nevada diversity group, observations in the last decade suggest that spring-running populations may currently occur in the Stanislaus and Tuolumne rivers (Franks 2015).

The CV spring-run Chinook salmon ESU is comprised of two known genetic complexes. Analysis of natural and hatchery spring-run Chinook salmon stocks in the Central Valley indicates that the northern Sierra Nevada diversity group spring-run Chinook salmon populations in Mill, Deer, and Butte creeks retain genetic integrity as opposed to the genetic integrity of the Feather River population, which has been somewhat compromised by introgression with the fall-run ESU (Good et al. 2005a; Garza et al. 2008; Cavallo et al. 2011).

Because the populations in Butte, Deer and Mill creeks are the best trend indicators for ESU viability, NMFS can evaluate risk of extinction based on VSP in these watersheds. Over the long term, these three remaining populations are considered to be vulnerable to anthropomorphic and naturally occurring catastrophic events. The viability assessment of CV spring-run Chinook salmon, conducted during NMFS' 2010 status review (NMFS 2011), found that the biological status of the ESU had worsened since the last status review (2005), and the status review recommends that the species status be reassessed in 2 to 3 years as opposed to waiting another 5 years if the decreasing trend continued. In 2012 and 2013, most tributary populations increased in returning adults, averaging more than 13,000. However, 2014 returns were lower again—approximately 5,000 fish—indicating the ESU remains highly fluctuating. The most recent status review was conducted in 2015 (NMFS 2016b), and it looked at promising increasing populations in 2012 to 2014; however, the 2015 returning fish were extremely low (1,488), with additional pre-spawn mortality reaching record lows. Since the effects of the 2012 to 2015 drought have not been fully realized, NMFS anticipates at least several more years of very low returns, which may result in severe rates of decline (NMFS 2016b).

Spring-run Chinook salmon adults are vulnerable to climate change because they over-summer in freshwater streams before spawning in autumn (Thompson et al. 2011). CV spring-run Chinook salmon spawn primarily in the tributaries to the Sacramento River, and those tributaries without cold water refugia (usually input from springs) will be more susceptible to impacts of climate change. Even in tributaries with cool water springs, in years of extended drought and warming water temperatures, unsuitable conditions may occur. Additionally, juveniles often rear in the natal stream for one to two summers prior to emigrating, and they would be susceptible to warming water temperatures. In Butte Creek, fish are limited to low elevation habitat that is currently thermally marginal, as demonstrated by high summer mortality of adults in 2002, 2003, and 2015, and will become intolerable within decades if the climate warms as expected. Ceasing water diversion for power production from the summer holding reach in Butte Creek resulted in cooler water temperatures, more adults surviving to spawn, and extended population survival time (Mosser et al. 2013).

2.2.2.1 Summary of the Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit Viability

In summary, the extinction risk for the CV spring-run Chinook salmon ESU was evaluated for years 2012 – 2014, which remained at moderate risk of extinction (Williams et al. 2016). However, based on the severity of the drought and the low escapements, as well as increased pre-spawn mortality in Butte, Mill, and Deer creeks in 2015, there is concern that these CV spring-run Chinook salmon strongholds will deteriorate into high extinction risk in the coming years based on the population size or rate of decline criteria (NMFS 2016b).

2.2.2.2 Critical Habitat and Physical or Biological Features for Central Valley Spring-run Chinook Salmon

The critical habitat designation for CV spring-run Chinook salmon lists the PBFs (70 FR 52488; September 2, 2005), which are described in Appendix B. In summary, the PBFs include freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine habitat. The geographical range of designated critical habitat includes stream reaches of the Sacramento, Feather, Yuba, and American rivers; Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks; and the Sacramento River as well as portions of the northern Delta (70 FR 52488; September 2, 2005).

2.2.2.3 Summary of Central Valley Spring-run Chinook Salmon Critical Habitat

Currently, many of the PBFs of CV spring-run Chinook salmon critical habitat are degraded and provide limited high quality habitat. Factors that lessen the quality of migratory corridors for juveniles include unscreened or inadequately screened diversions, altered flows in the Delta, scarcity of complex in-river cover, and the lack of floodplain habitat. Although the current conditions of CV spring-run Chinook salmon critical habitat are significantly degraded, the spawning habitat, migratory corridors, and rearing habitat that remain are considered to have high intrinsic value for the conservation of the species.

2.2.3 California Central Valley Steelhead

- Originally listed as threatened (63 FR 13347; March 19, 1998); reaffirmed (71 FR 834; January 5, 2006)
- Designated critical habitat (70 FR 52488; September 2, 2005)

The federally listed DPS of California Central Valley (CCV) steelhead and designated critical habitat for this DPS occur in the action area and may be affected by the PA. Detailed information regarding DPS listing and critical habitat designation history, designated critical habitat, DPS life history, and VSP parameters can be found in Appendix B.

Historic CCV steelhead run sizes are difficult to estimate given the paucity of data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s, the CCV steelhead run size had declined to about 40,000 adults (McEwan 2001). Current abundance data for CCV steelhead are limited to returns to hatcheries and redd surveys conducted on a few rivers. The hatchery data are the most reliable because redd surveys for steelhead are often made difficult by high flows and turbid water usually present during the winter-spring spawning period.

CCV steelhead returns to CNFH increased from 2011 to 2014 (see Appendix B for further information). After hitting a low of only 790 fish in 2010, 2013 and 2014 have averaged 2,895 fish. Wild adults counted at the hatchery each year represent a small fraction of overall returns, but their numbers have remained relatively steady, typically 200 to 300 fish each year. Numbers of wild adults returning each year ranged from 252 to 610 from 2010 to 2014, respectively.

Redd counts are conducted in the American River and in Clear Creek (Shasta County). An average of 143 redds have been counted on the American River from 2002 to 2015 (data from Hannon et al. 2003; Hannon and Deason 2008; Chase 2010). An average of 178 redds have been counted in Clear Creek from 2001 to 2015 following the removal of Saeltzer Dam, which allowed steelhead access to additional spawning habitat. The Clear Creek redd count data ranges from 100 to 1,023 and indicates an upward trend in abundance since 2006 (USFWS 2015).

The returns of CCV steelhead to the FRFH experienced a sharp decrease from 2003 to 2010, with only 679, 312, and 86 fish returning in 2008, 2009 and 2010, respectively. In recent years, however, returns have experienced an increase, with 830, 1,797, and 1,505 fish returning in 2012, 2013, and 2014, respectively. Overall, steelhead returns to hatcheries have fluctuated so much from 2001 to 2015 that no clear trend is present.

An estimated 100,000 to 300,000 naturally produced juvenile steelhead are estimated to leave the Central Valley annually, based on rough calculations from sporadic catches in trawl gear (Good et al. 2005). Nobriga and Cadrett (2001) used the ratio of adipose fin-clipped (hatchery) to unclipped (wild) steelhead smolt catch ratios in the USFWS Chipps Island trawl from 1998 through 2000 to estimate that about 400,000 to 700,000 steelhead smolts are produced naturally each year in the Central Valley. Trawl data indicate that the level of natural production of steelhead has remained very low since the 2011 status review, suggesting a decline in natural production based on consistent hatchery releases. Catches of steelhead at the fish collection facilities in the southern Delta are another source of information on the production of wild steelhead relative to hatchery steelhead (CDFW 2017). The overall catch of steelhead has declined dramatically since the early 2000s, with an overall average of 2,705 in the last 10 years. The percentage of wild (unclipped) fish in salvage has fluctuated, but has leveled off to an average of 36 percent since a high of 93 percent in 1999.

About 80 perent of the historical spawning and rearing habitat once used by CCV steelhead in the Central Valley is now upstream of impassible dams (Lindley et al. 2006). Many historical populations of CCV steelhead are entirely above impassable barriers and may persist as resident or adfluvial rainbow trout, although they are presently not considered part of the DPS. Steelhead are well-distributed throughout the Central Valley below the major rim dams (Good et al. 2005, NMFS 2016a). Most of the steelhead populations in the Central Valley have a high hatchery component, including Battle Creek (adults intercepted at the CNFH weir), the American River, Feather River, and Mokelumne River.

The CCV steelhead abundance and growth rates continue to decline, largely the result of a significant reduction in the amount and diversity of habitats available to these populations (Lindley et al. 2006). Recent reductions in population size are supported by genetic analysis (Nielsen et al. 2003). Garza and Pearse (2008) analyzed the genetic relationships among CCV steelhead populations and found that unlike the situation in coastal California watersheds, fish below barriers in the Central Valley were often more closely related to below barrier fish from other watersheds than to O. mykiss above barriers in the same watershed. This pattern suggests the ancestral genetic structure is still relatively intact above barriers, but may have been altered below barriers by stock transfers. The genetic diversity of CCV steelhead is also compromised by hatchery origin fish, placing the natural population at a high risk of extinction (Lindley et al. 2007). Steelhead in the Central Valley historically consisted of both summer-run and winter-run Chinook salmon migratory forms. Only winter-run (ocean maturing) steelhead currently are found in California Central Valley rivers and streams as summer-run have been extirpated (McEwan and Jackson 1996; Moyle 2002).

Although CCV steelhead will experience similar effects of climate change to Chinook salmon in the Central Valley, as they are also blocked from the vast majority of their historic spawning and rearing habitat, the effects may be even greater in some cases, as juvenile steelhead need to rear in the stream for one to two summers prior to emigrating as smolts. In the Central Valley, summer and fall temperatures below the dams in many streams already exceed the recommended temperatures for optimal growth of juvenile steelhead, which range from 57 degrees Fahrenheit (°F) to 66°F (14 degrees Celsius (°C) to 19°C). Several studies have found that steelhead require colder water temperatures for spawning and embryo incubation than salmon (McCullough et al. 2001). In fact, McCullough et al. (2001) recommended an optimal incubation temperature at or below 52°F to 55°F (11°C to 13°C). Successful smoltification in steelhead may be impaired by temperatures above 54°F (12°C), as reported in Richter and Kolmes (2005). As stream temperatures warm due to climate change, the growth rates of juvenile steelhead could increase in some systems that are currently relatively cold, but potentially at the expense of decreased survival due to higher metabolic demands and greater presence and activity of predators. Stream temperatures that are currently marginal for spawning and rearing may become too warm to support wild steelhead populations.

2.2.3.1 Summary of California Central Valley Steelhead Distinct Population Segment Viability

All indications are that natural CCV steelhead have continued to decrease in abundance and in the proportion of natural fish over the past 25 years (Good et al. 2005; NMFS 2016a); the long-term trend remains negative. Hatchery production and returns are dominant. Most wild CCV populations are very small and may lack the resiliency to persist for protracted periods if subjected to additional stressors, particularly widespread stressors such as climate change. The genetic diversity of CCV steelhead has likely been impacted by low population sizes and high numbers of hatchery fish relative to wild fish.

In summary, the status of the CCV steelhead DPS appears to have remained unchanged since the 2011 status review, and the DPS is likely to become endangered within the near future throughout all or a significant portion of its range (NMFS 2016a).

2.2.3.2 Critical Habitat and Physical or Biological Features for California Central Valley Steelhead

The critical habitat designation for CCV steelhead lists the PBFs (70 FR 52488; September 2, 2005), which are described in Appendix B. In summary, the PBFs include freshwater spawning sites; freshwater rearing sites; freshwater migration corridors; and estuarine areas. The geographical extent of designated critical habitat includes the following: the Sacramento, Feather, and Yuba rivers and the Deer, Mill, Battle, and Antelope creeks in the Sacramento River basin; the San Joaquin River, including its tributaries but excluding the mainstem San Joaquin River above the Merced River confluence; and the waterways of the Delta.

2.2.3.3 Summary of California Central Valley Steelhead Critical Habitat

Many of the PBFs of CCV steelhead critical habitat are degraded and provide limited high quality habitat. Passage to historical spawning and juvenile rearing habitat has been largely reduced due to construction of dams throughout the Central Valley. Levee construction has also degraded the freshwater rearing and migration habitat and estuarine areas as riparian vegetation has been removed, reducing habitat complexity and food resources and resulting in many other ecological effects. Contaminant loading and poor water quality in central California waterways pose threats to lotic fish, their habitat, and food resources. Additionally, due to reduced access to historical habitats, genetic introgression is occurring because naturally produced fish are interacting with hatchery-produced fish, which has the potential to reduce the long-term fitness and survival of this species.

Although the current conditions of CCV steelhead critical habitat are significantly degraded, the spawning habitat, migratory corridors, and rearing habitat that remain in the Sacramento-San Joaquin River watersheds and the Delta are considered to have high intrinsic value for the conservation of the species as they are critical to ongoing recovery efforts.

2.2.4 Southern Distinct Population Segment of North American Green Sturgeon

- Listed as threatened (71 FR 17757; April 7, 2006)
- Designated critical habitat (74 FR 52300; October 9, 2009)

The federally listed sDPS of North American green sturgeon and designated critical habitat for this DPS occur in the action area and may be affected by the PA. Detailed information regarding DPS listing and critical habitat designation history, designated critical habitat, DPS life history, and VSP parameters can be found in Appendix B.

Green sturgeon are known to range from Baja California to the Bering Sea along the North American continental shelf. During late summer and early fall, subadults and non-spawning adult green sturgeon can frequently be found aggregating in estuaries along the Pacific coast (Emmett et al. 1991, Moser and Lindley 2006). Using polyploid microsatellite data, Israel et al. (2009) found that green sturgeon within the Central Valley of California belong to the sDPS. Additionally, acoustic tagging studies have found that green sturgeon found spawning within the Sacramento River are exclusively sDPS green sturgeon (Lindley et al. 2011). In waters inland from the Golden Gate Bridge in California, sDPS green sturgeon are known to range through the estuary and the Delta and up the Sacramento, Feather, and Yuba rivers (Israel et al. 2009, Cramer Fish Sciences 2011, Seeholtz et al. 2014). It is unlikely that green sturgeon utilize areas of the San Joaquin River upriver of the Delta with regularity, and spawning events are thought to be limited to the upper Sacramento River and its tributaries. There is no known modern usage of the upper San Joaquin River by green sturgeon, and adult spawning has not been documented there (Jackson and Eenennaam 2013).

Recent research indicates that the sDPS is composed of a single, independent population, which principally spawns in the mainstem Sacramento River and also breeds opportunistically in the Feather River and possibly the Yuba River (Cramer Fish Sciences 2011, Seeholtz et al. 2014). Concentration of adults into a very few select spawning locations makes the species highly vulnerable to poaching and catastrophic events. The apparent, but unconfirmed, extirpation of spawning populations from the San Joaquin River narrows the available habitat within their range, offering fewer habitat alternatives. Whether sDPS green sturgeon display diverse phenotypic traits, such as ocean behavior, age at maturity, and fecundity, or if there is sufficient diversity to buffer against long-term extinction risk is not well understood. It is likely that the diversity of sDPS green sturgeon is low, given recent abundance estimates (NMFS 2015).

Trends in abundance of sDPS green sturgeon have been estimated from two long-term data sources: (1) salvage numbers at the state and Federal pumping facilities (CDFW 2017), and (2) by incidental catch of green sturgeon by the CDFW's white sturgeon sampling/tagging program (Dubois and Harris 2015, 2016). Historical estimates from these sources are likely unreliable because the sDPS was likely not taken into account in incidental catch data, and salvage does not capture rangewide abundance in all water year types. A decrease in sDPS green sturgeon abundance has been inferred from the amount of take observed at the south Delta pumping facilities, the Skinner Delta Fish Protection Facility (SDFPF), and the Tracy Fish Collection Facility (TFCF). This data should be interpreted with some caution. Operations and practices at the facilities have changed over the project lifetime, which may affect salvage data. These data likely indicate a high production year versus a low production year qualitatively, but cannot be used to rigorously quantify abundance.

Since 2010, more robust estimates of sDPS green sturgeon have been generated. As part of a doctoral thesis at the University of California at Davis (UC Davis), Ethan Mora has been using acoustic telemetry to locate green sturgeon in the Sacramento River and to derive an adult spawner abundance estimate (Mora et al. 2015). Preliminary results of these surveys estimate an average annual spawning run of 223 (using dual-frequency identification sonar (DIDSON) and 236 (using telemetry) fish. This estimate does not include the number of spawning adults in the lower Feather or Yuba rivers, where green sturgeon spawning was recently confirmed (Seesholtz et al. 2014).

The parameters of green sturgeon population growth rate and carrying capacity in the Sacramento Basin are poorly understood. Larval count data shows enormous variance among sampling years. In general, sDPS green sturgeon year class strength appears to be highly variable with overall abundance dependent upon a few successful spawning events (NMFS 2010). Other indicators of productivity such as data for cohort replacement ratios and spawner abundance trends are not currently available for sDPS green sturgeon.

The sDPS green sturgeon spawn primarily in the Sacramento River in the spring and summer. The Anderson-Cottonwood Irrigation District Diversion Dam (ACID) is considered the upriver extent of green sturgeon passage in the Sacramento River (71 FR 17757; April 7, 2006). The upriver extent of green sturgeon spawning, however, is approximately 30 kilometers downriver of ACID where water temperature is higher than ACID during late spring and summer (Heublein et al. in review). Thus, if water temperatures increase with climate change, temperatures adjacent to ACID may remain within tolerable levels for the embryonic and larval life stages of green sturgeon, but temperatures at spawning locations lower in the river may be more affected. It is uncertain, however, if green sturgeon spawning habitat exists closer to ACID, which could allow spawning to shift upstream in response to climate change effects. Successful spawning of green sturgeon in other accessible habitats in the Central Valley (i.e., the Feather River) is limited, in part, by late spring and summer water temperatures (NMFS 2015). Similar to salmonids in the Central Valley, green sturgeon spawning in tributaries to the Sacramento River is likely to be further limited if water temperatures increase and higher elevation habitats remain inaccessible.

2.2.4.1 Summary of Green Sturgeon Southern Distinct Population Segment Viability

The viability of sDPS green sturgeon is constrained by factors such as a small population size, lack of multiple populations, and concentration of spawning sites into just a few locations. The risk of extinction is believed to be moderate (NMFS 2010). Although threats due to habitat alteration are thought to be high and indirect evidence suggests a decline in abundance, there is much uncertainty regarding the scope of threats and the viability of population abundance indices (NMFS 2010). Lindley et al. (2008), in discussing winter-run Chinook salmon, states that an ESU (or DPS) represented by a single population at moderate risk of extinction is at high risk of extinction over a large timescale; this would apply to the sDPS for green sturgeon. The most recent 5-year status review for sDPS green sturgeon found that some threats to the species have recently been eliminated such as take from commercial fisheries and removal of some passage barriers (NMFS 2015). Since many of the threats cited in the original listing still exist, the threatened status of the DPS is still applicable (NMFS 2015).

2.2.4.2 Critical Habitat and Physical or Biological Features for Southern Distinct Population Segment Green Sturgeon

The critical habitat designation for sDPS green sturgeon lists the PBFs (74 FR 52300; October 9, 2009), which are described in Appendix B. In summary, the PBFs include the following for both freshwater riverine systems and estuarine habitats: food resources, water flow, water quality, migratory corridor, depth, and sediment quality. Additionally, substrate type or size is also a PBF for freshwater riverine systems. In addition, the PBFs include migratory corridor, water quality, and food resources in nearshore coastal marine areas. The geographical range of designated critical habitat includes the following:

- In freshwater, the geographical range includes:
  - The Sacramento River from the Sacramento I-Street bridge to Keswick Dam, including the Sutter and Yolo bypasses and the lower American River from the confluence with the mainstem Sacramento River upstream to the highway 160 bridge
  - The Feather River from its confluence with the Sacramento River upstream to Fish Barrier Dam
  - The Yuba River from its confluence with the Feather River upstream to Daguerre Point Dam
  - The Delta (as defined by California Water Code section 12220, except for listed excluded areas)
- In coastal bays and estuaries, the geographical range includes:
  - San Francisco, San Pablo, Suisun, and Humboldt bays in California
  - Coos, Winchester, Yaquina, and Nehalem bays in Oregon
  - Willapa Bay and Grays Harbor in Washington
  - the lower Columbia River estuary from the mouth to river kilometer (RK) 74

In coastal marine waters, the geographical range includes all United States coastal marine waters out to the 60-fathom-depth bathymetry line from Monterey Bay north and east to include waters in the Strait of Juan de Fuca, Washington.

2.2.4.3 Summary of Southern Distinct Population Segment Green Sturgeon Critical Habitat

Currently, many of the PBFs of sDPS green sturgeon are degraded and provide limited high quality habitat. Factors that lessen the quality of migratory corridors for juveniles include unscreened or inadequately screened diversions, altered flows in the Delta, and presence of contaminants in sediment. Although the current conditions of green sturgeon critical habitat are significantly degraded, the spawning habitat, migratory corridors, and rearing habitat that remain in both the Sacramento-San Joaquin River watersheds, the Delta, and nearshore coastal areas are considered to have high intrinsic value for the conservation of the species.

2.2.5 Southern Resident Killer Whales

- Listed as endangered (70 FR 69903; November 18, 2005)
- Designated critical habitat (71 FR 69054; November 29, 2006)

The federally listed Southern Resident killer whale DPS (herein referred to as Southern Residents) occurs in the action area and may be affected by the PA. The Southern Resident killer whale Recovery Plan (NMFS 2008) and the most recent 5-year status review (NMFS 2016) provides detailed information on the current status of and threats to Southern Residents.

In killer whale populations, groups of related matrilines form pods, and three pods (J, K, and L) make up the Southern Resident community. The historical abundance of Southern Residents is estimated from a low population level of 140 animals to an unknown upper bound. The minimum historical estimate (approximately 140) included whales killed or removed for public display in the 1960s and 1970s, which were added to the remaining population at the time the captures ended (NMFS 2008). Several lines of evidence – known kills and removals (Olesiuk et al. 1990), salmon declines (Krahn et al. 2002), and genetics (Krahn et al. 2002; Fort et al. 2011) – indicate that the population used to be much larger than it is now, but there is currently no reliable estimate of the upper bound of the historical population size. Over the last 5 decades, the Southern Resident population has remained at a similarly low population size fluctuating from about 80 to 90 individuals (Olesiuk et al. 1990, Center for Whale Research 2008).

NMFS has continued to fund the Center for Whale Research (CWR) to conduct an annual census of the Southern Resident population, and census data are available through July 2016. Between the July 2015 census count of 81 whales and July 2016, three whales died (a post-reproductive female and a young adult male from L pod and a J pod calf), and five Southern Residents were born (3 from J pod and 2 from L pod), bringing the number of SRKW to 83 (CWR, unpublished data). At the end of December 2016 the population numbered 78 individuals due to deaths of five individuals from J pod that were confirmed or assumed to have died in late 2016 (K Pod comprised 19 individuals, L Pod comprised 35 individuals, and J Pod comprised 24 individuals). The Southern Resident killer whale population has experienced an increase in reproductive females since the beginning of the annual censuses in the 1970s. There is weak evidence of a decline in fecundity rates through time for reproductive females. This decline is linked to fluctuations in abundance of Chinook prey, and possibly other factors (Ward et al. 2013). However, there were six births in 2015 which is higher than observed in recent times. It is unclear how these additions to the population will affect the Southern Resident population dynamics. .

Southern Residents spend a substantial amount of time from late spring to early autumn in inland waterways of Washington State and British Columbia, including the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound (Bigg 1982; Krahn et al. 2002). Southern Residents occur throughout the coastal waters of Washington, Oregon, and Vancouver Island and are known to travel as far south as central California and as far north as southeast Alaska. Although the entire Southern Resident DPS has the potential to occur in coastal waters at any time during the year, occurrence in coastal waters is more likely from November to May. Satellite-linked tag deployments on K and L pod animals indicate that those pods in particular use the coastal waters along Washington, Oregon, and California during non-summer months (NMFS Northwest Fisheries Science Center, 2017). Detection rates of K and L pods on passive acoustic recorders indicate the whales occur with greater frequency off the Columbia River delta and Westport, Oregon, and are most common in March (Hanson et al. 2013). Results of recent satellite tagging indicate the limited occurrence along the outer coast by J pod (NMFS Northwest Fisheries Science Center 2017) where J pod has also only been detected on one of seven passive acoustic recorders positioned along the outer coast; members of the J pod do not appear to travel to Oregon or California (Hanson et al. 2013).

As described in the final Recovery Plan for Southern Residents (NMFS 2008), several factors may be limiting recovery of the Southern Resident DPS. These factors include the following: quantity and quality of prey, toxic chemicals that accumulate in top predators, and disturbance from sound and vessels. Oil spills are also a risk factor. It is likely that multiple threats are acting together to impact the whales. Although it is not clear which threat or threats are most significant to the survival and recovery of Southern Residents, all identified threats are potential limiting factors in their population dynamics (NMFS 2008).

Significant attention has been paid in recent years to the relationship between the Southern Resident population and the abundance of important prey, especially Chinook salmon. Recently, Ford et al. (2016) confirmed the importance of Chinook salmon to Southern Residents in the summer months using DNA sequencing from whale feces. The researchers found that more than 90 percent of the whale's inferred diet consisted of salmonids; almost 80 percent was Chinook salmon. Researchers also found evidence of prey shifting at the end of summer towards coho salmon for all years analyzed; coho salmon contributed to more than 40 percent of the diet in late summer. Chum, sockeye, and steelhead made up relatively small contributions to the sequences (less than 3 percent each). Although less is known about the diet of Southern Residents off the Pacific coast during winter, the available information from observation of predation events indicates that salmon, and Chinook salmon in particular, are also important when the whales occur in coastal waters (Hanson et al. 2010).

Chinook salmon's relatively high energy content has been considered a reasonable explanation for killer whales' consumption of primarily Chinook salmon at times when Chinook are not the most abundant salmon available (Ford and Ellis 2006). Chinook salmon have the highest value of total energy content compared to other salmonids because of their larger body size and higher energy density (expressed in kcal/kg) (O'Neill et al. 2014). For a killer whale to obtain the total energy value of one average-sized adult Chinook salmon, the whale would need to consume approximately 2.7 average-sized coho salmon, 3.1 chum salmon, 3.1 sockeye salmon, or 6.4 pink salmon (O'Neill et al. 2014).

Ford et al. (2005, 2010) evaluated 25 years of demographic data from Southern and Northern Resident killer whales and found that changes in survival largely drive their population, and the populations' survival rates were strongly correlated with coast-wide availability of Chinook salmon. Ward et al. (2009) found that Northern and Southern Resident killer whale fecundity was highly correlated with Chinook salmon abundance indices, and reported the probability of calving increased by 50 percent between low and high Chinook salmon abundance years. More recently, Ward et al. (2013) considered new stock-specific Chinook salmon indices and found strong correlations between the indices of Chinook salmon abundance, such as the West Coast Vancouver Island (WCVI) used by the Pacific Salmon Commission, and killer whale demographic rates. However, no single stock or group of stocks was identified as being most correlated with the whales' demographic rates. Further, Ward et al. (2013) stress that the relative importance of specific stocks to the whales likely changes over time.

The health of individual Southern Residents is being studied closely. As a chronic condition, nutritional stress can lead to reduced body size and condition of individuals, and lower reproductive and survival rates of a population (e.g., Trites and Donnelly 2003). Very poor body condition is detectable by a depression behind the blowhole that presents as a "peanut-head" appearance. There have been several Southern Residents that have been observed in recent years with the peanut-head condition, and the majority of these individuals died relatively soon after these observations (NMFS 2017). The bodies of the Southern Residents that died following these observations were not recovered and therefore a definitive cause of death could not be identified. More recently, photographs of whales from an unmanned aerial system (i.e., a drone) have been collected and individual whales in poor condition have been observed. Both females and males across a range of ages were found in poor body condition.

Killer whales are exposed to persistent pollutants primarily through their diet, including Chinook salmon. These harmful pollutants are stored in blubber and can later be released and become redistributed to other tissues when the whales metabolize the blubber in response to food shortages or reduced acquisition of food energy that could occur for a variety of reasons or during gestation or lactation. High levels of these pollutants have been measured in blubber biopsy samples from Southern Residents (Ross et al. 2000; Krahn et al. 2007; Krahn et al. 2009), and more recently these pollutants were measured in scat samples collected from the whales, providing another potential opportunity to evaluate exposure of Southern Residents to these pollutants (Lundin et al. 2016). High levels of persistent pollutants have the potential to affect the whales' endocrine and immune systems and reproductive fitness (Krahn et al. 2002; Mongillo et al. 2016).

As described in NMFS (2011), vessel activities may affect foraging efficiency, communication, and/or energy expenditure through the physical presence of the vessels, underwater sound created by the vessels, or both. Houghton et al. (2015) found that the noise levels killer whales receive are largely determined by the speed of the vessel. Thus, to reduce noise exposure to the whales, Houghten et al. (2015) had recommended reduced vessel speeds. In 2011, NMFS announced final regulations to protect killer whales in Washington State from the effects of various vessel activities (April 14, 2011, 76 FR 20870).

2.2.5.1 Summary of Southern Resident Killer Whale DPS Viability

The viability of the Southern Resident killer whale is evaluated through consideration of the threats identified in the recovery plan and the population status relative to down-listing criteria. Since completing the recovery plan, NMFS has prioritized actions to address the threats with highest potential for mitigation: salmon recovery, oil spill response, and reducing vessel impacts. Several threats criteria have been met, but many will take years of research and dedicated conservation efforts to satisfy. Salmon recovery is a high priority on the West Coast, and there are numerous actions underway to address threats to salmon populations and monitor their status. Recovery of depleted salmon populations is complex and a long-term process. NMFS and partners have successfully developed an oil spill response plan for killer whales; however, additional work is needed to prepare for a major spill event. NMFS has developed special vessel regulations intended to reduce disturbance of killer whales from vessel traffic. It will take time to evaluate the effectiveness of any new regulations in improving conditions for killer whales. Even with progress toward minimizing the impacts of the threats, each of the threats still pose a risk to the survival and recovery of the whales (76 FR 20870; April 14, 2011).

At the time of listing in 2005, there were 88 whales in the population; at the end of 2016, there were 78 whales. Population growth has varied during this time with both increasing and decreasing years. The most recent assessment including data through 2016 now suggests a downward trend in population growth projected over the next 50 years, in part due to the changing age and sex structure of the population, but also related to the relatively low fecundity rate observed over the period from 2011 to 2016 (NMFS 2016c). The biological downlisting and delisting criteria, including sustained growth over 14 and 28 years, respectively, have not been met (NMFS 2016). While some of the biological down-listing and delisting criteria have been met (i.e., representation in all three pods, multiple mature males in each pod), the overall status of the population is not consistent with a healthy, recovered population. Considering the status and continuing threats, the Southern Resident killer whales remain in danger of extinction. Therefore, the recommended classification for Southern Resident killer whales remains as endangered (NMFS 2016).

2.2.5.2 Critical Habitat and Physical or Biological Features for Southern Resident Killer Whale

Designated critical habitat for the Southern Resident killer whale DPS consists of three specific marine areas of Puget Sound, Washington: (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca (71 FR 69054; November 29, 2006). These areas are not part of the action area, and are not expected to be affected by the PA; therefore, critical habitat for the Southern Resident killer whale DPS will not be discussed further in this Opinion.

2.3 Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR §402.02). For purposes of this consultation, the action area includes the entire legal Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay; the action area extends upstream within the channels of the Sacramento and American rivers below Keswick and Nimbus dams, respectively (Figure 2-10).

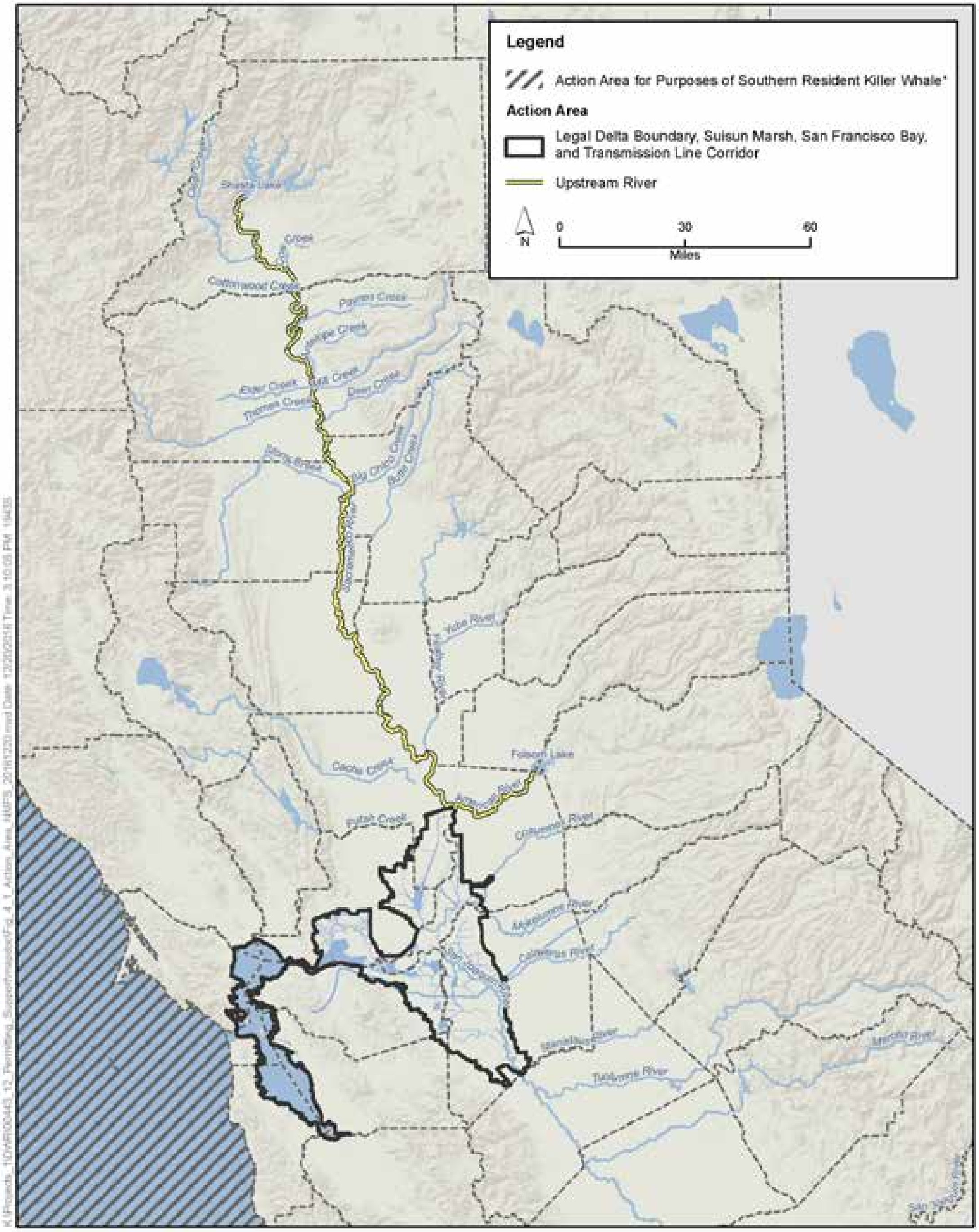


Figure 2-10. California WaterFix Action Area.

For purposes of the Southern Resident killer whale DPS only, the action area includes nearshore coastal areas in California, Oregon, and Washington (Figure 2-11).

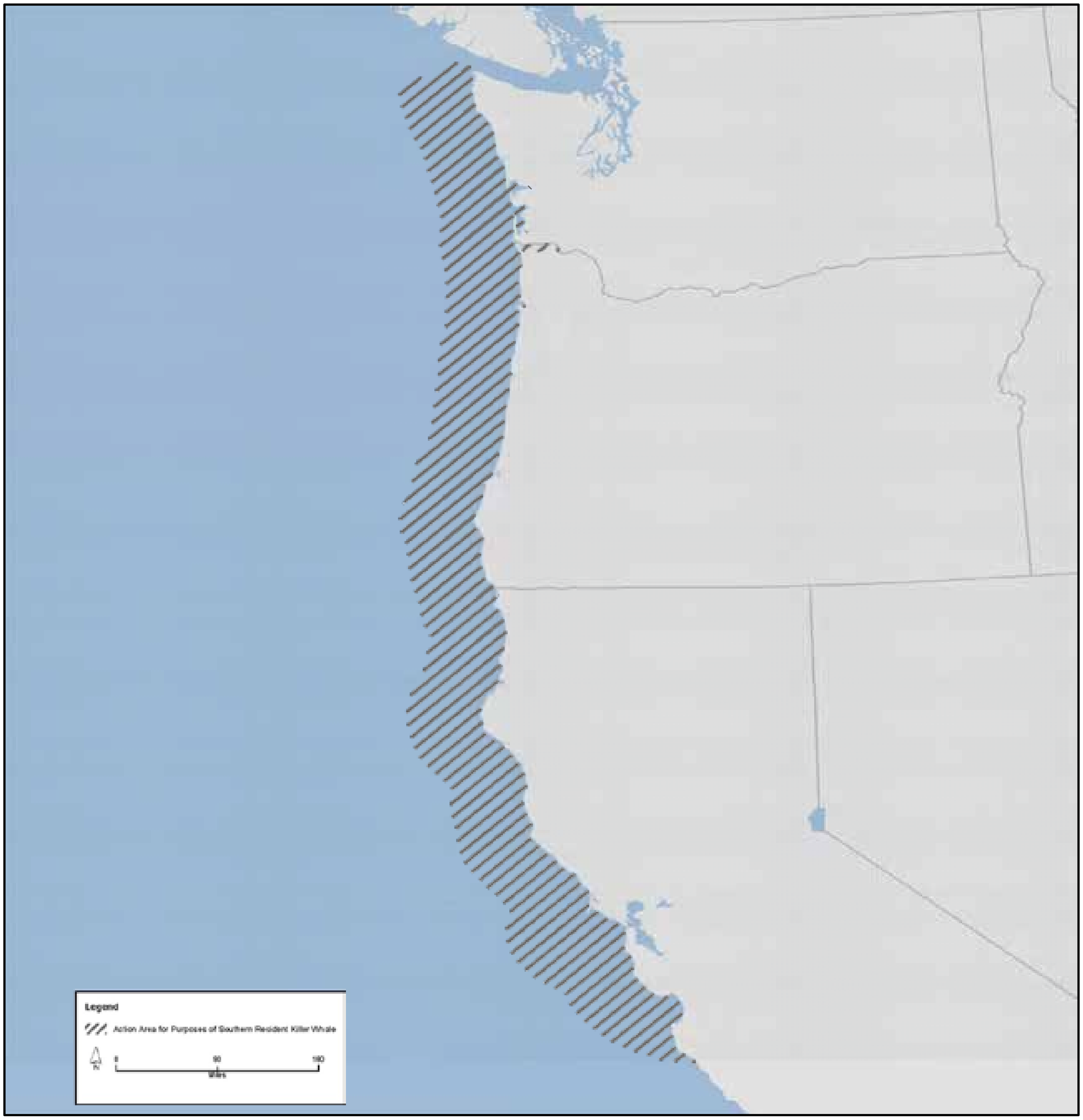


Figure 2-11. California WaterFix Action Area for Purposes of Southern Resident Killer Whale.

The action area was derived considering several factors to account for all effects of the PA. First, to determine the action area for listed fish and their designated critical habitat, the CALSIM II model was used to screen for the extent of potential effects within the Sacramento and San Joaquin rivers and their tributaries. Where CALSIM II results did not differ between the PA and No Action Alternative (NAA) conditions, no effect was assumed within the Sacramento and San Joaquin rivers and their tributaries. The similarity in CALSIM II results was assumed to indicate that the PA would not have an effect on operations and therefore would not affect species in those areas. The action area does not include those areas. This is discussed further in the BA in the introduction to Section 5.4.2, Upstream Hydrologic Changes. Additionally, the Feather River system is excluded from the action area due to the existing formal consultation on water operations in that system, as described in Section 1.3.1.2 above and in the BA in Section 4.4 Feather River Operations Consultation. The entire legal Delta and Suisun Marsh are included in the action area for fish species because the PA may affect any waterway in the Delta or Suisun Marsh. For listed anadromous species, the entire legal Delta was assumed to account for all of the potential construction effects, including the siting of offsetting measures including habitat restoration. To account for possible origination points of barge traffic serving construction activities, as detailed in Section 5.2.3 Barge Landings, of the BA, San Francisco and intervening waterways (San Francisco Bay) were included in the action area. For the Southern Resident killer whale, all nearshore coastal waters within their range in California, Oregon, and Washington are included in the action area because this distribution identifies the entire area of co-occurrence of Central Valley Chinook salmon and the Southern Resident killer whale.

2.4 Environmental Baseline

The "environmental baseline" includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR §402.02).

Because water temperatures are expected to increase in the action area due to air temperature warming (Lindley 2008, Beechie et al. 2012, Dimacali 2013) and reduced precipitation (i.e., more frequent drought conditions; Yates et al. 2008) from climate change, NMFS is including consideration of the impacts of climate change on species and habitat into the future in this section.

2.4.1 Sacramento River Winter-run Chinook Salmon

2.4.1.1 Status of Sacramento River Winter-run Chinook in the Action Area

The action area encompasses the entire critical habitat designation for winter-run Chinook salmon and includes almost all habitats utilized throughout the lifecycle of this species. Assessing the temporal occurrence of each life stage of winter-run Chinook in the action area is done through monitoring data in the Sacramento River and Delta as well as salvage data from the Tracey and Skinner fish collection facilities in the south Delta (CVP and SWP) (Table 2-5).

Table 2-5. The Temporal Occurrence of Adult (a) and Juvenile (b) Winter-run in the Sacramento River.

Relative Abundance	**High**				**Medium**				**Low**			
a) Adults freshwater												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River basin[a,b]	Medium	Medium	Medium	Medium	Medium	Medium	Medium				Medium	Medium
Upper Sacramento River spawning[c]					Low	High	High	Medium				
Delta	Medium	Medium	Medium	Medium	Low	Low	Low					Medium
b) Juvenile emigration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River at Red Bluff [d]	Low	Low	Low				Low	Medium	Medium	Medium	Medium	Medium
Sacramento River at Knights Landing[e]	High	Medium	Low							Low	Medium	High
Sacramento trawl at Sherwood Harbor[f]	Medium	High	High	Low							Medium	High
Midwater trawl at Chipps Island[g]	Medium	Medium	High	High	Low							Low

Sources: [a] (Yoshiyama et al. 1998); (Moyle 2002); [b](Myers et al. 1998) ; [c] (Williams 2006) ; [d] (Martin et al. 2001); [e] Knights Landing Rotary Screw Trap Data, CDFW (1999-2011); [f,g] Delta Juvenile Fish Monitoring Program, USFWS (1995-2012)

Adult winter-run Chinook salmon begin their upstream migration through the Sacramento/San Joaquin Delta in December and continuing through July with a peak occurring between the months of December and April (USFWS 1995, NMFS 2014b). Adult winter-run Chinook salmon return from the ocean prior to reaching full sexual maturity and hold in the Sacramento River for several months before spawning while they mature. Currently, the spawning range of winter-run Chinook salmon is confined to the Sacramento River between Red Bluff Diversion Dam (RBDD) (RM 243) and Keswick Dam (RM 302) (Vogel and Marine 1991, NMFS 2014b). Historically, spawning likely occurred upstream of Shasta Dam in spawning reaches, which are no longer accessible to anadromous fish (Yoshiyama et al. 1998), as well as in an upper tributary to the Sacramento River, Battle Creek (Lindley 2004).

The upper Sacramento River below Keswick Dam portion of the action area is critically important for the survival and recovery of this species as it contains the only known remaining spawning grounds. As winter-run spawning occurs in the summer months, naturally occurring summer flows in river reaches below Keswick Dam, where this species currently spawns, would have precluded spawning historically. This suggests that the area below Shasta and Keswick dams was likely utilized for winter-run juvenile rearing and migration only. Currently, flows in the Sacramento River are artificially managed at both Keswick and Shasta dams in order to provide appropriate spawning and egg incubation temperatures and flows through winter-run spawning grounds (Boles 1988; Yates et al. 2008; NMFS 2014b). There is an ongoing effort to restore 42 miles of salmon habitat on Battle Creek as part of the Battle Creek Salmon and Steelhead Restoration Project (Jones and Stokes 2005a,b), leading to Pacific Gas and Electricity's application to the Federal Energy Regulatory Commission to modify operations of hydropower projects on North Fork and South Fork Battle Creek (NMFS 2009e). Improving flows for and re-opening spawning and rearing habitat is expected to be utilized by winter-run Chinook salmon once reintroduced, and to aid in the recovery of this species.

There are uncertainties about Reclamation's ability to maintain an adequate coldwater pool in order to maintain suitable temperatures for winter-run Chinook salmon egg incubation, fry emergence, and juvenile rearing in the Sacramento River in critically dry years and extended drought periods. Through the 2009 Opinion on the long-term water operations of the CVP/SWP (NMFS 2009a), Reclamation has created and implemented Shasta Reservoir storage plans and year-round Keswick Dam release schedules and procedures with the goal of providing cold water for spawning and rearing (NMFS 2016e).

However, warm water releases from Shasta Dam have been a significant stressor to winter-run Chinook salmon, especially given the recent extended drought in California from 2012 through 2015 (NMFS 2016c). Warm water releases from Shasta Reservoir in 2014 and 2015 contributed to 5.9 percent and 4.2 percent egg-to-fry survival rates respectively, to RBDD. Under varying hydrologic conditions from 2002 to 2013, winter-run Chinook salmon egg-to-fry survival ranged from three to nearly 10 times higher than in 2014 and 2015. Measures taken as part of a coordinated drought response (Swart 2016) to reduce this threat and improve Shasta Reservoir cold water pool management have been to: (1) relax Wilkins Slough navigational flow requirements; (2) relax D-1641 Delta water quality requirements; (3) delay Sacramento River Settlement Contractor depletions, and transfer a volume of their water in the fall rather than increase depletions throughout the summer; (4) target slightly warmer temperatures during the SR winter-run Chinook salmon holding period (before spawning occurs); (5) replace the Spring Creek and Oak Bottom temperature control curtains in Whiskeytown Reservoir; and (6) install the Shasta Dam temperature control device curtain in 2015 (NMFS 2016e). Other efforts to reduce the likelihood of warm water releases from Shasta Dam include improving reservoir, meteorologic, and hydrologic modeling and monitoring in order to most efficiently and effectively manage the reservoir's limited amount of cold water, installation of additional temperature monitoring stations in the upper Sacramento River to better monitor real-time water temperatures, and enhanced redd, egg, and juvenile SR winter-run Chinook salmon monitoring (NMFS 2016e).

The Livingston Stone National Fish Hatchery (LSNFH) began operation in 1997 and functions to supplement the naturally occurring population of Sacramento River winter-run Chinook salmon in order to aid in its survival and recovery (California Hatchery Scientific Review Group (California HSRG) 2012). The facility is intended to be a temporary conservation measure and will cease operations once the population of winter-run is considered to be viable and fully recovered. Winter-run that are produced at LSNFH are intended to return to the upper Sacramento River as adults and become reproductively and genetically assimilated into the natural population (California Hatchery Scientific Review Group (California HSRG) 2012). In order to improve hatchery management, the USFWS has developed and implemented a secondary fish trapping location for the Livingston Stone NFH winter-run Chinook salmon supplementation program at the Anderson-Colusa Irrigation District dam to provide increased opportunity to capture a spatially representative sample and target numbers of broodstock (USFWS 2016). This hatchery program is expected to play a continuing role as a conservation hatchery to help recover winter-run Chinook salmon. The LSNFH captive broodstock and supplementation Hatchery and Genetic Management Plans are complete and currently undergoing section 7 consultation with NMFS.

Juvenile winter-run Chinook salmon use the Sacramento River for rearing and migration and small numbers have also been shown to utilize the lower American River for rearing (Reclamation 2015). Juveniles migrate downstream through the Sacramento River in late fall/early winter. Until 1978 when the State Water Resources Control Board instituted closures of the Delta Cross Channel (DCC) to protect migratory fish, the DCC posed a threat of entrainment into the interior Delta for outmigrating juvenile winter-run. Following the institution of additional operational criteria for the DCC, it now remains closed from February 1st through May 20th, protecting outmigrating juvenile winter-run and preventing entrainment (NMFS 2009a).

Juvenile winter-run Chinook salmon begin to enter the Delta in October and outmigration continues until April. Juvenile outmigration timing is thought to be strongly correlated with winter rain events that result in higher flows in the Sacramento River (del Rosario et al. 2013). Winter-run use the Delta primarily as a migration corridor as they make their way to Suisun and San Pablo Bays and eventually the Pacific Ocean. Relative abundance in the Delta is inferred through salvage monitoring data, CDFW rotary screw trap sampling, and U.S. Fish and Wildlife Service (USFWS) Delta Juvenile Fish Monitoring Program (DJFMP) data (see Appendix B for more information). Juvenile mortality in the Delta and San Francisco estuary continues to be investigated. A conclusive primary source has yet to be identified, though Delta outflow seems to play an important role (Baker and Morhardt 2001). Predation by piscivorous fish has been at the forefront of this debate and multiple studies have attempted to address the scale at which this source of mortality is affecting the population as a whole (Lindley and Mohr 2003, Demetras et al. 2016).

For winter-run Chinook salmon, the embryonic and larval life stages that are most vulnerable to warmer water temperatures occur during the summer (Boles 1988), so this run is particularly at risk from climate warming. The only remaining population of winter-run Chinook salmon relies on the cold water pool in Shasta Reservoir, which buffers the effects of warm temperatures in most years. The exception occurs during drought years, which are predicted to occur more often with climate change (Yates et al. 2008). The long-term projection of operations of the CVP/SWP expects to include the effects of climate change in one of three possible forms: less total precipitation; a shift to more precipitation in the form of rain rather than snow; or earlier spring snow melt (Reclamation 2008). Additionally, air temperature appears to be increasing at a greater rate than what was previously analyzed (Lindley 2008; Beechie et al. 2012; Dimacali 2013). These factors will compromise the quantity and/or quality of winter-run Chinook salmon habitat available downstream of Keswick Dam into the future. For this reason, it is imperative for additional populations of winter-run Chinook salmon to be re-established into historical habitat in Battle Creek and above Shasta Dam for long-term viability of the ESU (NMFS 2014). Section 2.4.4.7 includes a discussion of how additional populations are being re-established through the RPA in the (NMFS 2009b) Opinion on the long-term operations of the CVP/SWP and the associated 2011 amendments (NMFS 2009a, 2011).

2.4.1.2 Status of Sacramento River Winter-run Chinook Critical Habitat in the Action Area

The proposed action area encompasses the majority of the rangewide riverine and estuarine critical habitat PBFs for winter-run. Wide-spread degradation to these PBFs has had a major contribution to the status of the winter-run ESU, which is at high risk of extinction (NMFS 2016c). PBFs (as discussed in the Section 2.2 Rangewide Status of the Species) include: (1)

access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River, (2) the availability of clean gravel for spawning substrate (3) adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles, (4) water temperatures between 42.5 and 57.5°F (5.8 and 14.1°C) for successful spawning, egg incubation, and fry development, (5) habitat and adequate prey that are not contaminated, (6) riparian habitat that provides for successful juvenile development and survival, and (7) access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean.

Passage impediments in the northern region of the Central Valley are largely responsible for isolating the existing population from historical spawning reaches, which occurred upstream of Keswick and Shasta dams and included the upper Sacramento River, McCloud River, Pit River, Fall River and Hat Creek (Yoshiyama et al. 1996; Lindley et al. 2004; NMFS 2014b). Due to the installation of Keswick and Shasta dams, the winter-run ESU is now relegated to spawning downstream, in the Sacramento River. The majority of spawning occurs between Red Bluff (Red Bluff Diversion Dam) and Redding (below Keswick Dam) (Vogel and Marine 1991; NMFS 2014b). PBFs #2-4 for this ESU have been degraded in a number of ways. Spatially, the total area of viable spawning habitat has been significantly diminished. Physical features that are essential to the functionality of existing spawning habitat have also been degraded such as: loss of spawning gravel, and elevated water temperatures during summer months when spawning events occur (NMFS 2014b). Degradation of these features is actively mitigated through real-time temperature and flow management at Shasta and Keswick dams (NMFS 2009d) as well as gravel augmentation projects in the affected area, which have been occurring under a multi-year programmatic authority (NMFS 2016b).

PBFs related to the rearing and migration of juveniles and adults have been degraded from their historical condition within the action area as well. Adult passage impediments on the Sacramento River existed for many years at the RBDD and Anderson-Cottonwood Irrigation District's (ACID) diversion dam (NMFS 2014b). However, the RBDD was decommissioned in 2013 providing unimpaired juvenile and adult fish passage and a fish passage improvement project at the ACID was completed in 2015, so that adult winter-run Chinook salmon could migrate through the structure at a broader range of flows reaching spawning habitat upstream of that structure.

Juvenile migration corridors are impacted by reverse flows in the Delta that become exacerbated by water export operations at the CVP/SWP pumping plants. This is thought to result in impaired routing and timing for outmigrating juveniles and is evidenced by the presence of juvenile winter-run at the State and Federal fish salvage facilities. This impact is discussed in greater detail in Section 2.5.1.2.7.1 Travel Time and 2.5.1.2.7.2 Outmigration. Shoreline armoring and development has reduced the quality and quantity of floodplain habitat for rearing juveniles in the Delta and Sacramento River (Williams et al. 2009; Boughton and Pike 2013). Juveniles have access to floodplain habitat in the Yolo Bypass only during mid to high water years, and the quantity of floodplain available for rearing during drought years is currently limited. The Yolo Bypass Restoration Plan includes notching the Fremont Weir, which will provide access to floodplain habitat for juvenile salmon over a longer period (Department of Water and Resources and Bureau of Reclamation 2012).

2.4.2 Central Valley Spring-run Chinook Salmon and California Central Valley Steelhead

2.4.2.1 Status of Central Valley Spring-run Chinook in the Action Area

The Sacramento River, American River and Sacramento/San Joaquin Delta are included in the action area and aside from the American River (which only currently supports non-natal rearing of juveniles), are extensively utilized by various life stages of the Central Valley spring-run Chinook salmon ESU. Assessing the temporal occurrence of each life stage of spring-run Chinook salmon in the action area is done through analysis of monitoring data in the Sacramento River and select tributaries; monitoring in the Delta; and salvage data from the Tracey and Skinner fish collection facilities in the south Delta (CVP and SWP) (Table 2-6).

Table 2-6. The Temporal Occurrence of Adult (a) and Juvenile (b) Central Valley Spring-run Chinook Salmon in the Mainstem Sacramento River.

Relative Abundance	**High**				**Medium**				**Low**			
(a) Adult Migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Delta[a]												
San Joaquin Basin												
Sac. River Basin[b,c]												
Sac. River Mainstem[c,d]												
b) Adult Holding[b,c]												
c) Adult Spawning[b,c,d]												
(b) Juvenile Migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac. River at RBDD[d]												
Sac. River at KL[i]												
San Joaquin basin												
Delta[j]												

Sources: [a]CDFG (1998); [b]Yoshiyama et al. (1998); [c]Moyle (2002); [d]Myers et al. (1998); [e]Lindley et al. (2004); [f]CDFG (1998); [g]McReynolds et al. (2007); [h]Ward et al. (2003); [i]Snider and Titus (2000); [j]SacTrawl (2015)

Note:

Yearling spring-run Chinook salmon rear in their natal streams through the first summer following their birth. Downstream emigration generally occurs the following fall and winter. Most young-of-the-year spring-run Chinook salmon emigrate during the first spring after they hatch.

Adult spring-run Chinook salmon enter the San Francisco estuary to begin their upstream spawning migration in late January and early February (CDFG 1998b). They enter the Sacramento River between March and September, primarily in May and June (Yoshiyama et al. 1998, Moyle 2002). Generally, adult spring-run Chinook salmon are sexually immature when they enter freshwater habitat and must hold in deep pools for up to several months in preparation for spawning (Moyle 2002). The Delta and Sacramento River provide a critical migration corridor for spawning adults, allowing them access to spawning grounds upstream.

Monitoring of the Sacramento River mainstem during spring-run Chinook salmon spawning timing indicates that some spawning occurs in the river. Although physical habitat conditions in the accessible upper Sacramento River can support spring-run Chinook salmon spawning and incubation, significant hybridization/introgression with fall-run Chinook salmon due to lack of spatial/temporal separation, makes identification of spring-run Chinook salmon in the mainstem very difficult (CDFG 1998a), but counts of Chinook salmon redds in September are typically used as an indicator of the Sacramento River spring-run Chinook salmon population abundance. Less than fifteen Chinook salmon redds per year were observed in the Sacramento River from 1989 to 1993, during September aerial redd counts. Redd surveys conducted in September between 2001 and 2011 have observed an average of 36 Chinook salmon redds from Keswick Dam downstream to the RBDD, ranging from 3 to 105 redds; from 2012 to 2015, redds observed were close to zero except in 2013, when 57 redds were observed in September (CDFW 2017).

Currently, the majority of returning adult spring-run Chinook salmon spawn in the tributaries to the Sacramento River, which are not within the action area of this proposed action.

The Sacramento River mainly functions as both rearing habitat for juveniles and the primary migratory corridor for outmigrating juveniles and spawning adults for all the Sacramento River basin populations. The juvenile life stage of CV spring-run Chinook salmon exhibits varied rearing behavior and outmigration timing. Juveniles may reside in the action area for 12–16 months (these individuals are characterized as “yearlings”), while some may migrate to the ocean as young-of-the-year (NMFS 2014b).

The Delta is utilized by juveniles prior to entering the ocean. Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960, Dunford 1975). Juvenile spring-run Chinook salmon use Suisun Marsh extensively as a migratory pathway, though they likely move through quickly based on their size upon entering the bay (as compared to fall-run, which enter this area at a smaller size and likely exhibit rearing behavior prior to continuing their outward migration) (Brandes and McLain 2001, Williams 2012).

Some non-natal juvenile rearing has been observed in the Lower American River; however, there is no longer a viable population of CV spring-run Chinook associated with that system (Reclamation 2015).

An experimental population of spring-run Chinook salmon has been designated under section 10(j) of the ESA in the San Joaquin River from Friant Dam downstream to its confluence with the Merced River (78 FR 79622; December 31, 2013), and spring-run Chinook salmon are currently being reintroduced to the San Joaquin River. The experimental population area in the San Joaquin River is outside the action area. However, when these fish migrate to and from the ocean, they will pass through the action area, where they are considered part of the non-experimental Central Valley spring-run Chinook salmon ESU. A conservation stock of spring-run Chinook is being developed at the San Joaquin River Conservation and Research Facility at Friant Dam and individuals have been released annually since 2014 to the lower San Joaquin River (CDFW 2014). In 2016, the San Joaquin River Restoration Program released 57,320 Feather River Hatchery and 47,560 San Joaquin River Conservation and Research Facility spring-run Chinook salmon juveniles to the San Joaquin River just upstream of the confluence with the Merced River (NMFS 2016). 2016 was the first year in which the fish released in 2014 may have returned. No fish have been detected returning to the San Joaquin River to spawn from the initial 2014 release (Reclamation 2017, unpublished data).

In addition, observations in the last decade suggest that spring-running populations may currently occur in the Stanislaus and Tuolumne rivers (Franks 2014), tributary rivers to the mainstem San Joaquin River. Although the exact number of spring-running Chinook salmon in the San Joaquin basin is unknown, juvenile and adult spring-run use the portion of the lower San Joaquin River within the Delta as a migratory pathway.

Spring-run Chinook salmon adults are vulnerable to climate change because they over-summer in freshwater streams before spawning in autumn (Thompson et al. 2011). Spring-run Chinook salmon spawn primarily in the tributaries to the Sacramento River, and without cold water refugia (usually input from springs), those tributaries will be more susceptible to impacts of climate change. Even in tributaries with cool water springs, in years of extended drought and warming water temperatures, unsuitable conditions may occur. Additionally, juveniles often rear in their natal stream over the summer prior to emigrating (McReynolds et al. 2007), and would be susceptible to warming water temperatures.

The status of spring-run critical habitat in the action area is discussed in Section 2.4.2.3.

2.4.2.2 Status of California Central Valley Steelhead in the Action Area

CCV steelhead exhibit a similar life history to CV spring-run Chinook and occupy a similar geographical range (see Appendix B). As described in Section 2.3.1.2 above, CCV steelhead also extensively utilize the Sacramento River, Lower American River, and Sacramento/San Joaquin Delta. Assessing the temporal occurrence of each life stage of CCV steelhead in the action area is done through analysis of monitoring data in the Sacramento River and select tributaries; monitoring in the Delta; and salvage data from the Tracey and Skinner fish collection facilities in the south Delta (CVP and SWP) (Table 2-7). The only portion of the action area to contain spawning habitat is the Lower American River.

Table 2-7 shows the temporal occurrence of (a) adult and (b) juvenile California Central Valley steelhead at locations in the action area. Darker shades indicate months of greatest relative abundance.

Table 2-7. The Temporal Occurrence of (a) Adult and (b) Juvenile California Central Valley Steelhead at Locations in the Action Area.

Relative Abundance	High					Medium				Low		
(a) Adult migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Delta												
[1]Sacramento R. at Fremont Weir												
[2]Sacramento R. at RBDD												
[3]San Joaquin River												
(b) Juvenile migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
[1,2]Sacramento R. near Fremont Weir												
[4]Sacramento R. at Knights Landing												
[5]Chipps Island (clipped)												
[5]Chipps Island (unclipped)												
[6]San Joaquin R. at Mossdale												

Sources: [1](Hallock 1957); [2](McEwan 2001); [3]CDFG Steelhead Report Card Data 2007; [4]NMFS analysis of 1998-2011 CDFW data; [5]NMFS analysis of 1998-2011 USFWS data; [6]NMFS analysis of 2003-2011 USFWS data.

Spawning adults enter the San Francisco Bay estuary and Delta from August to November (with a peak in September (Hallock et al. 1961)). Spawning occurs in a number of tributaries to the Sacramento River, to which the Delta and Sacramento River serve as key migratory corridors (NMFS 2014b). Spawning occurs from December to April, with a peak in January through March, in rivers and streams where cold, well oxygenated water is available (Hallock et al.1961, McEwan and Jackson 1996, Williams 2006). Adults typically spend a few months in freshwater before spawning (Williams 2006), but very little is known about where they hold between entering freshwater and spawning in rivers and streams. Utilization of the Delta by adults is also poorly understood.

Juvenile CCV steelhead rear in cool, clear, fast-flowing streams and are known to prefer riffle habitat over slower-moving pools (NMFS 2014b; Reclamation 2015). The only portion of the action area containing optimal juvenile rearing habitat for CCV steelhead is the Lower American River, where juveniles belonging to the natal population are known to exhibit rearing behavior prior to outmigration (Reclamation 2015). The Sacramento River and Delta are likely utilized primarily as migratory corridors. Little is known about the rearing behavior of juveniles in the Delta; however, they are thought to exhibit short periods of rearing and foraging in tidal and non-tidal marshes and other shallow areas prior to their final entry into the ocean.

The Lower American River contains a naturally spawning population of CCV steelhead, which spawn downstream of Nimbus Dam. The dam is an impassable barrier to anadromous fish, isolating historical spawning habitat located in the North, Middle and South forks of the upper American River. The American River population is small, with only a few hundred individuals returning to spawn each year (Reclamation 2015). In recent years, spawning adults have been observed with intact adipose fins indicating that a portion of the in-river population is of wild origin (Hannon 2013). Juvenile O. mykiss (anadromous and resident forms) have been observed to occupy fast-flowing riffle habitat in the Lower American River, which is consistent with known life history traits of this species.

Nimbus hatchery, located on the Lower American River adjacent to Nimbus Dam, produces the anadromous form of O. mykiss; however, steelhead from Nimbus hatchery are not included in the CCV steelhead DPS due to genetic integrity concerns from use of out-of-basin broodstock (71 FR 834; January 5, 2006). To specifically address this issue and in response to RPA Action II.6.1 contained in the NMFS (2009) biological opinion for long-term operations of the CVP/SWP, genetic testing of American River O. mykiss population was completed in 2014 to inform the planning for Nimbus Hatchery broodstock replacement that will support the CCV steelhead DPS (NMFS 2016c).

The portion of the lower San Joaquin River within the Delta is used by migrating adult and juvenile CCV steelhead to reach spawning and rearing grounds in the tributaries (FISHBIO 2012, FISHBIO 2013, CDFW 2013).

Although steelhead will experience similar effects of climate change to Chinook salmon, as they are also blocked from the vast majority of their historic spawning and rearing habitat, the effects may be even greater in some cases, as juvenile steelhead may rear in freshwater over the summer prior to emigrating as smolts (Snider and Titus 2000). Several studies have found that steelhead require colder water temperatures for spawning and embryo incubation than salmon (McCullough et al. 2001). McCullough et al. (2001) recommended an optimal incubation temperature at or below 11°C to 13°C (52°F to 55°F), and successful smoltification in steelhead may be impaired by temperatures above 12°C (54°F) (Richter and Kolmes 2005). In some areas, stream temperatures that currently provide marginal habitat for spawning and rearing may become too warm to support naturally spawning steelhead populations in the future.

2.4.2.3 Status of Central Valley Spring-run Chinook Salmon and California Central Valley Steelhead Critical Habitat in the Action Area

A significant portion of designated critical habitat for both CV spring-run Chinook salmon and CCV steelhead is contained within the proposed project action area. PBFs for both species are concurrently defined in (70 FR 52488; September 2, 2005) and the following PBFs, in summary, for these species are present in the proposed action area: (1) freshwater spawning sites, (2) freshwater rearing sites, (3) freshwater migration corridors, and (4) estuarine areas.

Critical habitat for CV spring-run Chinook includes portions of the north Delta, as well as the Sacramento River and the lower American River (from the confluence with the Sacramento River to the Watt Avenue Bridge). With the exception of Clifton Court Forebay, the entirety of the proposed action area is designated critical habitat for CCV steelhead.

Historically, both CV spring-run Chinook salmon and CCV steelhead spawned in many of the headwaters and upstream portions of the Sacramento River and San Joaquin River basins. Similar to winter-run Chinook salmon, passage impediments have contributed to substantial reductions in the populations of these species by isolating them from much of their historical spawning habitat. Naturally spawning spring-run Chinook salmon had been extirpated from the San Joaquin River basin entirely; however, an experimental population has been reintroduced to the river under section 10(j) of the ESA and "spring-running" adults have been documented migrating into the San Joaquin tributaries (Franks 2014). Within the action area, spawning habitat for CV spring-run is currently limited to the mainstem of the Sacramento River between Red Bluff and Keswick Dam. CCV steelhead spawn in this reach of the upper accessible Sacramento River as well as throughout the lower American River between its confluence with the Sacramento River up to Nimbus Dam. The PBF of freshwater spawning sites for these species has been degraded within the action area due to high water temperatures, redd dewatering, and loss of spawning gravel recruitment in reaches below Keswick Dam (Wright and Schoellhamer 2004, Good et al. 2005, NMFS 2009a, Jarrett 2014). These issues are actively addressed by adaptive flow management in both rivers as well as spawning gravel augmentation projects in both reaches (NMFS 2009d, 2015a, 2016b).

Freshwater rearing and migration PBFs have been degraded from their historical condition within the action area. In the Sacramento River and San Joaquin, riverbank armoring has significantly reduced the quantity of floodplain rearing habitat for juvenile salmonids and has altered the natural geomorphology of the river (NMFS 2014). Similar to winter-run Chinook salmon, CV spring-run and CCV steelhead are only able to access large floodplain areas, such as the Yolo Bypass under certain hydrologic conditions which do not occur in dryer years. However, the Yolo Bypass Restoration Plan includes notching the Fremont Weir, which will provide access to floodplain habitat for juvenile spring-run Chinook salmon and steelhead over a longer period (Department of Water and Resources and Bureau of Reclamation 2016). Levee construction involves the removal of riparian vegetation, resulting in reduced habitat complexity and shading, making juveniles more susceptible to predation. Additionally, loss of riparian vegetation reduces aquatic macroinvertebrate recruitment resulting in decreased food availability for rearing juveniles (Anderson and Sedell 1979; Pusey and Arthington 2003).

The lower American River has experienced similar losses of rearing habitat; however, projects sponsored by Reclamation are restoring rearing habitat for juvenile CCV steelhead through the creation of side channels and placement of instream woody material (Reclamation 2015).

Within the proposed action area, the estuarine area PBF includes the legal Delta, encompassing significant reaches of the Sacramento and San Joaquin rivers that are tidally influenced (70 FR 52488; September 5, 2005). Estuarine habitat in the Delta is significantly degraded from its historical condition due to levee construction, shoreline development, and dramatic alterations to the natural hydrology of the system due to water export operations (NMFS 2014b). Though critical habitat for CV spring-run occurs in the north Delta and not the interior or south Delta, it is thought that some entrainment into the interior Delta may occur during Delta Cross Channel (DCC) gate openings. However, the 2014 drought year prompted protections for CV spring-run at the DCC (NMFS 2016a). Reverse flows in the central and south Delta resulting from water exports may exacerbate interior Delta entrainment by confounding flow and temperature-related migratory cues in outmigrating juveniles. The presence of these stressors, which cause altered migration timing and routing, degrade critical habitat PBFs related to rearing and migration. These impacts are discussed in greater detail in Section 2.5.1.2.7.1 Travel Timing and 2.5.1.2.7.2 Outmigration, and effects to critical habitat PBFs in the Delta for CV spring-run Chinook salmon are analyzed in Section 2.5.2.2.4 Estuarine Habitat for Rearing and Migration.

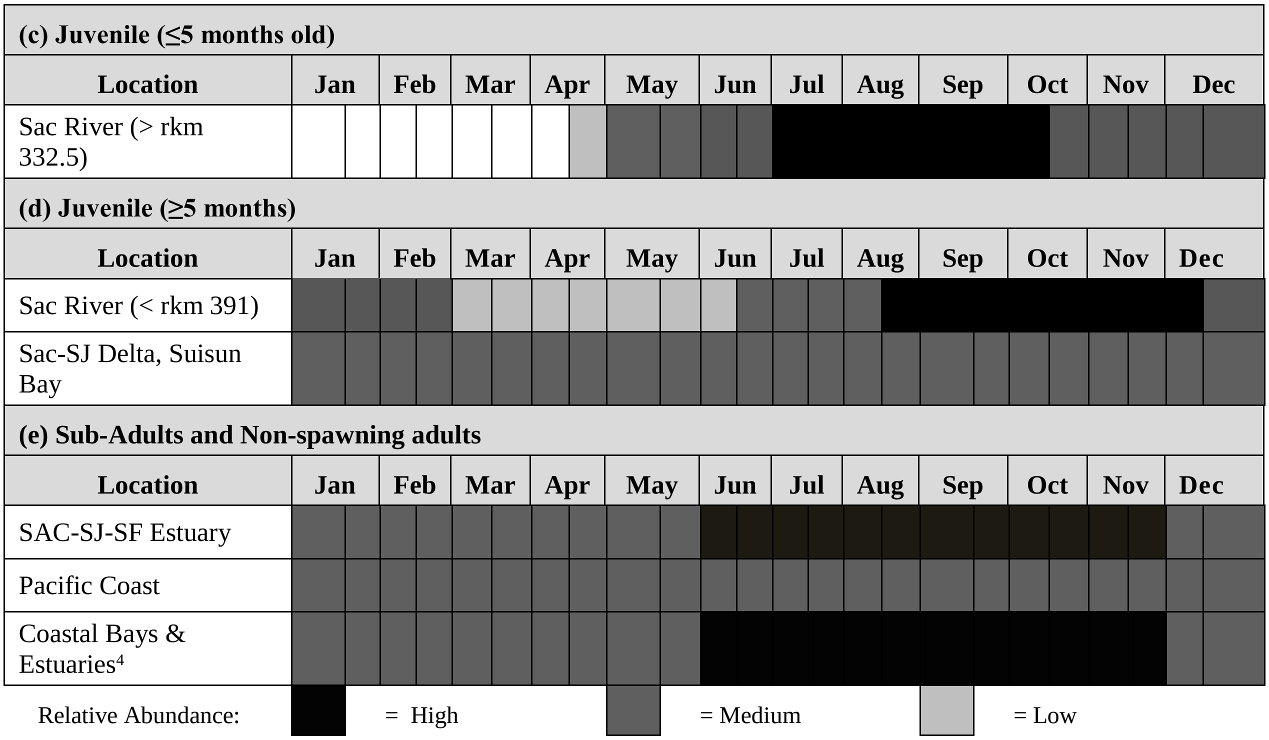
2.4.3 sDPS North American Green Sturgeon

2.4.3.1 Status of sDPS North American Green Sturgeon in the Action Area

The sDPS green sturgeon exhibit a more complex life history with respect to salmonids and less is known about the ecology and behavior of their various life cycle stages in the action area. Some acoustic telemetry (Kelly et al. 2007, Heublein et al. 2008) and multi-frequency acoustic survey work (Mora et al. 2015) has been done to study adult migration patterns and habitat use in the action area (Delta and Sacramento River). Field surveys have also been conducted on the Sacramento River to study spatial and temporal occurrence of early life stages (Poytress et al. 2010, 2011, 2012, 2013, Poytress et al. 2015b). These studies have documented some spatial patterns in spawning events on the upper reaches of the Sacramento River. Although Seesholtz et al. (2014a) observed spawning in the Feather River, no known spawning events have been observed in the lower American River or in the portion of the lower San Joaquin River that is included in the Delta. Additionally, several lab studies have been conducted using early life stages to investigate ontogenic responses to elevated thermal regimes as well as foraging behavior as a function of substrate type (Allen et al. 2006a, Allen et al. 2006b, Nguyen and Crocker 2006, Linares-Casenave et al. 2013). However, due to sparse monitoring data for juvenile, sub-adult and adult life stages in the Sacramento River and Delta, there are significant data gaps to describe the ecology of this species in the action area. It is understood that spawning occurs in the upper reaches of the Sacramento River and Feather River (Seesholtz et al. 2014b, Poytress et al. 2015a), so the mainstem Sacramento and Delta serve as rearing habitat and a migratory corridor for this species. Some rearing also may occur in the lowest reaches of the lower American River where deep pools occur for rearing of older lifestages (downstream of SR-160 bridge) (Thomas et al. 2013). Information gaps encountered in efforts to summarize information on sDPS green sturgeon life history are often addressed using known information about the nDPS.

Table 2-8 The Temporal Occurrence of (a) Spawning Adult, (b) Larval, (c) Young Juvenile, (d) Juvenile, and (e) Sub-adult and Non-spawning Adult Southern DPS Green Sturgeon at Locations in the Action Area. Darker shades indicate months of greatest relative abundance.

(a) Adult-sexually mature (≥145 cm TL females, ≥ 120 cm TL males), including pre- and post-spawning individuals.												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac River (rkm 332.5-451)												
Sac River (< rkm 332.5)												
Sac-SJ-SF Estuary												
(b) Larval												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac River (> rkm 332.5)												



Southern DPS green sturgeon spawn primarily in the Sacramento River in the spring and summer, with the farthest upstream spawning event in the Sacramento River documented near Ink's Creek at river km 426 (Poytress et al. 2015a). However, Heublein (2008) detected adults as far upstream as river km 451 near Cow Creek, suggesting that their spawning range may extend farther upstream than previously documented. The upstream extent of their spawning range lies somewhere below ACID (RM 206), as that dam impedes passage for green sturgeon in the Sacramento River (Heublein et al. 2008). It is uncertain, however, if green sturgeon spawning habitat exists closer to ACID, which could allow spawning to shift upstream in response to climate change effects. Successful spawning of green sturgeon in other accessible habitats in the Central Valley (i.e., the Feather River) is limited, in part, by late spring and summer water temperatures. Similar to salmonids in the Central Valley, green sturgeon spawning in the major lower river tributaries to the Sacramento River are likely to be further limited if water temperatures increase over time. In a bioenergetics study, 15-19°C was the optimal thermal range for age-0 green sturgeon (Mayfield and Cech 2004). If temperatures in spawning habitat exceed that range in the future, it may reduce the fitness of early life stages.

2.4.3.2 Status of sDPS North American Green Sturgeon Critical Habitat in the Action Area

Critical habitat for sDPS green sturgeon is contained in nearly all of the proposed action area with the exception of the lower American River from the SR-160 bridge upstream to Nimbus Dam. All PBFs for sDPS green sturgeon critical habitat are present in the action area, except PBFs for nearshore coastal marine areas. The PBFs in the action area include, in summary: (1) food resources; (2) substrate type or size; (3) water flow; (4) water quality; (5) migratory corridor; (6) depth; and (7) sediment quality. These PBFs apply to both riverine and estuarine areas except "substrate type or size," which pertains to spawning habitats and only applies to riverine areas. These PBFs are described in detail in the rangewide status of sDPS green sturgeon in Appendix B.

The historical spawning range of sDPS green sturgeon is not well known, though they are thought to have spawned in many of the major tributaries of the Sacramento River basin, many of which are isolated due to passage impediments (Beamesderfer et al. 2004). Green sturgeon utilize the lower Sacramento River for spawning and are known to spawn in its upper reaches between RBDD and Keswick Dam (Poytress et al. 2015a). Similar to the listed salmonid species addressed in this Opinion, PBFs related to spawning and egg incubation have been degraded as discussed in Sections 2.4.1.2 and 2.4.2.3. Changes in flow regimes and the installation of Keswick and Shasta dams have significantly reduced the recruitment of spawning gravel in the upper reaches of the lower Sacramento River. Flow conditions in the Sacramento River have also been significantly altered from their historical condition. The degree to which these altered flow regimes affects outmigration dynamics of juveniles is unknown; however, some suitable habitat exists and spawning events have been consistently observed annually (Poytress et al. 2015a).

PBFs for sDPS green sturgeon in the lower reaches of the Sacramento River and the Delta have also been significantly altered from their historical condition, similar to the impacts described in Sections 2.4.1.2 and 2.4.2.3. However, green sturgeon exhibit very different life history characteristics from those of salmonids and therefore utilize habitat within the proposed action area differently as follows. Green sturgeon are thought to exhibit rearing behavior in the lower reaches of the Sacramento River and the Delta as juveniles and subadults prior to migrating to the ocean, though little is known about the behavior of these lifestages in the Delta (Radtke 1966; NMFS 2015b). Loss of riparian habitat complexity in the Sacramento River and Delta has likely posed less of a threat to green sturgeon because these life stages are benthically oriented. However, it is likely that reverse flows generated by Delta water exports affect the green sturgeon juvenile and subadult life stages to some degree as evidenced by juvenile captures at CVP/SWP salvage facilities during high water years (CDFW 2017; ftp://ftp.dfg.ca.gov/salvage).

2.4.4 Other Factors Affecting Listed Fish Species and Critical Habitat in the Action Area

2.4.4.1 Water Quality

Current land use in the Sacramento River basin and Delta has seen a dramatic increase in urbanization, industrial activity, and agriculture in the last century. In a Sacramento River Basin-wide study, areas with relatively high concentrations of agricultural activity as well as areas that had previously experienced mining activity showed increased concentrations of dissolved solids and nitrite plus nitrate (Domagalski et al. 2000). Domagalski (2001) also found varying concentrations of mercury and methylmercury throughout the Sacramento River Basin. Concentrations of these contaminants were greatest downstream of previous mining sites (primarily Cache Creek). Both studies showed lower concentrations of contaminants in the American River as compared to other sites sampled in the Sacramento River Basin.

Multiple studies have documented high levels of contaminants in the Delta such as Polychlorinated Biphenyls (PCBs), organochlorine pesticides, Polycyclic Aromatic Hydrocarbons (PAHs), selenium, and mercury, among others (Stewart et al. 2004, Leatherbarrow et al. 2005, Brooks et al. 2011), suggesting that fish are exposed to them; however, the inability to characterize concentrations and loading dynamics makes it difficult to quantify transport and total contaminant loading in the system (Johnson et al. 2010). Harmful algal blooms also occur in the Delta and, although toxic exposure of estuarine fish has been documented, the extent of their impacts to the aquatic food web is unknown (Lehman et al. 2009). The Environmental Protection Agency (EPA) developed an action plan in 2012 to address water quality concerns in the Delta (U.S. Environmental Protection Agency 2012). This plan included the following actions: (1) Strengthen estuarine habitat protection standards; 2) Advance regional water quality monitoring and assessment, 3) Accelerate water quality restoration through Total Maximum Daily Loads, 4) Strengthen selenium water quality criteria, 5) Prevent pesticide pollution, 6) Restore aquatic habitats while managing methylmercury, and 7) Support the Bay Delta Conservation Plan.

2.4.4.1.1 Water Temperature Management

Sacramento River

The amount of cold water pool available for instream temperature management on the Sacramento River depends on carry-over storage, reservoir water temperature, and the amount, timing, and water temperature of inflows to and outflows from Shasta Reservoir. End of September storage targets of 1.9 MAF are part of the 2009 NMFS biological opinion RPA actions for the long-term operations of CVP/SWP intended to sustain cold water supply for winter- and spring-run Chinook salmon each year (NMFS 2009). This RPA action has not been met during some years (Swart 2016).

The Shasta RPA actions in the National Marine Fisheries Service (2009) BiOp on the long-term operations of the CVP/SWP and the associated 2011 amendments are being adjusted because of the unprecedented mortality for two consecutive winter-run Chinook salmon brood years (2014 and 2015), the availability of new studies and models, including the River Assessment for Forecasting Temperature (RAFT) model, and the SWFSC's temperature-dependent Chinook salmon egg mortality model (Martin et al. 2016), and the poor status of winter- and spring-run Chinook salmon. The RAFT model more accurately predicts temperatures to better manage reservoir releases to maintain suitable instream temperatures in the upper Sacramento River (Pike et al. 2013). This modeling is presented in Section 2.5.1.2.1 Increased Upstream Temperatures of this Opinion where the No Action Alternative (NAA) modeling represents current water temperature conditions.

On August 2, 2016, Reclamation requested using the adaptive management provision in the 2009 BiOp related to Shasta Reservoir operations. The basis for this request included recent, multiple years of drought conditions, new science and modeling, and data demonstrating the low population levels of endangered Sacramento River winter-run Chinook salmon and threatened Central Valley spring-run Chinook salmon. As a necessary step in the science-based adaptive management process, NMFS, in consultation with Reclamation, developed a draft proposed amendment to the NMFS' 2011 amendment to the 2009 RPA (NMFS 2017). The draft proposed amendment describes the proposed changes, lays out a phased approach, and states that a pilot approach to water temperature management will be implemented in 2017. The 2017 pilot approach (currently underway) applies new science on the thermal tolerance of Chinook salmon eggs (Martin et al. 2016) and is designed to efficiently utilize Shasta Reservoir limited supply of cold water by basing the spatial distribution of protective temperatures on the within-season spatial distribution of winter-run Chinook salmon redds. The intent is to provide daily average water temperatures of 53°F or less to the furthest downstream redds. The existing requirement is a daily average temperature of 56°F or less at compliance locations between Balls Ferry and Bend Bridge, which are not based on the within-season redd distribution. The science-based, within season management under the 2017 pilot approach, and additional adjustments to the NMFS' 2011 amendment to the 2009 RPA included in the draft proposed amendment intended to protect winter-run Chinook salmon are expected to result in improved survival over what is reflected in the modeling results (see Section 2.5.1.2.1 Increased Upstream Temperatures of this Opinion where the No Action Alternative modeling represents current water temperature conditions).

American River

RPA action II.3 in the NMFS biological opinion for the long-term operations of the CVP/SWP (NMFS 2009) requires Reclamation to implement physical and structural modifications to the American River Division of the CVP in order to improve water temperature management and develop an annual water temperature management plan for the lower American River. Structural changes to Folsom Dam have been completed to facilitate more control over temperature and amount of water releases into the American River for spawning Chinook salmon and steelhead, and migrating and rearing juveniles of both species. Annual water temperature management plans for the lower American River have been developed annually starting in 2010. In addition, an Iterative Coldwater Pool Management Model was developed by Reclamation in 2010 and is being used annually to evaluate coldwater pool availability in Folsom Reservoir and develop water temperature objectives in the lower American River that are as protective as possible for salmonids.

Predation of juvenile salmonids and green sturgeon is thought to be a contributing factor to high mortality at this life stage within the action area, though there is still more research needed on this topic in order to draw any substantial conclusions (Hanson 2009, Michel et al. 2015). Within the action area there have been significant alterations to aquatic habitat that are conducive to the success of non-native piscivorous fish such as riverbank armoring and reduction of habitat complexity (NMFS 2014b). A study led by the NOAA Southwest Fisheries Science Center has attempted to develop a quantitative tool to measure predation in the Delta using a novel method of observing predation events at a fine spatial scale (Demetras et al. 2016). This study identified some fine scale dynamics of predation on salmonids; however, the results were not comprehensive enough to make any sort of system-wide conclusions regarding the magnitude of predation on juveniles in the Delta.

2.4.4.2 Diversion Entrainment

The many existing unscreened water diversions on the Sacramento River pose a threat to early life stages of listed species. A study of 12 unscreened, small to moderate sized diversions (< 150 cfs) in the Sacramento River, found that diversion entrainment was low for listed salmonids (majority were identified as fall-run Chinook based on length-at-date criteria; other ESUs made up much smaller percentages), though the study points out that the diversions used were all situated relatively deep in the river channel (Vogel (2013). Juvenile green sturgeon also contributed to a small percentage of entrainment mortality in this study. In a previous mark-recapture study addressing mortality caused by unscreened diversions, Hanson (2001) also observed low mortality in hatchery-produced juvenile Chinook salmon released upstream of four different diversions throughout the Sacramento River (≤ 0.1 percent of individuals released).

The 2009 RPA for the continued operation of CVP/SWP included actions related to entrainment, such as to install NMFS-approved, state-of-the-art fish screens at the Tehama Colusa Canal diversion. An additional requirement is to implement term and condition 4c from the biological opinion on the Red Bluff Pumping Plant Project, which calls for monitoring, evaluating, and adaptively managing the new fish screens at the Tehama Colusa Canal diversion to ensure the screens are working properly and impacts to listed species are minimized (NMFS 2009b). These actions will reduce entrainment of listed fish in the upper Sacramento River into the future. In addition, the 2009 RPA included the requirement to identify and implement any required projects to assure the M&T Ranch water diversion is adequately screened to protect winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. A short-term screen is currently functioning at the site and a permanent screening option is under development.

2.4.4.3 Dredging and Other Physical Disturbance

Dredging operations periodically occur throughout the action area for a variety of purposes including the maintenance of shipping channels; maintenance of diversion intakes; and to remove accumulated sediments from recreational and commercial facilities such as boat docks and marinas. Dredging can have detrimental impacts to listed fish species through physical disturbance, and through the resuspension of sediment. The adverse effects of dredging operations to anadromous fish are discussed in greater detail in Section 2.5.1.1.3.4 Dredging and effects to critical habitat are discussed in Section 2.5.2.1.1 Sedimentation and Turbidity. ESA consultations are periodically conducted by NMFS for dredging projects of varying scope and scale throughout the action area (NMFS 2014b, 2016d).

Flow fluctuations from Sacramento River operations of the CVP cause Chinook salmon redd dewatering and scour to occur. An analysis of these impacts is presented in Section 2.5.1.2.2. Redd Dewatering and 2.5.1.2.3 Redd Scour in this Opinion where the NAA modeling represents current redd dewatering and scour conditions. Flow fluctuations in the upper Sacramento River can also cause stranding of juvenile salmonids to varying degrees depending on water year type and subsequent water operations. An analysis of these impacts is presented in Section 2.5.1.2.3 Isolation and Stranding in this Opinion where the NAA modeling represents current stranding conditions.

2.4.4.4 Vessel Traffic in the Action Area

Select portions of the action area currently experience heavy commercial and recreational vessel traffic, creating hazards to listed fish species through both physical and acoustic disturbance. These impacts may lead to direct mortality or may induce changes in behavior that impair feeding, rearing, migration, and/or predator avoidance. Further details on the effects of vessel traffic to fish are included in Section 2.5.1.1.7 Physical Impacts to Fish. Within the action area, the Stockton Deep Water Ship Channel (DWSC) and Sacramento DWSC experience frequent large commercial vessel traffic. The mainstem Sacramento River; American River; Delta; and remainder of Suisun, San Pablo, and San Francisco bays receive occasional commercial tugboat traffic as construction barges and other heavy equipment are transported upstream. Finally, recreational vessel traffic occurs throughout the action area. In a report on Delta boating needs through the year 2020, the California Department of Boating and Waterways stated an expected increase in boating activity in the Delta area (California Department of Boating and Waterways 2003).

2.4.4.5 Acoustic Impacts in the Action Area

Construction activities in the action area occur periodically, and some involve pile driving, which generates acoustic effects potentially causing acute injury and/or behavioral impacts to fish. In the last few decades, observed acoustic impacts to fish have prompted research into physiological effects caused by excess sound generated in water (Gaspin 1975; Hastings 1995; Hastings and Popper 2005). These effects are described in greater detail in Section 2.5.1.1.1 Acoustic Stress. Recent NMFS Opinions for projects involving take caused by acoustic-related effects in the action area include bridge replacements at Jelly's Ferry (Sacramento River) and Miner Slough (north Delta) (NMFS 2014, 2016c).

2.4.4.6 Restoration Actions from NMFS (2009) RPA Opinion on the Long-term Operations of CVP/SWP Biological Opinion

As part of the consultation process for this Opinion, DWR, Reclamation and the State and Federal Water Contractors re-commit to non-operational habitat and related actions that are part of the RPA in the National Marine Fisheries Service (2009b) BiOp on the long-term operations of the CVP/SWP and the associated 2011 amendments (NMFS 2009a, 2011), including:

RPA Action I.7: Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass (Improve Yolo Bypass Adult Fish Passage)

Pursuant to the RPA in the NMFS (2009) BiOp on the long-term operations of the CVP/SWP, DWR, Reclamation and the State and Federal Water Contractors shall improve adult salmonid and sturgeon passage through the Yolo Bypass, including the Fremont Weir, by modifying or removing barriers. This action will include preventing straying at Wallace Weir; improving several agricultural road crossings; improving Lisbon Weir; and improving the existing Fremont Weir fish ladder. This is expected to reduce migratory delays and straying of adult salmonids and sturgeon because insufficient adult fish passage at flood bypass weirs combined with attraction flows leads to stranding risk and reduced fish survival, timing, and condition. Additional updated information related to implementation is available in the Salmon Resiliency Strategy (California Natural Resources Agency 2017).

RPA Action I.6.1: Restoration of Floodplain Rearing Habitat (Increase Juvenile Salmonid Access to Yolo Bypass, and Increase Duration and Frequency of Yolo Bypass Floodplain Inundation)

Pursuant to the RPA in the NMFS (2009) BiOp on the long-term operations of the CVP/SWP, DWR, Reclamation and the State and Federal Water Contractors shall increase juvenile salmonid access to the Yolo Bypass and improve adult fish passage by constructing an operable gated structure in the Fremont Weir. The facility shall be operated to increase the duration and frequency of Yolo bypass inundation between November 1 and mid-March, providing 17,000+ acres of enhanced floodplain habitat. This is expected to benefit salmonids because lack of floodplain connectivity limits food availability and production and leads to reduced fish growth and subsequent survival. Additional updated information related to implementation is available in the Salmon Resiliency Strategy (California Natural Resources Agency 2017).

RPA Action NF 4: Implementation of Pilot Reintroduction Program (Implementation of Pilot Reintroduction Program above Shasta Dam)

Pursuant to the RPA in the (NMFS) 2009 BiOp on the long-term operations of the CVP/SWP, DWR, Reclamation and the State and Federal Water Contractors shall complete all required actions, monitoring, and reporting to guide establishment of an additional population of winter-run Chinook salmon and identify the benefits and risks of reintroduction for spring-run Chinook salmon and steelhead in the McCloud River and/or upper Sacramento River. This action is a Priority 1 NMFS recovery action and is required by Action Suite 5 Near-Term Fish Passage Actions of the NMFS (2009) BiOp. Additional updated information related to implementation is available in the Salmon Resiliency Strategy (California Natural Resources Agency 2017).

RPA Action IV.1.3: Consider Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta, and Reduce Exposure to CVP and SWP Export Facilities (Including Georgiana Slough Non-Physical Barrier)

Pursuant to the RPA in the NMFS (2009) BiOp on the long-term operations of the CVP/SWP, DWR, Reclamation and the State and Federal Water Contractors shall increase the overall through-Delta survival of salmonids by reducing juvenile salmon entry into the interior Delta. This action is expected to benefit salmonids because it affects multiple habitat attributes that are hypothesized to affect juvenile survival, including predation and competition, outmigration cues, and entrainment risk. This action is consistent with a priority 1 NMFS recovery action for winter-run Chinook salmon. Additional updated information related to implementation is available in the Salmon Resiliency Strategy (California Natural Resources Agency 2017).

RPA Action I.2.6: Restore Battle Creek for Winter-Run, Spring-Run, and CV Steelhead (Complete Battle Creek Salmon and Steelhead Restoration Project)

Pursuant to the RPA in the NMFS (2009) BiOp on the long-term operations of the CVP/SWP, DWR, Reclamation and the State and Federal Water Contractors shall provide improved instream flow releases and safe fish passage to prime salmon and steelhead habitat on Battle Creek for winter-run Chinook salmon, spring-run Chinook salmon, and California Central Valley steelhead. This is a Priority 1 NMFS recovery action and required Action I.2.6, pursuant to the NMFS (2009) Opinion. The project has been supported with Federal, State and private funding. Additional updated information related to implementation is available in the Salmon Resiliency Strategy (California Natural Resources Agency 2017).

Other RPA Actions

Specific smaller scale fish habitat restoration actions mandated as part of the NMFS (2009) BiOp (NMFS 2009a) are occurring on the upper reaches of the Sacramento River between Keswick Dam and RBDD as well as on the lower American River between Nimbus Dam and the State Route 160 Bridge (NMFS 2015a, 2016b). At select sites within these areas, the projects involve creation of side channels, addition of spawning gravel, and placement of in-water woody material. NMFS has determined that these actions are likely to adversely affect listed species as projects are implemented; however, these actions will contribute aquatic habitat with high value for the conservation of listed species and will ultimately contribute to the recovery of ESA-listed salmonids in the Central Valley.

2.4.4.7 EcoRestore

California EcoRestore is a California Natural Resources Agency initiative implemented in coordination with State and Federal agencies to advance the restoration of at least 30,000 acres of Delta habitat by 2020. Driven by world-class science and guided by adaptive management, California EcoRestore will pursue habitat restoration projects with clearly defined goals, measurable objectives, and financial resources to help ensure success. The types of habitat targeted include tidal wetlands, floodplain, upland, riparian, fish passage improvements and others.

Specific restoration targets include a focus on implementing a comprehensive suite of habitat restoration actions to support the long-term health of the Delta and its native fish and wildlife species. Specifically, the program aims to achieve 3,500 acres of managed wetlands created, 17,500 acres of floodplain restoration, 30,000 acres of delta habitat restoration and protection, 9,000 acres of tidal and sub-tidal habitat restoration, and 1,000 acres of proposition 1 and 1E funded restoration projects.

There have been seven completed actions as part of EcoRestore to date (California Natural Resources Agency 2017), which include:

1. **Knights Landing Outfall Gate –** Located one-quarter mile from the confluence with the Sacramento River near Knights Landing, just below RM 90, in Yolo County. This Fish Passage Restoration project constructed a positive fish barrier (with new concrete wing walls and installation of a metal picket weir) to serve primarily as a fish passage improvement action that will prevent salmon entry into the Colusa Basin Drain while also maintaining outflows and appropriate water surface elevations. The project was initiated because adult salmon may be able to enter the Colusa Basin Drain through the Knights Landing Outfall Gates when certain flow velocities are met that attract migrating salmon. Once salmon enter the Colusa Basin Drain, there is no upstream route for salmon to return to the Sacramento River and, absent fish rescue operations, the fish perish and are lost from production.
2. **Lindsey Slough –** Completed in 2014. The project consisted of (1) excavation and debris removal to enlarge an existing north embankment breach on Calhoun Cut at a northern arm of Lindsey Slough; (2) breaching of the south embankment of Calhoun Cut; (3) excavation of a one mile long channel at the historic southern arm of Lindsey Slough; (4) lowering of an existing earthen causeway on the historic channel; and (5) beneficial reuse of sediment excavated from the channel to create low habitat berms within the marsh and raise the remnant marsh site to a more mature marshplain form. The project was implemented to restore habitat function and connectivity to Delta wetlands and waterways that had been degraded by the construction of dikes and culverts 100 years earlier. Restored habitat function and connectivity to 159 acres of freshwater emergent wetlands and 69 acres of alkali wetlands, and recreated and reconnected a one-mile tidal channel.
3. **Sherman Island: Mayberry Farms –** The Mayberry Farms Subsidence Reversal and Carbon Sequestration Project is a permanently flooded wetland on a 307-acre parcel on Sherman Island that is owned by the Department of Water Resources (DWR). The project has restored approximately 192 acres of emergent wetlands and enhanced approximately 115-acres of seasonally flooded wetlands. This project was completed in 2010.
4. **Sherman Island: Whale's Mouth** – The Wetland Restoration Project will restore approximately 600 acres of palustrine emergent wetlands, within an 877-acre Project boundary, on a nearly 975-acre parcel of property on Sherman Island. Additional project goals include increasing stability and reduced seepage on a threatened section of levee; determining the rates/amounts of carbon sequestered for project; determining the air and

water quality impacts of project; and providing recommendations for Delta-wide implementation. This project was initiated in 2013 and was completed in 2015.

5. **Sherman Island: Mayberry Slough –** Tidal Marsh, Shaded Aquatic Riverine, and Upland Habitats Restoration Targets: 192 acres' emergent wetlands 115 acres seasonally flooded wetlands. The Department of Water Resources, in coordination with Reclamation District 341, constructed 6,100 linear feet of habitat setback levee to increase levee stability and provide waterside habitat restoration along Mayberry Slough on Sherman Island. This project was initiated in 2004 and was completed in 2009.
6. **Twitchell Island: East End –** The Twitchell Island East End Wetland Restoration Project restored approximately 740 acres of palustrine emergent wetlands and approximately 50 acres of upland and riparian forest habitat on Twitchell Island. The property was previously managed as flood irrigated corn and alfalfa. It was completed in 2013.
7. **Wallace Weir Fish Rescue Facility –** The proposed project includes replacing the seasonal earthen dam at Wallace Weir with a permanent, operable structure that would provide year-round operational control. The project would also include a fish rescue facility that would return fish back to the Sacramento River. Wallace Weir has been treated as a common element to the larger habitat restoration and fish passage projects included in the 2009 NMFS biological opinion. This project will serve primarily as a fish passage improvement action that will prevent upstream migration of straying adult salmonids and sturgeon into the Colusa Basin Drain. Operational control of water levels would also provide greater flexibility for managing water releases for agriculture and wetlands habitat. Background: In water year 2014, the California Department of Fish and Wildlife (CDFW) and National Marine Fisheries Service (NMFS) documented several hundred adult salmon in dead end agricultural ditches in the Colusa Basin Drain system, and while many of these fish were rescued from the drain, the stress from the poor water quality conditions prevented these salmon from successfully contributing to the reproductive population. In the remainder of water year 2014 and in water year 2015, CDFW operated a fyke trap with wing walls at Wallace Weir to prevent straying adult salmonids and sturgeon from entering the Colusa Basin Drain; rescued fish were returned to the Sacramento River. These fish rescue operations have proven resource intensive and are not efficient at higher flows in the Knights Landing Ridge Cut (KLRC). Wallace Weir is a key water control structure in the bypass for flood conveyance and irrigation, but it is an obsolete structure which must be installed and removed annually using inflexible, labor intensive methods. Purpose: Return special status migratory fish species to the Sacramento River that are unable to pass volitionally over Wallace Weir.

The implementation of these projects has improved migration and rearing habitats for listed anadromous fish in the lower Sacramento River and Delta.

2.4.4.8 Summary of Climate Change Impacts

One major factor affecting the rangewide status of the threatened and endangered anadromous fish in the Central Valley and aquatic habitat at large is climate change.

Warmer temperatures associated with climate change reduce snowpack and alter the seasonality and volume of seasonal hydrograph patterns (Cohen et al. 2000). Central California has shown trends toward warmer winters since the 1940s (Dettinger and Cayan 1995). An altered seasonality results in runoff events occurring earlier in the year due to a shift in precipitation falling as rain rather than snow (Roos 1991; Dettinger et al. 2004). Specifically, the Sacramento River basin annual runoff amount for April-July has been decreasing since about 1950 (Roos 1987, 1991). Increased temperatures influence the timing and magnitude patterns of the hydrograph.

The magnitude of snowpack reductions is subject to annual variability in precipitation and air temperature. The large spring snow water equivalent (SWE) percentage changes, late in the snow season, are due to a variety of factors including reduction in winter precipitation and temperature increases that rapidly melt spring snowpack (VanRheenen et al. 2004). Factors modeled by VanRheenen et al. (2004) show that the melt season shifts to earlier in the year, leading to a large percent reduction of spring SWE (up to 100 percent in shallow snowpack areas). Additionally, an air temperature increase of 2.1°C (3.8°F) is expected to result in a loss of about half of the average April snowpack storage (VanRheenen et al. 2004). The decrease in spring SWE (as a percentage) would be greatest in the region of the Sacramento River watershed, at the north end of the Central Valley, where snowpack is shallower than in the San Joaquin River watersheds to the south.

Projected warming is expected to affect Central Valley Chinook salmon. Because the runs are restricted to low elevations as a result of impassable rim dams, if climate warms by 5°C (9°F), it is questionable whether any Central Valley Chinook salmon populations can persist (Williams 2006). Based on an analysis of an ensemble of climate models and emission scenarios and a reference temperature from 1951–1980, the most plausible projection for warming over Northern California is 2.5°C (4.5°F) by 2050 and 5°C by 2100, with a modest decrease in precipitation (Dettinger 2005). Chinook salmon in the Central Valley are at the southern limit of their range, and warming will shorten the period in which the low elevation habitats used by naturally-producing fall-run Chinook salmon are thermally acceptable. This would particularly affect fish that emigrate as fingerlings, mainly in May and June, and especially those in the San Joaquin River and its tributaries.

2.4.5 Importance of the Action Area for the Survival and Recovery of Listed Fish Species

The action area defined for this PA includes critical habitat designated for all species of ESA-listed fish addressed in this Opinion. It includes spawning habitat that is critical for the natural production of these species; rearing habitat that is essential for growth and survival during early life stages and enhances overall productivity and population health; migratory corridors that facilitate anadromous life history strategies; and estuarine habitat that serves as additional rearing habitat and provides a gateway to marine phases of their lifecycle.

The NMFS Recovery Plan for the Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon ESUs and the California Central Valley Steelhead DPS (NMFS 2014b) provides region-specific recovery actions that were identified by NMFS in order to facilitate recovery of these species. Implementation of some of these actions has already begun and more are in the planning phase. A Recovery Outline was produced in 2010 for sDPS green sturgeon and includes a list of recovery tasks specific to the California Central Valley including the action area (NMFS 2010). A draft Recovery Plan for sDPS green sturgeon is currently being developed and is scheduled for completion in late 2017.

2.4.6 Southern Resident Killer Whale

2.4.6.1 Status of Southern Resident Killer Whale in the Action Area

The Federally listed Southern Resident killer whale DPS (herein referred to as Southern Residents) occurs in the action area and may be affected by the proposed action. Please refer to Southern Resident killer whale Recovery Plan (NMFS 2008) and the most recent 5-year status review (NMFS 2016) for more detailed information on the state of knowledge about the status of Southern Residents and overall threats that are currently facing the species.

In killer whale populations, groups of related matrilines form pods, and three pods (J, K, and L) make up the Southern Resident community. The historical abundance of Southern Residents is estimated from a low population level of 140 animals to an unknown upper bound. The minimum historical estimate (~140) included whales killed or removed for public display in the 1960s and 1970s, which were added to the remaining population at the time the captures ended (NMFS 2008). Several lines of evidence (i.e., known kills and removals (Olesiuk et al. 1990), salmon declines (Krahn et al. 2002), and genetics (Krahn et al. 2002, Ford et al. 2011)) all indicate that the population used to be much larger than it is now, but there is currently no reliable estimate of the upper bound of the historical population size. Over the last 5 decades, the Southern Resident population has remained at a similarly low population size fluctuating from about 80-90 individuals (Olesiuk et al. 1990, Center for Whale Research 2008).

NMFS has continued to fund the Center for Whale Research (CWR) to conduct an annual census of the Southern Resident population, and census data are now available through July 2016. Between the July 2015 census count of 81 whales and July 2016, three whales died (a post-reproductive female and a young adult male from L pod and a J pod calf), and five Southern Residents were born (3 from J pod and 2 from L pod), bringing the number of SRKW to 83 (CWR, unpublished data). At the end of December 2016, the population numbered 78 individuals due to deaths of five individuals from J pod that were confirmed or assumed to have died in late 2016; K Pod=19, L Pod=35, J Pod=24. The Southern Resident killer whale population has experienced an increase in reproductive females since the beginning of the annual censuses in the 1970s. There is weak evidence of a decline in fecundity rates through time for reproductive females. This decline is linked to fluctuations in abundance of Chinook prey, and possibly other factors (Ward et al. 2013). However, there were 6 births in 2015, which is higher than observed in recent times. It is unclear yet how these additions to the population will affect the Southern Resident population dynamics.

Southern Residents spend a substantial amount of time from late spring to early autumn in inland waterways of Washington State and British Columbia, including the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound (Bigg 1982, Krahn et al. 2002). Southern Residents occur throughout the coastal waters of Washington, Oregon, and Vancouver Island and are known to travel as far south as central California and as far north as southeast Alaska. Although the entire Southern Resident DPS has the potential to occur in coastal waters at any time during the year, occurrence in coastal waters is more likely from November to May. Satellite-linked tag deployments on K and L pod animals indicate that those pods in particular use the coastal waters along Washington, Oregon, and California during non-summer months (Northwest Fisheries Science Center, unpublished data). Detection rates of K and L pods on passive acoustic recorders indicate the whales occur with greater frequency off the Columbia River delta and Westport, Oregon, and are most common in March (Hanson et al. 2013). Results of recent satellite tagging indicate the limited occurrence along the outer coast by J pod (Northwest Fisheries Science Center, unpublished data) where J pod has also only been detected on one of seven passive acoustic recorders positioned along the outer coast; members of the J pod do not appear to travel to Oregon or California like K and L pods (Hanson et al. 2013).

As described in the final Recovery Plan for Southern Residents (NMFS 2008), several factors may be limiting recovery of the Southern Resident DPS. These factors include: quantity and quality of prey, toxic chemicals that accumulate in top predators, and disturbance from sound and vessels. Oil spills are also a risk factor. It is likely that multiple threats are acting together to impact the whales. Although it is not clear which threat or threats are most significant to the survival and recovery of Southern Residents, all identified threats are potential limiting factors in their population dynamics (NMFS 2008).

Significant attention has been paid in recent years to the relationship between the Southern Resident population and the abundance of important prey, especially Chinook salmon. Recently, Ford et al. (2016) confirmed the importance of Chinook salmon to Southern Residents in the summer months using DNA sequencing from whale feces. The researchers found that salmonids made up to over 98 percent of the whales inferred diet, of which almost 80 percent were Chinook salmon. Researchers also found evidence of prey shifting at the end of summer towards coho salmon for all years analyzed; coho salmon contributed to over 40 percent of the diet in late summer. Chum, sockeye, and steelhead made up relatively small contributions to the sequences (less than 3 percent each). Although less is known about the diet of Southern Residents off the Pacific coast during winter, the available information from observation of predation events indicates that salmon, and Chinook salmon in particular, are also important when the whales occur in coastal waters (Hanson et al. 2010).

One hypothesis as to why killer whales primarily consume Chinook salmon even when they are not the most abundant salmon available is because of the Chinook salmon’s relatively high energy content (Ford and Ellis 2006). Chinook salmon have the highest value of total energy content compared to other salmonids because of their larger body size and higher energy density (expressed in kcal/kg) (O’Neill et al. 2014). For example, in order for a killer whale to obtain the total energy value of one average size adult Chinook salmon, it would need to consume approximately 2.7 averaged size coho salmon, 3.1 chum salmon, 3.1 sockeye salmon, or 6.4 pink salmon (O’Neill et al. 2014).

Ford et al. (2005 and 2010) evaluated 25 years of demographic data from Southern and Northern Resident killer whales and found that changes in survival largely drive their population, and the populations’ survival rates were strongly correlated with coast-wide availability of Chinook salmon. Ward et al. (2009) found that Northern and Southern Resident killer whale fecundity was highly correlated with Chinook salmon abundance indices, and reported the probability of calving increased by 50 percent between low and high Chinook salmon abundance years. More recently, Ward et al. (2013) considered new stock-specific Chinook salmon indices and found strong correlations between the indices of Chinook salmon abundance, such as the West Coast Vancouver Island (WCVI) used by the Pacific Salmon Commission, and killer whale demographic rates. However, no single stock or group of stocks was identified as being most correlated with the whales’ demographic rates. Further, they stress that the relative importance of specific stocks to the whales likely changes over time (Ward et al. 2013).

The health of individual Southern Residents is being studied closely. As a chronic condition, nutritional stress can lead to reduced body size and condition of individuals, and lower reproductive and survival rates of a population (e.g., Trites and Donnelly 2003). Very poor body condition is detectable by a depression behind the blowhole that presents as a "peanut-head" appearance. There have been several Southern Residents that have been observed in recent years with the "peanut-head" condition, and the majority of these individuals died relatively soon after these observations (NMFS 2017). The bodies of the Southern Residents that died following these observations were not recovered and therefore a definitive cause of death could not be identified. More recently, photographs of whales from an unmanned aerial system (i.e., a drone) have been collected and individual whales in poor condition have been observed. Both females and males across a range of ages were found in poor body condition.

Killer whales are exposed to persistent pollutants primarily through their diet, including Chinook salmon. These harmful pollutants are stored in blubber and can later be released and become redistributed to other tissues when the whales metabolize the blubber in response to food shortages or reduced acquisition of food energy that could occur for a variety of other reasons including during gestation or lactation. High levels of these pollutants have been measured in blubber biopsy samples from Southern Residents (Ross et al. 2000, Krahn et al. 2007, Krahn et al. 2009), and more recently these pollutants were measured in scat samples collected from the whales, providing another potential opportunity to evaluate exposure of Southern Residents to these pollutants (Lundin et al. 2016). High levels of persistent pollutants have the potential to affect the whales' endocrine and immune systems and reproductive fitness (Krahn et al. 2002, Mongillo et al. 2016). As described in NMFS (2011c), vessel activities may affect foraging efficiency, communication, and/or energy expenditure through the physical presence of the vessels, underwater sound created by the vessels, or both. Houghton et al. (2015) found that the noise levels killer whales receive are largely determined by the speed of the vessel. Thus, to reduce noise exposure to the whales, they had recommended reduced vessel speeds. In 2011, NMFS announced final regulations to protect killer whales in Washington State from the effects of various vessel activities (NMFS 2011b (April 14, 2011; 76 FR 20870)).

2.4.6.2 Summary of Southern Resident Killer Whale DPS Viability

The viability of the Southern Resident killer whale DPS is evaluated through the consideration of the threats identified in the recovery plan and the population status relative to downlisting criteria. Since completing the recovery plan, NMFS has prioritized actions to address the threats with highest potential for mitigation: salmon recovery, oil spill response, and reducing vessel impacts. Several threats criteria have been met, but many will take years of research and dedicated conservation efforts to satisfy. Salmon recovery is a high priority on the West Coast and there are numerous actions underway to address threats to salmon populations and monitor their status. Recovery of depleted salmon populations is complex and a long-term process. NMFS and partners have successfully developed an oil spill response plan for killer whales; however, we still have additional work to prepare for a major spill event. NMFS has developed special vessel regulations intended to reduce disturbance of killer whales from vessel traffic. It will take time to evaluate the effectiveness of any new regulations in improving conditions for the whales. Even with progress toward minimizing the impacts of the threats, each of the threats still pose a risk to the survival and recovery of the whales (NMFS 2016).

At the time of listing in 2005, there were 88 whales in the population and at the end of 2016, there were 78 whales. Population growth has varied during this time with both increasing and decreasing years. The most recent assessment including data through 2016 now suggests a downward trend in population growth projected over the next 50 years, in part due to the changing age and sex structure of the population, but also related to the relatively low fecundity rate observed over the period from 2011 to 2016 (NMFS 2016). The biological downlisting and delisting criteria, including sustained growth over 14 and 28 years, respectively, have not been met (NMFS 2016). While some of the biological downlisting and delisting criteria have been met (i.e., representation in all three pods, multiple mature males in each pod), the overall status of the population is not consistent with a healthy, recovered population. Considering the status and continuing threats, the Southern Resident killer whales remain in danger of extinction (NMFS 2016).

2.4.6.3 Critical Habitat and Physical or Biological Features for Southern Resident Killer Whale

Designated critical habitat for the Southern Resident killer whale DPS consists of three specific marine areas of Puget Sound, Washington: (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca (November 29, 2006, 71 FR 69054). These areas are not part of the action area, and are not expected to be affected by the proposed action; therefore, critical habitat for the Southern Resident killer whale DPS will not be discussed further in this opinion.

2.4.7 Factors Affecting the Prey of Southern Residents in the Action Area

The impacts of various activities and factors affecting Chinook salmon populations in the freshwater environment of the action area are described in detail above, including major influences such as water operations in the Central Valley and climate change. All of these important influences on Chinook in the freshwater environment contribute to the health, productivity, and abundance of Chinook that ultimately survive to reach the ocean environment and influence the prey base and health of Southern Residents. The analysis in the NMFS 2009 BiOp on the long-term operations of the CVP/SWP (NMFS 2009b) concluded that the proposed action was likely to jeopardize the continued existence of several ESA-listed Chinook salmon ESUs. Additionally, NMFS concluded that the increased risk of extinction of the winter- and spring-run Chinook salmon, along with loss of diversity in fall-run, as a long-term consequence of the proposed action is likely to reduce the likelihood of survival and recovery of the Southern Resident killer whale DPS. The implementation of the RPA actions for reducing adverse impacts to Chinook salmon were determined sufficient to also reduce adverse impacts on Southern Residents and avoid jeopardy. Given that the factors influencing Chinook in the freshwater environment of the action area have been described already, the rest of this section focuses on important factors for Chinook salmon and for Southern Residents in the marine environment.

Significance of Prey and Prey Reductions

As described in Section 2.2.5 Rangewide Status of Southern Resident Killer Whale, statistical correlations between various Chinook salmon abundance indices and the vital rates (fecundity and survival) of Southern Resident killer whales have been outlined in several papers. In addition to examining whether any fundamental linkages between vital rates and prey abundance are evident, another primary purpose of many of these analyses has been aimed at distinguishing which Chinook salmon stocks, or grouping of Chinook salmon stocks, may be the most closely related to these vital rates for Southern Residents. Largely, attempts to compare the relative importance of any specific Chinook salmon stocks or stock groups using the strengths of these statistical relationships have not produced clear distinctions as to which are most influential, as most Chinook salmon stock indices are highly correlated with each other. It is also possible that different populations may be more important in different years. Large aggregations of Chinook salmon stocks that reflect abundance on a coastwide scale appear to be as equally or better correlated with Southern Resident vital rates than any specific or smaller aggregations of Chinook salmon stocks, including those that originate from the Fraser River that have been positively identified as key sources of prey for Southern Residents during certain times of the year in specific areas (see Ward et al. 2013; Hilborn et al. 2012). However, there are still questions about the diet preferences of Southern Residents throughout the entire year, as well as the relative exposure of Southern Residents to various Chinook salmon or other salmon stocks outside of inland waters during the summer and fall.

In 2012, NMFS convened an independent science panel (Panel) to critically evaluate the effects of salmon fisheries on the abundance of Chinook salmon available to Southern Residents (Hilborn et al. 2012). The Panel found good evidence that Chinook salmon are a very important part of the Southern Resident diet and that some Southern Residents have been in poor condition recently, which is associated with higher mortality rates. They further found that the data and correlations developed to date provide some support for a cause and effect relationship between salmon abundance and Southern Resident survival and reproduction. They identified "reasonably strong" evidence that vital rates of Southern Residents are, to some degree, ultimately affected by broad-scale changes in their primary Chinook salmon prey. They suggested that the effect is likely not linear, however, and that predicted improvements in Southern Resident survival may not be realistic or may diminish at Chinook salmon abundance levels beyond the historical average (Hilborn et al. 2012). Given all the available information, and considering the uncertainty that has been highlighted, we assume that the overall abundance of Chinook salmon as experienced by foraging Southern Resident killer whales throughout their range may be as influential on their vital rates as any other relationships with any specific Chinook salmon stocks.

Link between Southern Residents and Central Valley Chinook as Prey

As described in Section 2.2.5 Rangewide Status of Southern Resident Killer Whale, Southern Residents (particularly K and L pod) are known to reside in coastal waters along the west coast of U.S. and Canada during the winter and spring, including at least occasional visits to California. The BA describes in general what is known about the distribution of Central Valley Chinook salmon in the Pacific Ocean in comparison to the distribution of Southern Residents. Largely, our knowledge of the distribution of these Chinook salmon in the ocean comes from the data obtained from coded wire tags (CWT) and genetic information (GSI) obtained from fish harvested in ocean fisheries that generally occur sometime between April and October. Unfortunately, the timing of ocean salmon fisheries does not overlap well with the occurrence of Southern Residents in coastal waters during the winter and spring. Ocean distribution of Chinook salmon populations based on summer time fishery interactions generally indicates northern movements of Chinook salmon from their spawning origins (Weitkamp 2010), although the range of these movements is quite variable between populations and run timings, and the distribution of Chinook salmon populations in the winter and spring when Southern Residents are likely to encounter Central Valley Chinook salmon stocks is not known. Without any additional information available that would suggest the distribution of Central Valley Chinook salmon shifts during the winter or spring, we assume the distribution of Central Valley Chinook salmon during the winter and spring is similar to what has been documented during the summer and fall, and that data collected from hatchery fish (usually where CWTs are applied) are representative of the distribution of both wild and hatchery populations.

The available data from CWT and GSI confirm that Chinook salmon from the Central Valley (particularly fall-run) occur in small numbers as far north as Vancouver Island, British Columbia (Weitkamp 2010), but are primarily encountered by ocean salmon fisheries south of the Columbia River (Weitkamp 2010; Bellinger et al. 2015). Recent GSI studies by Bellinger et al. (2015) indicated that Central Valley Chinook salmon (primarily fall-run) made up significant proportions of Chinook salmon sampled off the coast of Oregon and California during a fishing season where comprehensive GSI data were collected.5 In total, the available data suggest that Central Valley Chinook salmon constitute a relatively large percentage of Chinook salmon that would be expected to be encountered by Southern Residents in coastal waters south of the Columbia River, especially off of California, and at least a small portion of Chinook salmon in the ocean as far north as British Columbia. In addition, ratios of contaminants in blubber biopsies found that the blubber of K and L pod match with similar ratios of contaminants in Chinook salmon from California, which was indicated by the relatively high concentrations of dichlorodiphenyltrichloroethane (DDT). These DDT fingerprints suggest fish from California form a significant component of their diets (Krahn et al. 2007, Krahn et al. 2009, O'Neill et al. 2012). As a result, we conclude that Central Valley Chinook salmon are an important part of the diet for most Southern Residents during portions of the year when Southern Residents occur in coastal waters off the North American coast especially south of the Columbia River.

Relationship of Central Valley Chinook to Overall Ocean Abundance

Given that the best information available links Southern Resident population dynamics to the abundance of Chinook salmon available to Southern Residents at a coastwide level, and that impacts from the proposed action are expected to occur only to salmon from the California Central Valley, it is important to understand how significant Central Valley Chinook salmon are to the abundance of Chinook salmon within the range of Southern Residents. Currently, there is no capability to generate specific estimates of the number of Chinook salmon that may be found in the ocean within any defined boundary that would include likely or possible coastal migrations of Southern Residents during the winter and spring. There are many different management and monitoring schemes that are employed for Chinook salmon along the western North American coast that make it difficult to directly relate and compare metrics of Chinook salmon abundance. A commonly used approach involves use of relative indexes as opposed to absolute measures of abundance, such as the WCVI index that has been previously related to Southern Resident population dynamics. In addition, many of the estimates or forecasts of Chinook salmon abundance used for management are related to escapements that are not inclusive of adult Chinook salmon that remain in the ocean to mature, or succumb to predation or other forms of mortality. In combination, use of catch and escapement data from Chinook salmon populations

[5] The BA referenced data appended to Bellinger et al. (2015) to estimate that Central Valley Chinook salmon made up about 22 percent of the Chinook salmon sampled off the Oregon coast and about 50 percent of those sampled off the California coast (south to Big Sur) during that one year study. Chinook salmon stocks originating from the northern Oregon coast and other systems northward were not detected at all off the California coast. A wide variety of Chinook salmon stocks can be found off the coast of Oregon, although the influences of major systems such as the Columbia River becomes more prominent off the coast of northern Oregon.

that occur in the range of Southern Residents could provide some minimum measure of the absolute abundance of Chinook salmon that are available, although all of these Chinook salmon individuals would not necessarily always overlap with Southern Residents during any specific time period given the uncertain and variable migratory nature of Chinook salmon and Southern Residents. Without any comprehensive and consistent monitoring and assessment methodology across Chinook salmon populations throughout the range of Southern Residents, we will combine the data and information that is available for use in generally characterizing the abundance of coastwide Chinook salmon potentially available to Southern Residents, as well as the relative importance of Central Valley Chinook salmon to that total.

In the BA, Reclamation cites ocean abundance estimates for Chinook salmon that originate from U.S. systems provided by the Pacific Fisheries Management Council (PFMC 2016a). The estimated 2016 ocean abundance of Sacramento River Fall-run Chinook salmon, which constitutes the majority of Chinook salmon that return to the Central Valley in terms of abundance, as represented through the Sacramento Index (SI), is 299,600 fish.[6] Since the early 1980s, SI values commonly range from 500,000 to 1 million fish, although recent abundances have been much smaller than historical averages (PFMC 2016a). In 2016, the Klamath River is estimated to have a 2016 ocean abundance of 142,200 fish, although historically the ocean abundance of Klamath is typically several hundred thousand fish. Including escapement forecasts for Columbia River Chinook salmon stocks (1,317,700 fish) with other stocks south of the Strait of Juan de Fuca (65,500 fish); along with Puget Sound, Hood Canal, and the Strait of Juan de Fuca combined (150,600 fish); the BA cites a total Chinook salmon abundance from these sources to 1,975,600 fish in 2016, of which 299,600/1,975,600=15 percent originate from the Central Valley (Reclamation 2016). As mentioned, 2016 was expected to be a relatively low season for Sacramento River Fall-run Chinook salmon.

While this total presented in the BA does reflect most of the significant populations of Chinook salmon along the U.S. coast, this does not include any totals from significant Canadian Chinook salmon populations that are likely encountered by Southern Residents to some degree, in particular Fraser River and West Coast Vancouver Island stocks. Although abundance estimates or escapement forecasts for 2016 are not readily available for these Chinook salmon stocks (largely managed through relative abundance indices), it is possible to look at historical catch and escapement numbers to get a sense of at least the minimum number of these fish that are in the ocean in the range of Southern Residents at some point each year. During the Science Panel process, historical estimates of catch and escapement for most major Chinook salmon stocks from British Columbia to California were produced (Kope and Parken 2011). Across all major Chinook salmon populations, Kope and Parken (2011) reported that the total number of Chinook salmon that were either captured or escaped annually from 1979-2010 ranged from about 2-6 million; commonly between 3 and 4 million fish. Although these totals are certainly an underestimate of all the Chinook salmon that could be present in coastal waters along the west coast associated with these populations, and the precise overlap of Southern Residents with all these populations at all times during the year is not well established, we conclude based on the historical catch and escapement data presented above that the relative magnitude of Chinook

[6] The Sacramento Index (SI) is limited to a measure of catch and escapement abundance, and not absolute abundance in the ocean. The SI index is the sum of (1) adult Sacramento River Fall Chinook (SRFC) salmon ocean fishery harvest south of Cape Falcon, OR (2) adult SRFC impacts from non-retention ocean fisheries when they occur, (3) the recreational harvest of adult SRFC in the Sacramento River Basin, and (4) the SRFC adult spawner escapement. The SI forecasting approach uses jack escapement estimates to predict the SI (PFMC 2016a)

salmon in the range of Southern Residents each year is likely at least several million fish. Based on the tabulations of catch and escapement conducted by Kope and Parken (2011), we can get a sense of the relative contribution of Central Valley Chinook salmon (as represented by the Sacramento Index to the total abundance of Chinook salmon in the range of Southern Residents. On average since the early 1980s, it appears that the SI constitutes about 20 percent of the total catch and escapement of all these Chinook salmon populations that are likely encountered by Southern Residents to some degree, although this proportion varies from about 10-30 percent each year depending on varying strengths in run size (Kope and Parken 2011). As a result, we conclude that Central Valley Chinook salmon make up a sizeable and significant portion of the total abundance of Chinook salmon available to Southern Residents throughout their range; likely at least several hundred thousand individual fish even during years of relative low abundance for Central Valley Chinook salmon. In addition, the known distributions of Chinook salmon along the coast suggest that Central Valley Chinook salmon are an increasingly significant prey source during any southerly movements of Southern Residents along the coast of Oregon and California that may occur during the winter and spring (Weitkamp 2010).

2.4.7.1 Climate Change and Environmental Factors in the Ocean

The availability of Chinook salmon to Southern Residents is affected by a number of environmental factors and climate change. Predation in the ocean contributes to natural mortality of salmon in addition to predation in freshwater and estuarine habitats as discussed in Section 2.4.4.2 Predation. Salmonids are prey for pelagic fishes, birds, and a wide variety of marine mammals (including Southern Residents). Recent studies have provided evidence that growth and survival rates of salmon in the California Current off the Pacific Northwest can be linked to fluctuations in ocean conditions related to Pacific Decadal Oscillation and the El Nino-Southern Oscillation conditions and events (Peterson et al. 2006, Wells et al. 2008). Evidence exists that suggests early marine survival for juvenile salmon is a critical phase in their survival and development into adults. The correlation between various environmental indices that track ocean conditions and salmon productivity in the Pacific Ocean, both on a broad and a local scale, provides an indication of the role they play in salmon survival in the ocean. Moreover, when discussing the potential extinctions of salmon populations, Francis and Mantua (2003) point out that climate patterns would not likely be the sole cause, but could certainly increase the risk of extinction when combined with other factors, especially in ecosystems under stress from humans.

2.4.7.2 Salmon Harvest Actions

NMFS has consulted on the effects of numerous salmon fishery harvest actions that may affect Chinook availability in coastal waters for Southern Residents, including the Pacific Coast Salmon Plan fisheries (NMFS 2009c), and the 10-year terms of the Pacific Salmon Treaty (term of biological opinion from 2009-2018; NMFS 2008a), the United States v. Oregon 2008 Management Agreement (term of biological opinion from 2008-2017; NMFS 2008b). In these past harvest opinions, NMFS has considered the short-term effects to Southern Residents resulting from reductions in Chinook abundance that occur during a specified time period and the long-term effects to whales that could result if harvest affected viability of the salmon stock over time by decreasing the number of fish that escape to spawn. These past analyses suggested that short-term prey reductions were small relative to remaining prey available to the whales. In the long term, harvest actions have been designed or modified via an RPA to meet the conservation objectives of harvested stocks in a manner determined not likely to appreciably reduce the survival or recovery of listed Chinook salmon, and therefore ultimately not likely to jeopardize the continued existence of listed Chinook salmon. The harvest opinions referenced above that considered potential effects to Southern Residents have all concluded that the harvest actions cause prey reductions, but were not likely to jeopardize the continued existence of ESA-listed Chinook salmon or Southern Residents.

As described above, an independent science panel evaluated the state of science regarding the effects of salmon fisheries on the abundance of Chinook salmon available to Southern Residents. Overall, the panel concluded that the impact of reduced Chinook salmon harvest on future availability of Chinook salmon to Southern Residents is not clear and cautioned against overreliance on correlative studies, although they acknowledged that available data provide some support for a cause and effect relationship between salmon abundance and Southern Resident survival and reproduction (Hilborn et al. 2012).

2.4.7.3 Quality of Prey

Contaminants of various types, including persistent organic pollutants that are believed to pose significant risks for Southern Residents and other marine life, enter marine waters from numerous sources throughout the action area but are typically concentrated near populated areas of high human activity and industrialization (Mongillo et al. 2016). The majority of growth in salmon occurs while feeding in saltwater (Quinn 2005). Therefore, the majority (> 96 percent) of persistent pollutants in adult salmon are accumulated while feeding in the marine environment (Cullon et al. 2009, O'Neill and West 2009). The marine distribution of salmon is an important factor affecting pollutant accumulation as is evident across the different salmon populations. For example, Chinook populations feeding in close proximity to land-based sources of contaminants have higher concentrations (O'Neill et al. 2006). In addition, ratios of contaminants in blubber biopsies found that the blubber of K and L pod match with similar ratios of contaminants in Chinook from California, which was indicated by the relatively high concentrations of dichlorodiphenyltrichloroethane (DDT). These DDT fingerprints suggest fish from California form a significant component of their diets (Krahn et al. 2007, Krahn et al. 2009, O'Neill et al. 2012).

2.4.7.4 Other Factors Affecting Southern Residents in the Action Area

2.4.7.4.1 Vessel Activity and Sound

Commercial, military, recreational and fishing vessels traverse the coastal range of Southern Residents in the action area. Vessels may affect foraging efficiency, communication, and/or energy expenditure by their physical presence and by creating underwater sound and disturbance (Williams et al. 2006, Holt 2008, Holt et al. 2011). Collisions of Southern Residents with vessels are rare, but remain a potential source of serious injury and mortality. Large ships that traverse coastal waters of the whales' range move at relatively slow speeds and are likely detected and avoided by Southern Residents.

Sound generated by large vessels (e.g., large ships, tankers, and tugs) is a major source of low frequency human-generated sound (5 to 500 Hz) in the world's oceans (National Research Council 2003). At close range large vessels can be a significant source of background noise at frequencies important to the whales (Holt 2008). Commercial sonar systems designed for fish finding, depth sounding, and sub-bottom profiling are widely used on recreational and commercial vessels and are often characterized by high operating frequencies, low power, narrow beam patterns, and short pulse length (National Research Council 2003). Many of these sound sources fall within the hearing range of many marine mammals, including Southern Residents, and may produce masking effects of other important sound detection or communication abilities.

2.4.7.4.2 Non-vessel Sound

Anthropogenic (human-generated) sound in the range of Southern Residents is generated by other sources besides vessels, including oil and gas exploration, construction activities, and military operations. Natural sounds in the marine environment include wind, waves, surf noise, precipitation, thunder, and biological noise from other marine species. The intensity and persistence of certain sounds (both natural and anthropogenic) in the vicinity of marine mammals vary by time and location and have the potential to interfere with important biological functions (e.g., hearing, echolocation, communication). In the coastal waters of the action area, military sonar and seismic surveys also have the potential to disturb Southern Residents killer whales.

2.4.7.4.3 Oil Spills

Oil spills have occurred in the coastal range of Southern Residents in the past, and there is potential for spills in the future. The magnitude of risk posed by oil discharges in the action area is difficult to precisely quantify, but improvements in oil spill prevention procedures since the 1980s likely provide some reduced risk of spill. In marine mammals, acute exposure to petroleum products can cause changes in behavior and reduced activity, inflammation of the mucous membranes, lung congestion, pneumonia, liver disorders, neurological damage (Geraci and St. Aubin 1990), potentially death, and long-term effects on population viability (Matkin et al. 2008). In addition, oil spills have the potential to adversely impact habitat and prey populations, and, therefore, may adversely affect Southern Residents by reducing food availability.

2.4.7.4.4 Scientific Research

Research activities on Southern Residents are typically conducted between May and October in inland waters, and some permits include authorization to conduct research in coastal waters as well. In general, the primary objective of this research is population monitoring or data gathering for behavioral and ecological studies. Recent permits issued by NMFS include research to characterize the population size, structure, feeding ecology, behavior, movement patterns and habitat use of the Southern Residents, especially during the winter and spring when Southern Residents are using coastal waters extensively. Impacts from permitted research include temporary disturbance and potential short term disruptions or changes in behavior such as feeding or social interactions with researchers in close proximity, and any injuries that may be associated with biopsy samplings or attachment of tags for tracking movements and behavior.

2.4.7.5 Summary of Southern Residents Environmental Baseline

Southern Residents are exposed to a wide variety of human activities and environmental factors in the action area. All the activities discussed above in Section 2.4.7 are likely to have some level of impact on Southern Residents when they are in the action area. No single threat has been directly linked to or identified as the cause of the relative lack of growth of the Southern Resident population over time, although three primary threats that have been identified are: prey availability, environmental contaminants, and vessel effects and sound (Krahn et al. 2002). There is limited information on how these factors or additional unknown factors may be affecting Southern Residents when in coastal waters; however, the small size of the population increases the level of concern about all of these risks (NMFS 2008c).

The action area was derived considering several factors to account for all effects of the PA. First, to determine the action area for listed fish and their designated critical habitat, the CALSIM II model was used to screen for the extent of potential effects within the Sacramento and San Joaquin rivers and their tributaries. Where CALSIM II results did not differ between the PA and No Action Alternative (NAA) conditions, no effect was assumed within the Sacramento and San Joaquin rivers and their tributaries. The similarity in CALSIM II results was assumed to indicate that the PA would not have an effect on operations and therefore would not affect species in those areas. The action area does not include those areas. This is discussed further in the BA in the introduction to Section 5.4.2, Upstream Hydrologic Changes. Additionally, the Feather River system is excluded from the action area due to the existing formal consultation on water operations in that system, as described in Section 1.3.1.2 above and in the BA in Section 4.4 Feather River Operations Consultation. The entire legal Delta and Suisun Marsh are included in the action area for fish species because the PA may affect any waterway in the Delta or Suisun Marsh. For listed anadromous species, the entire legal Delta was assumed to account for all of the potential construction effects, including the siting of offsetting measures including habitat restoration. To account for possible origination points of barge traffic serving construction activities, as detailed in Section 5.2.3 Barge Landings, of the BA, San Francisco and intervening waterways (San Francisco Bay) were included in the action area. For the Southern Resident killer whale, all nearshore coastal waters within their range in California, Oregon, and Washington are included in the action area because this distribution identifies the entire area of co-occurrence of Central Valley Chinook salmon and the Southern Resident killer whale.

2.5 Effects of the Action

Under the ESA, "effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR §402.02). Indirect effects are those that are caused by the PA and are later in time, but still are reasonably certain to occur.

As described in Section 1.2 Consultation History, with its request for initiation of formal consultation on August 2, 2016, Reclamation submitted a BA, which described the proposed action. In addition, Reclamation requested two additional components be added to the proposed action on November 7, 2016, and Reclamation transmitted a log of responses to NMFS' request for information and clarification on December 20, 2016. NMFS prepared an Initial Draft Biological Opinion for the CWF (dated January 21, 2017, NMFS 2017) based on the proposed action as described in the BA and revisions to the proposed action in these additional submissions. After release of preliminary draft sections of the CWF project analysis for the Delta Science Program's Independent Science Panel review (dated December 23, 2016, NMFS 2016), and the Initial Draft Biological Opinion for the CWF, Reclamation submitted additional revisions to the PA (dated June 2, 2017, Reclamation 2017). The final revised PA is identified in

Appendix A1, and the June 2017 revisions primarily include the following components: 1) adjustments to specific construction activity work windows: 2) modifications to south Delta operational criteria: 3) revisions to the real-time operations of the north Delta diversions, and 4) increased commitment to habitat restoration.

The objective of these revisions are to minimize and/or mitigate adverse impacts identified in the Initial Draft Biological Opinion effects analysis. NMFS has supplemented the effects analysis in the Initial Draft Biological Opinion to reflect components of the June 2017 revisions to the PA as summarized below:

1) Adjustments to specific construction activity in-water work windows are analyzed in Section 2.5.1.1 Construction Effects. Substantial changes to the construction activities include truncated in-water work windows that minimize potential exposure of salmonids and sturgeon to turbidity, acoustic impacts from pile driving, and barge vessel interaction. Barge vessel interaction is also reduced with specificity of travel routes to barge landings that avoid primary migration routes for listed fish.

2) Modifications to south Delta operational criteria that provide flexibility for exports in October, November, and December during periods when north Delta diversion exports are limited due to fish pulse protections. It is expected that the criteria flexibility based on these modifications does not create changes in hydrology that substantially differ from what NMFS analyzed in the Initial Draft Biological Opinion.

3) Revisions to the real-time operations of the north Delta diversions are analyzed in Section 2.5.1.2 Operations Effects. Key changes in the June 2017 revisions to the PA include unlimited pulse protection flows (UPP) in the north Delta to minimize impacts to salmonids migrating into the Delta. The UPP scenario, which will be in effect when the primary juvenile winter-run and spring-run Chinook salmon migration is occurring, is triggered in response to real-time capture of juvenile winter-run and spring-run Chinook salmon upstream of the Delta. The PA and L1 scenarios (described in A and B below) are applicable when UPP is not in effect (i.e., during post-pulse protection). NMFS analyzed the effects of PA and L1 in the Initial Draft Biological Opinion and in Section 2.5.1.2.7 of this biological opinion. NMFS added in this Opinion analysis of a third scenario (described below at C) to analyze revisions to the real-time operations of the north Delta diversions that were included in the June 2017 revisions to the PA. Together the three scenarios describe the range of effects on survival of juvenile salmonids from the proposed north Delta diversion operations.

    A. Proposed Action (PA): The operations of the proposed action under the bypass rules for the new north Delta diversions. The bypass rules have not been substantially revised in the June 2017 revisions to the PA. Thus, the analysis of the effects of these operations in Section 2.5.1.2.7 of this Opinion reflect potential impacts to salmonids downstream of the north Delta diversion resulting when north Delta diversion operations are at Levels 1, 2, and/or 3 (i.e., times when UPP is not triggered and criteria allow for higher diversion levels). The analyses considering impacts to salmonid travel (i.e., time and route), entrainment, survival probability, cohort replacement rate and population abundance (life-cycle model), as well as critical habitat are provided in Section 2.5.1.2.7 in this Opinion and have not substantially changed from the analysis in the Initial Draft Biological Opinion.

B. Level 1 Only (L1): The north Delta diversion pumping operations of the L1 scenario. The L1 scenario provides context to the range of effects that may be experienced by salmonids given the different levels of pumping that may occur under the north Delta diversion bypass rules after restrictions have been implemented to protect a pulse of fish. The bypass rules related to these levels of pumping have not been substantially revised in the June 2017 revisions to the PA. Thus, the analysis of the effects of these operations in Section 2.5.1.2.7 of this Opinion reflects potential impacts to salmonids downstream of the north Delta diversion resulting when north Delta diversion operations are capped at Level 1. The analyses considering impacts to salmonid travel (i.e., time and route), entrainment, survival probability, cohort replacement rate, and population abundance (life-cycle model), as well as critical habitat are provided in Section 2.5.1.2.7 in this Opinion and have not substantially changed from the analysis in the Initial Draft Biological Opinion.

C. Unlimited Pulse Protection (UPP): The unlimited pulse protection scenario (UPP) is described in the June 2017 revisions to the PA. These revisions comprise modifications to the real-time operations of the north Delta diversions such that an unlimited number of fish migration events would trigger low-level pumping diversion rates (i.e., pulse protection) and higher diversion rates would be allowed during pulse protection events as long as bypass flows remain above 35,000 cfs. This scenario is summarized and analyzed in Section 2.5.1.2.7.4 using empirical flow and fish monitoring data and the Perry 2017 survival model with adjustments to the modeling assumptions to fit the flow and fish monitoring inputs. This analyses is described further in Appendix E. Unlike the analyses for PA and L1 described above, this analysis focuses exclusively on the probability of survival for salmonids. The UPP scenario is only evaluated using the Perry Survival model (as described below).

4) The June 2017 revisions to the PA include increased commitment to habitat restoration. The increased commitment to habitat restoration includes 80 acres of expanded habitat upstream of Red Bluff Diversion Dam and 1800 acres of restoration in the Delta. The winter-run Chinook salmon life cycle model was used to evaluate the impact that restoration actions plus existing restoration commitments would have on cohort replacement rate of this population relative to the original PA. Two juvenile Chinook salmon fish routing elements of the original PA (reduction of routing into Georgiana Slough and increased routing into Yolo Bypass) were also modeled in conjunction with the habitat restoration actions to capture the full-range of benefits from these actions that are intended to improve juvenile survival.

2.5.1 Effects of the Action on the Species

This effects section focuses on the listed species that are impacted by the PA: Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, CCV steelhead, sDPS green sturgeon, and Southern Resident killer whale. Impacts to Central Valley fall/late-fall run Chinook salmon from the PA are also analyzed in this Opinion even though the Central Valley fall/late-fall run Chinook salmon ESU is not listed under the ESA. There are three primary reasons that we included the analysis of project effects to fall/late-fall run Chinook salmon: (1) to inform the prey base effects analysis for Southern Resident killer whale; (2) the relationship between fall/late-fall run Chinook salmon and listed Chinook salmon covered in this Opinion (spring-run and winter-run) relative to quantity and quality of effects to these species, which makes fall/late-fall run Chinook salmon an appropriate surrogate in some cases for the listed Chinook salmon; and (3) the utility of the Opinion effects analysis for Pacific salmon (fall/late-fall, spring-run, and winter-run Chinook salmon) as a consistent foundation for the EFH analysis.

Because fall/late-fall Chinook salmon are not an ESA-listed species and do not have designated critical habitat, this species will not be evaluated based on a jeopardy or adverse modification standard. Therefore, fall/late-fall Chinook salmon are only addressed in the this section of this Opinion because their relative species status—both rangewide and within the action area (i.e., environmental baseline)—are irrelevant to the Opinion's conclusion. Life history information for fall/late-fall Chinook salmon is presented in the EFH Assessment as the foundation for evaluating impacts to EFH for this ESU.

Due to the variability and uncertainty associated with the response of anadromous fish species to the effects of the PA, the varying population size of each species, annual variations in the timing of spawning and migration, and individual habitat use within the action area, it will be impracticable in most cases to quantify and track the amount or number of individuals at each life stage of each species that will be adversely affected. Because of this, we have used the following terms to provide some information on expected amount: small proportion, medium proportion, or large proportion.

For construction-related effects, NMFS' analysis relies on the proposed minimization and avoidance measures to reduce effects to the greatest degree possible. The effects to species that cannot be minimized and avoided are identified in the effects analysis and any incidental take is described as appropriate in the incidental take statement. Permanent impacts to critical habitat are mitigated as described in NMFS' analysis through appropriate habitat restoration actions.

2.5.1.1 Construction Effects

The PA includes both aquatic and terrestrial construction-related activities that are expected to create acoustic impacts to aquatic species in specific locations or "activity areas" within the action area. As described in the BA, each activity has a proposed in-water work window, as described in Table 2-9.

Table 2-9. Proposed In-water Construction Work Windows.

Construction Locations/Activities	Timeframe (Months)	Work Seasons to Complete
North Delta Intakes[1]	June 15 through October 31	7
Clifton Court Forebay	July 1 through October 31	7
Head of Old River Gate	August 1 through October 31	2
Barge Landings	July 1 through August 31	2
Geotechnical Investigations	August 1 through October 31	4

[1] Impact pile driving will be restricted to June 15 through September 15.

Species presence in the specific activity areas within the action area varies by month and is described in the tables below for winter-run Chinook salmon (Table 2-10), CV spring-run Chinook salmon (Table 2-11), CCV steelhead (Table 2-12), and sDPS green sturgeon (Table 2-13).

Table 2-10. The Temporal Occurrence of Adult (a) and Juvenile (b) Winter-run Chinook Salmon in the Sacramento River.

(a) Adults Freshwater												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River basin[a,b]												
Upper Sacramento River spawning[c]												
(b) Juvenile Emigration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River at Red Bluff [d]												
Sacramento River at Knights Landing[e]												
Sacramento trawl at Sherwood Harbor[f]												
Midwater trawl at Chipps Island[g]												

Sources: [a] (Yoshiyama et al. 1998); (Yoshiyama et al. 1998; Moyle 2002b); (Moyle 2002b); [b](Myers et al. 1998); [c] (Williams 2006); [d] (Martin et al. 2001); [e] Knights Landing Rotary Screw Trap Data, CDFW (1999–2011); [f,g] Delta Juvenile Fish Monitoring Program, USFWS (1995–2012)

Table 2-11. The Temporal Occurrence of Adult (a) and Juvenile (b) Central Valley Spring-run Chinook Salmon in the Sacramento River.

(a) Adult Migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Delta[a]												
San Joaquin Basin												
Sac. River Basin[b,c]												
Sac. River Mainstem[c,d]												
Mill Creek[e]												
Deer Creek[e]												
Butte Creek[e,h]												
b) Adult Holding[b,c]												
c) Adult Spawning[b,c,d]												
(b) Juvenile Migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac. River Tribs[f]												
Upper Butte Creek[g,h]												
Mill, Deer, Butte creeks[e,h]												
Sac. River at RBDD[d]												
Sac. River at KL[i]												
San Joaquin basin												
Delta[j]												

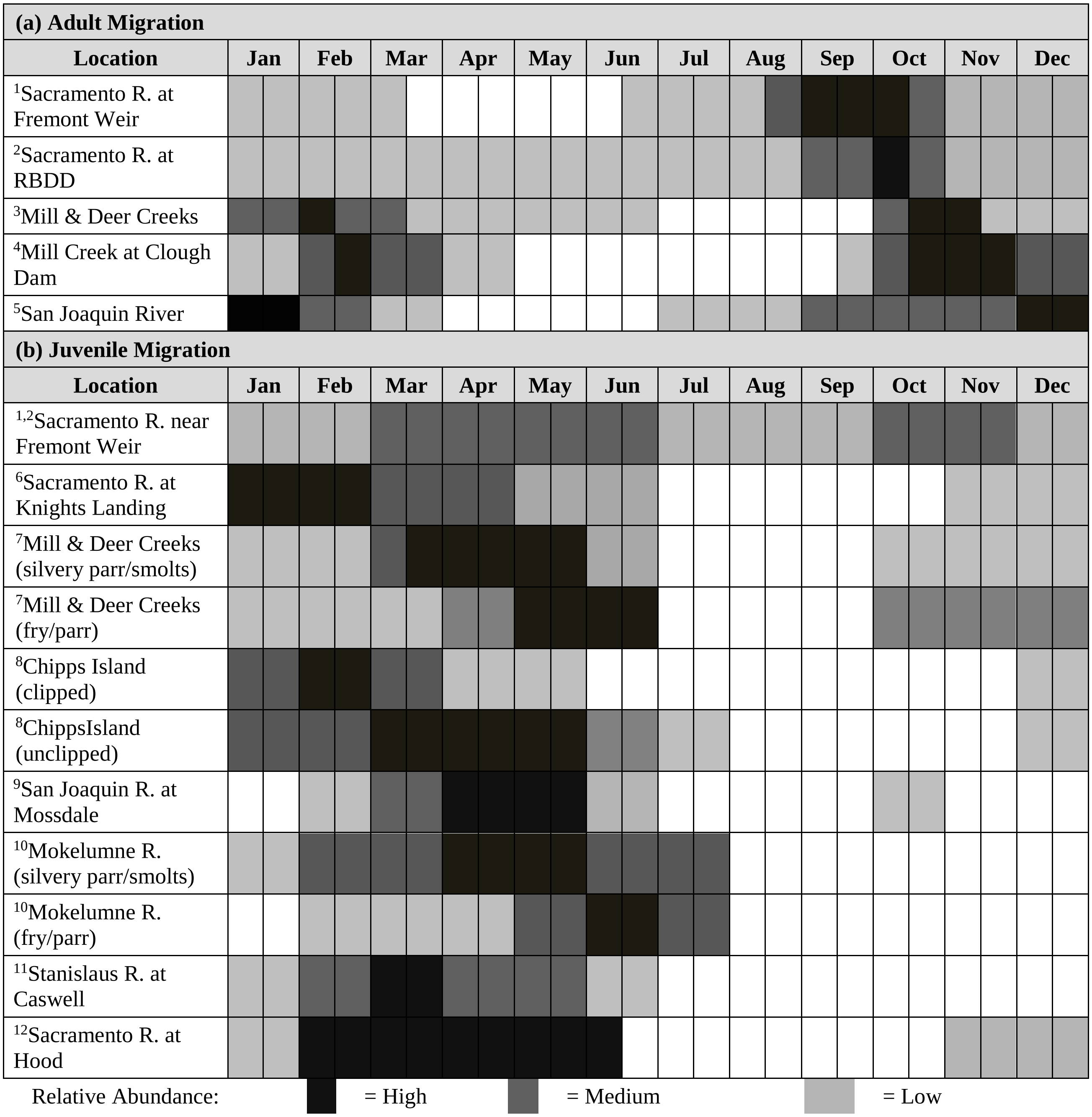
Relative Abundance: = High = Medium = Low

Sources: [a]CDFG (1998); [b]Yoshiyama et al. (1998); [c]Moyle (2002); [d]Myers et al. (1998); [e]Lindley et al. (2004); [f]CDFG (1998); [g]McReynolds et al. (2007); [h]Ward et al. (2003); [i]Snider and Titus (2000); [j]SacTrawl (2015)

Note:

Yearling spring-run Chinook salmon rear in their natal streams through the first summer following their birth. Downstream emigration generally occurs the following fall and winter. Most young-of-the-year spring-run Chinook salmon emigrate during the first spring after they hatch.

Table 2-12. The Temporal Occurrence of (a) Adult and (b) Juvenile California Central Valley Steelhead at Locations in the Central Valley.



Sources: 1(Hallock 1957); 2(McEwan 2001); 3(Harvey 1995); 4CDFW unpublished data; 5CDFG Steelhead Report Card Data 2007; 6NMFS analysis of 1998-2011 CDFW data; 7(Johnson and Merrick 2012); 8NMFS analysis of 1998–2011 USFWS data; 9NMFS analysis of 2003-2011 USFWS data; 10unpublished EBMUD RST data for 2008–2013; 11Oakdale RST data (collected by FishBio) summarized by John Hannon (Reclamation); 12(Schaffter 1980).

Table 2-13. The Temporal Occurrence of (a) Spawning Adult, (b) Larval, (c) Young Juvenile, (d) Juvenile, and (e) Sub-adult/Non-spawning Adult Southern Distinct Population Segment Green Sturgeon.

(a) Adult-sexually mature (≥145 cm TL females, ≥ 120 cm TL males), including pre- and post-spawning individuals.												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac River (rkm 332.5-451)												
Sac River (< rkm 332.5)												
Sac-SJ-SF Estuary												
(b) Larval												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac River (> rkm 332.5)												
(c) Juvenile (≤5 months old)												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac River (> rkm 332.5)												
(d) Juvenile (≥5 months)												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac River (< rkm 391)												
Sac-SJ Delta, Suisun Bay												
(e) Sub-adults and Non-spawning adults												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
SAC-SJ-SF Estuary												
Pacific Coast												
Coastal Bays & Estuaries [1]												

Relative Abundance: = High = Medium = Low

[1] Outside of Sac-SJ-SF estuary (e.g., Columbia River, Grays Harbor, Willapa Bay)

Locations emphasize the Central Valley of California. Darker shades indicate months of greatest relative abundance.

2.5.1.1.1 Acoustic Stress

Major activities included in the PA that have potential to cause acoustic impacts include using heavy construction equipment, excavators or drilling equipment, and pile drivers. Stress from noise can also be expected due to increased vessel traffic for delivery of construction equipment and materials and operation of tunnel boring machines (TBMs) under Delta waterways. Acoustics-related stress is considered a direct effect of the construction activities included in the PA.

Construction activities within the aquatic environment are described in the BA for multiple locations throughout the Delta. These activities include driving steel sheet pile sections for cofferdam construction and steel or concrete support pilings for infrastructure. The BA proposes using vibratory hammers to initially drive the sheet piles to the approximate final depth required and impact hammers to achieve the final required tip depth and load-bearing strength. Installing the sheet pile cofferdams will take several construction weeks, as described in BA Chapter 3 and Appendix 3.D, after which the isolated construction area will be dewatered for continued construction activities. Installation of steel support piles assumes exclusive use of an impact hammer to drive piles to the required depth and the load-bearing resistance necessary to support concrete floor foundations.

Installing piles with either a vibratory or impact hammer is expected to result in adverse effects to salmonids and sturgeon due to high levels of underwater sound, but to differing degrees. NMFS considers using a vibratory hammer to be less harmful to fish than that of an impact hammer because of the continuous characteristics of the sound wave produced by a vibratory hammer with lower peak sound pressures (Buehler et al. 2015). While exposure to continuous sound for a long duration could harm fish, noise from an impact hammer is an impulsive sound source with a high intensity and rapid rise time and is known to injure or kill fish.

Driving sheet and pipe piles creates a wave of energy that propagates from the pile location. Sheet and steel pipe piles are driven into the substrate until the hammer encounters a predetermined level of resistance. As the pile is driven into the substrate and meets resistance, a wave of energy travels down the pile, causing it to resonate radially and longitudinally, much like a large bell. Most of the acoustic energy results from the outward expansion and inward contraction of the walls of the steel pile as the compression wave moves down the pile from the hammer to the end of the pile buried in the substrate. Because water is virtually incompressible, the outward movement of the pile followed by the pile walls pulling back inward to their original shape sends an underwater pressure wave that propagates outward from the pile in all directions. The pile resonates, sending a succession of pressure waves as it is pushed several inches deeper into the substrate (Burgess and Blackwell 2003).

The physical injury or damage to body tissues associated with very high sound level exposure and drastic changes in pressure are collectively known as barotraumas. Fish can survive and recover from some barotrauma, but in other cases, death can be instantaneous, occur within minutes after exposure, or occur several days later. The degree to which an individual fish is affected by underwater sound exposure depends on a number of variables, including differences in sensitivity to acoustic pressure, fish species, presence of a swim bladder, hearing sensitivity, the proximity and linkage of the swim bladder to the inner ear, and fish size (Popper et al. 2003; Ramcharitar et al. 2006; Braun and Grande 2008; Deng et al. 2011). Because the air within a fish’s swim bladder is less dense than water or the fish body, the air and swim bladder can be easily compressed by sound pressure waves traveling through the fish’s body. As sound pressure waves pass through the fish’s body, the swim bladder routinely expands and contracts with the fluctuating sound pressures, resulting in injury through the routine expansion and contraction of the bladder. The characteristics of the sound source also play an important role in effect to fish. For high sound pressure level exposure, such as impact hammer pile driving, the swim bladder may rapidly and repeatedly expand and contract and pound against the internal organs. This pneumatic pounding may result in hemorrhage and rupture of blood vessels and internal organs, including the swim bladder, liver, and kidneys. External damage, such as loss of scales or hematoma in the eyes or at the base of fins, has also been documented (Yelverton et al. 1975; Wiley et al. 1981; Linton et al. 1985; Gisiner 1998; Godard et al. 2008; Carlson et al. 2011; Halvorsen et al. 2012a; Halvorsen et al. 2012b; Casper et al. 2012).

The severity of injury sustained by a fish may also be dependent upon the amount of air in the swim bladder during sound exposure, which characterizes the state of buoyancy (Govoni et al. 2003; Halvorsen 2012a; Stephenson et al. 2010; Carlson 2012), and the physiological state of fish at the time of exposure. For example, a deflated swim bladder (i.e., negatively buoyant) could put the fish at a lower risk of injury from the sound pressure exposure compared to a fish with an inflated swim bladder (i.e., positively buoyant). Given the rapid rise time of impact hammer pile driving, however, the inability of fish to quickly regulate buoyancy and the inability to know the buoyancy state of the fish during exposure to these sound sources, NMFS assumes the worst-case scenario: that swim bladders are positively buoyant, and, therefore, exposed fishes could be subjected to the highest degree of trauma.

Besides injuries to the soft tissues surrounding the swim bladder, additional acoustic-related injuries can occur within the auditory structures of fish exposed to high intensity sounds. Injury from exposure to high levels of continuous sound manifests as a loss of hair cells of the inner ear (Popper and Hastings 2009), which may result in a temporary decrease in hearing sensitivity or temporary threshold shift (TTS).

TTS is considered a temporary reduction in hearing sensitivity due to exposure durations lasting a few minutes to hours. This type of noise-induced hearing loss in fishes is generally considered recoverable because fish, unlike mammals, are able to regenerate damaged hair cells (Smith et al. 2006). An important consideration when evaluating auditory structure damage due to noise is determining the sound level at which hearing loss has significant implications for behavior and associated fitness consequences such as preventing individuals from detecting biologically relevant signals. Hastings (2002) expected damage of auditory hair cells in salmon to occur with exposure to continuous sound at about 200 decibel (dB) (Root Mean Square - RMS), which equates to a peak sound level of 203-dB peak as the onset of damage to the sensory hearing cells of salmon.

Beyond barotrauma-related tissue damage, additional direct physiological effects to fishes from exposure to sound include increases in stress hormones or changes to other biochemical stress indicators (Sverdrup et al. 1994; Santulli et al. 1999; Wysocki et al. 2006; Nichols et al. 2015). These effects can affect both predation risk by compromising predator evasion and feeding success by affecting prey detection, leading to reduced fitness or survival success.

Besides direct physical injury because of the sound pressure wave, underwater sounds have also been shown to alter the behavior of fishes (see review by Hastings and Popper 2005; Hawkins et al. 2012; Popper et al. 2014). There is significant variation among species. The potential for adverse behavioral effects will depend on a number of factors, including the sensitivity to sound, the type and duration of the sound, and the life stages of fish present. Observed behavioral responses to anthropogenic sounds may include startle responses, changes in swimming directions and speeds, increased group cohesion, and bottom diving (Engas et al. 1995; Wardle et al. 2001; Mitson and Knudsen 2003; Boeger et al. 2006; Sand et al. 2008; Neo et al. 2014), and "alarm" as detected by Fewtrell et al. (2003) and Fewtrell and MacCauley (2012).

The startle response in fishes is a quick burst of swimming that may be involved in avoidance of predators (Popper 1997). Other potential changes in behavior in response to underwater sounds include reduced predator awareness and reduced feeding (Voellmy et al. 2014; Simpson et al. 2015) and changes in distribution in the water column or schooling behavior (e.g., Skalski et al. 1992; Feist et al. 1992; Engås et al. 1996; Engås and Løkkeborg 2002; Slotte et al. 2004). A fish that exhibits a startle or other behavioral response may not necessarily be injured, but is exhibiting behavior that suggests it perceives a stimulus that indicates potential danger in the immediate environment. Therefore, these types of responses likely do not have a fitness consequence for the individual unless the reaction increases susceptibility to predation or some other negative effect.

The tolerance of sound pressure levels causing either direct injury or behavioral responses varies among species and life stage. Adult salmonids, because of their large size, can usually tolerate higher pressure levels (40 to 50 pounds per square inch [psi]) (Hubbs and Rechnitzer 1952), so immediate mortality rates for adults are expected to be less than those for juvenile salmonids. However, some uncertainty regarding the relative sensitivity of larger fishes remains (Halvorsen et al. 2012). Given that adult green sturgeon are on average significantly larger than salmon, they could, presumably, tolerate higher levels of sound pressure and be less affected by pile-driving activities. Similarly, juvenile green sturgeon are typically between 200 to 600 mm long (Radtke 1969) by the time they inhabit the Delta. Because of the similarity in size to adult salmonids, juvenile green sturgeon are expected to be more tolerant than juvenile salmonids of temporary sound disturbances associated with pile driving. Green sturgeon are vulnerable to injury or death from pile driving, however, especially if within close proximity, as demonstrated by the lethal sound pressure levels (SPLs) resulting in the death of a white sturgeon (likely a juvenile) documented during the construction of the Benicia-Martinez Bridge (Abbott 2007).

Criteria have been established to support assessing acoustics effects to west coast fish species. The Fisheries Hydroacoustic Working Group (FHWG), which consists of representatives from NMFS, USFWS, the Federal Highway Administration, and the West Coast Departments of Transportation, established interim thresholds to assess physical injury to fish exposed to underwater sound produced during pile driving (FHWG 2008). Thresholds include a single strike peak sound pressure level of 206-dB (re: 1 micro pascal [µPa]) and an accumulated sound exposure level (cSEL) of 187-dB (re: 1 µPa2-sec) for fish greater than 2 grams and 183-dB (re: 1 µPa2-sec) for fish less than 2 grams. Physical injury is assumed to occur if either the peak or cSEL threshold is exceeded. The SEL limit referred to as "effective quiet," however, can be used to identify the distance beyond which no physical injury is expected from a single strike, regardless of the number of strikes. The effective quiet currently assumed for fish is 150-dB (re: 1 µPa2*sec). When the received SEL from a single individual pile strike is below this level, the accumulated energy from multiple strikes is not expected to contribute to injury, regardless of how many pile strikes occur. The effective quiet level is used to identify the maximum distance from the pile where injury to fishes is expected to occur. It is the distance at which the sound from a single strike to a piling attenuates to 150-dB using the SEL measurement metric. At this distance, the cumulative sound exposure, as referenced by the number of strikes to the pile, is calculated to reach the 187-dB cSEL threshold.

In areas where we have limited information, we have developed assumptions about fish behavior and the recovery time of affected tissue to determine fish response (i.e., avoidance, injury, and death) based on the limited available information. Sonalysts (1997) suggested that although fish (including Atlantic salmon) exhibit a startle response during the first few acoustic exposures, they do not move away from areas of very loud underwater sounds and can be expected to remain in the area unless they are carried away by currents or normal movement patterns. Therefore, NMFS assumes that fish will remain in the vicinity of a construction site unless currents or behavior patterns unrelated to loud underwater sound avoidance would indicate that movement is likely to occur.

Although there may be some tissue recovery between the completion of one pile and the beginning of driving at the next, given the level of uncertainty that exists, NMFS will sum the underwater sound energy produced during the installation of all piles on any given day until a break of 12 hours or longer occurs to determine potential physical effects to listed salmonids and sturgeon each day pile driving occurs. NMFS assumes that normal behavior patterns will move any actively migrating salmonids and green sturgeon out of the affected area within 1 day, and therefore, underwater sound energy will not be summed over consecutive days. This would not be the case if the construction site was located in an area where either adult salmonids or sturgeon were spawning or juveniles were rearing for extended periods of time in the action area, in which case they could experience repeated exposures.

While aquatic ecosystems can logically be expected to experience some degree of effect from construction activities within the aquatic environment, construction activities in non-aquatic (i.e., terrestrial) areas have potential to cause acoustic stress to aquatic species as well because noise generated by sheet pile wall installation in upland areas can transmit sound into adjacent waterways (Burgess and Blackwell 2003). Because the noise generated by terrestrial activities is expected to attenuate relatively quickly, however, it is unlikely that the resulting noise level in the waterway will cause mortality or injury (Burgess and Blackwell 2003). Instead, it will more likely cause behavioral responses that may result in harassment or other effects such as increased predation risk or a decreased ability to detect biologically relevant sounds in the surrounding environment (Chan et al. 2010; Voellmy et al. 2014a; Voellmy et al. 2014b; Simpson et al. 2015; Simpson et al. 2016). It is anticipated that aquatic noise levels resulting from terrestrial activities may initially deter fish from the affected area (startle response and initial avoidance), although they may return or stay in the area as they habituate to the new acoustic environment. Because noise coupled with increased human activity (i.e., motion, shadows, etc.) may initially be sufficient to deter fish from the work area for periods of time ranging from minutes to hours, NMFS expects that any fish within the areas adjacent to land-based construction activities will avoid the shoreline and move into deeper, open water, where predation stress is greater. When activity on the shoreline ceases (such as at night) or the fish become accustomed to the activity, they may return to their original locations along the banks. The additional noise caused by land-based activities may also mask important ecological reception of sounds necessary for the detection of nearby predators or increase stress hormones that may affect predator avoidance and prey detection. Therefore, elevated noise within the aquatic environment may potentially expose fish to increased predation risk due to reduced use of shallow shoreline refuge areas, increased masking of predators within the immediate areas, and reduced response to avoidance cues.

The use of several TBMs to cut underground tunnels through the Delta sediment horizons will create both vibrations and low frequency noise due to the operational sounds of the machines and the action of the rotating cutterheads grinding through the native soils. Tunneling projects in several different countries have experienced situations in which TBMs tunneling beneath occupied areas have produced vibrations and low frequency noise that could be perceived at the surface. As an example, environmental documents produced for the Silvertown traffic tunnel below the Thames River in London (City of London 2015) described the potential effects of a large TBM boring beneath the River Thames. Using the Rupert Taylor Finite Difference Time Domain Model (Finitewave©), the level of sound propagated into the overlying water column was greater than 120 dB (re: 1 µPa) from approximately 4 hertz (Hz) to 30 Hz and from approximately 50 Hz to approximately 400 Hz. The model predicted a peak sound pressure level of 140 dB between approximately 100 Hz and 250 Hz with the greatest magnitudes near the channel bottom. These modeled sound levels are within the hearing thresholds of most fish and extend into the infrasound range, which can elicit avoidance behavior in fish, including salmonids (Knudsen et al. 1997; Sand et al. 2001).

Fish are particularly sensitive to low frequency linear accelerations (i.e., infrasound). The otilith organs responsible for the detection of infrasound are sensitive enough to detect noise generated by a swimming fish. This ability is thought to be important in courtship behavior and predator-prey interactions. Knudsen et al. (1997) and Sand et al. (2001) reported that Chinook salmon, rainbow trout (*O. mykiss*), and European silver eels (*Anguilla anguilla*) were sensitive to infrasound at the 10-Hz level and were actively deterred. Fish exposed to the noise source avoided or fled the area. Habituation to the noise did not occur even after repeated exposures. Thus, the infrasound created by the TBMs along the tunneling alignment when they cross under waterways may cause behavioral responses that result in fish altering their use of waterways, which affects migratory routing and potential habitat accessibility.

2.5.1.1.1.1 Pile Driving

The PA includes extensive pile-driving activities throughout the construction period at the north Delta diversion intake locations, CCF, the HOR, and barge landing locations. Activities at each location are described below. The PA also includes protocols designed to minimize the potential exposure of listed fish species to pile-driving noise by conducting all pile driving within work windows when most species are least likely to occur in the action area. DWR will follow standard and provided avoidance and minimization measures (AMMs), including development and implementation of an underwater sound control and abatement plan outlining specific measures that will be implemented to avoid and minimize the effects of underwater construction noise on listed fish species (BA Appendix 3.F General Avoidance and Minimization Measures, AMM9 Underwater Sound Control and Abatement Plan). These measures may include various methods of sound energy attenuation that will act to change and dissipate the energy (Christopherson et al. 2002).

Proposed methods include using vibratory and other non-impact driving methods as well as other physical and operational measures to limit the intensity and duration of underwater noise levels when listed fish species may be present. Where impact pile driving is required, hydroacoustic monitoring will be performed to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and identify corrective actions to be taken should the thresholds be exceeded. To minimize pile-driving noise for sheet pile installation, sheet piles will first be driven into the channel bottom using a vibratory hammer to the greatest extent practicable, then an impact hammer will be used to drive the piles to their final tip elevation.

2.5.1.1.1.1.1 North Delta Intake Locations

The construction of the NDD requires extensive pile driving. According to the PA, pile-driving activities at the NDD intake locations are expected to last from 2022 through 2028, with sheet or foundation piles being driven throughout this period. The project description includes a proposed in-water work window of June 15 to October 31, with impact pile driving restricted to June 15 to September 15, for the NDD intake locations for each construction year. The risk of injury to fish is highest in the early part of the first work season for each intake because sheet piles for cofferdam installation will occur in the wetted channel during this early phase of each intake's construction. Pile-driving activities will be staggered to occur at each of the three intakes of the NDD (Intakes 2, 3, and 5) in different years. In most years, there will only be active in-water work occurring at one diversion intake at a time. In 2025, sheet pile driving at Intake 2 is proposed to occur simultaneously with foundation pile driving at Intake 3, which is two RM downstream. As noted in Section 2.5.1.1.1.1 Pile Driving, the action agency has included AMMs to minimize impacts of the activity. These include using a vibratory hammer for approximately 70 percent of the driving and including best management practices (BMPs) for sound attenuation.

Details of the proposed pile installation activities at the three intakes of the NDD (Intakes 2, 3, and 5) are shown in Table 2-14. At each location, all sheet pile driving required for cofferdam installation is expected to be completed within a single year's work window by using multiple pile drivers at each intake location. Similarly, using multiple drivers at a location is expected to result in all foundation piles at a single location being installed within a single work window, though in a year subsequent to cofferdam construction.

Table 2-14. Intake Sheet Pile Installation Details.

Task Name	River Mile	Duration (days)	Start Date	End Date	Number of Piles	Extension into River (feet)	Length (feet) construction along river bank
Intake 2 Sheet piles	41.1	42	6/2/2025	10/31/2025	2,500	60	2,000
Intake 2 Foundation steel piles	41.1	19	6/1/2026	10/31/2026	1,120 (42 in)	NA	1,667
Intake 3 Sheet piles	39.4	42	6/3/2024	10/31/2024	2,500	60	1,600
Intake 3 Foundation steel piles	39.4	414	6/2/2025	10/31/2025	850 (42 in)	NA	1,373
Intake 5 Sheet piles	36.8	42	6/2/2022	10/31/2022	2,500	60	2,000
Intake 5 Foundation steel piles	36.8	19	6/1/2023	10/31/2023	1,120 (42 in)	NA	1,667

While the PA provides the information in Table 2.14, complete acoustics analysis still requires several assumptions for information that cannot be completely determined at this early stage of project design. Although additional sound attenuation methods (other than vibratory hammer use) may not be feasible during installation of the steel sheet piles because of the location and configuration of the cofferdam, DWR proposes to use an experimental bubble curtain. Efficacy of the bubble curtain and assumed decrease of magnitude by 5 dB at the source will be monitored. As clarified by DWR during consultation discussions, NMFS assumes that the 42-inch steel piles of the intake foundations will first be driven with a vibratory hammer. An impact hammer is expected to be used for final driving, which is expected to produce very high levels of sound pressure. The foundation piles are expected to be driven within a dewatered cofferdam or behind a bubble curtain, however, which will reduce the extent of the water column that is affected by deleterious underwater noise levels. As above, it is assumed for the purposes of this consultation that the use of sound attenuation will decrease the magnitude of pile driving sound by 5 dB at the source. Therefore, calculations are used with the referenced point source measurement reduced by 5 dB. Multiple pile drivers are expected to be used at each intake location. According to the PA and information provided by DWR, a maximum of four pile drivers may be required to meet the proposed work schedule. NMFS has used this as an assumption for analysis of effects of pile-driving activities on salmonids and sturgeon. Specifically, these assumptions were used to identify the area of potential injury and mortality associated with the sound pressure levels as quantified by the distance to reach "effective quiet," the distance beyond which no physical injury is expected from a single strike, regardless of the number of strikes.

Based on this information, NMFS has identified the distances at which sound pressure thresholds for fish are anticipated to be met for each pile driving scenario and intake location. For the construction of Intakes 2, 3, and 5 using four pile drivers, NMFS does not anticipate sound pressure thresholds for fish (more than 2 g) to be exceeded beyond the following distances shown in Table 2-15.

Table 2-15. Distances at which Sound Pressure Thresholds are Met.

Site[1]	Attenuation (dB)[2]	Assumed Source Levels (dB) (10 m, single strike)			Effective Quiet (187 dB)		Physical Injury (Onset) (Distance (feet) to threshold)		Behavior Affect (Distance (feet) to threshold)	Length of River Affected with Multiple Drivers[4] (feet)		
		Peak	SEL	RMS	Distan-ce to (ft)	# Strikes to	Peak SPL (206 dB)	Cum. SEL (187 dB)	RMS 150 dB	Peak (206 dB)	Cum. SEL	150 dB RMS
Intake sheet pile cofferdam	03	205	179	189	2,814	5,012	29.5	2,814	13,061	29.5	6,463	26,949
Intake sheet pile cofferdam w/ attenuation	-5	200	174	184	1,306	5,012	13	1,306	6,063	13	3,438	12,953
Intake steel pile foundation w/o attenuation	0	208	180	195	3,281	5,012	46	3,281	32,808	46	7,389	66,443
Intake steel pile foundation w/ attenuation	-5	203	175	190	1,522	5,012	19.7	1,522	15,230	19.7	3871	31,283

[1] All intake locations will have the same acoustic measurements based on the type of materials and the pile driving method used during construction.

[2] Attenuation occurs either from a bubble curtain or dewatered cofferdam.

[3] The use of bubble curtain may not be feasible with sheet piles, but the project applicants will be implementing them as an experimental trial, which is expected to attenuate by 5 dB if successful.

[4] Length of river includes two times the single strike distance plus 827 feet for the four pile drivers.

Pile driving at intake locations is expected to create adverse acoustic conditions for any fish that are present during these actions, and are physically located within the river channel adjacent to the intake location within the zone of water ensonified above the 150 dB RMS threshold. Adverse acoustic conditions may encompass effects ranging from behavioral avoidance and harassment (150 dB RMS threshold) to injury (187 dB cSEL threshold) or death (206 dB SPL peak).

Intake 2 is the most upstream intake location, but will be the last constructed (in 2025 to 2026). This location is on an outside bend of the eastern bank of the Sacramento River downstream of an 11,000-foot-long straight reach. From the Intake 2 site, the river gradually bends to the west to the site of Intake 3, 0.7 miles downstream. For the unattenuated impact pile driving of the sheet pile cofferdam, the calculated distance to the 206 dB SPL threshold that causes injury per a single strike for installation of sheet piles is 30 feet, or approximately 4.3 percent of the channel width of 700 feet at the Intake 2 location. The distance to the 187-dB cumulative SEL injury threshold based on the distance to effective quiet for one day's piling driving activity is calculated as 2,814 feet. This completely encompasses the entire river channel width at the Intake 2 location and extends the zone of injury for one day's pile driving activity upriver 3,228 feet (984 m) and downriver an additional 3,228 feet (984 m) for a total river length of 6,463 feet (1,970 m). The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet (Table 2-15). Therefore, discernable impacts (behavioral modification) from the pile driving of the Intake 2 sheet piles will extend upstream and downstream of the intake site within the channel until the alignment of the channel is altered by bends in the river channel approximately 7,000 feet to the south and 11,000 feet to the north-northwest. More severe impacts will occur closer to the pile driving location.

For attenuated impact pile driving of the cofferdam sheet piles using the proposed bubble curtain, NMFS assumes a 5-dB reduction in the acoustic signal. The calculated distance to the 206-dB SPL threshold that causes injury per a single strike for installation of sheet piles is 13 feet, or approximately 1.9 percent of the channel width of 700 feet at the Intake 2 location. The distance to the 187-dB cumulative SEL injury threshold based on the distance to effective quiet for one day's piling driving activity is calculated as 1,305 feet. This completely encompasses the entire river channel width at the Intake 2 location and extends the zone of injury for one day's pile driving activity upriver 1,719 feet (524 m) and downriver an additional 1,719 feet (524 m) for a total river length of 3,438 feet (1,048 m). The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 6,500 feet (Table 2-15). Therefore, discernable impacts (behavioral modification) from the attenuated pile driving of the Intake 2 sheet piles will extend upstream and downstream of the intake site within the channel until just before the alignment of the channel is altered by bends in the river channel approximately 7,000 feet to the south and approximately 6,500 feet to the north-northwest. More severe impacts will occur closer to the pile driving location.

For foundation pile installation, the distance to the 206-dB SPL threshold with attenuation created by the dewatered cofferdam is approximately 20 feet (6 m) or approximately 2.9 percent of the channel width at that location (700 feet). The 187-dB cSEL threshold for injury based on the distance to "effective quiet" threshold extends for a total distance of 1,522 feet upstream and downstream from the Intake 2 site for a total river reach distance of 3,871 feet and completely encompasses the width of the river at this location. Because the distance for the 150-dB RMS threshold is estimated to extend 15,230 feet upstream and downstream (a total river reach of 31,286 feet), the entire river length between the bends is expected to be affected by the pile driving of the foundation piles even with a -5 dB attenuation of pile driving sound.

Intake 3 is on a transitional point on the Sacramento River between two curves located approximately 2,800 feet upstream and 2,000 feet downstream of the intake site. Therefore, approximately 7,700 feet of river channel between the two bends may be impacted by the acoustics effects of pile driving. During the 2024 to 2025 construction period at this intake, the calculated distance to the 206-dB SPL single strike threshold for sheet pile installation is 30 feet, or approximately 6 percent of the channel width at that location (500 feet). The distance to the 187-dB cumulative SEL injury threshold based on the distance to effective quiet for one day's piling driving activity is calculated as 2,814 feet. This completely encompasses the entire river channel width at the Intake 3 location and extends the zone of injury for one day's pile driving activity upriver 3,228 feet (984 m) and downriver an additional 3,228 feet (984 m) for a total river length of 6,463 feet (1,970 m). The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 13,000 feet (Table 2-15). Discernable impacts (behavioral modification) from the pile driving of the Intake 3 sheet piles will cover the entire width of the river channel and extend upstream and downstream of the intake site within the channel until the alignment of the channel is altered by bends in the river channel approximately 2,000 feet to the southwest and 2,800 feet to the northeast. More severe impacts will occur closer to the actual pile driving activities.

For attenuated impact pile driving of the cofferdam sheet piles using the proposed bubble curtain, NMFS assumes a 5 dB reduction in the acoustic signal. The calculated distance to the 206 dB SPL threshold that causes injury per a single strike for installation of sheet piles is 13 feet, or ~2.6 percent of the channel width of 500 feet at the Intake 3 location. The distance to the 187 dB cumulative SEL injury threshold based on the distance to effective quiet for one day's piling driving activity is calculated as 1,305 feet. This completely encompasses the entire river channel width at the Intake 3 location and extends the zone of injury for one day's pile driving activity upriver 1,719 feet (524 m) and downriver an additional 1,719 feet (524 m) for a total river length of 3,438 feet (1,048 m). The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 6,500 feet (Table 2-15). Discernable impacts (behavioral modification) from the pile driving of the Intake 3 sheet piles will cover the entire width of the river channel and extend upstream and downstream of the intake site within the channel until the alignment of the channel is altered by bends in the river channel approximately 2,000 feet to the southwest and 2,800 feet to the northeast. More severe impacts will occur closer to the actual pile driving activities.

For foundation pile installation, the distance to the peak 206 dB SPL threshold with attenuation created by the dewatered cofferdam is approximately 20 feet (6 m) or ~ 4 percent of the 500-feet wide river channel. The single day 187 dB cumulative SEL injury threshold distance based on the effective quiet threshold is estimated to be 1,522 feet (464 m) with attenuation, with a total distance along the channel alignment of 3,871 feet (1,180 m). This completely encompasses the width of the river at the intake location and creates adverse conditions along nearly 4,000 feet of river channel that have a high potential of causing injury to exposed fish during the pile driving actions. The distance for the 150 dB RMS threshold is 15,230 feet (4, 642 m) upstream and downstream, and is estimated to extend along a total river length of 31,286 feet (9,536 m). This encompasses the entire river length between the bends.

Additionally, the sheet pile driving for Intake 2 during 2025 will potentially overlap with the foundation pile driving for Intake 3, creating a potential for approximately 2,400 feet of overlap for the 150-dB RMS threshold for behavioral effects if both sites have concurrent pile driving.

Intake 5, the first of the three intakes to be constructed, is on a relatively straight reach of the Sacramento River between two curves located approximately 6,500 feet upstream and 6,500 feet downstream of the intake site. Therefore, approximately 14,000 feet of river channel between the two bends may be impacted by the acoustics effects of pile driving at Intake 5. During the 2022-2023 construction period at this intake, the calculated distance to the 206-dB SPL single strike threshold for sheet pile installation is 30 feet, or approximately 5 percent of the channel width at that location (600 feet). The distance to the 187 dB cumulative SEL injury threshold for one day's piling driving activity is calculated as 2,814 feet. This completely encompasses the entire river channel width at the Intake 5 location and extends the zone of injury for one day's pile driving activity upriver 3,228 feet (984 m) and downriver an additional 3,228 feet (984 m) for a total river length of 6,463 feet (1,970 m). The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 13,000 feet.

For attenuated impact pile driving of the cofferdam sheet piles using the proposed bubble curtain, NMFS assumes a 5 dB reduction in the acoustic signal. The calculated distance to the 206 dB SPL threshold that causes injury per a single strike for installation of sheet piles is 13 feet, or ~2.2 percent of the channel width of 600 feet at the Intake 5 location. The distance to the 187 dB cumulative SEL injury threshold based on the distance to effective quiet for one day's pile driving activity is calculated as 1,305 feet. This completely encompasses the entire river channel width at the Intake 3 location and extends the zone of injury for one day's pile driving activity upriver 1,719 feet (524 m) and downriver an additional 1,719 feet (524 m) for a total river length of 3,438 feet (1,048 m). The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 6,500 feet (Table 2-15). Discernable impacts (behavioral modification) from the pile driving of the Intake 5 sheet piles will cover the entire width of the river channel and extend upstream and downstream of the intake site within the channel until the alignment of the channel is altered by bends in the river channel approximately 6,500 feet upstream and downstream of the Intake 5 location. More severe impacts will occur closer to the actual pile driving activities.

For foundation pile installation, the distance to the peak 206-dB SPL threshold with attenuation created by the dewatered cofferdam is approximately 20 feet (6 m) or approximately 3.3 percent of the 600-foot-wide river channel. The single day 187 dB cumulative SEL injury threshold distance based on the effective quiet threshold is estimated to be 1,522 feet (464 m) with attenuation, with a total distance along the channel alignment of 3,871 feet (1,180 m). This completely encompasses the width of the river at the intake location and creates adverse conditions along nearly 4,000 feet of river channel that have a high potential of causing injury to exposed fish during the pile driving actions. The distance for the 150 dB RMS threshold is 15,230 feet (4,642 m) upstream and downstream, and is estimated to extend along a total river length of 31,286 feet (9,536 m). This encompasses the entire river length between the bends.

2.5.1.1.1.1.1.1 Winter-run Exposure and Risk

The life history and spatial and temporal presence of winter-run Chinook salmon is described in Section 2.4 Environmental Baseline, and above in Table 2-10 in Section 2.5.1.1 Construction Effects. More detailed information is available for winter-run Chinook salmon presence at the location of the NDD intake construction. A small proportion (approximately 2 percent) of outmigrating juvenile winter-run Chinook salmon may enter the upper reaches of the Delta starting in October (DJFMP 2017), although the entry timing is highly correlated with the first high flows of the migration season. December to February is the peak of juvenile winter-run Chinook salmon presence at the NDD intake location (del Rosario et al. 2013). After a brief period of rearing, most juvenile winter-run will exit the Delta in March and April (del Rosario et al. 2013; Pyper et al. 2013). Adult winter-run Chinook salmon enter the San Francisco Bay from November to June (Hallock and Fisher 1985), migrating up the Sacramento River past the Red Bluff Diversion Dam (RBDD) from mid-December to early August (NMFS 1997). The majority of the run passes RBDD between January and May, with a peak in mid-March (Hallock and Fisher 1985).

The Sacramento River is the primary migration route for both juvenile and adult winter-run Chinook salmon to enter and leave the northern Delta. In certain hydrologic conditions, however, fish may pass over the Fremont Weir into the Yolo Bypass or toe drain, which provides an alternative migratory route for both downstream outmigrating juveniles and upstream adult migrants. High river flow conditions that result in passage over the Fremont Weir typically occur in late fall and winter in response to heavy precipitation events, but not in every year. Fish migrating via the Sacramento River or over the Fremont Weir will converge in the Sacramento River at the confluence of Cache Slough, Steamboat Slough, and the main stem Sacramento River for access to the estuary.

Pile-driving activities at the NDD intake locations have the potential to affect both juvenile and adult winter-run Chinook salmon, though exposure is expected to be minimized. Approximately 2 percent of the winter-run-sized juvenile Chinook occur at the NDD intake location as early migrants in October. Juvenile winter-run Chinook salmon typically complete their outmigration by March or April. Although all pile driving at the NDD intake locations is expected to be completed during the proposed in-water work window of June 15 through October 31, attenuated impact pile driving of sheet piles will only continue to September 15, which reduces the exposure of impact pile driving to juvenile winter-run to less than 2 percent of the population. Adult winter-run Chinook salmon are not expected to be present at the NDD intake locations during pile-driving activities. Because the large majority passes the NDD intake location by May, their presence after June 1 is highly unlikely. Exposure of winter-run Chinook salmon to acoustics effects of pile driving is not limited to a single year. Installation of sheet piles and foundation pilings at the NDD intake locations is proposed to last five years (2022 through 2026), potentially exposing several year classes to pile-driving effects.

Given the extended construction period and the timing of juvenile and adult winter-run presence, NMFS therefore expects that the noise generated by pile-driving activities at the NDD intake locations will adversely affect a small proportion of juvenile winter-run Chinook salmon.

2.5.1.1.1.1.1.2 Spring-run Exposure and Risk

The life history and spatial and temporal presence of spring-run Chinook salmon is described in Section 2.4 Environmental Baseline, and above in Table 2-11 in Section 2.5.1.1 Construction Effects.

More detailed information is available for spring-run Chinook salmon presence at the location of the NDD intake construction. Outmigrating juvenile spring-run Chinook salmon will enter the upper reaches of the Delta starting in November and continuing through May or June (DJFMP 2017). Only 5 percent of spring-run sized juvenile Chinook salmon are found near the NDD intake location in May and less than 1 percent in June. February to April is the peak of juvenile spring-run Chinook salmon presence at the NDD intake location, with the overwhelming majority (52 percent) of spring-run-sized fish entering the Delta in April. Although a few remaining fish may still be migrating through the Delta in early June in some years, juvenile spring-run Chinook salmon typically spend very little time rearing in the Delta. Most juveniles are large, actively migrating smolts that have been shown to move rapidly through the Delta and estuary during their seaward migration (Williams 2006).

Adult spring-run Chinook salmon enter the San Francisco Bay from late January to early February (CDFG1998) and enter the Sacramento River in March (Yoshiyama et al. 1998), although adults may travel to tributaries as late as July (Lindley et al. 2004). Spring-run Chinook salmon adults will hold during the summer either far upstream or in cool water refugia before initiating spawning in September to October (Moyle 2002a). The observed patterns of adult immigration into Mill Creek indicates that adult spring-run Chinook salmon will be well upstream of the Delta during most of June through October.

As with winter-run Chinook salmon, the Sacramento River is the primary migration route for both juvenile and adult spring-run Chinook salmon to enter and leave the northern Delta. Because high river flow conditions that result in passage over the Fremont Weir typically occur in late fall and winter, but not in every year, most juvenile and adult spring-run Chinook salmon will pass the NDD intake location.

Although all pile driving at the NDD intake locations is expected to be completed during the proposed in-water work window of June 15 through October 31, attenuated impact pile driving of sheet piles will only continue to September 15, which further reduces the potential for exposure of impact pile driving to juvenile spring-run Chinook salmon. Recent monitoring data, however, show that a few juvenile spring-run sized Chinook salmon have been found at the NDD intake location after May (DJFMP 2017). NMFS therefore expects that the noise generated by pile-driving activities at the NDD intake locations would adversely affect a very small proportion of juvenile spring-run Chinook salmon.

Adult spring-run Chinook salmon are not expected to be present at the NDD intake locations during pile-driving activities. Because the large majority of adult spring-run Chinook salmon pass the NDD intake locations earlier in the year and are observed immigrating into natal streams from April through June, their presence at the NDD intake location after June 1 is highly unlikely. NMFS therefore expects that the noise generated by pile driving at the NDD intake locations would not adversely affect adult spring-run Chinook salmon.

2.5.1.1.1.1.1.3 Steelhead Exposure and Risk

The life history and spatial and temporal presence of California Central Valley steelhead is described in Section 2.4 Environmental Baseline, and above in Table 2-12 in Section 2.5.1.1 Construction Effects. Juvenile steelhead are present in the Delta throughout the year, as indicated by monitoring results at Chipps Island (USFWS) and CVP/SWP salvage data, but the emigration period may depend on origin. Hatchery smolts are present from January through March, with the peak occurring in February and March. Wild steelhead outmigration also peaks in February and March, but is spread over a longer period, lasting from fall or early winter through early summer. Wild fish that are present in the Delta late in the season may be from the San Joaquin River system rather than the Sacramento River basin, based on the proximity of the basin to the pumps and the April-May timing of tributary spring pulse flows.

At the NDD intake locations (as inferred from the Sacramento trawl (Sherwood Harbor) conducted by the USFWS from 1998 through 2015 (DJFMP 2017)) wild steelhead are typically captured starting in December (1.9 percent of average annual catch) and continues through June (7.5 percent of average annual catch), with rare catches in the early fall. Juvenile wild steelhead catches at Sherwood Harbor peak in the winter during January and February and again in April, with 90 percent of the captured wild steelhead occurring between January and May. However, over the period between 1998 and 2015, only 96 wild steelhead were captured in the Sacramento Trawl and the total number of fish captured in June represents 5 fish during this period. Presence of steelhead smolts in the Delta typically occurs by November and continues into June, based on CVP/SWP salvage data. Presence increases through December and January (22 percent of average annual salvage), peaks in February (37 percent) and March (31 percent), and declines in

April (8 percent). By June, steelhead smolt outmigration through the Delta has essentially ended. Adult steelhead start to enter the Delta region as early as June, with approximately 12 percent in August, 44 percent in September, 24 percent in October, and 7 percent in November. Low levels of adult CCV steelhead continued to emigrate upriver through March.

As with Chinook salmon, the Sacramento River is the primary migration route for both juvenile and adult CCV steelhead from the Sacramento River basin to enter or leave the northern Delta. High river flow conditions that result in passage over the Fremont Weir typically occur in late fall and winter and can provide access to a large number of steelhead in some years, but the majority of juvenile and adult steelhead from the Sacramento River basin are typically assumed to pass the NDD intake location.

Pile-driving activities at the NDD intake locations may potentially affect both juvenile and adult steelhead, though to differing extents. Approximately 1 to 2 percent of the emigrating juvenile CCV steelhead population (based on Delta presence from CVP/SWP salvage data) will be exposed to the effects of pile-driving-induced noise during the June 15 to October 31 in-water work window, which is further reduced by attempting attenuation of impact sheet pile driving and ending the work window for impact sheet pile driving by September 15. Most of this exposure will occur in either the beginning or the end of the work window. There is little probability of exposure of juvenile CCV steelhead to pile-driving-induced noise during the summer months of July and August.

Despite the in-water work window, a much greater proportion of the adult population of CCV steelhead will be exposed to pile-driving activities at the NDD intake locations. Approximately 80 percent of the annual adult upstream migration occurs within the June through October window. The peak upstream movement of adult fish occurs in September (44.5 percent) and October (24.6 percent) accounting for 69 percent of annual escapement. NMFS therefore expects a substantial proportion of the adult CCV steelhead to be exposed to pile-driving activities at NDD intake locations during the June 15 through September 15 work window for impact pile driving (estimated at ~36 percent of the annual adult population). The work window continuing through the end of October, adds an additional 46 percent of the adult population to potential exposure to pile driving activities.

The exposure of CCV steelhead to acoustics effects of pile driving is not limited to a single year. Installation of sheet piles and foundation pilings at the NDD intake locations is proposed to last five years (2022 through 2026). Therefore, at least six different year classes could potentially be exposed to pile-driving effects. Though active in-water work is expected to be limited to a single intake location in most years, the PA proposes at least 1 year (2025) during which work will occur simultaneously at adjacent intake locations (Intakes 2 and 3). Because these intakes are separated by only 0.7 river miles, the extent of the sound field generated by pile-driving activities is expected to overlap and cover several miles. Therefore, the risk of exposure to CCV steelhead is increased due to multiple years of exposure and overlap of effects of activities in close proximity to each other.

Exposure of CCV steelhead to the adverse acoustics effects is related to the timing of steelhead presence at the NDD intake locations. The expected annual duration for the insertion of 2,500 sheet piles is 42 days. This is approximately 46 percent of the days from June 15 through September 15 for continuous pile driving (7 days per week) and approximately 65 percent for pile driving limited to weekdays. Since the in-water work window is extended through October

31 for non-impact pile driving behind the cofferdam, the estimated work period of 42 days is 30.4 percent of the available work days (7 days per week) and 44 percent of the available days if work is limited to weekdays. The installation of foundation piles is expected to take 14–19 days depending on intake, which is 15 to 22 percent of the work window period if limited to only weekdays.

Only steelhead from the Sacramento River basin are expected to be present at the NDD intake locations during the work window because adult steelhead from the San Joaquin River basin are not expected to be moving upriver into the Sacramento River. Monitoring on the Sacramento River shows that few juvenile CCV steelhead would be expected to be present in the June through October period (less than or equal to 2 percent annual catch based on CVP/SWP salvage data).

In contrast, approximately 83 percent of the adult CCV steelhead population from the Sacramento River basin is expected to be migrating upstream and past the NDD intake locations during the extended in-water work period of June through October. Because a smaller proportion of the population (approximately 2 percent) migrates past the NDD intake locations in June and July, if pile driving occurs during those earlier months of the in-water work window, then a minimal proportion of the adult population is at risk of exposure to effects. Conversely, if pile driving is delayed until later in the work window, especially during September and October, then a much greater proportion of the population is at risk of adverse effects.

Given that the exact timing of pile driving activity is not yet determined and there is potential for a high proportion of the adult CCV steelhead population from the Sacramento River basin to be repeatedly exposed to pile-driving activities over several years, NMFS expects that the acoustic effects of construction-related pile driving at the NDD intake locations will adversely affect a large proportion of CCV steelhead each year of the construction period.

2.5.1.1.1.1.1.4 Green Sturgeon Exposure and Risk

Because of sparse monitoring data for juvenile, sub-adult, and adult life stages in the Sacramento River and Delta, there are significant data gaps to describing the presence of this species at the NDD intake location.

The life history and spatial and temporal presence of sDPS green sturgeon is described in Section 2.4 Environmental Baseline and above in Table 2-13 in Section 2.5.1.1 Construction Effects. Young green sturgeon are believed to rear for the first one to two months in the Sacramento River (CDFG 2002) before migrating downstream in the first two to three years (Nakamoto et al. 1995). CVP/SWP salvage data show that green sturgeon are present in the Delta throughout the year, and mostly as juveniles or sub-adults. The lack of any juveniles smaller than approximately 200 mm in the Delta suggests that younger individuals rear in the Sacramento River or its tributaries. Juvenile sDPS green sturgeon may even hold in the mainstem Sacramento River for up to 10 months, as suggested by Kynard et al. (2005). While juvenile sDPS green sturgeon may be present in the Delta during any month of the year (California Department of Fish and Game 2002), the presence of the species in the vicinity of the NDD is likely limited to emigrating juveniles and adults either on their way to or from upstream spawning habitat. In addition, the exposure of spawning or post-spawn adults to the acoustic effects associated with pile driving at the NDD locations is expected to be minimal since the in-water work window will avoid the upstream movements of these fish that exhibit peak spawning behavior between April and June on their upstream spawning habitat. Nevertheless, based on the different migratory behaviors (i.e., spring outmigration or holding over summer for outmigration in the fall or winter) of post spawn adult green sturgeon transiting the Delta on their way back to the ocean, NMFS expects the majority of these fish will probably avoid exposure to the acoustic effects associated with pile driving at the NDD locations. It is believed that juveniles use the Delta for rearing for a period of approximately three years because the majority of juveniles that were captured in the Delta were between 2- to 3-years-old based on age/growth studies (Nakamoto et al. 1995).

Given that the exact timing of pile driving activity is not yet determined and there is potential for juvenile green sturgeon to be present year-round at the NDD intake locations and experience multiple years of exposure to the pile-driving activities, NMFS expects that the acoustic effects of construction-related pile driving at the NDD intake locations will adversely affect a small proportion of juvenile and post spawn adult green sturgeon each year of the construction period.

2.5.1.1.1.1.1.5 Fall/Late Fall-run Exposure and Risk

Fall-run Chinook Salmon

Juvenile fall-run Chinook salmon are present at the NDD intake locations from December through August, with a peak from February through May, based on Sacramento trawl data for RM 55. These fish would likely be smaller sub-yearlings that may migrate more slowly than large smolts (such as outmigrating spring-run Chinook salmon). Adult fall-run Chinook salmon enter the San Francisco Bay starting in June and immigrate past the NDD intake locations between July and December (Vogel and Marine 1991), with a peak in October.

As with other salmonids, the Sacramento River is the primary migration route for both juvenile and adult fall-run Chinook salmon to enter and leave the northern Delta. Because high river flow conditions that result in passage over the Fremont Weir typically occur in late fall and winter, but not in every year, most juvenile and adult fall-run Chinook salmon will pass the NDD intake location.

Pile-driving activities at NDD intake locations are likely to affect juvenile and adult fall-run Chinook salmon, though to different extents. Juvenile presence during the work window would be limited to June through August, which represents a period of lowest occurrence of fall-run Chinook salmon juveniles in the Sacramento trawl. Because impact sheet pile-driving activities at the NDD intake sites is expected to occur from June 15 to September 15, and attenuated pile driving is expected to continue to October 31, adult fall-run Chinook salmon would be exposed to acoustics effects during the peak migration month of October. The exposure of fall-run Chinook salmon to acoustics effects of pile driving is not limited to a single year. Installation of sheet piles and foundation pilings at NDD intake locations is proposed to last five years (2022 through 2026), potentially exposing several year classes to pile-driving effects.

Given the extended construction period and the timing of juvenile and adult fall-run presence, NMFS therefore expects that the noise generated by pile-driving activities at the NDD intake locations will adversely affect a small proportion of juvenile fall-run Chinook salmon and a large proportion of adult fall-run Chinook salmon, although adverse effects to adult fall-run will likely be limited to behavioral modifications due to attenuation of piles driving behind the cofferdam during October.

Late Fall-run Chinook Salmon

Late fall-run Chinook salmon smolts migrate downstream from the Sacramento River through the Delta and Bay at a rate ranging from 11 to 22 miles per day (Michel et al. 2015).

Juvenile late fall-run Chinook salmon are present at the NDD intake locations from July through January, peaking in December, based on Sacramento trawl data for RM 55 (Sherwood Harbor). Adult late fall-run Chinook salmon enter the San Francisco Bay starting in October and continue to immigrate past the NDD intake locations between the end of October through March (Vogel and Marine 1991).

Because the Sacramento River is the primary migration route for both juvenile and adult late fall-run Chinook salmon to enter and leave the northern Delta and high river flow conditions that overtop the Fremont Weir allowing for juvenile passage into Yolo Bypass and attracting adults into Cache Slough do not occur every year and only occur for a limited time during the migration windows, most if not all juvenile and adult late fall-run Chinook salmon will be exposed to the NDD intake location in years when Fremont Weir does not overtop, and many will be exposed in years when Fremont Weir does overtop.

Pile-driving activities at NDD intake locations are likely to affect juvenile and adult late fall-run Chinook salmon, though to different extents. Juvenile presence during the work window would extend from July through September 15 during impact pile driving, and through October 31 for attenuated pile driving behind the cofferdam, potentially exposing juveniles to effects of pile driving during this time. Adult late fall-run Chinook salmon, however, would not be exposed to the action except for October when pile driving is attenuated from behind the cofferdam, the very beginning of the upstream migration period. The exposure of late fall-run Chinook salmon to acoustics effects of pile driving is not limited to a single year. Installation of sheet piles and foundation pilings at the NDD intake locations is proposed to last five years (2022 through 2026), potentially exposing several year classes to pile driving effects.

Therefore, given the extended construction period and the timing of juvenile and adult late fall-run presence, NMFS expects that the noise generated by pile-driving activities at the NDD intake locations will adversely affect a large proportion of juvenile late fall-run Chinook salmon and a small proportion of adult late fall-run Chinook salmon.

2.5.1.1.1.1.2 Clifton Court Forebay

The PA includes an expansion and modification to Clifton Court Forebay, an approximately 2,500-acre water body that serves as a storage reservoir for off-peak pumping by the SWP. As described in Chapter 3 of the BA, Appendix 3.B of the BA, and the September 28, 2016 memo from DWR, construction associated with expansion and modification of Clifton Court Forebay (CCF) is estimated to last eight years (2021 through 2028), with in-water construction occurring between 2023 and 2027. All in-water work, including pile driving, is expected to occur during the July 1 through October 31 work window in each construction year. The work will be phased according to:

- Phases 1 and 2: Expansion of south CCF (SCCF).
- Phase 3: Construction of the divider wall between north CCF (NCCF) and SCCF.
- Phases 4 and 5: Construction of the west and east embankments.
- Phase 6: Construction of the NCCF east, west, and north side embankments.

- Construction of the siphon between the NCCF and the conveyance canals.

Actions that will require driving sheet piles include construction of:

- the channel between the new southern expansion area and the existing CCF (Phase 2),
- the divider wall separating the existing CCF into northern and southern halves (Phase 3),
- a cofferdam on the eastern and western sides of the newly created SCCF to allow construction of new embankments (Phases 4 and 5), and
- two cofferdams to allow construction of the siphon between the newly created NCCF and the conveyance canals to the south.

The PA includes plans to install 5,125 sheet piles for the construction of embankment cofferdams, 5,169 sheet piles for the dividing wall across CCF, and 2,160 14-inch concrete or steel foundation piles for the NCCF siphon.

The PA does not specify the number of sheet piles to be used for construction of the cofferdam surrounding the NCCF siphon construction site or for construction of the sheet pile channel in the southern CCF embankment to allow flooding the newly constructed expansion cell of the SCCF. Specific activity durations, start dates, and end dates are show in Table 2-16, while locations of actions and details on pile type and driving details are in Table 2-17 and Table 2-18.

Table 2-16. Clifton Court Forebay Modification Specific Activity Durations, Start Dates, and End Dates.

Task Name	Duration (days)	Start Date	End Date
NCCF installation of sheet piles for siphon (season 1)	109	7/3/23	11/30/23
NCCF installation of sheet piles for siphon (season 2)	109	7/1/24	11/28/24
Construct SCCF earthen embankment	500	7/7/23	6/5/25
Install sheet pile channel in southern embankment	30	7/1/25	8/11/25
SCCF remove existing southern dike	200	6/6/25	3/11/26
Install Action 1 sheet piles for CCF dividing wall	109	7/1/25	11/28/25
Install Action 2 sheet piles to close partition sheet piles	30	7/1/26	8/11/26
SCCF installation of sheet piles for east and west embankments	109	7/1/27	11/30/27

Table 2-17. Pile Driving Activity Details for Clifton Court Forebay Modification.

Facility/ Structure	Lat/ long	River depth	River width	Width of in-river construction	Length of construction along river bank	Proportion of river available for passage	Distance to concurrent pile driving sites
Embankment cofferdams (in water)	37.83204, -121.57494	-3	10,500 (width of CCF)	25	20,800	NA	Unknown
Divider wall (in water)	37.83961, -121.57514	-3	10,500 (width of CCF)	<5% of total surface area of CCF	9,800	NA	Unknown
NCCF siphon (in cofferdam; 20–30 ft from open water)	37.83257, -121.59218	-17	600 (width of entrance channel)	300	150	50%	300

1. Measuring straight line distance to river bend (furthest upstream or downstream location) (ft) is not applicable; and (2) all distance measurements are in feet.

Table 2-18. Physical Data for Pilings at Clifton Court Forebay.

Structure	Pile Type/ Size	Total Piles	# of concurrent pile drivers	Piles per day	Strikes per pile (impact driving only)	Total strikes per day	Sound Attenuation Devices	Expected acoustic dampening in dB
Embankment cofferdams	Sheet piles (AZ-28-700)	5,125	4	60	2101	12,600	None	NA
Divider wall	Sheet piles (AZ-28-700)	5,169	4	60	210	12,600	None	NA
NCCF Siphon	14-inch concrete or steel piles	2,160	2	30	1,050	31,500	Dewatering or bubble curtains, if feasible/ practicable	5 dB

1. Assumes 70% of pile can be driven using vibratory driving followed by impact driving to drive the remainder of the pile.
General: All assumptions will be refined as part of next engineering phase when site-specific geotechnical data are collected.

Table 2-19 presents the extent, timing, and duration of pile-driving noise levels predicted to exceed the interim injury and behavioral thresholds at the CCF based on application of the NMFS spreadsheet model and the assumptions presented in Appendix 3.E Pile Driving Assumptions for the Proposed Action (excerpted from Table 3.E-1 and 3.E.2.). During sheet pile installation, it is assumed that approximately 70 percent of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement.

Table 2-19. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the Site.

Clifton Court Forebay						
Facility	**Distance to 206-dB SPL Injury Threshold (feet)**	**Distance to Cumulative 187-dB SEL Injury Threshold[1,2] (feet)**	**Distance to 150-dB RMS Behavioral Threshold[2] (feet)**	**Number of Construction Seasons**	**Timing of Pile Driving**	**Duration of Pile Driving (days)**
Embankment cofferdams	30	2,814	13,058	1 (Year 6)	Jul-Oct	85
Divider wall	30	2,814	13,058	2 (Year 4 and 5)	Jul-Oct	86
NCCF siphon (no attenuation)	46	1,774	9,607	2 (Years 2 and 3)	Jul-Oct	72
NCCF siphon (with attenuation)	20	823	4,458	2 (Years 2 and 3)	Jul-Oct	72

1 Computed distances to injury thresholds are governed by the distance to "effective quiet" (150-dB SEL). Calculation assumes that single strike SELs <150-dB do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance.

2 Distance to injury and behavioral thresholds assume an attenuation rate of 4.5-dB per doubling of distance and an unimpeded propagation path; on-land pile driving, vibratory driving or other non-impact driving methods, dewatering of cofferdams, and the presence of major river bends or other channel features can impede sound propagation and limit the extent of underwater sounds exceeding the injury and behavioral thresholds.

Clifton Court Forebay currently is an approximately 2,500-acre water body that serves as a storage reservoir for off-peak pumping by the SWP. It is approximately 2.5 miles long by 2.0 miles wide with an average depth of 6.5 feet.

NCCF Siphon

As proposed in the PA, pile driving at the NCCF siphon site will create substantial adverse acoustic conditions to exposed fish in CCF. Pile driving for the NCCF siphon will occur adjacent to the inlet channel to the Skinner Fish Protection Facility on the western side of the forebay and will occur in years 2 and 3 of the construction schedule (Table 2-9). The width of the opening from the forebay to the inlet channel is approximately 600 feet. The width of the forebay from the inlet channel opening to the opposite shoreline (due east) is approximately 10,800 feet. The proposed cofferdam will occupy one half of the inlet channel, leaving a channel 300-foot-wide. The total length of the NCCF siphon cofferdam will be 3,260 feet, with half of the channel occupied by the cofferdam for the siphon construction in each year of the 2-year construction schedule. Based on engineering drawings in Appendix 3.C in the BA, NMFS estimated that in each construction season, two walls 750-feet-long will be installed on each side of the siphon alignment, with an end wall 130-feet-long joining the two parallel cofferdam walls. This creates the dewatered work space for construction of the three 23-foot-wide siphon box culverts.

After the first construction season, the cofferdam will be constructed on the opposite side of the inlet opening, the previous cofferdam removed, and the remainder of the siphon completed. As described in Appendix 3.E of the BA, the calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet, or approximately 5 percent of the 600-foot channel width when measured from the levee edge, or maximum of 10 percent when the sheet piles are being driven mid-channel (30 feet of the remaining 300-foot passage channel to the adjacent levee). The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 2,814 feet. This completely encompasses the entire inlet channel width at the siphon location and extends the zone of injury for one day's pile driving activity the same distance out into CCF. The distance to the 187-dB SEL threshold is approximately 26 percent of the distance across the forebay. The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet. Therefore, discernable impacts (behavioral modification) from pile driving of the siphon cofferdam will extend across the entire width of the forebay to the opposite shore and encompass the entire water body of CCF because the distance to any shoreline on the opposite side of the forebay is less than 13,000 feet.

The BA states that thirty 14-inch steel or concrete piles will be driven each day to construct the foundation of the siphons (BA Appendix 3.E). Pile driving associated with installing the NCC siphon foundation piles is calculated to have a 206-dB SPL threshold distance of 46 feet (7.7 percent of the 600-foot-wide inlet channel opening) and 20 feet (3.3 percent of the channel opening) with a 5-dB reduction due to attenuation practices. Attenuation will typically be achieved by dewatering the interior of the cofferdam prior to pile driving. If dewatering cannot be achieved, bubble curtains may be employed to surround each pile while being driven into place. If the piles are being driven in a mid-channel location, the percentage of the channel blocked is doubled. The calculated distance to the 187-dB SEL cumulative injury threshold without any attenuation devices is 1,774 feet; 823 feet with a 5-dB attenuation device. Under attenuated and unattenuated conditions, the entire inlet channel will exceed the 187-dB SEL threshold. The distance to the 187-dB threshold for unattenuated pile driving will extend approximately 16 percent of the width of the forebay and approximately 7.6 percent of the forebay width for attenuated conditions. The calculated distance to the 150-dB RMS threshold for behavioral effects is 9,607 feet. Therefore, discernable impacts (behavioral modification) from pile driving the siphon foundation piles will extend almost completely across the entire width of the forebay to the opposite shore (approximately 90 percent), which leaves approximately a 1,000-foot buffer around the perimeter of the entire water body of CCF.

Adverse effects related to the acoustic conditions created by the pile driving will occur over two consecutive years at the siphon location (2023 and 2024). NMFS anticipates it will take approximately 28 days to drive the 815 sheet piles (approximately 1,630 lineal feet of cofferdam) associated with each cofferdam per work season, driving 30 piles per day with two pile drivers operating concurrently. Driving the foundation piles is expected to take an additional 72 days. NMFS anticipates that pile driving will last at least 100 days and as long as 109 days each in-water work season, as described in the work schedule (BA Appendix 3.D).

Sheet Pile Channel in Southern Embankment

Pile driving associated with construction of the southern embankment channel is expected to create adverse acoustic conditions in the surrounding waters of CCF, which may result in the injury or death of exposed fish. Pile driving for the channel that will allow flooding the expanded southern CCF on Byron Tract will occur on the southwestern end of the currently existing earthen embankment during the in-water work window in 2025 and will last 30 days (Table 2-19). The width of the forebay from the channel location to the farthest opposite side of the forebay (northern side) is approximately 13,200 feet. The proposed cofferdam channel will pierce the earthen southern embankment, leaving a channel 60-feet-wide when completed. The cofferdam channel will require driving sheet pile walls on both sides of the channel, approximately 200-feet-long, and driving end walls at the end of the channel. A temporary 60-foot-wide sheet pile end wall will be constructed to block flow from the current forebay into the new southern cell of the forebay on Byron Tract. This temporary wall will be pulled to allow controlled flooding of the new southern forebay cell when it is ready.

Following removal of the existing earthen embankment on the southern side of CCF, the sheet pile channel will be removed. The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet, or approximately 0.2 percent of the 13,200-foot width of the existing forebay. The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 2,814 feet. This extends the zone of injury for one day's pile driving activity the same distance out into CCF. The distance to the 187-dB SEL threshold is approximately 21 percent of the distance across the forebay. The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet. Therefore, discernable impacts (behavioral modification) from pile driving of the channel cofferdam will extend across the entire width of the forebay to the opposite shore and encompass the entire water body of CCF because the farthest distance to the shoreline on the opposite side of the forebay is just slightly greater than 13,000 feet.

This will be the initial case. Concurrent with the installation of the channel through the southern embankment, however, the cross forebay partition cofferdam separating the northern and southern halves of the forebay will be constructed. As the cofferdam partition wall is constructed, the straight-line path across the forebay will be altered by the lengthening sections of the dividing wall, which should partially block the transmission of sound through the forebay creating a more complex sound field in the forebay. The closest point of the partition wall to the southern embankment channel is approximately 5,000 feet. Therefore, there is the potential that overlapping fields of sound during construction of the channel and the forebay partition wall will create a field of sound that exceeds the 187-dB SEL threshold across the western half of the forebay during the month of July 2025 when construction periods overlap. This will expose any fish present to levels of sound that may result in injury or death.

Adverse effects related to the acoustic conditions created by pile driving for this element of the PA will occur in only 1 year of construction (currently scheduled for 2025) and pile driving is not scheduled to last more than 30 days within the period (July 1 to August 11, 2025). The distance to the 187-dB SEL threshold will not extend to the inlet channel opening at the western end of CCF, and thus is not expected to cause injury to fish entering the inlet channel leading to the Skinner Fish Salvage Facility.

CCF Partition Dike (Cofferdam Wall)

Adverse acoustic effects are expected to result from pile driving sheet piles associated with the partition dike element of the PA. Construction of the partition dike will allow for separating the current CCF water body into a northern and southern half.

Following completion of the partition dike, the northern side of the forebay (now called NCCF) will be dewatered and construction allowed to continue in the dry for the remaining actions, including excavating the forebay to the design depth, building the earthen embankments across the forebay and around the perimeter of the NCCF, and constructing the spillway and CCF pumping plants.

Once the earthen embankment is constructed behind the partition dike, the dike will be removed or cut off at the mud line. The project description for the PA describes the partition dike as approximately 10,500-feet-long, spanning the entire width of the CCF, and will require 5,169 sheet piles to complete. It is anticipated that using four pile drivers, operating concurrently, 60 sheet piles per day can be installed, requiring 86 days, but perhaps as long as 109 days, to complete the first phase of the partition dike installation. The proposed in-water work window is from July 1 through October 31 and will overlap with portions of adult migrations of CCV steelhead from both the Sacramento and San Joaquin river basins as described above.

As described in the September 28, 2016, memo to NMFS, the entire partition dike will be installed in the first season of work, except for two, 100-foot wide gaps on the eastern and western ends of the dike to allow water to flow between the two halves. The partition dike will be installed during the same in-water work season as the channel in the southern embankment (2025). The following work season (2026), the two gaps will be closed with sheet piles, isolating the northern portion of CCF from the southern CCF during the in-water work window. It is anticipated that this will take 30 days within the period July 1 to August 11, 2026.

Based on the proposed alignment of the partition dike from east to west across the CCF, the northern perimeter of the forebay is no more than 6,800 feet from the partition dike alignment. The southern current embankment is typically no more than 5,300 feet from the alignment. The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet. Because the partition dike is surrounded on both sides by water, the width of the zone that exceeds 206-dB SPL is 60 feet or approximately 0.4 percent of the 13,200-foot width of the existing forebay.

The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 2,814 feet. This extends the zone of injury for one day's pile driving activity the same distance out into CCF on either side of the partition dike alignment (a band 5,628-feet-wide). The distance to the 187-dB SEL threshold covers approximately 43 percent of the distance across the forebay on either side of the alignment. The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet.

Therefore, discernable impacts (behavioral modification) from pile driving the partition dike cofferdam will extend across the entire width and length of the forebay because the farthest distance to the shoreline from the partition dike alignment is 6,800 feet, and four pile drivers will be operating concurrently along the alignment.

Adverse effects related to the acoustic conditions created by the pile driving for this element of the PA will occur in two different years of construction (2025 and 2026). In the first year of construction, adverse acoustic effects may occur over a period of 4 months (July 1 through October 31), with an estimated maximum of 109 days of pile driving. In the second year of construction, it is estimated that only 30 days will be needed to close the two gaps in the partition dike, which will occur during July 2026.

Alignment of the partition dike will act as a guidance barrier leading fish across the CCF towards the inlet to the intake channel and the Skinner Fish Protection Facility. Pile driving will form a band of sound along the entire length of the partition dike alignment from the eastern perimeter of CCF to the inlet channel on the western side of the forebay that will exceed the 187-dB SEL threshold. Thus, it is expected that injury to fish will occur as they follow the partition dike to the inlet channel.

Embankment Cofferdams

Adverse acoustic effects are expected to result from pile driving sheet piles associated with the construction of cofferdams around the perimeter of CCF to allow for constructing earthen embankments behind them. These cofferdams will be situated on the eastern and western sides of the current CCF. On the eastern side of CCF, the cofferdams will extend from the location of the current radial gates and forebay inlet to the location of the partition dike. On the western side of CCF, the cofferdams will extend from the current location of the southern embankment to the inlet to the intake channel where the NCCF siphon will be constructed. The combined length of the cofferdams is approximately 10,000 linear feet, requiring 5,125 sheet piles to construct. The project description for the PA indicates that four pile drivers will be operated concurrently to install the sheet piles, installing 60 piles per day. Installation of the piles will take 85 days over the 109-day in-water work window in 2027 (July 1 through October 31).

Based on the proposed location of the embankment cofferdams, the farthest distance to the opposite shore of CCF is 12,600 feet from the western cofferdam to the northeastern corner of CCF and approximately 11,000 feet from the eastern cofferdam adjacent to the radial gates to the northern edge of CCF. The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet. The width of the zone that exceeds 206-dB SPL is 30 feet or approximately 0.2 percent of the 12,600-foot width of the existing forebay. This is doubled, however, because cofferdams are being installed on both the eastern and western sides of CCF simultaneously.

The distance to the 187-dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 2,814 feet. This extends the zone of injury for one day's pile driving activity the same distance out into CCF from the shoreline location of the cofferdams. The distance to the 187-dB SEL threshold covers approximately 44 percent of the distance across the forebay when both cofferdams are being installed concurrently on the eastern and western sides of the forebay.

The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet. Therefore, discernable impacts (behavioral modification) from pile driving embankment cofferdams will extend across the entire width and length of the forebay because the farthest distance to the opposite shoreline is 12,600 feet, and both the eastern and western sides of this construction element will operate concurrently.

Adverse effects related to the acoustic conditions created by pile driving for this element of the PA will occur in 1 year of construction (2027) over a period of four months (July 1 to October 31), with an estimated maximum of 109 days of pile driving. The eastern and western sides of the forebay will have areas where acoustic effects from pile driving will exceed the 187-dB SEL threshold. Thus, it is expected that injury to fish will occur as they enter the forebay from the radial gates or exit the forebay as they enter the western inlet to the intake channel.

2.5.1.1.1.1.2.1 Chinook Salmon Exposure and Risk

The CCF is not part of the natural migration routes of any of the Central Valley Chinook salmon species. Continued operation of CCF throughout the construction period, however, increases the risk of exposing listed fish species to adverse acoustic effects from pile driving.

Based on the salvage of fish collected from the Tracy Fish Collection Facility and the Skinner Fish Protective Facility, juvenile winter-run sized fish are typically in or near the CCF from December through April. Spring-run sized fish are expected to be in CCF from February through

June, and the overwhelming majority (greater than 99 percent) of juvenile fall-run and late fall-run sized fish is present from January through June.

Adult fall-run Chinook salmon will migrate through the action area from July through December. Although adult fall-run Chinook returning to spawn may potentially be found in the vicinity of CCF, those fish migrating into the San Joaquin River basin are most likely to pass by the CCF radial gates and enter the forebay. Inside the forebay, these fish may be exposed to the CCF construction site and be subject to pile-driving-induced acoustic effects. The adult fall-run population of the Central Valley is somewhat insulated from these effects because only about 1 percent of Central Valley fall-run spawn in the San Joaquin River basin (Hannon 2009).

Limiting pile-driving activities at CCF to the July 1 through October 31 work window is expected to minimize exposure to Chinook salmonid species because

- Juvenile winter-run Chinook salmon are potentially present in CCF from December to April. Adult winter-run are present in the Delta between November and June, but are unlikely to be found in CCF because it is outside of their main upstream migratory route.
- Juvenile spring-run Chinook salmon are potentially present in CCF from February to June, while adult spring-run are present in the Delta between January and March.
- Juvenile fall- and late fall-run Chinook salmon are potentially present in CCF from January through June, with a small proportion of the run present during July to December. Although adult fall-run will be migrating through the action area from July through December, only a small proportion of the Central Valley population is expected to pass near CCF.

Given the timing of in-water construction activities, NMFS expects that the acoustics effects of pile driving in CCF will not adversely affect winter-run or spring-run Chinook salmon. Although the in-water work window will greatly reduce the exposure of juvenile fall-run and late fall-run Chinook salmon to pile-driving-induced acoustic effects, NMFS expects a small proportion of juvenile fall-run and late fall-run will be adversely affected. Adult fall-run, particularly the segment of the population spawning in the tributaries of the San Joaquin River, are also likely to be adversely affected by pile-driving-induced acoustics at the CCF construction site.

2.5.1.1.1.1.2.2 Steelhead Exposure and Risk

CCV steelhead are expected to be present in CCF during construction activities. It is expected that Old River will be accessible to CCV steelhead juveniles from the Sacramento River basin via an open DCC gate, providing exposure to the forebay. Old River will also be accessible to San Joaquin River basin fish emigrating downstream from the east side tributaries (Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries. The likelihood of fish from the Sacramento River being present, however, diminishes with distance from the main stem of the San Joaquin River. Less than 1 percent of the annual juvenile emigration is expected to occur during the proposed work window of July 1 through October 31. Most juvenile steelhead presence in the CCF location will occur from December through March, based on CVP/SWP salvage data. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location, but in lower abundance than for fish originating in the Sacramento River basin.

The timing of in-water work (July 1 through October 31) overlaps with approximately 90 percent of the Central Valley adult steelhead upstream migration, however most of these fish are destined for the Sacramento River basin. It is expected that the timing of adult steelhead presence at CCF will be later than that observed for the north Delta. This is due to the southern Delta location of CCF and the likelihood that the majority of adult fish present are from the San Joaquin River basin population, which has a later peak in upstream migration compared to the Sacramento River basin population. Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta starting in September, with most of the population passing through the Delta from November to January based on data from the Stanislaus River fish weir. This slightly later upstream migration for San Joaquin River basin CCV steelhead overlaps from September through October with the proposed in-water work window.

The CCF inlet and radial gates are located on the Old River corridor, which is one of the potential migratory routes for adult San Joaquin River basin CCV steelhead. Because of this, a greater proportion of this basin's population is expected to migrate past this location than those from the Sacramento River basin.

Given the proportion of the adult CCV steelhead population that could be exposed to pile-driving activities over several years, NMFS expects that the acoustic effects of construction-related pile driving at CCF will adversely affect a large number of individual adult CCV steelhead each year of the construction period, though this effect could be reduced by construction early in the work period.

2.5.1.1.1.1.2.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.4 Environmental Baseline. Juvenile and sub-adult sDPS green sturgeon may be present during any month of the year throughout the waters of the Delta where they may spend extended periods of time foraging or sheltering, whereas adult green sturgeon are less widespread keeping primarily to the principal migration route through the waters of the north Delta on their way to and from upstream spawning habitats in the Sacramento River. Because of the widespread and year-round presence of juvenile and sub-adult life stages in the waters of the Delta, NMFS expects that these life stages of sDPS green sturgeon could be present in the south Delta and could, therefore, become exposed to the pile-driving-induced acoustic effects related to the expansion and modification of the Clifton Court Forebay during the July 1 through October 31 in-water construction period associated with that effort. Exposure is expected to be limited in number because the density of green sturgeon in the waters of the south Delta is minimal compared to the rest of the Delta and the Sacramento River in general.

2.5.1.1.1.1.3 HOR Gate

Construction of the HOR gate is expected to take two years and will include pile-driving activities. According to the preliminary design presented in the BA, the gate will be 210-feet-long and 30-feet-wide (BA Appendix 3.C Conceptual Engineering Report, Volume 2) and includes seven bottom-hinged gates, a fish passage structure, a boat lock, a control building, a boat lock operator's building, and a communications antenna. According to the BA in Appendix 3.D Construction Schedule for the Proposed Action, the HOR gate will be constructed in two phases using sheet pile cofferdams to isolate and dewater half the channel during the first phase and the other half during the second phase. A sheet pile retaining wall will be installed in the levee where the operable barrier connects to it. All in-water construction work, including construction of cofferdams, sheet pile walls, and pile foundations, would be restricted to a work window of August 1 through October 31 to minimize or avoid potential effects on listed fish species. All pile driving that requires using an impact pile driver in or near open water (cofferdams and foundation piles) will also be restricted to the in-water work period. Use of an experimental bubble curtain/sound barrier with acoustic monitoring will occur during impact pile driving with the assumption a decrease in 5 dB will result.

The BA presents an estimate of the number of piles required for each component of the construction, including approximately 550 sheet piles (275 per season) for installing the cofferdams. Approximately 15 piles are expected to be set per day with an estimated 210 strikes per pile over a period of approximately 19 days per season. Sheet piles installation will begin with a vibratory hammer; an impact hammer will be used if refusal is encountered before target depths. Installment of the foundation for the operable barrier will require 100 steel pipes or H-piles (50 per season) to be set with a single-pile driver on site. Approximately 15 piles are expected to be set per day with an estimated 1,050 strikes per pile over a period of approximately three days per season. Foundation pile driving may be done in the dry or in the wet. Though cast-in-drilled-hole concrete foundation piles may be able to be used, the feasibility is currently unknown, and NMFS assumes use of impact driving.

Phase 1 (the first construction season) involves installing a cofferdam in half the channel and then dewatering that area (see BA Section 3.2.10.7 Dewatering). The cofferdam will remain in the water until completion of the first half of the gate. The cofferdam will then be flooded and removed or cut off at the required invert depth, and another cofferdam installed in the other half of the channel during phase 2 (second season). In this phase, the second half of the gate will be constructed using the same methods, with the cofferdam either removed or cut off upon completion of the gate.

In both phases, cofferdam construction will begin in August and last approximately 19 days. Construction has been designed so that the south Delta temporary barriers located at this site can continue to be installed and removed as currently done until the permanent gates are fully operable. Installation and removal of the temporary barriers, however, is not part of the PA.

Table 2-20 (BA Tables 3.E-1 and 3.E-2) describe the physical locations and details of pile-driving actions described for the construction of the HOR gate.

Table 2-20. HOR Gate Pile Driving Activity Details.

Facility/ Structure	Location	Lat/long	Width of In-river Construction	Length of Construction along River Bank	Proportion of River Available for Passage	Distance to Concurrent Pile Driving Sites
HOR gate coffer dams (in water)	Old River 400 ft from SJR junction	37.80798 -121.32912	75	50–100	50%	100
HOR gate foundation (in cofferdam; 20–30 ft from open water)	Old River 400 ft from SJR junction	37.80798, -121.32912	NA	30–80	NA	80

Straight line distance to river bend (furthest upstream/downstream location) is 700–1,500; river depth is -6 feet at both locations; river width is 150 feet at both locations; all distance measurements are in feet.

Table 2-21. Physical Data for Pilings at HOR Gate.

Structure	Pile Type/Sizes	Total Piles Per Site	# of Concurrent Pile Drivers Per Site	Piles Per Day	Strikes Per Pile (impact driving only)	Total Strikes Per Day
HOR gate cofferdams	Sheet piles (AZ-28-700)	550	1	15	2,101	3,150
HOR gate foundation	14-inch steel pipe or H-piles	100	1	15	1,050	15,750

1 Assumes 70% of pile can be driven using vibratory driving followed by impact driving to drive the remainder of the pile.
General: All assumptions will be refined as part of next engineering phase when site-specific geotechnical data are collected.

2 There are no sound attenuation devices in use, therefore the is no expected acoustic dampening.
Straight line distance to river bend (furthest upstream/downstream location) is 700–1,500; river depth is -6 feet at both locations; river width is 150 feet at both locations; all distance measurements are in feet.

Table 2-22 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds at the HOR gate based on application of the NMFS spreadsheet model and the assumptions presented in the BA in Appendix 3.E Pile Driving Assumptions for the Proposed Action (excerpted from Table 3.E-1 and 3.E.2.). During installation of sheet piles, it is assumed that approximately 70 percent of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement.

Table 2-22. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the HOR Gate Site.

Facility	Distance to 206-dB SPL Injury Threshold (feet)	Distance to Cumulative 187-dB SEL Injury Threshold[1,2] (feet)	Distance to 150-dB RMS Behavioral Threshold[2] (feet)	Number of Construction Seasons	Timing of Pile Driving	Duration of Pile Driving (days)
HOR gate cofferdams	30	2,063	13,058	2 years	Aug 1-October 31	19
HOR gate cofferdams (with attenuation)	13	1,306	6,063	2 years	Aug 1-October 31	19
HOR gate foundation (no attenuation)	46	1,774	9,607	2 years	Aug 1-October 31	4
HOR gate foundation (with attenuation)	20	823	4,458	2 years	Aug1-October 31	4

1 Computed distances to injury thresholds are governed by the distance to “effective quiet” (150-dB SEL). Calculation assumes that single strike SELs with a magnitude <150-dB SEL do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance since the sound has attenuated to less than 150 dB SEL.

2 Distance to injury and behavioral thresholds assume an attenuation rate of 4.5-dB per doubling of distance and an unimpeded propagation path; on-land pile driving, vibratory driving or other non-impact driving methods, dewatering of cofferdams, and the presence of major river bends or other channel features can impede sound propagation and limit the extent of underwater sounds exceeding the injury and behavioral thresholds.

The HOR gate location is approximately 400 feet downstream of the mouth of the divergence of Old River from the main stem of the San Joaquin River. At this location, the channel of Old River extends approximately 1,500 feet to the west before turning to the northwest. The Old River channel extends approximately 400 feet to the east to meet the San Joaquin River.

Based on the description provided, a single pile driver will be operating at this location for 19 days to drive sheet piles for the cofferdam during each of the two construction seasons. The pile driver is anticipated to drive 15 sheet piles per day with a cumulative total of 275 sheet piles per year over the two-year construction schedule. The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 30 feet, or approximately 20 percent of the channel width of 150 feet when measured from the levee edge, or maximum of 40 percent when the sheet piles are being driven mid-channel (30 feet of the remaining 75-foot passage channel to the adjacent levee). The distance to the 187-dB SEL cumulative injury threshold for one day’s pile driving of sheet piles is calculated as 2,063 feet. This completely encompasses the entire river channel width at the HOR gate location and extends the zone of injury for one day’s pile driving activity the same distance up and down the river channel from the construction location until the sound waves encounter the river banks approximately 1,500 feet to the west and 700 to 1,500 feet to the east (depending on which side of the channel pile driving is occurring on) which will attenuate the further propagation of the sound waves.

The estimated cumulative distance along the length of the river channel that exceeds the 187-dB SEL threshold from pile driving the sheet piles is 1,500 feet to the west and 700 to 1,500 feet to the east. When pile driving occurs on the northern side of the Old River channel (season 2), then the farthest straight line distance to the east before encountering the opposite bank of the San Joaquin River is approximately 1,500 feet. The calculated distance to the 150-dB RMS threshold for behavioral effects is nearly 13,000 feet. Therefore, discernable impacts (behavioral modification) from pile driving of the HOR gate sheet piles will extend upstream and downstream of the gate site within the channel until the alignment of the channel is altered by bends in the river channel approximately 1,500 feet to the west and 700–1,500 feet to the east.

Exposure of fish to the adverse acoustic environment is related to the timing of presence at the HOR gate location. The expected duration each year for the insertion of 275 sheet piles is 19 days. This amounts to approximately 61 percent of the days in each individual month (August through October) if pile driving is continuous (7 days per week) or approximately 80 percent if pile driving only occurs on weekdays and not over the weekend.

Regarding pile driving of foundation pilings within the cofferdam, the expected distance to the 206-dB SPL is 46 feet without accounting for any attenuation of sound due to being behind the cofferdam or dewatering, or 20 feet if a conservative reduction of 5 dB is applied for sound attenuation resulting from dewatering of the space behind the cofferdam. This equates to approximately 31 percent of the channel width (150 feet) or 62 percent (if measured from the end of the cofferdam with only 75 feet of passage between the end of the cofferdam and the adjacent levee bank) for unattenuated sound, or 13 percent and 26 percent of the river channel for attenuated sound conditions.

The distance to the 187-dB SEL cumulative injury threshold for one day's unattenuated pile driving of foundation piles is calculated as 1,774 feet (823 feet attenuated). This completely encompasses the entire river channel width at the HOR gate location and extends the zone of injury for one day's pile driving activity the same distance up and down the river channel from the construction location until the sound waves encounter river banks.

For unattenuated pile driving conditions, the banks of the river channel will block further propagation of the sound waves up and down the channel length as described above. For the attenuated conditions, the distance to the 187-dB SEL level will not encounter the bend in the river to the west, but will partially encounter the river banks to the east, depending on which side of the river the piles are being driven (see above description). In any case, the junction of the San Joaquin River with Old River will fall within the area affected by the sound fields generated by pile driving. The distance to the 150-dB RMS behavioral modification threshold is calculated as 9,607 feet unattenuated, or 4,458 feet for attenuated conditions. As described above, bends in the river channel alignment will block the propagation of sound at shorter distances than these.

The expected duration each year for the insertion of 50, 14-inch steel pilings or H-piles is 4 days. This amounts to approximately 13 percent of the days in each month (August through October). It is anticipated that completion of the cofferdam installation, dewatering, and driving of foundation pilings will be accomplished within 30 days of starting the construction because these elements are considered to be sequential operations.

2.5.1.1.1.1.3.1 Chinook Salmon Exposure and Risk

The location of HOR gate is not along present-day migration routes of winter-run or late fall-run Chinook salmon. Fall-run and any spring-run Chinook salmon originating from, or migrating to, the San Joaquin River basin, however, would pass in close proximity to the site, potentially exposing individuals of that run to the adverse effects of pile-driving-induced acoustics. Juvenile fall-run sized Chinook salmon occur near the HOR gate construction site in December through July (DJFMP 2017), with the majority (greater than 99 percent) in April through June.

Adult fall-run Chinook salmon will migrate through the action area July through December. Most adult fall-run Chinook return to spawn in the rivers and tributaries of the Sacramento River basin, migrating through the channels of the Delta far from the HOR gate. Those fish migrating to the various tributaries within the San Joaquin River basin, however, will pass the HOR gate construction site and be subject to pile-driving-induced acoustic effects.

Limiting pile driving at the HOR gate to the August 1 through October 31 work window is expected to minimize exposure to Chinook salmon species because:

- Winter-run Chinook salmon are not expected to be present near the HOR gate because it is far from their migration routes.
- The primary populations of spring-run Chinook salmon are located in the Sacramento River basin. A small proportion of juvenile spring-running fish may be present near the HOR gate in April and May. Yearling smolt spring-run Chinook salmon may also be present in the vicinity of the HOR gate in October, though likely in very low numbers.
- Late fall-run Chinook salmon are not expected to be present in the vicinity of the HOR gate because this area is far from any migration routes used by this run.
- Fall-run Chinook salmon are expected to be present in the vicinity of the HOR gate from April through June. And while adult fall-run will be migrating through the action area primarily in October, but may be present July through December, only a small proportion of the Central Valley population is expected to pass near the HOR gate.
- Given the timing of in-water construction activities, NMFS expects that the effects of pile-driving-induced acoustics at the HOR gate will not adversely affect winter-run, spring-run, or late fall-run Chinook salmon. NMFS expects that juvenile fall-run Chinook salmon will not be adversely affected, but a small proportion of immigrating adult fall-run in the Stanislaus River will be adversely affected by pile-driving-induced acoustic effects at the HOR gate construction site.

2.5.1.1.1.1.3.2 Steelhead Exposure and Risk

Juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Based on regional monitoring and CVP/SWP salvage data, less than 1 to 2 percent of the annual juvenile emigration from either basin is expected to occur during the proposed work window. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location, but their numbers appear to be considerably lower than those fish originating in the Sacramento River basin. It is not expected that that juvenile steelhead from the Sacramento River basin will be present at the location of the HOR gate. Because pile driving associated with construction of the HOR gate occurs from August 1 through October 31, no temporal overlap with the presence of juvenile CCV steelhead is expected.

Adult CCV steelhead from the Sacramento River basin are present in the Delta from June through November. Peak migration (approximately 69 percent of annual run) occurs in September and October. Adult CCV steelhead from the San Joaquin River basin migrate into the

Delta beginning in September and October, with peak migration occurring between November and January. Because pile driving at HOR gate occurs during from August 1 through October 31, only those adult steelhead migrating into the San Joaquin River basin during these months will be affected. It is anticipated that only a small proportion of the annual adult upriver migration will overlap with pile driving at HOR gate.

All adult and juvenile CCV steelhead migrating from the San Joaquin River basin during the construction period must pass through the lower San Joaquin River and the junction with Old River (Head of Old River) adjacent to the location of the HOR gate on their way downstream to the ocean. A proportion of downstream migrating fish in the mainstem are expected to enter Old River and migrate past the location of the HOR gate.

Pile-driving activities may potentially affect CCV steelhead at the HOR gate, but to differing degrees. Steelhead from the Sacramento River basin are not expected to be present at HOR gate. Adult steelhead from the San Joaquin River are present from September and October with peak upstream migration from November through January, after the end of the in-water work window. Minimal exposure of juveniles from the San Joaquin River basin is expected during this time frame (less than 1 percent of annual juvenile steelhead salvage occurs during the August 1 through October 31 time frame). Based on the spatial location of the proposed HOR gate and construction timing, NMFS expects that the acoustics effects of pile driving at HOR gate will adversely affect a small proportion of juvenile and adult San Joaquin River basin steelhead.

2.5.1.1.1.1.3.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.4 Environmental Baseline. Juvenile and sub-adult sDPS green sturgeon may be present throughout the Delta during every month of the year, whereas spawning and post-spawn adults are unlikely to migrate through the waters of the south Delta because their principal migratory route between the ocean and upstream spawning habitats lies primarily in the Sacramento River and the channels of the north Delta. Because of the widespread and year-round presence of juveniles and sub-adult life stages in the waters of the Delta, NMFS expects these life stages to be present in the south Delta, including the vicinity of the HOR gate, during construction periods. Juveniles and sub-adults could therefore become exposed to the pile-driving-induced acoustic effects associated with construction of the Head of Old River gate during the August 1 through October 31 in-water construction period. Exposure is expected to be limited due to the low density of green sturgeon in the waters of the south Delta and the San Joaquin River compared to the waters of the north Delta and the Sacramento River in general. NMFS therefore expects that the acoustics effects of pile driving at the HOR gate will adversely affect a small proportion of juvenile and sub-adult green sturgeon.

2.5.1.1.1.1.4 Barge Landing Locations

According to the proposed action description in the BA, contractors are expected to use barges to transport tunnel boring machine (TBM) components and other heavy or bulky equipment or materials to and from TBM launch sites. Barge landings are expected to be constructed to accommodate this activity. A total of seven barge landings are currently proposed in the BA (BA Appendix 3.A Map Book for the Proposed Action) at the following locations:

- Snodgrass Slough north of Twin Cities Road (adjacent to proposed intermediate forebay)

- Little Potato Slough (Bouldin Island south)
- San Joaquin River (Venice Island south)
- San Joaquin River (Mandeville Island east at junction with Middle River)
- Middle River (Bacon Island north)
- Old River (Victoria Island northwest)

Old River (junction with West Canal at Clifton Court Forebay) However an additional barge landing location was identified by the applicant during consultation and may be built at the contractor’s discretion at the following location:

- Sacramento River at NDD Intake 2

Construction of barge landings will include in-water pile driving as one of several activities that are likely to generate underwater noise. The BA proposes using barge landing docks supported by steel piles, though floating barges will be used where possible to minimize in-water construction activities. Docks would each occupy an overwater area of approximately 300 by 50 feet (0.34 acre) spanning 5-9 percent of the total channel widths at the proposed locations. It is estimated that each barge landing would require vibratory and/or impact driving of 107 steel pipe piles (24-in diameter) to construct the dock and connecting bridge. Based on the concurrent operation of four impact pile drivers at each site and an estimated installation rate of 60 piles per day, pile driving noise would be expected to occur over two days at each barge landing.

The timing of pile-driving activities at each barge landing location are shown in Table 2-23 through Table 2-30.

Table 2-23. Timing for Construction Activities at Snodgrass Slough Landing.

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2018	10/31/2018
Install support structure for decking	88 days	11/1/2018	3/4/2019
Cast Barge Deck	66 days	3/5/2019	6/4/2019
Finish Barge Landing	44 days	6/5/2019	8/5/2019

Table 2-24. Timing for Construction Activities at Little Potato Slough.

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2018	10/31/2018
Install support structure for decking	88 days	11/1/2018	3/4/2019
Cast Barge Deck	66 days	3/5/2019	6/4/2019
Finish Barge Landing	44 days	6/5/2019	8/5/2019

Table 2-25. Timing for Construction Activities at San Joaquin River Landings.

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2019	10/31/2019
Install support structure for decking	88 days	11/1/2019	3/4/2020
Cast Barge Deck	66 days	3/5/2020	6/4/2020
Finish Barge Landing	44 days	6/5/2020	8/5/2020

Table 2-26. Timing for Construction Activities on Middle River.

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2019	10/31/2019
Install support structure for decking	88 days	11/1/2019	3/4/2020
Cast Barge Deck	66 days	3/5/2020	6/4/2020
Finish Barge Landing	44 days	6/5/2020	8/5/2020

Table 2-27. Timing for Construction Activities on Old River at Victoria Island.

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2019	10/31/2019
Install support structure for decking	88 days	11/1/2019	3/4/2020
Cast Barge Deck	66 days	3/5/2020	6/4/2020
Finish Barge Landing	44 days	6/5/2020	8/5/2020

Table 2-28. Timing for Construction Activities on Old River at CCF.

Task Name	Duration (days)	Start Date	End Date
Install piles (in water work window)	66 days	8/1/2018	10/31/2018
Install support structure for decking	88 days	11/1/2018	3/4/2019
Cast Barge Deck	66 days	3/5/2019	6/4/2019
Finish Barge Landing	44 days	6/5/2019	8/5/20190

Tables 2-29 and 2-30 (excerpted from Table 3.E-1 and 3.E-2 of the BA) describe the physical locations and details of the pile-driving actions described for the barge landings.

Table 2-29. Pile Driving Activity Details for Barge Landing Construction.

Barge Landings										
Facility/ Structure	Location	Lat/long	On land (distance to water in feet) or in water	River depth (ft)[1]	River width (ft)	Width of in-river construction (ft)	Length of construction along river bank (ft)	Proportion of river available for passage (percent)	Straight line distance to river bend (furthest upstream/ downstream location) (ft)	Distance to concurrent pile driving sites (ft)[2]
Dock piles	Intake 2	38.40541, -121.51452	In water	-14	700	50	300	95	6,500-12,00	300
Dock piles	IF barge	38.28106, -121.49816	In water	-11	265	50	300	81	1,400-2,700	300
Dock piles	Bouldin Is. barge landing	38.08762, -121.54505	In water	-11 to -18	980	50	300	95	1,800-2,900	300
Dock piles	Venice Is. barge landing	38.06630, -121.54130	In water	-19 to -36	1,030	50	300	95	2,000-4,700	300
Dock piles	Mandeville Is. barge landing	38.04264, -121.53177	In water	-5 to -47	760	50	300	93	6,500-8,500	300
Dock piles	Bacon Is. barge landing	38.00392, -121.54343	In water	-8 to -28	340	50	300	85	1,200-1,800	300
Dock piles	VictoriaIs. barge landing	37.91087, -121.56185	In water	-7	433	50	300	88	2,200-3,200	300
Dock piles	CCPP barge landing	37.85505, -121.56435	In water	-4 to -10	285	50	300	82	705-720	300

1. Depths at barge landings are based on NOAA navigation charts 18661 and 18662. Depths are feet at lower low water, based on WGS84.
2. Pile drivers may operate concurrently within this range.

Table 2-30. Physical Data for Pilings at Barge Landing Locations.

Barge Landings—Physical Data for Pilings								
Structure	**Pile Type and Sizes**	**Total Piles per site**	**# of concurrent pile drivers per site**	**Piles per day**	**Strikes per pile (impact driving only)**	**Total strikes per day**	**Sound Attenuation Devices**	**Expected acoustic dampening in dB**
Dock piles	24-inch steel piles	107	4	60	3,151	18,900	None	NA

Table 2-31 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds at the barge landings based on application of the NMFS spreadsheet model and the assumptions presented in the BA, in Appendix 3.E Pile Driving Assumptions for the Proposed Action (excerpted from Table 3.E-1 and 3.E.2.). During installation of the dock piles, it is assumed that approximately 70 percent of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement.

Table 2-31. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the Barge Landing Sites.

Facility	Distance to 206 dB SPL Injury Threshold (feet)	Channel width	Percent of Channel Width (206)	Distance to Cumulative 187 dB SEL Injury Threshold [1, 2] (feet)	Percent of Channel Width (187)	Cumulative Distance (187)	Distance to 150 dB RMS Behavioral Threshold[2] (feet)	Number of Construction Seasons (Year 1 or 2)	Timing of Pile Driving	Duration of Pile Driving (days)
Barge Landings Locations										
Intake 2 Location	46	700	7	1,774	100	3,848	9,607	1	July–Aug	2
Snodgrass Slough	46	265	17.3	1,774	100	3,848	9,607	1	July-Aug	2
Potato Slough	46	980	5	1,774	100	3,848	9,607	1	July-Aug	2
San Joaquin (Venice Island)	46	1,030	4.5	1,774	100	3,848	9,607	1	July-Aug	2
San Joaquin River (Mandeville)	46	760	6	1,774	100	3,848	9,607	1	July-Aug	2
Middle River (Bacon)	46	340	13.5	1,774	100	3,848	9,607	1	July-Aug	2
Old River (Victoria Island)	46	433	10.6	1,774	100	3,848	9,607	1	July-Aug	2
Old River (CCF)	46	285	16	1,774	100	3,848	9,607	1	July-Aug	2

1. Computed distances to injury thresholds are governed by the distance to "effective quiet" (150 dB SEL). Calculation assumes that single strike SELs with a magnitude of <150 dB SEL do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance since the sound has attenuated to less than 150 dB SEL.

2. Distance to injury and behavioral thresholds assume an attenuation rate of 4.5 dB per doubling of distance and an unimpeded propagation path; on-land pile driving, vibratory driving or other non-impact driving methods, dewatering of cofferdams, and the presence of major river bends or other channel features can impede sound propagation and limit the extent of underwater sounds exceeding the injury and behavioral thresholds.

The proposed action proposes to minimize the potential exposure of listed fish species to pile-driving noise by conducting all pile driving at barge landing locations between July 1 and August 31 when most species are least likely to occur in the action area. DWR will follow standard and provided AMMs, including the development and implementation of an underwater sound control and abatement plan outlining specific measures that will be implemented to avoid and minimize the effects of underwater construction noise on listed fish species (Appendix 3.F General Avoidance and Minimization Measures, AMM9 Underwater Sound Control and Abatement Plan).

2.5.1.1.1.1.4.1 Chinook Salmon Exposure and Risk

Because barge landing locations are spread over a broad area of the Delta, activities at the landings may occur in areas where Chinook salmon are present. General run-timing in the Delta has been identified in Section 2.4 Environmental Baseline and in Tables 2-10 and 2-11 in Section 2.5.1.1 Construction Effects.

Although Chinook salmon are likely to be present during this activity at some level, limiting pile driving at the barge landing locations to the July 1 through August 31 in-water work window is expected to minimize exposure to some runs and life stages of Chinook salmonid. The following summarize timing:

- Juvenile winter-run Chinook salmon are generally expected to be present in the Delta from November to April, but with small numbers possible in September and October; while adult winter-run are present in the Delta between November and May. Winter-run Chinook salmon exposure is also minimized compared to other runs because six of the seven landings are located on or near the San Joaquin River, which is not the main migratory corridor for winter-run Chinook salmon.
- Juvenile spring-run Chinook salmon are expected to be present in the Delta from November through May, with adult spring-run presence between January and June.
- Adult late fall-run Chinook salmon are expected to be present in the Delta from October through March, peaking in December and January. However, juvenile late fall-run Chinook salmon may be present between July and January.
- Adult fall-run Chinook salmon may be present July through December, peaking in October. Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, with only small numbers present in July and August.

Given the timing and location of in-water construction activities, NMFS expects that the effects of pile-driving-induced acoustic disturbances at the barge landing locations will not adversely affect juvenile or adult winter-run or spring-run Chinook salmon. The in-water work window will reduce the exposure of juvenile and adult fall-run and adult late fall-run Chinook salmon to pile-driving-induced acoustic effects. NMFS expects adverse effects to a small proportion of adult and juvenile late fall-run Chinook salmon to occur, as reduced exposure is expected, as they are generally not found in the San Joaquin River basin. NMFS also expects adverse effects will occur to a small proportion of juvenile fall-run, and a large proportion of adult fall-run Chinook salmon.

2.5.1.1.1.1.4.2 Steelhead Exposure and Risk

As previously described in Section 2.4 Environmental Baseline, Appendix B Section 1.3.3, and Section 2.5.1.1 Construction Effects, CCV steelhead originating from the Sacramento and San Joaquin River basins can be present throughout the Delta. Accordingly, steelhead can potentially access one if not several of the barge landing locations in either the north (e.g., Snodgrass Slough) or south (e.g., CCF) Delta. The Sacramento River is the primary migration route for both juvenile and adult CCV steelhead from the Sacramento River basin and the only viable route during summer and early fall months because of the lack of sufficient flow to provide access to the Yolo Bypass. Because the Delta Cross Channel on the Sacramento River will be open during the in-water construction window, Sacramento River basin fish as well as the

Mokelumne River basin fish are expected to have access to the Snodgrass Slough location. Waterways that access other landing locations, such as those on Little Potato Slough, the San Joaquin River, Middle River, and Old River, may be accessed by Sacramento River fish via the DCC as well as by San Joaquin basin fish outmigrating from the east side tributaries (e.g., Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries.

At nearly all barge landing locations, less than 1-2 percent of the annual juvenile population is expected to be present during the proposed work window (July 1 through August 31) because the majority of juvenile steelhead presence in the Delta near the barge landing locations is from January through May.

Because adult steelhead start to enter the Delta region as early as June, however, with peak presence in September and October, the in-water work window could overlap with up to approximately 30 percent of the annual adult escapement to activities at the barge landing locations, though the extent of exposure for the populations of the two basins (i.e., Sacramento vs. San Joaquin) depends on location. For landing locations in the central and south Delta, Sacramento River basin fish may be exposed by moving through the San Joaquin River corridor en route to the Sacramento River via Georgiana Slough or the open DCC gates. Locations on the mainstem of the lower San Joaquin River will expose a greater proportion of the Sacramento River basin's population because this portion of the San Joaquin River is one of the expected migratory routes for this population. Also, the fraction of Sacramento River origin fish exposed to central and south Delta tributary locations will vary with location due to the greater distance from the mainstem San Joaquin River and the variations of the hydrodynamics in the central and south Delta that may disorient fish and reroute their migrations.

Given the timing and location of in-water construction activities, NMFS expects that the effects of pile-driving-induced acoustics at the barge landing locations will adversely affect a small proportion of juvenile steelhead at the barge landing locations. Because of the large proportion of the adult steelhead population that is present throughout the Delta during the in-water work window and the wide distribution of the barge landing locations throughout the Delta, NMFS expects that pile-driving activities at barge landings will adversely affect a large proportion of the adult steelhead.

Intake 2 NDD Location

The location with the highest likelihood of exposure to CCV steelhead during construction of a barge landing is the one proposed at Intake 2 on the Sacramento River. Based on the description provided, four pile drivers will be operating concurrently at this location for two consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site.

The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 46 feet, or approximately 7 percent of the channel width of 700 feet. The distance to the 187-dB SEL cumulative injury threshold for one day's pile driving activity is calculated as 1,774 feet. This completely encompasses the entire river channel width at the barge landing location and extends the zone of injury for one day's pile driving activity the same distance up and down river from the barge landing location.

The estimated cumulative distance along the length of the river channel that exceeds the 187-dB SEL threshold is 3,848 feet. The distance to the 150-dB RMS threshold for behavioral effects is nearly 10,000 feet. Therefore, discernable impacts (behavioral modification) of the pile driving of barge landing pilings will extend nearly two miles upstream and downstream of the barge landing site if the channel were a straight linear alignment. The actual geometry of the site indicates that behavioral effects will extend upstream to the Clarksburg Bend and downstream to the location of Intake 3, a distance of nearly four river miles before river channel bends block the acoustic path of pile-driving noise.

The expected duration of pile driving is two days for completely inserting 107 piles. This amounts to approximately 6.5 percent of the days in each month (July through August). Twelve percent of the Sacramento River basin adult population will be exposed in August. The majority of the adult run occurring in September and October will be protected from impacts due to the work window.

Thus, depending on the month in which pile driving occurs, between 0.12 and 0.8 percent of the adult population of CCV steelhead will be exposed to pile driving during piling installation for barge landings at the Intake 2 site.

The risk of exposure to emigrating juvenile steelhead is considered to be negligible as no juvenile steelhead are captured in July and August in the Sacramento trawl at Sherwood Harbor, and few steelhead are recovered at the SWP and CVP fish salvage facilities during this same period.

Intermediate Forebay (Snodgrass Slough) Location

This location has a very low probability of exposure of CCV steelhead to acoustic energy generated by pile driving during construction of a barge landing.

The IF barge landing location is approximately 2.8 miles upstream of the DCC on Snodgrass Slough and is located on a non-migratory dead-end channel. Although the channel is open to waters that may contain CCV steelhead (DCC and Mokelumne River system), it is unlikely that many fish would move up into the dead-end slough. This is particularly true for adults moving upriver to spawning grounds.

Based on the description provided, four pile drivers will be operating concurrently at this location for two consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site.

The calculated distance to the 206-dB SPL threshold that causes injury per a single strike is 46 feet, or 17.3 percent of the 265-foot-wide channel at this location. The distance to the 187-dB SEL cumulative injury threshold for one day’s pile driving activity is calculated as 1,774 feet. This completely encompasses the entire river channel width at the Snodgrass Slough barge landing location and extends the zone of injury for one day’s pile driving activity the same distance up and down river from the barge landing location.

The estimated cumulative distance along the length of the river channel that exceeds the 187-dB SEL threshold is 3,848 feet. The actual geometry of the Snodgrass Slough channel at this location will allow the 187-dB SEL threshold to extend halfway to the mid-channel island to the south where the channel bends and divides into multiple channels.

The distance to the 150-dB RMS threshold for behavioral effects is nearly 10,000 feet. Therefore, discernable impacts (behavioral modification) of the pile driving of the barge landing pilings will extend nearly two miles upstream and downstream of the barge landing site if the channel were a straight linear alignment. The actual geometry of the site indicates that behavioral effects will extend downstream to the first channel bifurcation and bend associated with a mid-channel island (approximately 3,800 feet away).

The expected duration of pile driving is two days to completely insert 107 piles. This amounts to approximately 6.5 percent of the days in each month (July through August). The percentage of exposed Sacramento River basin CCV steelhead adult population per month, assuming equal distribution over each month is shown in the table below.

Table 2-32. Percentage of Exposed Sacramento River Basin California Central Valley Steelhead Adult Population Per Month.

Month	Percentage Annual Passage	Percentage Exposed
July	1.8	0.12
August	12.1	0.78

Thus, depending on the month in which the pile driving occurs, between 0.12 and 0.78 percent of the adult population of CCV steelhead will be moving through the Delta waterways on those two particular days. A smaller fraction of this will have the potential to be exposed to pile driving during installation of pilings for the barge landings at the Snodgrass Slough Intermediate Forebay site.

The risk of exposure to emigrating juvenile steelhead is considered to be negligible as no juvenile steelhead are captured in July and August in the Sacramento trawl at Sherwood Harbor, and few steelhead are recoverd at the SWP and CVP fish salvage facilities during this same period.

Bouldin Island (Potato Slough) Location

This location has a high likelihood of exposure for adult CCV steelhead from both the Sacramento and San Joaquin River basins. The Bouldin Island location is on Potato Slough, just off of the main stem San Joaquin River and just upstream of the mouth of the Mokelumne River and Georgiana Slough junctions. Adult steelhead from both basin populations are present in these waters during their upstream migrations. The landing dock location is situated on the apex of a 90-degree bend in the Slough. Based on the description provided, four pile drivers will be operating concurrently at this location for 2 consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site. The calculated distance to the 206 dB SPL threshold that causes injury per a single strike is 46 feet, or ~5 percent of the channel width of 980 feet. The distance to the 187 dB SEL cumulative injury threshold for one day’s pile driving activity is calculated as 1,774 feet. This completely encompasses the entire river channel width at the barge landing location and extends the zone of injury for one day’s pile driving activity the same distance up and down the slough from the barge landing location until the sound waves encounter several bends and mid-channel islands in the slough which will attenuate the distance the sound will travel. The estimated cumulative distance along the length of the slough channel that exceeds the 187 dB SEL threshold is 3,848 feet. The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 10,000 feet. Therefore, discernable impacts (behavioral modification) from the pile driving of the barge landing pilings will extend upstream and downstream of the barge landing site within the channel until the alignment of the slough is altered by mid-channel islands and bends in the channel approximately 4,000 feet to the southwest and 3,700 feet to the southeast.

The expected duration of the pile driving is 2 days for the completion of inserting 107 piles. This amounts to approximately 6.5 percent of the days in each month (July 1 through August 31). The percentage of exposed Sacramento River basin CCV steelhead adult population per month, assuming equal distribution over each month is shown in Table 2-32.

The percentage of adult San Joaquin River origin CCV steelhead present at this location is expected to be considerably lower during the July 1 through August 31 period as the peak of migration does not occur until the November through January time frame. Thus, depending on the month in which the pile driving occurs, between 0.12 percent and 0.78 percent of the adult population of Sacramento River basin CCV steelhead will be migrating through the Delta waterways on those particular days. A smaller fraction than this will have the potential to be exposed to pile driving during the installation of pilings for the barge landings at the Bouldin Island site, with a lower percentage of the San Joaquin River population exposed due to the expected later run timing.

The risk of exposure to emigrating juvenile steelhead is considered to be negligible as no juvenile steelhead are captured in July and August in the Sacramento trawl at Sherwood Harbor, and few steelhead are recovered at the SWP and CVP fish salvage facilities during this same period.

Venice Island (Venice Reach) Location

This location has a high likelihood of exposure for adult CCV steelhead from both the Sacramento and San Joaquin River basins. The Venice Island location is on the northern outside bend of the natural river channel of the San Joaquin River, just off of the dredged shipping channel (Mandeville Cut) and just upstream of Prisoners Point and the mouth of Potato Slough. The landing dock location is situated near the apex of a 180-degree reversal in the channel. Based on the description provided, four pile drivers will be operating concurrently at this location for 2 consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site. The calculated distance to the 206 dB SPL threshold that causes injury per a single strike is 46 feet, or ~4.5 percent of the channel width of 1,030 feet. The distance to the 187 dB SEL cumulative injury threshold for one day's pile driving activity is calculated as 1,774 feet. This completely encompasses the entire river channel width at the barge landing location and extends the zone of injury for one day's pile driving activity the same distance up and down the river channel from the barge landing location. The estimated cumulative distance along the length of the river channel that exceeds the 187 dB SEL threshold is 3,848 feet. The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 10,000 feet. Therefore, discernable impacts (behavioral modification) from the pile driving of the barge landing pilings will extend upstream and downstream of the barge landing site within the channel until the alignment of the channel is altered by mid-channel islands or the banks of the river channel caused by the sinuous bends in the channel approximately 6,000 to the southwest and 2,500 feet to the east.

The expected duration of the pile driving is 2 days for the completion of inserting 107 piles. This amounts to approximately 6.5 percent of the days in each month (July 1 through August 31). The percentage of exposed Sacramento River basin CCV steelhead adult population per month, assuming equal distribution over each month is shown in Table 2-32.

The percentage of adult San Joaquin River origin CCV steelhead present at this location is expected to be considerably lower during the July 1 through August 31 period as the peak of migration does not occur until the November through January time frame. Thus, depending on the month in which the pile driving occurs, between 0.12 percent and 0.78 percent of the adult population of Sacramento River basin CCV steelhead will be moving through Delta waterways on those particular days. A smaller fraction than this will have the potential to be exposed to pile driving during the installation of pilings, with a lower percentage of the San Joaquin River population exposed due to the expected later run timing.

The risk of exposure to emigrating juvenile steelhead is considered to be negligible as no juvenile steelhead are captured in July and August in the Sacramento trawl at Sherwood Harbor, and few steelhead are recovered at the SWP and CVP fish salvage facilities during this same period.

Mandeville Island (Middle River) Location

This location has a low likelihood of exposure for adult CCV steelhead from the Sacramento River basins. The Mandeville Island location is on the eastern shore of Mandeville Island near the junction of Middle River and Three-river Reach. The landing dock location is situated near the sharp bend in the channel to the north and a fairly straight channel to the northeast (Three-river Reach). Based on the description provided, four pile drivers will be operating concurrently at this location for 2 consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site. The calculated distance to the 206 dB SPL threshold that causes injury per a single strike is 46 feet, or ~6 percent of the channel width of 760 feet. The distance to the 187 dB SEL cumulative injury threshold for one day's pile driving activity is calculated as 1,774 feet. This completely encompasses the entire river channel width at the barge landing location and extends the zone of injury for one day's pile driving activity the same distance up and down the relic San Joaquin River channel to the north (relic San Joaquin River channel) and to the northeast (Three-river channel) from the barge landing location. The estimated cumulative distance along the length of the river channel that exceeds the 187 dB SEL threshold is 3,848 feet. The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 10,000 feet. Therefore, discernable impacts (behavioral modification) from the pile driving of the barge landing pilings will extend upstream and downstream of the barge landing site within the relic San Joaquin River channel until the alignment of the channel is altered by mid-channel islands or the banks of the river channel where it intercepts the Stockton Deep Water Ship Channel (DWSC). The straight-line distance to the Stockton DWSC is less than the estimated distance to the 150-dB threshold, approximately 6,500 feet to the north and 7,000 feet to the northeast.

The expected duration of the pile driving is 2 days for the completion of inserting 107 piles. This amounts to approximately 6.5 percent of the days in each month (July 1 through August 31). The percentage of exposed Sacramento River basin CCV steelhead adult population per month, assuming equal distribution over each month is shown in Table 2-32.

Because of the location of the Mandeville Island barge landing, however, the likelihood of adult Sacramento River basin steelhead being present is diminished. The actual risk is expected to be less than the theoretical percentage.

The percentage of adult San Joaquin River origin CCV steelhead present at this location is expected to be considerably lower during the July 1 through August 31 period compared to the

Sacramento River basin as the peak of migration does not occur until the November through January time frame. Thus, depending on the month in which the pile driving occurs, a maximum of between 0.12 percent and 0.78 percent of the adult population of Sacramento River basin CCV steelhead will be moving through the Delta waterways on these particular days. A smaller fraction of the San Joaquin River population will have the potential to be exposed to pile driving during the installation of pilings, due to the expected later run timing.

The risk of exposure to emigrating juvenile steelhead is considered to be negligible as no juvenile steelhead are captured in July and August in the Sacramento trawl at Sherwood Harbor, and few steelhead are recovered at the SWP and CVP fish salvage facilities during this same period.

Bacon Island (Connection Slough) Location

This location has a low likelihood of exposure for adult CCV steelhead from the Sacramento River basins compared to the previously discussed barge landing locations as it lies between the Old and Middle river corridors in the south Delta, 2.5 miles south of the San Joaquin River main stem. The Bacon Island location is on the northern shore of Bacon Island, adjacent to Connection Slough, which runs between Old River to the west, and Middle River to the east. The landing dock location is situated on the southern channel around an instream island located in Connection Slough. Connection Slough is a fairly straight channel that runs in an east-west alignment. Based on the description provided, four pile drivers will be operating concurrently at this location for 2 consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site. The calculated distance to the 206 dB SPL threshold that causes injury per a single strike is 46 feet, or ~13.5 percent of the channel width of 340 feet. The distance to the 187 dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 1,774 feet. This completely encompasses the entire southern channel width at the barge landing location and extends the zone of injury for one day's pile driving activity the same distance to the west along the southern channel and approximately 1,200 feet to the northeast until the straight-line path intercepts another in-channel island that will block any further sound transmission. In addition, the southerly channel rejoins the northern channel of Connection Slough at an approximately 45-degree junction and the joined channels continue to the east of the barge landing location. The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 10,000 feet. However, discernable impacts (behavioral modification) from the pile driving of the barge landing pilings will extend only 3,800 feet to the west before the straight-line path is intercepted by an in-channel island to the west. The easterly path is only 1,200-feet-long before the straight-line path is blocked by the in-channel island previously described. The northern channel of Connection Slough is not apparently affected by the pile driving actions as the in-channel island will block the straight-line transmission of the pile driving generated sounds, leaving this channel unobstructed for the movement of steelhead.

Victoria Island (Old River) Location

This location has a low likelihood of exposure for adult CCV steelhead from the Sacramento River basins compared to previously discussed barge landing locations as it lies on the Old river corridors in the south Delta, 12.5 miles south of the San Joaquin River main stem. The Victoria Island location is on the northwestern shore of Victoria Island, adjacent to Old River to the west and the Woodward/ North Victoria Canal to the north, which runs between Old River to the west, and Middle River to the east. The landing dock location is situated on the east bank of Old River which runs in a general north–south alignment at this location. Based on the description provided, four pile drivers will be operating concurrently at this location for 2 consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site. The calculated distance to the 206 dB SPL threshold that causes injury per a single strike is 46 feet, or ~10.6 percent of the channel width of 433 feet. The distance to the 187 dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 1,774 feet. This completely encompasses the width of Old River at this location and extends the zone of injury for one day's pile driving activity the same distance to the northwest and to the southwest along the channel alignment. The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 10,000 feet. However, discernable impacts (behavioral modification) from the pile driving of the barge landing pilings will extend only 3,300 feet to the northwest before the straight-line path is intercepted by the bank of Old River as the river channel bends back to the northeast. The southwesterly path is approximately 4,000-feet-long before the straight-line path is blocked by the bank of Old River as the channel alignment swings back to the southeast.

The expected duration of the pile driving is 2 days for the completion of inserting 107 piles. This amounts to approximately 6.5 percent of the days in each month (July 1 through August 31). The percentage of exposed Sacramento River basin CCV steelhead adult population per month, assuming equal distribution over each month is shown in Table 2-32.

Because of the location of the Victoria Island barge landing, however, the likelihood of adult Sacramento River basin steelhead being present is greatly diminished. The actual risk is expected to be substantially less than the theoretical percentage.

The percentage of adult San Joaquin River origin CCV steelhead present at this location is expected to be considerably lower during the July 1 through August 31 period compared to the Sacramento River basin as the peak of migration does not occur until the November through January time frame. Thus, even though the timing of the proposed pile driving overlaps with some of the Sacramento River basin adult upstream migration for CCV steelhead, few if any are expected to be in the waters adjacent to the Victoria Island barge landing location. Likewise, few if any San Joaquin River basin adult steelhead are expected to be in the waters adjacent to this location as the upstream migration period is still several months away.

The risk of exposure to emigrating juvenile steelhead is considered to be negligible as juvenile steelhead are rarely recovered in July and August at the SWP and CVP fish salvage facilities during this same period.

Clifton Court Forebay (Old River) Location

This location has a lowest likelihood of exposure for adult CCV steelhead from the Sacramento River basins as compared to the previously discussed barge landing locations as it lies on the Old river corridors in the south Delta, 17 miles south of the San Joaquin River main stem. The CCF location is on the northeastern corner of Clifton Court Tract, adjacent to Old River to the east (technically it is West Canal, which is the manufactured channel that was dredged from this point southwards to the CCF intake channel to improve flow efficiencies and increase volumes of water conveyed southwards), Italian Slough to the north, and the Victoria Canal to the northeast, which runs between Old River to the west, and Middle River to the east. The landing dock location is situated on the western bank of Old River (West Canal) which runs in a general north–south alignment at this location. Based on the description provided, four pile drivers will be operating concurrently at this location for 2 consecutive days. Each pile driver is anticipated to drive 15 pilings per day, for a cumulative total of 60 piles per day at the barge landing site. The calculated distance to the 206 dB SPL threshold that causes injury per a single strike is 46 feet, or ~16 percent of the channel width of 285 feet. The distance to the 187 dB SEL cumulative injury threshold for one day's piling driving activity is calculated as 1,774 feet. This completely encompasses the width of Old River (West Canal) at this location and extends the zone of injury for one day's pile driving activity the same distance to the northwest and to the southwest along the channel alignment. The calculated distance to the 150 dB RMS threshold for behavioral effects is nearly 10,000 feet. However, discernable impacts (behavioral modification) from the pile driving of the barge landing pilings will extend only 5,500 feet to the northwest before the straight-line path is intercepted by the bank of Old River as the river channel bends back towards the west and then back towards the northeast. The southeasterly path is approximately 1,800-feet-long before the straight-line path is blocked by the bank of Old River as the channel alignment swings back to the south.

Due to the location of the CCF barge landing, the likelihood of adult Sacramento River basin steelhead being present is negligible during the proposed work window of July 1 through August 31. The percentage of adult San Joaquin River origin CCV steelhead present at this location is expected to be also low during the July 1 through August 31 period compared to the Sacramento River basin as the peak of migration does not occur until the November through January time frame. Thus, even though the timing of the proposed pile driving overlaps with some of the Sacramento River basin adult upstream migration for CCV steelhead, few if any are expected to be in the waters adjacent to the CCF barge landing location. Likewise, few if any San Joaquin River basin adult steelhead are expected to be in the waters adjacent to this location as the upstream migration period is still a month or more away.

The risk of exposure to emigrating juvenile steelhead is considered to be negligible as juvenile steelhead are rarely recovered in July and August at the SWP and CVP fish salvage facilities during this same period.

In summary, the risk of exposure of adult steelhead to the effects of pile driving at the multiple barge landing locations is substantially reduced by the very short duration of actual pile driving and the action occurring in July and August when few adult steelhead are present in Delta waters. The description of the pile driving actions described under the PA indicated that actual pile driving at each site will typically be completed in two days with four pile drivers operating concurrently at that site. Although the proposed in-water work window covers two months, actual pile driving for this portion of the proposed PA construction actions will last a fraction of that period. The percentages of adult steelhead passing through the Delta waterways for that short period will be substantially less than the potential 14 percent of the population that would migrate through during the in-water work window. Furthermore, exposure to the elevated sound levels generated by the pile driving actions will be moderated by the geometry of the various channels on which the landing sites are located. Channel bends and in-channel islands will markedly reduce the distances that the sounds can travel, providing increased attenuation and shielding of adjacent waterways. Although the reduced duration of pile driving and the effects of the channel geometry will considerably reduce the exposure of the adult steelhead population to the effects of the pile driving produced noise, a very small proportion of steelhead are expected to be within the sound field generated by the pile driving, and will be adversely affected by the noise. The effects are expected to range from behavioral modifications and increased stress responses, to injury and mortality dependent on the proximity and duration of the exposure.

2.5.1.1.1.1.4.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.4 Environmental Baseline. As discussed in those sections, juvenile and sub-adult sDPS green sturgeon may be present during any month of the year throughout the waters of the Delta, whereas adult green sturgeon are less widespread, primarily occurring in the waters of the north Delta along the principal migratory pathway between the ocean and upstream spawning habitats in the Sacramento River from late winter and early spring months into the late summer and early fall months each year. As the locations for the proposed barge landings are spread widely across the Delta, the potential for exposure of juvenile, sub-adult, and adult sDPS green sturgeon to the pile-driving-induced acoustic effects associated with their construction is tempered only by the July 1 through August 31 in-water construction period established for that effort. NMFS therefore expects that the acoustics effects of pile driving at the barge landing locations will adversely affect a small proportion of juvenile, sub-adult, and adult green sturgeon.

2.5.1.1.1.2 Barge Traffic

According to the PA description in the BA, contractors are expected to use barges to deliver tunnel boring machine (TBM) components to TBM launch sites. Barges may also be used to transport other heavy or bulky equipment or materials to or from those sites. Barge landings will therefore be constructed at each TBM launch shaft site for loading and unloading construction equipment, materials, fill, and tunnel spoils. A total of seven barge landings are currently proposed in the PA (BA Appendix 3.A Map Book for the Proposed Action) at the following locations:

- Adjacent to Proposed Intermediate Forebay (on Snodgrass Slough north of Twin Cities Road)
- South Bouldin Island (on Little Potato Slough)
- South Venice Island (on San Joaquin River)
- East Mandeville Island (on San Joaquin River at junction with Middle River)
- North Bacon Island (on Middle River)
- Northwest Victoria Island (on Old River)
- Clifton Court Forebay (Old River at junction with West Canal)

In addition to the seven barge landing locations described above, Reclamation and its partners have indicated that an additional barge landing location was identified by the applicant during consultation and may be built at the contractor's discretion on the Sacramento River at NDD Intake 2.

Based on information provided by the applicant, the two main destinations are the barge landings at CCF and Bouldin Island.

Barge operations associated with these landings are described as follows:

- From June 1 through October 31, barge traffic may travel from all three origins (Stockton, San Francisco, and Antioch).
- From November 1 through February 28, barge traffic will be limited to travel from Port of Stockton to Bouldin Island.
- From March 1 through May 31, barge traffic will be restricted to move only critical heavy construction equipment in the San Joaquin River.
- Barges will be commercial vessels propelled by tugboats. Barge sizes have not been finalized, but are expected to be approximately 200- to 250-feet-long and 50-feet-wide with a draft of 6 to 12 feet. Commercial barge operators on the Sacramento River are required to operate in compliance with navigational guidelines.
- Barges will be required to use existing landings where possible and maintain a minimum waterway width greater than 100 feet (assuming maximum barge width of 50 feet).
- Barge operations will occur only during the work week and will not occur on weekends.
- Barges and tugs will travel at 5 knots loaded and 8 knots empty through Delta waterways and San Francisco Bay estuary.
- Each landing will be in use during the entire construction period at each location (5 to 6 years). All landings will be removed at the end of the PA construction period.
- Barges are expected to be used for delivery of TBM components and may also be used for transport of precast tunnel segment liner sections, reusable tunnel material (RTM), crushed rock and aggregate, etc.; pile-driving rigs and barge-mounted cranes; suction dredging equipment; post-construction underwater debris removal; and other activities.
- According to information provided in the PA, approximately 5,530 barge trips are projected to carry tunnel segment liners from ports in San Francisco, Antioch, and Stockton to two primary landings of CCF and Bouldin Island via the Sacramento and San Joaquin rivers and adjacent waterways. This averages to approximately four one-way trips per day for up to 5.5 years to each of the two landing locations during the June 1 to October 31 work window, with an equal distribution from the ports of origin (i.e., one third of the trips originate, respectively, from the Port of Stockton, Port of Antioch, and San Francisco). During the November 1 to February 28 period, up to four trips per day will be made from the Port of Stockton to Bouldin Island landing. From March 1 to May 31, only those trips deemed absolutely necessary to transport critical materials to Bouldin Island will be made from the Port of Stockton. During the period from November 1 to May 31, no trips will originate from the ports in San Francisco or Antioch. The assumed number of trips to CCF is 729 (one-way) and to Bouldin Island is 1115 (one-way). This information is shown in Table 2-33.
- Because barges may also be used for transport of bulk materials to the other landings as described above, a total of 9,400 one-way barge trips are projected as a conservative assumption (i.e., a greater number of trips is not expected to occur) for transport of all materials required by the PA. Number of trips and anticipated extent of use for secondary locations are shown in Table 2-34.

- To protect aquatic habitat and listed fish species, the barge operations plan (AMM7) will require barges and towing vessels to comply with standard navigation and operating rules to avoid or minimize physical disturbances and water quality impacts in the navigable waterways of the Delta. Where avoidance is not possible, the plan will include provisions to minimize effects as described in the BA in Appendix 3.F General Avoidance and Minimization Measures, Section 3.F.2.7.4 Environmental Training and Section 3.F.2.7.5 Dock Approach and Departure Protocol.

Table 2-33. Barge Route and Operation Assumptions Provided by DWR for the Three Anticipated Barge Origin Locations and Two Primary Landing Locations.

Barge Origin	Barge Landing Location	Estimated One-Way Distance (miles)	Number of Trips for Route (Assume 1/3 of trips from each Origin)
San Francisco	Bouldin Island	75.0	1115
Stockton	Bouldin Island	18.5	1115
Kie-Con (Antioch)	Bouldin Island	14.2	1115
San Francisco	Clifton Court	93.6	729
Stockton	Clifton Court	37.1	729
Kie-Con (Antioch)	Clifton Court	32.8	729

Table 2-34. Barge Operation and Use Assumptions Provided by DWR for the Secondary Landing Locations.

Barge Landing Location	Number of One-Way Trips to Landing	Assumptions for Use
Intermediate Forebay	435	This site is near major highway so most if not all segment, fill, material, and equipment deliveries will be trucked in. Dock would be of limited use. One trip every five days.
Venice Island	500	No road access. This site may be used for 6 months of geotechnical investigations and 12 months' construction of potential emergency access shaft and safe haven; 100 barge trips total for equipment deliveries; 400 to build emergency access and safe havens.
Mandeville Island	400	No road access. This site may be used for 12 months of geotechnical investigations and 18 months' construction of potential emergency access shaft and safe haven; 300 trips to build emergency construction access and safe haven; 100 barge trips total for equipment deliveries.
Bacon Island	2150	Road access is available. Unloading facility will be used for months for geotech investigations, 12 months to build retrieval pad, 24 months to build retrieval shaft and safe havens; 1400 barge trips for construction of retrieval pad; 200 trips for equipment deliveries and TMB removal; 600 trips for emergency construction access and safe haven.
Victoria Island	375	Road access is available. Unloading facility will be used for 24 months to build retrieval shafts and safe havens; 300 trips for construction of emergency access and safe havens; 75 barge trips total for equipment deliveries.

NMFS used the above information provided by the applicant to develop assumptions related to barge traffic in determining effects to listed species.

Because water depth in the Old River corridor to CCF is limited to 10 feet (i.e., the controlling depth at mean lower low water), vessels should not have a deeper draft than 10 feet (with a clearance of 2 feet from the bottom). The assumed length of tug boats is 65 to 100 feet with a beam of approximately 35 feet and a draft of approximately 6 to 8 feet. NMFS assumes that propeller disc diameter is approximately 70 percent of the draft, thus propeller discs will be approximately 50 to 70 in. in diameter, which corresponds to the dimensions for typical tugs operating in the Delta and San Francisco Bay. Tugs in the San Francisco Bay and Delta typically use shrouded propellers (e.g., Kort nozzles) that direct the thrust of the propeller jet in a confined cone providing more maneuverability, but potentially a more confined and longer lasting jet of propeller wash.

Based on an assumed velocity of 5 to 8 knots, a barge trip from the San Francisco port to the furthest landing location at CCF and back (187 miles round trip) can take upwards of 24 hours. NMFS therefore assumes that there is potential for barge operations to occur throughout a 24-hour period each day of the work week.

Based on the information provided by the applicant NMFS assumes that approximately 5,530 one-way trips will originate from one of the three origin locations and terminate at one of the two main barge landing locations at Bouldin Island or CCF throughout the construction phase of the PA. The assumed number of one-way trips to CCF is 2,185 and to Bouldin Island is 3,344. It is assumed that there will be four trips to each of these barge landings per day and four returning trips back to the port of origin for a total of 16 trips per day combined for both sites during the June 1 through October 31 period. From November 1 through February 28, barge trips will only go between the Port of Stockton and Bouldin Island, with the expectation that there will be 4 round trips per day (8 one way trips total). From March 1 through May 31, trips will be less frequent and limited to those deemed absolutely necessary to move critical equipment and materials that cannot be moved by land. Based on the estimated barge traffic information provided by the applicant, this results in 1,672 days of barge travel to Bouldin Island and 1,093 days of barge travel to CCFB.

During the 5 to 6 years of constructing the tunneled conveyance and other facilities, it is projected that up to 9,400 barge trips may be added to the daily vessel traffic in the action area. This is estimated based on an anticipated additional 3,900 one-way trips to the secondary locations show in Table 2-34. These trips will occur during the June 1 through October 31 period spread over the time of constructing the tunneled conveyance and other facilities. Assuming that the 3,900 one-way trips and the required return trips (for a total of 7,800 one-way trips) are distributed over the five landing locations throughout a 5-year period, the increase in traffic to four of these landings results in approximately one trip per day per landing. Only Bacon Island will require four trips per day during the June 1 through October 31 time period to meet its projected total of 2,150 one-way trips in the 5-year construction period.

Vessels originating from San Francisco will have to transit the middle and north San Francisco Bay regions, San Pablo Bay, the Carquinez Strait, Suisun Bay, and then either follow the Sacramento or Stockton deep water ship channels (DWSC) to their terminal barge landing locations. Sites located adjacent to the NDD locations will have to follow the Sacramento River channel upstream of Rio Vista. Barge landing sites located at Snodgrass Slough, Venice Island, or Bouldin Island will require barges and tugs to move through the Stockton DWSC from Antioch to approximately Webb Point on the San Joaquin River (RM 22). Barges destined for Snodgrass Slough will have to navigate upriver through the Mokelumne River system (likely the North Fork of the Mokelumne River). Barges destined for Bouldin Island will enter Potato Slough from the San Joaquin River at RM 22. Barges destined for the Venice Island location will continue up the Stockton DWSC to Prisoners Point (RM 25) and then move into the Venice Reach. Barge traffic destined for either Mandeville Island or Bacon Island will move upriver in the Stockton DWSC to Middle River, then move southwards in Middle River to the barge landing locations. Barge traffic destined for either Victoria Island or the CCF locations will move through the Stockton DWSC to Old River, and then move southwards in Old River to those barge landing locations.

Vessels originating from the Port of Antioch will transit either the Sacramento DWSC or the Stockton DWSC. Routes are essentially the same as those barges originating from San Francisco, except that barge traffic destined for NDD locations may either go upstream in the Stockton DWSC and access the Sacramento DWSC via Threemile Slough (RM 15) or go back downstream and enter the Sacramento DWSC via Broad Slough.

Vessels originating from the Port of Stockton will use the Stockton DWSC to access the different barge landing sites at the previously mentioned navigation points.

2.5.1.1.1.2.1 Acoustic Effects of Barge and Tugboat Traffic

Barge and tugboat traffic will create additional sources of anthropogenic noise in the aquatic environment. This will be an acoustic-related stressor that can result in negative impacts to exposed aquatic organisms. Ships under power produce a substantial amount of mechanical- and flow-induced noise from power plant, propeller, and hull turbulence. Measurements of sound intensity from commercial shipping have shown sound levels up to approximately 180-dB (ref. 1 μPa) at the point source (1 meter from ship) (Kipple and Gabriele 2007). This level of noise will drop off by 40-dB at 100 yards away and approximately 53-dB lower at one quarter mile (Kipple and Gabriele 2007). The narrow confines of channels in the Delta region would indicate that the elevated noise levels generated by the passage of commercial vessels such as tugboats would extend essentially from bank to bank in the San Joaquin or Sacramento rivers, thus subjecting all fish within the confines of the channel to anthropogenic-produced noise conditions. The relatively rapid passage of the barge and tugboat past a given point will somewhat attenuate these effects by decreasing the duration of the elevated sound levels, but some temporary effects can be anticipated to occur, depending on the proximity of the exposed fish to the sound source.

The presence of underwater anthropogenic noise, such as that originating with shipping, may adversely affect a fish’s ability to detect predators, locate prey, or sense their surrounding acoustic environment (Slabbekoorn et al. 2010; Radford et al. 2014). Other species of fish have been shown to respond to recorded ambient shipping noise by either reacting more slowly to predators, thus increasing their susceptibility to predation (Simpson et al. 2015; Simpson et al. 2016), or becoming hyper-alert and reacting more quickly to a visual predator stimulus, causing them to cease feeding and hide (Voellmy et al. 2014b). Voellmy et al. (2014a) states that elevated sound levels could affect foraging behavior in three main ways:

- Noise could act as a stressor, decreasing feeding behavior directly through reduced appetite or indirectly through a reduction in activity and locomotion and alterations to the cognitive processes involved in food detection, classification, and decision making;
- Noise could act as a distracting stimulus, diverting an individual’s limited amount of attention from their primary task to the noise stimuli that have been added to the environment;
- Noise could mask crucial acoustic cues such as those made by both prey and predators.

Fish also may exhibit noise-induced avoidance behavior that causes them to move into less suitable habitat for foraging or to feed when the noise has abated. Voellmy et al. (2014a) surmised that sustained decreases in food consumption could have long-term energetic impacts that result in reductions in growth, survival, and breeding success. Moreover, compensatory feeding activities could increase predation risks by increasing time exposed to predators or by forcing animals to feed in less favorable conditions, such as in times or areas of higher predation pressure.

In the PA, the increased noise produced by barge and tugboat traffic may result in salmonids and green sturgeon fleeing the area of those noises and moving into the channel’s shallowest margins or adjacent habitat. The channel margins of many Delta waterways have submerged and emergent vegetation (e.g., Egeria) and rock rip-rapped levees where predatory species are likely to occur in greater numbers than in the open waters of the channel. This scenario therefore could increase the predation risk of salmonids, particularly smolts. Likewise, elevated noise exposure can reduce the ability of fish to detect piscine predators either by reducing the sensitivity of the auditory response in the exposed fish or masking the noise of an approaching predator. Such would be the case if open water predators such as striped bass encounter the juvenile fish in the open channel while a barge and tug are present.

Within the context of the PA, the exposure to anthropogenically produced shipping noise will occur over a very broad area (San Francisco estuary and the Sacramento-San Joaquin Delta) and over an extended period of time (5.5 to 6 years). Barge traffic will traverse nearly a hundred miles of waterways from San Francisco to the Port of Stockton and the sites of the NDD construction sites and CCF barge landing. Exposure to anthropogenically produced sounds will occur during each passage of a tugboat and barge and has been estimated to be approximately 18,800 cumulative individual trips over the course of the 5.5 to 6 years of construction (see Table 2-16). The frequency of trips leading to either the CCF location in the south Delta or to Bouldin Island on the main stem San Joaquin River during the June 1 through October 31 period will be approximately 8 times a day to each primary barge landing site (four round trips per day per primary barge landing site), with less frequent trips to the other barge landing sites. This is estimated to be at least 16 individual trips through the lower San Joaquin River reach between Antioch and Stockton each work day for the entire construction period of 5.5 to 6 years during the June 1 to October 31 work season. During the work season from November 1 through February 28, only trips between the Port of Stockton and Bouldin Island will occur, with the same 4 round trips per day (8 one-way trips). From March 1 through May 31, the trips between the Port of Stockton and Bouldin Island are restricted to only essential trips. Barge traffic to other landings and from the ports of San Francisco and Antioch are prohibited during these two periods.

Noise associated with barge traffic may potentially affect multiple life stages of winter-run, spring-run, fall-run, and late fall-run Chinook salmon, steelhead, and green sturgeon. Both juveniles and adults of these species must pass through the Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary while migrating to and from the ocean. A number of potential migration routes, such as Yolo Bypass, depend on the size and duration of available flows.

Barge activity from Chipps Island to the Golden Gate will affect all migrating fish regardless of migration route. Effects related to the increased frequency and level of shipping noise related to the project are primarily expected to alter behavior in juvenile salmonids more so than adults because juveniles are more likely to be actively feeding and using the Delta and estuarine areas for rearing. Increased levels of shipping noise will influence their responses to foraging because elevated shipping noise can disrupt the effectiveness of foraging behavior by reducing the time spent actively feeding or increasing the effort required to successfully attack and consume prey items. The noise can affect predator avoidance by masking sounds of predator approach.

2.5.1.1.1.2.1.1 Winter-run Exposure and Risk

Detailed timing and spatial occurrence of winter-run Chinook salmon presence has previously been described in Section 2.5.1.1 Construction Effects. Juvenile winter-run Chinook salmon are present in the Delta from October through April, with peak occurrence from December through March. Adult winter-run Chinook salmon enter the San Francisco Bay in November with their migration through the Delta and up the Sacramento River continuing until June. The bulk of the run passes RBDD between January and May, with the peak in mid-March. Relevant to barge traffic associated with the PA, adult winter-run Chinook salmon may be found in the Delta from November through June.

The increased level of anthropogenic shipping noise associated with the PA is expected to have an effect on winter-run Chinook salmon. Both adult and smolting juvenile winter-run Chinook salmon will be exposed during their migrations through the Delta waterways. Exposure for winter-run Chinook salmon is minimized because all barge traffic is expected to use the Stockton DWSC between the Port of Stockton and Bouldin Island during the temporal overlap of barge traffic and winter-run migrations through the Delta from November 1 through May 31. These locations are outside of the typical migratory corridors of winter-run Chinook salmon with only a small overlap of potential migratory routes and barge traffic near the confluence of the Mokelumne River and the lower San Joaquin River near Bouldin Island. Winter-run juveniles could be present here if they move downstream through Georgiana Slough to the San Joaquin River during their outmigration. Likewise, adults moving upstream could use the San Joaquin River to access Georgiana Slough and move upstream into the Sacramento River channel. There is also the possibility that early migrating juvenile winter-run could enter the Delta in October due to precipitation events upriver on the Sacramento River and overlap in time and space with barge traffic on the Sacramento River going to the Intake 2 location on the Sacramento River in October. Those winter-run that are exposed are most likely to be rearing, feeding juveniles. They are expected to have reduced fitness due to disruptions in their feeding behavior and may be at a higher risk of predation due to masking of acoustic signals from predators and disruption of predator avoidance behavior in exposed fish. NMFS expects that the acoustics effects of barge traffic will adversely affect a small proportion of Sacramento River winter-run Chinook salmon.

2.5.1.1.1.2.1.2 Spring-run Exposure and Risk

The timing and spatial occurrence of spring-run Chinook salmon presence has been described in Section 2.5.1.1 Construction Effects.

Juvenile spring-run Chinook salmon may be present in the north Delta from November to June, with the majority (greater than 98 percent) of juveniles having outmigrated by the end of May. In some years, a few remaining fish may be migrating in early June, but the use of nearshore areas by juvenile salmon is generally reduced by June because most juveniles are large, actively migrating smolts that are known to move rapidly through the Delta and estuary during their seaward migration (Williams 2006). Adult spring-run Chinook salmon are present in the Delta from January to March as they begin to migrate upstream into the Sacramento River or San Joaquin River basin.

The increased level of anthropogenic shipping noise associated with the PA is expected to have an adverse effect on spring-run Chinook salmon exposed to the noise generated by the barge traffic. Some portion of both adult and juvenile spring-run Chinook salmon will be exposed to barge traffic for the approximately 5 to 6 years of activity. Both adult and smolting juvenile spring-run Chinook salmon will be exposed during their migrations through the Delta waterways. Exposure for spring-run Chinook salmon is minimized because all barge traffic is expected to use the Stockton DWSC between the Port of Stockton and Bouldin Island from November 1 through May 31, which is the period of greatest temporal overlap with spring-run migrations through the Delta. These locations are outside of the typical migratory corridors of spring-run Chinook salmon originating from the Sacramento River basin with only a small overlap between potential migratory routes and barge traffic near the confluence of the Mokelumne River and the lower San Joaquin River near Bouldin Island. Spring-run juveniles could be present here if they moved downstream through Georgiana Slough to the San Joaquin River during their outmigration from the Sacramento River basin. Likewise, adults moving upstream could use the San Joaquin River to access Georgiana Slough and move upstream into the Sacramento River channel. There is also the possibility that early migrating yearling spring-run could enter the Delta in October due to precipitation events in the upper watershed of the Sacramento River and overlap in time and space with barge traffic on the Sacramento River going to the Intake 2 location on the Sacramento River in October. For progeny of the experimental spring-run population currently being established in the San Joaquin River basin, there is complete temporal overlap with the adult and juvenile migrations from this basin. Barge traffic will occur year-round on the mainstem San Joaquin River between the Port of Stockton and Bouldin Island. Impacts are minimized to some degree by limiting barge traffic from March 1 to May 31 to only movements of essential equipment and materials, which substantially reduces the number of trips made along this route during the peak periods of spring-run migration into and out of the San Joaquin River basin. In addition, the Stockton DWSC is fairly wide on the order of several hundred feet near the Port of Stockton to nearly half a mile near the confluence with the Mokelumne River and has a dredged channel 40-feet-deep to accommodate large ocean going ships. This is much deeper than the draft of the tugboats and barges. This allows some separation between the alignment of the barge traffic and where fish may be located in the channel's cross-section.

The juvenile life stage of spring-run Chinook salmon is more likely to be adversely affected by barge traffic exposure due to reduced fitness from disruptions in their feeding behavior and may be at a higher risk of predation due to masking of acoustic signals from predators and the disruption of predator avoidance behavior in exposed fish. NMFS expects that the acoustics effects of barge traffic will adversely affect a small proportion of spring-run Chinook salmon.

2.5.1.1.1.2.1.3 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of juvenile and adult CCV steelhead presence has previously been described in Section 2.5.1.1 Construction Effects.

Juvenile CCV steelhead are typically present in the Delta from November through June, with peak occurrence from March through May at Chipps Island and 2 to 3 months earlier at the more upstream locations in the Delta. Adult CCV steelhead from the Sacramento River basin begin to migrate upriver from the Delta in June, with increasing numbers of fish arriving from August through September before tapering off in October and November. Peak migration (approximately 69 percent of the annual run) occurs in September and October. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January.

The increased level of anthropogenic shipping noise is expected to have an effect on CCV steelhead. Both adult and smolting juvenile steelhead from the Central Valley will be exposed considering the wide spatial and temporal overlap of the stressor with steelhead migrations. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by both juvenile and adult life stages of CCV steelhead from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, adult life stages of CCV steelhead overlap with projected routes of the barge traffic from San Francisco from June 1 through October 31. Steelhead smolts are generally absent from these areas of the estuary or present at very low levels during the June 1 through October 31 period when barge traffic is coming from San Francisco and Antioch. Barge traffic in the San Joaquin River and Stockton DWSC will overlap with all steelhead migrating into and out of the San Joaquin River basin, as barge traffic occurs year-round in this area of the Delta. During steelhead smolt migration from the Sacramento River basin, some fish will be exposed at the confluence of the Mokelumne River and the San Joaquin River due to migration movements through Georgiana Slough. Impacts are minimized to some degree by limiting barge traffic from March 1 through May 31 to only movements of essential equipment and materials, which substantially reduces the number of trips made along this route during the peak periods of steelhead smolt migration out of the San Joaquin River basin. In addition, the Stockton DWSC is fairly wide on the order of several hundred feet near the Port of Stockton to nearly half a mile near the confluence with the Mokelumne River and has a dredged channel 40-feet-deep to accommodate large ocean going ships. This is much deeper than the draft of the tugboats and barges. This allows some separation between the alignment of the barge traffic and where fish may be located in the channel's cross-section. Therefore, all juvenile and adult steelhead from the Central Valley will have some potential of exposure to the noise generated by barge traffic during their movements through the Delta and San Francisco Estuary regions.

A higher level of exposure is anticipated for steelhead originating in the San Joaquin River basin because most barge traffic will use the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF. Since steelhead will be present as both adult and juvenile life history forms in the Delta, including the post-spawning adult form known as a kelt, it is expected that both life history forms will be using the Delta as both a migratory corridor and for foraging. Exposed steelhead are expected to have reduced fitness due to disruptions in their feeding behavior and may be at a higher risk of predation due to masking of acoustic signals from predators and disruption of predator avoidance behavior in exposed fish.

NMFS expects that the acoustics effects of barge traffic will adversely affect a small proportion of CCV steelhead throughout the Delta.

2.5.1.1.1.2.1.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1.1.1.1.4 Green Sturgeon Exposure and Risk.

Duration of juvenile rearing in the estuary before ocean entry and transition to the sub-adult life stage is currently unknown. Juveniles captured in the Delta by Radtke (1966) ranged in size from 200 to 580 mm, suggesting that juveniles remain upriver for at least several months before entering the Delta. Recent studies of juvenile movement patterns in the Delta suggest that some individuals in the sDPS may enter the ocean and transition to the sub-adult life stage during their first year (Thomas and Klimley 2015), although the typical length of fish encountered in the ocean (greater than 600 mm) suggests that ocean entry typically occurs much later, probably at age 2 or 3. Length distributions of green sturgeon captured in the ocean may be biased high, however, because most of those records represent the incidental bycatch reported by commercial fisheries targeting relatively large fish species.

Adult sDPS green sturgeon enter San Francisco Bay between late January and early May, transiting the Delta and entering the Sacramento River from late winter through early summer to migrate to upstream spawning habitats. Post-spawn outmigration through the Delta typically occurs the following fall, although early outmigration has been observed in late spring and summer and may be related to elevated flows (Benson et al. 2007; Heublein et al. 2009).

When not in rivers for spawning, adults and sub-adults may enter the estuaries and bays along their coastal migration routes during early spring to summer months, presumably for feeding or seeking thermal refugia from cold upwells in the ocean during the summer months, returning to the ocean during the late summer and fall (Moser and Lindley 2007; Dumbauld et al. 2008; Lindley et al. 2011).

The lack of angler records of sub-adult-sized fish (roughly 60–100 cm) upstream of the Delta suggest sub-adults do not use freshwater riverine habitats. Recent studies in Oregon and Washington state estuaries, however, suggest that the majority of the sDPS sub-adult and adult population may occupy non-natal estuaries during summer months (NMFS 2015). Despite the uncertainty and variability associated with Delta residence time by life stage, spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year.

NMFS has determined that juvenile, adult, and sub-adult sDPS green sturgeon are expected to be exposed to an increased level of anthropogenic noise originating from the continuous operation of barges for the 5- to 6-year construction period because of the widespread and year-round presence of these life stages of sDPS green sturgeon in the waters of the Delta.

The increased level of anthropogenic shipping noise is expected to have an effect on juvenile, sub-adult, and adult sDPS green sturgeon. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by juvenile and sub-adult life stages of sDPS green sturgeon rearing in the Delta during every month of the year. Additionally, the annual spawning migrations of adult green sturgeon between the ocean and upstream spawning habitats overlap with projected routes of the barge traffic from the Golden Gate Bridge in San Francisco to Chipps Island only at the very beginning and end of the June 1 through October 31 seasonal period when barge traffic can originate from San Francisco ports. However, it is also expected that adult green sturgeon may be using the San Francisco Bay for rearing and foraging during this summer work period, and therefore be exposed to barge traffic while not engaged in spawning related behavior. Therefore, all juvenile, sub-adult, and spawning adult sDPS green sturgeon will have some level of exposure to the noise generated by barge traffic during their movements through the Delta and San Francisco Estuary.

A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon owing to their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats through the waters of the Delta where most of the barge traffic, using the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF, is expected to occur. Those sDPS green sturgeon exposed to the increased anthropogenic noise associated with barge traffic throughout the action area are expected to have reduced fitness due to disruptions in their feeding behavior and spawning migrations. NMFS expects that the acoustics effects of barge traffic will adversely affect a small proportion of sDPS green sturgeon throughout the Delta.

2.5.1.1.1.2.1.5 Fall/Late Fall-run Exposure and Risk

Detailed timing and spatial occurrence of fall and late fall-run Chinook salmon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving. Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, while adult fall-run Chinook salmon enter the San Francisco Bay in July and immigrate through the north Delta between July and December (Vogel and Marine 1991), with a peak in October.

The increased level of noise caused by the PA's barge traffic is expected to act as a stressor on fall-run Chinook salmon. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by both juvenile and adult life stages of fall-run Chinook salmon from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all adult life stages of fall-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco during the June 1 through October 31 seasonal period during the height of their upstream migration. Because the barges will be operating in locations that Central Valley fall-run Chinook salmon adults and juveniles must pass through, the probability that both the adult and juvenile life stages will be exposed to noise caused by the PA barge traffic for the 5- to 6-year construction period is high. Barge traffic occurs year-round on the San Joaquin River between the Port of Stockton and Bouldin Island, thus all San Joaquin River basin fall-run Chinook salmon will have some level of exposure. Fish from the Sacramento River basin will have less exposure. A large fraction of the adult population and a few juveniles will be exposed during the June 1 through October 31 seasonal period of barge operations in the Sacramento River channel. The remainder of the year, only those fish which migrate through the Georgiana Slough route to the San Joaquin River are expected to be exposed to the effects of barge traffic.

The life stage of exposed fall-run Chinook salmon more likely to be adversely affected are juveniles, as they are expected to have reduced fitness due to disruptions in their feeding behavior and may be at a higher risk of predation due to masking of acoustic signals from predators and disruption of predator avoidance behavior in exposed fish. The vast majority of the Central Valley fall-run Chinook salmon population originates in the Sacramento River basin. A small fraction of this basin's fall-run juvenile Chinook salmon population is expected to overlap with barge traffic in the Sacramento River emigration route between June 1 and October 31 because most juveniles emigrate through the Delta by June. The remaining small proportion of the population will emigrate through the Delta until August and may be exposed to barge traffic in the Sacramento River migration route. The majority of the Sacramento River basin's juvenile fall-run population will not be exposed to any barge traffic during the winter and spring outmigration, with only the fraction that outmigrates through Georgiana Slough to the San Joaquin being exposed to barge traffic. Juvenile fall-run from the San Joaquin River basin will emigrate through the Delta during barge traffic in winter and spring, but will experience substantially reduced barge traffic during their peak outmigration months of April and May. NMFS expects that the barge traffic noise will adversely affect a small proportion of fall-run Chinook salmon in the San Francisco Bay-Delta

Late Fall-run Chinook Salmon

Juvenile late fall-run Chinook salmon are present in the Delta from July through January, with a peak in December. Adult late fall-run Chinook salmon begin entering the San Francisco Bay in October and are present in the Delta through March (Vogel and Marine 1991).

The increased level of noise caused by the barge operations of the PA is expected to act as a stressor on late fall-run Chinook salmon. The exposure and risk for late fall-run Chinook salmon is different than that described for fall-run Chinook salmon originating from the Sacramento River. That is, juvenile late fall-run Chinook salmon have a higher likelihood of exposure to barge traffic noise than fall-run due to their earlier migratory period, but their peak of emigration through the system (December) occurs after the end of barge traffic on the Sacramento River (October 31). The early portion of adult upstream migration overlaps with the end of the June 1 through October 31 seasonal window for Delta wide barge traffic, which includes the Sacramento River corridor. Exposure to PA barge traffic noise in the San Francisco Bay-Delta mostly results in adverse effects to juvenile late fall-run Chinook salmon. These effects to juvenile late fall-run Chinook salmon are expected to reduce fitness due to disruptions in their feeding behavior and creating conditions that increase the predation risk of exposed fish due to masking of acoustic signals from predators and disruption of predator avoidance behavior. NMFS expects that the barge traffic noise will adversely affect a small proportion of late fall-run Chinook salmon in the action area.

2.5.1.1.2 Sediment Concentration and Turbidity Stress

The PA includes activities that are likely to increase suspended sediments and elevate turbidity above natural levels in the water column, which may affect listed fish. Re-suspension and deposition of instream sediments are an indirect effect of pre-construction, construction, and maintenance activities occurring in the river channel and on the river banks within the action area. Specific activities that will contribute to suspended sediments and elevated turbidity include pre-construction dredging; geotechnical borings; clearing and grubbing at construction sites; pile driving at intake sites, HOR, CCF, and at barge landings; and increased vessel traffic during construction.

Elevated turbidity and suspended sediment levels have the potential to adversely affect salmonids during all freshwater life stages by clogging or abrading gill surfaces, adhering to eggs, hampering fry emergence (Phillips and Campbell 1961), burying eggs or alevins, scouring and filling in pools and riffles, reducing primary productivity and photosynthesis activity (Cordone and Kelley 1961), and affecting intergravel permeability and dissolved oxygen levels (Zimmerman and Lapointe 2005; Lisle and Eads 1991).

Fish behavioral and physiological responses indicative of stress include: gill flaring, coughing, avoidance, and increased blood sugar levels (Berg and Northcote 1985; Servizi and Martens 1992). Excessive sedimentation over time can cause substrates to become embedded, which reduces successful salmonid spawning and egg and fry survival (Waters 1995).

Increased turbidity and suspended sediment levels associated with proposed action construction activities will occur downstream of primary spawning, egg incubation, and fry emergence areas and therefore are not expected to impact redds or incubating eggs.

Given the activity locations, increased turbidity and suspended sediment levels may negatively impact fish populations temporarily when deposition of fine sediments fills interstitial substrate spaces in food-producing riffles, reducing the abundance and availability of aquatic insects and cover for juvenile salmonids (Bjornn and Reiser 1991).

Suspended solids and turbidity generally do not acutely affect aquatic organisms unless they reach extremely high levels (i.e., levels of suspended solids reaching 25 mg/L). At these high levels, suspended solids can adversely affect the physiology and behavior of aquatic organisms and may suppress photosynthetic activity at the base of food webs, affecting aquatic organisms either directly or indirectly (Alabaster and Lloyd 1980, Lloyd 1987, Waters 1995).

Another impact to fish from suspended sediment is exposure to contaminant-laden sediments released into the water column. As contaminants remaining in buried sediments are re-suspended, introduction of compounds into the overlying water column result in exposure risks to passing aquatic organisms, including listed salmonids and green sturgeon. This is discussed further in Section 2.5.1.1.3 Contaminant Exposure.

Increased sediment concentrations can also affect fish by reducing feeding efficiency or success and stimulating behavioral changes. Sigler et al. (1984) found that turbidities between 25 and 50 NTUs reduced growth of juvenile coho salmon and steelhead, and Bisson and Bilby (1982) reported that juvenile coho salmon avoid turbidities exceeding 70 NTUs. Turbidity likely affects Chinook salmon in much the same way it affects juvenile steelhead and coho salmon because of similar physiological and life history requirements between the species. Newcombe and Jensen (1996) also found increases in turbidity could lead to reduced feeding rate (sublethal effects) and behavioral changes such as alarm reactions, displacement or abandonment of cover, and avoidance, which can lead to increased predation and reduced feeding. At high suspended sediment concentrations for prolonged periods, lethal effects can occur.

The proposed action includes implementation of a SWPPP and BMPs to control erosion and storm water sediment runoff as necessary to minimize erosion and sediment-laden runoff from construction areas (BA Appendix 3.F AMM4). Additionally, the Clean Water Act § 401 Water Quality Certification that will be issued by the U.S. Army Corps of Engineers for the proposed action will limit the potential effects of fine sediment on fish by limiting the maximum increase of turbidity in the water column over background levels.

NMFS (2008) reviewed observations of turbidity plumes during installation of riprap for bank protection projects along the Sacramento River and concluded that visible plumes are expected to be limited to only a portion of the channel width, extend no more than 1,000 feet downstream, and dissipate within hours of cessation of in-water activities. Based on these observations, NMFS concluded that turbidity levels produced by such activities could disrupt normal feeding and sheltering behavior of salmonids (NMFS 2008). Although turbidity increases during construction activities can typically result in short-term and localized impacts, some of the proposed activities are expected to last for the majority of daylight hours through all months of the year and will therefore more likely result in longer-term impacts. Once cofferdams have been constructed, isolating the work area, the potential for the proposed project activities to cause significant increases in downstream turbidity levels is low.

2.5.1.1.2.1 Pile Driving

2.5.1.1.2.1.1 North Delta Diversion Intake Locations

Pile-driving activities at the north Delta diversion intake locations are described in Section 2.5.1.1.1.1.1 North Delta Intake Locations.

2.5.1.1.2.1.1.1 Species Exposure and Risk

Pile driving at the NDD intake locations is expected to cause minimal turbidity-related impacts to juvenile salmonids because few juveniles will be present within the work window. For construction of the NDD, small numbers of juvenile winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, and steelhead are expected to occur at the locations during the margins of the June 15 through October 31 (impact pile driving ending September 15) in-water work window, which may cause those individuals to be exposed to increased turbidity caused by pile driving. In October about 2 percent of juvenile winter-run sized Chinook salmon are expected to be found in the vicinity of the NDD, while in June less than 2 percent of spring-run sized Chinook salmon and about 1-2 percent of juvenile steelhead could be migrating past the NDD intake location. Less than 1 percent of the annual juvenile fall-run Chinook salmon population would be found near the NDD site in June through October.

Adult winter-run Chinook salmon and adult spring-run Chinook salmon would not be expected to be found in the vicinity of the NDD during the in-water work window. Adult steelhead and green sturgeon may potentially be found within the Delta during any month of the year, and unlike winter- and spring-run Chinook salmon, steelhead and sturgeon can spawn more than once. Thus, post-spawn adults may potentially move back downstream through the Delta after completing spawning in their natal streams. Typically, adult steelhead moving into the Sacramento River basin begin to enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to November. Adult fall-run Chinook salmon are expected to pass the NDD intake locations between July and December, with the peak of the migration in October. Timing of adult fall-run Chinook salmon, steelhead, and green sturgeon presence in the Delta has the potential to expose fish destined for the Sacramento River basin to the effects of pile-driving-induced turbidity.

Therefore, NMFS expects that increased sediment concentrations from pile driving at the NDD intake location will adversely affect a small proportion of juvenile and adult winter-, spring-, and fall-run Chinook salmon; a small proportion of juvenile and adult steelhead; and a small proportion of juvenile and adult green sturgeon.

2.5.1.1.2.1.2 Clifton Court Forebay

Pile-driving activities at the Clifton Court Forebay are described in Section 2.5.1.1.1.1.2 Clifton Court Forebay, with in water-work window July 1 to October 31.

2.5.1.1.2.1.2.1 Species Exposure and Risk

Because continued operation of CCF includes potential entrainment of Chinook into CCF during construction activities, there is the potential for adverse effects of pile driving at the Clifton Court Forebay including turbidity-related impacts to juvenile winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, and steelhead, which may also disrupt the normal behavior or foraging success of exposed adult steelhead and green sturgeon. For CCF construction, the action agency has proposed a modified in-water work window of July 1 to October 31, which will limit the potential for exposure to pile-driving-induced turbidity. Winter- and spring-run Chinook salmon would not be present in the CCF during the in-water work window, while less than 1 percent of fall-run juvenile Chinook salmon would be expected to be present July through October.

Based on the timing of adult migrations, adult winter-run Chinook salmon, adult spring-run Chinook salmon, and adult late fall-run Chinook salmon would not be expected to be found in the CCF during the in-water work window.

Adult steelhead may potentially be found within the Delta during any month of the year, and, typically, adult steelhead moving into the Sacramento River basin will enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to November. Steelhead entering the San Joaquin River basin are believed to have a later spawning run, where adults enter the system starting in September through January, indicating presence in the Delta a few weeks earlier.

Timing of adult steelhead migration has the potential to expose fish destined for either the Sacramento River basin or the San Joaquin River basin to the turbidity-related impacts of pile driving. Green sturgeon are also thought to be present in the Delta at any time of the year, potentially exposing that species to pile-driving-induced turbidity. Turbidity impacts caused by pile driving operations are somewhat minimized by the relatively small area of effect relative to ambient turbidity.

NMFS expects that increased sediment concentrations from pile driving at CCF would not adversely affect juvenile steelhead, adult green sturgeon, and juvenile winter-run and spring-run Chinook salmon. Given the multiple years of pile driving activity and the documented presence at the CCF during the in-water work window, however, NMFS expects that increased sediment concentrations from pile driving at CCF will adversely affect a small proportion of juvenile fall-run Chinook salmon, juvenile green sturgeon, and adult steelhead.

2.5.1.1.2.1.3 HOR Gate

Pile driving activities at the Head of Old River gate are described in Section 2.5.1.1.1.1.3 HOR Gate.

2.5.1.1.2.1.3.1 Species Exposure and Risk

Pile driving at the Head of Old River gate is not expected to cause turbidity-related impacts to juvenile winter-run Chinook salmon, juvenile spring-run Chinook salmon, fall-run Chinook salmon, or juvenile steelhead, but may disrupt the normal behavior of exposed green sturgeon and those adult fall-run Chinook salmon and CCV steelhead coming from or going to the San Joaquin River.

For the HOR gate construction, the action agency has proposed a reduced in-water work window of August 1 to October 31, which will limit the potential for exposure to pile-driving-induced turbidity. Based on the timing of their migrations, adult and juvenile winter-run Chinook salmon and spring-run Chinook salmon, juvenile fall-run Chinook salmon and juvenile steelhead are not expected to be present during the in-water work window. Adult steelhead may potentially be found within the Delta during any month of the year, and, typically, adult steelhead moving into the Sacramento River basin will enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to November. Steelhead entering the San Joaquin River basin enter the system starting in September through January. Timing of adult steelhead migration has the potential to expose fish destined for the San Joaquin River basin to the physical impacts of pile driving. Green sturgeon are also thought to be present in the Delta at any time of the year, which potentially exposes that species to pile-driving-induced turbidity at the HOR gate as well.

Turbidity impacts caused by pile-driving operations are somewhat minimized by the relatively small area of effect. NMFS expects that increased sediment concentrations from pile driving at the HOR gate would not adversely affect winter-run Chinook salmon, spring-run Chinook salmon, and juvenile fall-run Chinook salmon and steelhead. Given the multiple years of pile driving activity and the documented presence at the HOR gate during the in-water work window, however, NMFS expects that the increased sediment concentrations from pile driving will adversely affect a small proportion of adult fall-run Chinook salmon, adult steelhead, and juvenile, sub-adult, and adult green sturgeon.

2.5.1.1.2.1.4 Barge Landing Locations

Pile driving activities at the barge landing locations are described in Section 2.5.1.1.1.1.4 Barge Landing Locations.

2.5.1.1.2.1.4.1 Species Exposure and Risk

There are seven barge landing locations throughout the Delta identified in the BA, and an additional barge landing location was identified by the applicant during consultation and may be built at the contractor's discretion on the Sacramento River at NDD Intake 2. For their construction, the action agency has proposed a reduced in-water work window of July 1 to August 31, which will limit the potential for exposure to pile-driving-induced turbidity.

Pile driving during construction of the barge landing locations is not expected to expose juvenile winter-run and spring-run Chinook salmon, and juvenile steelhead, as well as adult winter-run, spring-run and adult late fall-run Chinook salmon, to increased turbidity because the in-water work window falls outside the migration period. Displacement or disruption of normal behavior of exposed adult fall-run Chinook salmon, steelhead, and green sturgeon, as well as juvenile fall-run and late fall-run Chinook salmon and green sturgeon may occur.

Adult steelhead may potentially be found within the Delta during any month of the year. Typically, adult steelhead moving into the Sacramento River basin will start entering the Delta during mid to late summer, with the majority of fish entering the Sacramento River system from August through November. Steelhead entering the San Joaquin River basin enter the system starting in September and peaking in December and January. Timing of the adult fall-run Chinook salmon and steelhead, and juvenile fall-run and late fall-run Chinook salmon migrations has the potential to expose fish destined for either the Sacramento River basin or the San Joaquin River basin to the turbidity impacts of pile driving. Green sturgeon are potentially present in the Delta at any time of the year, potentially exposing that species to pile-driving-induced turbidity at the barge landing locations as well.

Turbidity impacts caused by pile-driving operations are somewhat minimized by the relatively small area of effect. NMFS expects that increased sediment concentrations from pile driving at the barge landing locations would not adversely affect adult or juvenile winter-run and spring-run Chinook salmon, adult late fall-run Chinook salmon, and juvenile steelhead. NMFS expects that increased sediment concentrations from pile driving will adversely affect a small proportion of adult fall-run Chinook salmon, adult steelhead, juvenile fall-run and late fall-run Chinook salmon, and juvenile, sub-adult, and adult green sturgeon, however, because of their documented presence at the barge landing locations during the in-water work window.

2.5.1.1.2.2 Barge Traffic

Barge operations, routes, and assumptions are described in Section 2.5.1.1.1.2 Barge Traffic.

Sediment Concentration and Turbidity Effects of Barge and Tugboat Traffic

Large vessel operation can cause sediment disturbance, potentially increasing localized turbidity levels and exposing latent contaminants through sediment resuspension. The passage of a ship hull through the water creates a series of complex hydraulic actions that are affected by hull shape, vessel speed, channel geometry, and hull displacement. The forward movement of the hull displaces water both forward and laterally, producing waves that spread both at an angle and perpendicular to the sailing line (Seelig 2002). These wakes encounter the shallow edges of the channel and disturb bottom sediment forcing it into the water column as resuspended sediment (Mazumder et al. 1993; Parchure et al. 2001).

Passage of large ships can create a “drawdown” of water level along the bank, followed by the sharp jump in the water level created by the following transverse wave front that typically creates a breaking wave along the shoreline. The effects of this are accentuated by increased ship speeds, shallow channel depths, shallow-water berms along the channel edge, and the proximity to the vessel’s sailing line. This effect is magnified in confined channels such as the Old River corridor. NMFS will assume that along the entire length of the tug and barge transit, the physical phenomena of hull displacement wakes will be present, and these wakes will interact with the channel bathymetry and shoreline, although the magnitude of these wakes and the turbulence they create along the shallow margins will vary with channel configuration.

Large and small vessels operated in confined channels with minimal under-keel clearance introduce additional disturbance opportunity as the propeller jet interacts with the bottom sediment (Mazumder et al. 1993; Beachler and Hill 2003). Studies have also indicated that propeller washes directed at confining structures like levee banks or dock structures or in tight quarters requiring extensive maneuvering accelerate erosion of the bottom substrate (Hamill et al. 1999). Large vessel traffic can resuspend and expose heavier grain sediments to fairly deep depths (greater than 23 m) within maritime ports and navigation channels while maneuvering (Lepland et al. 2010).

Within the context of the proposed action, the disturbance of sediments will occur over a very broad area (San Francisco estuary and the Sacramento-San Joaquin Delta) and over an extended period of time (5.5 to 6 years). Barge traffic will traverse nearly 100 miles of waterways from San Francisco to the Port of Stockton and the sites of the NDD construction sites and CCF barge landing. While most of the route will be in open water with fairly deep dredged channels (shipping channels), where the effects of the wakes will be attenuated by distance to the shoreline and depth of the water, the barge landing locations in the Delta will require maneuvering in confined, shallow waterways where the effects of the wakes and propeller jets will be more pronounced.

It is expected that the passage of barges and tugs coupled with the effects of propeller jet during normal operations and docking could resuspend thousands to hundreds of thousands of tons of sediment material each year. Resuspension of material will occur during each passage of a vessel and barge and has been estimated to be approximately 18,800 trips over the course of the 5.5 to 6 years of construction. The frequency of disturbance will be approximately eight times a day to each of the primary barge landing sites (four round trips per day per primary barge landing site), with less frequent trips to the other barge landing sites. During each trip, however, sediment that has been resuspended by the passage of one barge is likely to be resuspended again during the return trip of that same barge or by other barges bringing materials to that same landing. This essentially produces a constant influx of newly resuspended materials in the channels leading to the primary barge landing sites on a near daily basis when the barge schedule allows barge traffic to occur.

The increased sediment concentration associated with barge traffic has potential to affect multiple life stages of winter-run, spring-run, fall-run, and late fall-run Chinook salmon, steelhead, and green sturgeon. Both juveniles and adults of these species must pass through the Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary while migrating to and from the ocean. Barge activity from Chipps Island to the Golden Gate will affect all migrating fish regardless of their initial migration route during the period from June 1 through October 31, when delta-wide barge traffic is permitted by the barge traffic schedule. From November 1 through May 31, barge traffic is limited to the San Joaquin River between the Port of Stockton and Bouldin Island, greatly reducing the level of exposure to migrating fish, particularly within the Sacramento migratory corridor and the waters of the San Francisco Bay estuary. Effects related to the increased frequency of shipping activity related to the project are primarily expected to alter behavior in juvenile salmonids more so than adults because juveniles are more likely to be actively feeding and using the Delta and estuarine areas for rearing. Those exposed will be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress. Such responses include gill clogging, abrading, or flaring; location avoidance; interstitial filling of riffle substrate; and reduced feeding success.

2.5.1.1.2.2.1 Winter-run Exposure and Risk

Detailed timing and spatial occurrence of winter-run Chinook salmon presence has previously been described in Section 2.5.1.1 Construction Effects.

Juvenile winter-run Chinook salmon are present in the Delta from October through April, with peak occurrence from December through March. Adult winter-run Chinook salmon may be found in the Delta from November through June. All adult and juvenile winter-run Chinook salmon must pass through the Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary on their way to and from the ocean.

The potential for increased sediment concentration because of increased barge traffic will act as a stressor on winter-run Chinook salmon. Both adult and smolting juvenile winter-run Chinook salmon will be exposed considering that the upper reach of the Sacramento River below Keswick Dam is the single spawning location for winter-run Chinook salmon. Exposure for winter-run Chinook salmon is somewhat attenuated because most of the barge traffic is expected to use the Stockton DWSC and waterways associated with the lower San Joaquin River, rather than the Sacramento River, to reach the main landing locations at Bouldin Island and CCF. These locations are outside the typical migratory corridors of winter-run Chinook salmon. Exposure is further reduced by the restrictions on barge operations limiting barge traffic to the San Joaquin River between the Port of Stockton and Bouldin Island from November 1 through May 31. Additional reductions in the frequency of barge trips to only essential barge traffic between the Port of Stockton and Bouldin Island from March 1 through May 31 creates conditions that have lower exposure rates for fish in this migratory corridor to barge traffic. Due to the limitations on barge traffic routes in the operations schedule from November 1 through May 31, exposure of winter-run adults and juveniles should be eliminated from Chipps Island to the Golden Gate, as no barge traffic is permitted along this route during the period of time that winter-run are expected to be migrating through these waters. There is an overlap in the period of adult and juvenile winter-run migrations from November through May when exposure to barge traffic may occur in the lower reaches of the San Joaquin River near the confluence with the Mokelumne River. Both adult and juvenile winter-run Chinook salmon may be present here due to the accessibility to the Georgiana Slough migratory route which connects the San Joaquin River with the Sacramento River migratory corridor.

Exposed fish will be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress. Adverse effects resulting in injury or death are not expected to occur. However, because of reduced fitness and stress caused by the barge traffic-induced turbidity plumes in the migratory corridor and the long-term traffic activity, NMFS expects that the sediment concentration and turbidity effects of barge traffic will adversely affect a small proportion of Sacramento River winter-run Chinook salmon.

2.5.1.1.2.2.2 Spring-run Exposure and Risk

The timing and spatial occurrence of spring-run Chinook salmon presence has been described in Section 2.5.1.1 Construction Effects.

Juvenile spring-run Chinook salmon may be present in the north Delta from November to June, with the majority (greater than 98 percent) of juveniles having emigrated by the end of May. In some years, a few remaining fish may be migrating in early June, but the use of nearshore areas by juvenile salmon is generally reduced by June because most juveniles are large, actively migrating smolts that are known to move rapidly through the Delta and estuary during their seaward migration (Williams 2006). Adult spring-run Chinook salmon are present in the Delta from January to March, with a small number possibly migrating through the Delta in May and June, as they begin to migrate upstream into the Sacramento River or San Joaquin River basin.

The potential for increased sediment concentration due to increased barge traffic will act as a stressor on spring-run Chinook salmon. Some portion of both adult and juvenile spring-run Chinook salmon will be exposed to barge traffic for the approximately 6 years of activity. Although there are multiple barge landing locations in the north, central, and south Delta, most barge activity is expected to use the Stockton DWSC and waterways associated with the lower San Joaquin River, rather than the Sacramento River, to reach the main landing locations at Bouldin Island and CCF. Exposure is further reduced by the restrictions on barge operations limiting barge traffic to the San Joaquin River between the Port of Stockton and Bouldin Island from November 1 through May 31. Additional reductions in the frequency of barge trips to only essential barge traffic between the Port of Stockton and Bouldin Island from March 1 through May 31 creates conditions that have lower exposure rates for fish in this migratory corridor to barge traffic. Due to the limitations on barge traffic routes in the operations schedule from November 1 through May 31, exposure of spring-run adults and juveniles should be eliminated (except for an occasional adult migrating in May or June) from Chipps Island to the Golden Gate, as no barge traffic is permitted along this route during the period of time that spring-run are expected to be migrating through these waters. There is an overlap in the period of Sacramento River basin adult and juvenile spring-run migrations from November through May when exposure to barge traffic may occur in the lower reaches of the San Joaquin River near the confluence with the Mokelumne River. Both adult and juvenile spring-run Chinook salmon may be present here due to the accessibility to the Georgiana Slough migratory route which connects the San Joaquin River with the Sacramento River migratory corridor. Overall, the barge traffic schedule should decrease the likelihood of Sacramento basin origin spring-run Chinook exposure. Although there is some uncertainty regarding the current number of spring-run Chinook salmon in the San Joaquin basin each year, monitoring shows that they are present and will therefore be exposed to barge traffic in these areas as barge traffic will occur year-round in the lower San Joaquin River migratory route. Adverse effects are expected to be limited to reduced fitness because of stress related to turbidity plumes from barge traffic in the migratory corridors.

Exposed fish will be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress. Adverse effects resulting in injury or death are not expected to occur. However, adverse effects resulting in reduced fitness and stress are expected to be caused by the barge traffic-induced turbidity plumes in the migratory corridor. NMFS expects that the sediment concentration and turbidity effects of barge traffic will adversely affect a small proportion of spring-run Chinook salmon.

2.5.1.1.2.2.3 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of CCV steelhead presence has previously been described in Section 2.5.1.1 Construction Effects.

Juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Adult CCV steelhead from the Sacramento River basin begin to migrate upriver from the Delta in June, with increasing numbers of fish arriving from August through September, before tapering off in October and November. Peak migration (approximately 69 percent of the annual run) occurs in September and October. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January. All adult and juvenile CCV steelhead must pass through the Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary on their way to and from the ocean.

The potential for increased sediment concentration due to increased barge traffic will act as a stressor on steelhead. Both adult and smolting juvenile steelhead from the Central Valley will be exposed considering the wide spatial and temporal overlap of the stressor with steelhead migrations. Multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by both juvenile and adult life stages of CCV steelhead from both Sacramento and San Joaquin river basins. However, most barge landings are on waterways associated with migratory routes originating in the San Joaquin River basin. Therefore, exposure to Sacramento River basin fish is reduced based on the number of landings present in the northern Delta. Sacramento River basin juvenile steelhead exposure is further reduced by the restrictions on barge operations limiting barge traffic to the San Joaquin River between the Port of Stockton and Bouldin Island from November 1 through May 31. Additional reductions in the frequency of barge trips to only essential barge traffic between the Port of Stockton and Bouldin Island from March 1 through May 31 creates conditions that have lower exposure rates to barge traffic for fish in this migratory corridor. Due to the limitations on barge traffic routes in the operations schedule from November 1 through May 31, exposure of juvenile steelhead should be eliminated from Chipps Island to the Golden Gate, as no barge traffic is permitted along this route during the period of time that these fish are expected to be migrating through these waters.

Barge traffic occurs throughout the Delta from June 1 through October 31, which overlaps both spatially and temporally with migratory movements of adult steelhead from both main river basins in the Central Valley, but primarily those adults from the Sacramento River basin. Adult steelhead from the Sacramento River basin are exposed to barge traffic along the Sacramento River migratory route as well as those routes which use part of the lower San Joaquin River to access the estuary. In addition, the barge traffic routes will also use the waterways from Chipps Island to the Golden Gate during the majority of time that adult steelhead are migrating into the Delta and Sacramento River (July through October). During September and October, the first adult steelhead migrating into the San Joaquin River basin will have overlap with barge traffic along travel routes from San Francisco Bay to the Port of Stockton, and barge landings in the central and southern Delta.

After November 1, there is some overlap in the period of Sacramento River basin adult and juvenile steelhead migrations from November through May when exposure to barge traffic may occur in the lower reaches of the San Joaquin River near the confluence with the Mokelumne River. Both adult and juvenile steelhead from the Sacramento River basin may be present here during their periods of migration due to the accessibility to the Georgiana Slough migratory route which connects the San Joaquin River with the Sacramento River migratory corridor.

Both adult and juvenile steelhead from the San Joaquin River basin will have exposure to barge traffic in the lower San Joaquin River between the Port of Stockton and Bouldin Island during their periods of migratory movements in the Delta. Barge traffic within this section of the San Joaquin River migratory corridor will occur over the entire year, thus overlapping with both juvenile and adult migratory timing. Reductions in exposure to emigrating juvenile steelhead will occur from March 1 through May 31 due to the restrictions in barge traffic frequency. Barge traffic from the Port of Stockton to Bouldin Island during this time will be limited to only essential trips which transport materials or equipment deemed critical to the PA and which cannot be moved by land.

All juvenile and adult steelhead from the Central Valley will have some level of exposure to suspended sediments generated by barge traffic during their movements through the Delta and San Francisco Estuary regions. However, while exposure to suspended sediments is likely to occur,. adverse effects resulting in injury or death are not expected to occur. Those fish exposed will be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress. Exposed steelhead are expected to have reduced fitness because of stress related to turbidity plumes from the pulsed sediment plumes in the migratory corridors. Given these effects and the high certainty of long-term traffic activity, coinciding with steelhead migration periods, NMFS expects that the sediment concentration and turbidity effects of barge traffic will adversely affect a small proportion of CCV steelhead throughout the Delta.

2.5.1.1.2.2.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving. Spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year.

NMFS has determined that juvenile, adult, and sub-adult sDPS green sturgeon are expected to be exposed to elevated concentrations of suspended sediment and increased frequency of turbidity plumes originating from the operations of barges throughout the action area during the 5- to 6-year construction period owing to their widespread and year-round presence in the waters of the Delta.

The potential for increased suspended sediment concentrations and frequency of turbidity plumes in the Delta due to increased barge traffic is expected to have an effect on juvenile, sub-adult, and adult sDPS green sturgeon. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by juvenile and sub-adult life stages of sDPS green sturgeon rearing in the Delta during every month of the year. Additionally, the annual spawning migrations of adult green sturgeon between the ocean and upstream spawning habitats overlap with the projected routes of barge traffic anticipated between the Golden Gate and Chipps Island. Therefore, all juvenile, sub-adult, and spawning adult sDPS green sturgeon will have some level of exposure to the periodic increases of turbidity plumes and elevated concentrations of suspended sediment generated by barge traffic during their movements through the Delta and San Francisco Estuary.

A higher level of exposure is anticipated for juvenile and sub-adult life stages of green sturgeon compared to adults. Juveniles and sub-adults have an extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats.

The adverse effects to fish typically associated with elevated concentrations of suspended sediment in the water column has been generally described in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress. It is unclear, however, to what extent those sDPS green sturgeon that are exposed to the increased concentrations of suspended sediment and frequency of turbidity plumes associated with increased barge traffic throughout the action area will be affected. It is likely that higher concentrations of suspended sediment and frequency of turbidity plumes in the Delta will interfere with normal sturgeon feeding and migratory behavior. As these fish are benthically oriented and have evolutionarily adapted to turbid flowing waters, however, adverse effects associated with this particular stressor may not be as deleterious to sturgeon feeding and movement through the Delta as they are to salmonids in general.

NMFS expects that the elevated suspended sediment concentrations and frequency of turbidity plumes in the waters of the Delta associated with increased barge traffic will adversely affect a medium proportion of sDPS green sturgeon throughout the Delta, though adverse effects resulting in injury or death are not expected to occur.

2.5.1.1.2.2.5 Fall/Late Fall-run Exposure and Risk

Detailed timing and spatial occurrence of fall and late fall-run Chinook salmon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving. Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, while adult fall-run

Chinook salmon enter the San Francisco Bay in July and immigrate through the north Delta between July and December (Vogel and Marine 1991), with a peak in October.

The potential for increased sediment concentration due to increased barge traffic will act as a stressor on fall-run Chinook salmon. Multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by both juvenile and adult life stages of fall-run Chinook salmon from both Sacramento and San Joaquin river basins during their migratory periods. From Chipps Island to the Golden Gate, migrating juvenile and adult life stages of fall-run Chinook salmon from both the Sacramento and San Joaquin river basins will overlap with projected routes of the barge traffic from San Francisco during the June 1 through October 31 operations period. This overlap will be comprised predominately of adult fall-run Chinook salmon migrating upriver to spawning areas, while only a small proportion of the juvenile population will be emigrating downstream through the Delta and estuary during this period. Fish that migrate through the system from November 1 through May 31 will not be exposed to barge traffic in the waters from Chipps Islands to the Golden Gate, as barge traffic is restricted from these waters during this period of time. Fish that are moving through the Sacramento River migratory corridor during the June 1 through October 31 period will be exposed to barge traffic, while those fish that move through this route from November 1 through May 31 will not be exposed to barge traffic within the Sacramento River migratory corridor because of the restrictions in the barge operations. Some exposure to adults and juveniles from the Sacramento River basin may occur during the November 1 through May 31 period in relation to those fish that enter the Georgiana Slough route and continue downstream through the lower San Joaquin River as discussed for winter-run and spring-run Chinook salmon previously. These fish may come into contact with barge traffic at the confluence of the Mokelumne River and the lower San Joaquin River.

Fall-run Chinook salmon that migrate through the San Joaquin River system will be exposed to year-round barge traffic that will overlap with their migratory presence in the waters of the central and southern Delta. Reductions in the frequency of barge traffic from March 1 through May 31, as previously described, will reduce the exposure of fall-run Chinook salmon emigrating from the San Joaquin River basin during their peak migratory period (April and May).

Exposed fall-run Chinook salmon will be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress. Exposed juvenile fall-run Chinook salmon are expected to have reduced fitness because of stress related to turbidity plumes from the pulsed sediment plumes in the migratory corridors. Adverse effects resulting in injury or death are not expected to occur. NMFS expects that the sediment concentration and turbidity effects of barge traffic will adversely affect a small proportion of fall-run Chinook salmon in the San Francisco Bay-Delta.

Late Fall-run Chinook Salmon

Juvenile late fall-run Chinook salmon are present in the Delta from July through January with a peak in December. Adult late fall-run Chinook salmon enter the San Francisco Bay in October and may be present through March (Vogel and Marine 1991).

Exposure and risk for late fall-run Chinook salmon is the same as described for fall-run Chinook salmon originating from the Sacramento River. That is, from Chipps Island to the Golden Gate, juvenile and adult life stages of late fall-run Chinook salmon from the Sacramento River basins overlap with projected routes of the barge traffic from San Francisco during the June 1 through October 31 operations period. It is expected that there will be some overlap with juvenile late fall-run Chinook salmon from July through October, although the peak of emigration will occur after this. Adult fish will start to enter the Delta in October and will overlap with the -end of the barge traffic operations in the San Francisco estuary during this month. Fish that migrate through the system from November 1 through May 31 will not be exposed to barge traffic in the waters from Chipps Islands to the Golden Gate, as barge traffic is restricted from these waters during this period of time. Fish that are moving through the Sacramento River migratory corridor during the June 1 through October 31 period will be exposed to barge traffic, while those fish that move through this route from November 1 through May 31 will not be exposed to barge traffic within the Sacramento River migratory corridor because of the restrictions in the barge operations. Some exposure to adults and juveniles from the Sacramento River basin may occur during the November 1 through May 31 period in relation to those fish that enter the Georgiana Slough route and continue downstream through the lower San Joaquin River as discussed for winter-run and spring-run Chinook salmon previously. These fish may come into contact with barge traffic at the confluence of the Mokelumne River and the lower San Joaquin River.

Exposed late fall-run Chinook salmon will be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress. Exposed juvenile late fall-run Chinook salmon are expected to have reduced fitness because of stress related to turbidity from the pulsed sediment plumes in the migratory corridors. Adverse effects resulting in injury or death are not expected to occur. NMFS expects that the sediment concentration and turbidity effects of barge traffic will adversely affect a small proportion of late fall-run Chinook salmon in the action area.

2.5.1.1.2.3 Geotechnical Analysis

Geotechnical analysis will be required in order to adequately characterize ground conditions and evaluate site-specific soil characteristics to better define the strength, permeability, and compressibility of the supporting foundation soils surrounding the proposed tunnels and shafts along the alignment of the proposed conveyance facilities and their associated structures. A geologic model will then be developed that will appropriately identify and mitigate geologic risks and hazards associated with the construction and long-term operation of the PA. These analyses are expected to be completed at all locations that will be subject to pile driving, as identified in the PA. NMFS therefore assumes that geotechnical borings will be drilled at the NDD intake locations, CCF, the HOR gate locations, and all barge landing locations.

Activities associated with geotechnical analysis can cause bed disturbance, potentially resuspending bed materials and increasing suspended sediment concentrations and local turbidity levels. Approximately 90 to 100 overwater geotechnical borings and cone penetration tests (CPTs) are proposed to be drilled in the Delta waterways between 2017 and 2018. These include approximately 30 overwater geotechnical borings and CPTs in the Sacramento River to obtain geotechnical data for the proposed intake structures (between 6 and 10 borings and CPTs being conducted at each of the proposed Intake sites) located on the Sacramento River between Courtland and the Clarksburg area. The depths of borings and CPTs are planned to range between 100 and 200 feet below the mud line (i.e., river bottom).

The PA indicates that overwater drilling will only occur during the time period from August 1 through October 31 between the hours of sunrise and sunset. This period is the recognized window of opportunity to avoid or minimize disturbance for sensitive environmental resources. Duration of drilling at each location will vary depending on the number and depth of the holes at each location, drill rate, and weather conditions, but are not expected to exceed 60 days at any one location.

The drilling will be conducted with a rotary drilling rig mounted on a shallow-draft barge or ship. Multiple barges or ships may be operated concurrently. The barge or ship will be anchored into the bottom of the channel with two to four spuds to prevent the vessel from drifting while the work is being performed. The spuds are steel pipes mechanically lowered into the channel bottom. The barge or ship will be mobilized from an established marina and will be anchored either at the drill sites or at Coast Guard established anchorage points. Personnel will access the barge or ship via a support boat from an established marina. When a drill rig remains on a boring location for more than one day, the drill apparatus and casing will remain in the water column and drill hole to minimize sediment disturbance of the river bottom.

The drill apparatus consists of a 6- to 8-inch-diameter conductor casing that extends from the barge deck, through the water column, and into the soft sediments of the river bottom. The small diameter of the casing would not impede water flow or the migration patterns of fish. All drilling rods, samplers, and other down-hole equipment pass through the inside of the casing, which effectively separates them from the water.

There are no loose items or netting on the casing that would entrap or snag fish. The borings will be advanced using the mud rotary method and will be drilled and sampled to a maximum depth of approximately 200 feet below the bottom of the channel. In this case, the term “mud” refers to the use of bentonite clay added to the boring to allow removal of drill cuttings and to stabilize the boring. Initially, the boring will be advanced by pushing an approximate 6- to 8-inch-diameter conductor casing, which will extend from the top of the barge or drill ship deck, an approximate depth of 10 to 15 feet or more below the mud line of the river channel. The conductor casing will be used to confine the drill fluid and cuttings within the drill hole and operating deck of the barge or drill ship and prevent any inadvertent spillage into the water. Soil samples will be collected from within the conductor casing. The drill hole below the conductor casing will be approximately 3.5 to 5.5 in. in diameter.

Only water will be circulated through the pumps and conductor casing when drilling and sampling within 15 to 20 feet of the channel bottom. For deeper drilling, the drilling fluid, consisting of a mixture of circulating water and bentonite clay, will be introduced into the conductor casing via the drill string to create a more viscous drilling fluid. The drilling fluid will pass down the center of the drill rod to the cutting face in the formation being drilled and will return up the drilled hole with the suspended cuttings. The drilling fluids and cuttings will be confined by the borehole walls and the conductor casing. Return drill fluids will pass through the conductor casing to the barge or ship deck and then through a tee connection at the head of the conductor casing into the drilling fluid recirculation tank.

With the conductor casing in place, the drilling fluids will be kept in the closed system formed by the conductor casing and a tank at the top of the hole on the barge deck and a precautionary provision of a heavy plastic sleeve over the conductor casing, which drapes into an external mud tank. This system will provide a reliable seal and prevent significant spillage of the drilling fluid into the water. The drill rod and sample rod connections will be disconnected either directly over the conductor casing or the recirculation tank. Furthermore, positive barriers consisting of hay waddles or other suitable type of spill-stoppage materials will be placed around the work area on the barge and ship decks. Drill cuttings that settle out in the recirculation tank will be collected into 55-gallon storage drums. Good work practices will be observed and maintained in containing the drilling fluid, including taking care when transferring drill cuttings from the recirculation tank to the drums. The drums will be placed adjacent to the recirculation tank. If drilling fluid or drill cuttings material accidently spill onto the barge deck outside the containment area, they will be immediately picked up with a flat blade shovel and placed either into the recirculation tank or a storage drum, and the affected area will then be cleaned and mopped. Discarded soil samples will also be placed in the storage drums.

Samples will be obtained using a combination of split spoon samples, thin-walled tubes (Shelby tubes or piston samplers), and soil coring techniques. Standard penetration tests, a process of conducting split spoon sampling, will be taken in the sandy and clayey soils, and Shelby and piston tube (push) undisturbed soil samples will be taken in soft clay soils.

Standard penetration tests are performed by dropping a 140-pound automatic hammer on the drill string to drive a sampler about 1.5 feet. This is a test conducted in short durations (a few minutes for each test) using a relatively small energy source. Vibrations from the test are minimal. The Shelby tube samples would be collected by pushing on the drill string with the weight of the drill rig, and piston samplers would be collected using hydraulic fluid pressure. No vibrations are produced from pushing tube samples. A punch core or similar soil coring technique will be utilized to retain disturbed soil samples in an inner core barrel within the drill string.

Upon completion of each hole, the borings will be grouted from the bottom of the borehole to within approximately 10 to 15 feet of the top with 5 percent (by weight) bentonite and 95 percent (by weight) cement grout. Water will first be introduced inside the drilled hole and circulated within the conductor casing to clear out any remaining drilling mud before grouting. Grouting of the drilled hole will be accomplished by the tremie method from the bottom upward to a depth of approximately 10 feet below the bottom of the river based on a calculated grout take volume to prevent grout migration into the river water. At completion of the grouting, the conductor casing will then be pulled out of the channel bottom to complete the overwater boring operation.

Cone penetration testing, also performed from the deck of a shallow-draft barge or ship anchored to the channel bottom by spuds as described above, consists of pushing a cone connected to a series of rods (about 1.75 inch in diameter) from the barge deck, through the water column, and into the soft sediments of the river bottom at a constant rate, allowing continuous measurements of resistance to penetration both at the cone tip and the sleeve behind the cone tip. There are no loose items or netting on the CPT rods that would entrap or snag fish.

An environmental scientist stationed on the barge or ship will observe the drilling operation to ensure that all drilling fluid and cuttings are kept and confined within the recirculation tanks and storage drums. The environmental scientist will pay special attention to the river water for the presence of colored or increasingly opaque plumes when drilling, grouting, and pulling casing. All personnel on the barge or ship will report any observations of colored plumes in the water or leaking of the drilling fluids to the Environmental Scientist. Colored plumes are an indication that material may be leaking into the water. If an unauthorized discharge is discovered by any personnel on board the barge or ship, drilling activities will cease until appropriate corrective measures have been completed. Cuttings and excess drilling fluid will be contained in drums or bins, periodically off-loaded to a land-based staging area, and disposed of at a State-approved landfill site. The overwater borings will be supervised by a licensed drilling contractor under the direction of Department of Water Resources' personnel or its contractor. An engineering geologist or an engineer will be on site at the drill rig to supervise activities at all times during the operation. An environmental scientist will be on-site during all active drilling work to monitor activities.

2.5.1.1.2.3.1 Species Exposure and Risk

As described in Section 2.5.1.1 Construction Effects, for construction of the NDD, CCF, HOR, and barge landings, small numbers of juvenile winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, and steelhead are expected to occur at the margins of the in-water work windows, which may cause those individuals to be exposed to increased turbidity caused by the geotechnical exploration. Larger proportions of adult CCV steelhead and green sturgeon are expected to be present and therefore likely to be exposed to geotechnical activities throughout the action area.

Although exposure to increased turbidity as a result of geotechnical activities may occur, the effects on fish present are expected to be so minimal that no adverse effects are expected to occur.

2.5.1.1.2.4 Dredging

As noted in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress, the construction phase of the PA includes dredging activities that can mobilize bottom substrate material, increasing concentrations of suspended sediment concentration and turbidity downstream of the project construction area, which may adversely affect listed fish.

Although mobilized sediment can injure fish, as described in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress, the proposed action includes implementation of BMPs and the following AMMs, which are expected to minimize the potential for injury during dredging activities:

- AMM1 Worker Awareness Training;
- AMM2 Construction Best Management Practices and Monitoring;
- AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material.

Depending on location, dredging may also use a hydraulic cutterhead dredge, which will substantially reduce the amount of resuspended materials escaping into the surrounding water column by entraining the sediment into a slurry that is transported to an upland confined disposal site.

With the implementation of BMPs and AMMs, increases in turbidity and suspended sediment levels during dredging activities will be temporary, localized, and unlikely to reach levels causing direct injury to anadromous fish. Because only a relatively small portion of the channel will be affected and activity will be limited to daylight hours, disruptions to migration, holding, and rearing behavior are expected to be minor.

As described above in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress, juvenile fish, because of their smaller size and reliance on shallower, nearshore waters and associated cover, are likely to respond to increased sediment concentration by avoiding or moving away from affected shoreline areas. Such behavior could result in displacement of juveniles from preferred habitat or protective cover, which may reduce growth and survival by affecting foraging success or increasing their susceptibility to predation (described further in Section 2.5.1.1.6 Increased Predation Risk). Such disruptions are expected to be brief and unlikely to adversely affect the growth of individual salmonids.

2.5.1.1.2.4.1 North Delta Intake Locations

Dredging activities are associated with the construction of the north Delta diversion intakes as proposed in the PA. The three intakes of the NDD will be constructed on the east bank of the Sacramento River between Clarksburg and Courtland RMs 41.1, 39.4, and 36.8 (Intakes 2, 3, and 5). Each intake has its own construction duration with Intakes 2, 3, and 5 each projected to take approximately 4 to 5 years for a total construction period of 7 years (currently scheduled to be completed from 2022 to 2029). The area behind the cofferdam at each intake will be dewatered, and dredging activities will proceed within the confines of the cofferdams. It is assumed that after intake construction is complete, however, the area in front of each intake will need to be dredged to provide appropriate flow conditions at the intake entrance. If required, dredging will occur during the approved in-water work window of June 15 through October 31 to minimize exposure of listed fish species to construction-related impacts on sediment-related water quality and other hazards and will be minimized to the greatest extent practicable.

Construction of intake facilities would result in temporary impacts on sediment-related water quality, which may result in adverse effects to fish species. Any dredging associated with construction activities could potentially disturb sediment, increasing sediment mobilization and turbidity downstream of the dredging activity.

2.5.1.1.2.4.1.1 Winter-run Exposure and Risk

The timing and spatial occurrence of winter-run Chinook salmon presence has been described in Section 2.5.1.1 Construction Effects.

The vast majority of both adult and juvenile winter-run Chinook salmon will use the main stem Sacramento River to enter or leave the northern Delta. Therefore, nearly all juvenile and adult winter-run Chinook salmon must pass the NDD construction site on their way to and from Sacramento-San Joaquin Delta waterways and the San Francisco Bay Estuary. Juvenile winter-run Chinook salmon are present in the Delta from October through April, with peak occurrence from December through March. Beach seine and trawl data from 2006 through 2015 indicate that about 2 percent of a year’s juveniles would be found near the vicinity of the NDD project site in October (DJFMP 2017). Adult winter-run Chinook salmon may be found in the Delta from primarily November through May though only about 4 percent of adult passage at RBDD (about 200 RM north of NDD) occurs after May.

Exposure of winter-run Chinook salmon to construction activities at the NDD intake location will be limited by the in-water work window. Based on juvenile outmigration timing, the June 1 through October 31 in-water work window is expected to greatly reduce the exposure of winter-run Chinook salmon to dredging activities because neither juveniles nor adults are typically present during this time of year. In some years, a small proportion of the total number of winter-run Chinook salmon migrating through the construction area may occur as late as June (as adults) or as early as October (as juveniles). Although mobilized sediment can injure fish, the

PA includes minimization measures and the use of BMPs during dredging, which are expected to further reduce mobilization of sediment and turbidity plumes (BA Appendix 3.F).

Increases in turbidity and suspended sediment levels during dredging activities will be temporary and localized, unlikely to reach levels causing direct injury to anadromous salmonids. Because a relatively small portion of the channel will be affected and during daylight hours only, disruptions to migration, holding, and rearing behavior of winter-run Chinook salmon are expected to be minor. Juveniles, because of their small size and reliance on shallower, nearshore waters and associated cover, are likely to respond to dredging operations by avoiding or moving away from affected shoreline areas. This behavior could result in displacement of juveniles from preferred habitat or protective cover, which may in turn reduce growth and survival by affecting foraging success, though this is not likely to occur as they are actively migrating through this activity area. A more likely effect is increasing their susceptibility to predation (described further in Section 2.5.1.1.6 Increased Predation Risk), or delayed migration. These disruptions are expected to be brief and are unlikely to adversely affect the growth of individual salmonids. Given the timing of winter-run Chinook salmon migration and the proposed in-water work window, however, NMFS expects that the sediment concentration and turbidity effects of construction dredging at the NDD intake locations will adversely affect a small proportion of individuals of Sacramento River winter-run Chinook salmon.

2.5.1.1.2.4.1.2 Spring-run Exposure and Risk

The timing and spatial occurrence of spring-run Chinook salmon presence has been described in Section 2.5.1.1 Construction Effects.

Juvenile spring-run Chinook salmon may be present in the north Delta from November through June. It is very unlikely, however, for spring-run Chinook salmon to be present during the June 1 through October 31 dredging activities at the NDD intake location because the majority (greater than 98 percent) of juveniles have emigrated by the end of May. In some years, a few remaining fish may be migrating in early June, but the use of nearshore areas by juvenile salmon is generally reduced by June because most juveniles are large, actively migrating smolts that are known to move rapidly through the Delta and estuary during their seaward migration (Williams 2006). Adult spring-run Chinook salmon are present in the Delta from January to March, with very few migrating in May and early June. Therefore, they are not expected to be present during the dredging activities at the NDD intake location because they would have migrated through much earlier than the work window start date of June 15.

As described for winter-run Chinook salmon, increases in sediment concentration during dredging will be temporary and localized, affecting a small portion of the channel, and will potentially cause juveniles to be displaced from preferred habitat or protective cover. Although displacement could result in decreased foraging success, adverse effects are unlikely due to the rapid migration. Because of the potential for juveniles migrating in June to be exposed to dredging activities, NMFS expects that the increased sediment concentration and turbidity effects of construction dredging at the NDD intake locations will adversely affect a small proportion of CV spring-run Chinook salmon each year of the construction period. Adverse effects may be limited to behavioral modifications, which could result in increased risk of predation (described further in Section 2.5.1.1.6 Increased Predation Risk), or delayed migration.

2.5.1.1.2.4.1.3 Steelhead Exposure and Risk

The timing and spatial occurrence of CCV steelhead presence has been described in Section 2.5.1.1 Construction Effects.

In summary, juvenile CCV steelhead are present in the NDD intake locations from November through June, with peak occurrence from January through March. It is unlikely that more than 1-2 percent of the annual juvenile population would be present at the NDD location during the June to October work window. In some years, a few remaining fish may be migrating downstream in early June, or in September and October, and this is typically in response to transient flow increases in the river, such as occurs with fall storms.

In summary, adult CCV steelhead begin to migrate upriver into the Sacramento River from the Delta in June, with increasing numbers of fish arriving from August through September, before tapering off in October and November. Peak migration (approximately 69 percent of annual run) occurs in September and October, and up to 83 percent of the adult population is expected to move upriver during the in-water work window of June 1 through October 31.

As described for winter-run Chinook salmon, increases in sediment concentration during dredging will be temporary and localized, affecting a small portion of the channel, and will potentially cause juveniles to be displaced from preferred habitat or protective cover. Although displacement could result in decreased foraging success, impacts are expected to be minimal. Because of the potential for juvenile steelhead migrating in June, September, and October to be exposed to dredging activities, NMFS expects that the increased sediment concentration and turbidity effects of construction dredging at NDD intake locations will adversely affect a small proportion of individual juvenile CCV steelhead each year of the construction period. Adverse effects are expected to be limited to behavioral modifications, such as avoidance of the turbidity plume, which could result in decreased foraging, but is more likely to result in increased risk of predation of juvenile CCV steelhead displaced from their preferred habitat locations (described further in Section 2.5.1.1.6 Increased Predation Risk), or delayed migration. Physical injury from elevated sediment concentrations are not expected to occur due to the short duration of exposure and the low concentrations of suspended sediments expected, which fall below the thresholds required for physical injury.

A large fraction of the annual adult upstream migration has the potential to be affected by sediment resuspension related to dredging actions. NMFS expects, however, that adult steelhead will either move away volitionally from the turbidity plume into more suitable waters or move rapidly upstream through the area of increased turbidity to find more suitable waters. In either case, exposure to elevated suspended sediment concentrations is expected to be brief and not result in any demonstrable adverse physical or behavioral effects. This is due to the relatively small area impacted by dredging in front of the new intakes and the minimization measures and uses of BMPs during dredging, which are expected to further reduce mobilization of sediment and turbidity plumes. Therefore, NMFS expects that the increased sediment concentration and turbidity effects of construction dredging at the NDD intake locations will not adversely affect adult CCV steelhead.

2.5.1.1.2.4.1.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving.

Spawning adults migrate through the Delta between the ocean and upstream spawning habitats during the early spring, summer, and fall months, whereas juvenile sDPS green sturgeon are present throughout the Delta during every month of the year. NMFS has determined that both juvenile and spawning or post-spawn adult sDPS green sturgeon may be present in the action area during the June 1 through October 31 in-water work window owing to their widespread and year-round presence in the waters of the north Delta. They could therefore become exposed to turbidity plumes and elevated concentrations of suspended sediment resulting from dredging operations in the vicinity of the NDD during that time.

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids by having their feeding behavior disrupted, although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because they are a benthically oriented species evolutionarily adapted for life in turbid flowing waters. They may rely on biomagnetic electroreception or olfactory cues more consistently than vision to locate prey. Any reductions in the availability of foraging habitat and food due to sedimentation of benthic habitat would likely have little or no effect on growth or survival due to the temporary, localized nature of these effects. Given the potential presence of several life-stages of green sturgeon at the NDD intake locations during the work window, NMFS expects that the increased sediment effects of dredging at the NDD intake site will adversely affect a small proportion of adult, juvenile, and sub-adult green sturgeon.

2.5.1.1.2.4.1.5 Fall/Late Fall-run Exposure and Risk

Fall-run Chinook Salmon

Detailed timing and spatial occurrence of fall and late fall-run Chinook salmon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving.

Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, while adult fall-run Chinook salmon enter the San Francisco Bay in July and immigrate through the north Delta between July and December (Vogel and Marine 1991), with a peak in October.

Juvenile fall-run Chinook salmon will be exposed to increased sedimentation from NDD dredging during June through August. This conclusion is based on the temporal overlap between Sacramento trawl catches of fall-run Chinook salmon juveniles (December through August) and the June through October work window.

Fall-run Chinook salmon adults are likely to be exposed to increased sedimentation due to dredging at the NDD. Adult fall-run Chinook salmon immigration past the NDD construction site will occur from July through December (Vogel and Marine 1991). NDD dredging will occur from June through October. Therefore, adult fall-run Chinook salmon will overlap in time and space with NDD dredging from July through October. The overlap will occur during peak immigration (October).

Exposed late fall-run Chinook salmon will be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress. Increases in turbidity and suspended sediment levels during dredging activities will be temporary and localized, unlikely to reach levels causing direct injury to anadromous salmonids. Because a relatively small portion of the channel will be affected and during daylight hours only, disruptions to migration, holding, and rearing behavior of fall-run Chinook salmon are expected to be minor. Juveniles, because of their small size and reliance on shallower, nearshore waters and associated cover, are likely to respond to dredging operations by avoiding or moving away from affected shoreline areas. This behavior could result in displacement of juveniles from preferred habitat or protective cover, but the disruptions are expected to be brief and over a limited area, so they are unlikely to reduce juvenile growth.

Given that June through August represents a period of low occurrence of fall-run Chinook salmon juveniles in the Sacramento trawl, some individuals are expected to experience adverse effects, but the overall exposure and risk to that life stage would likely be minimal. Though the peak adult migration month of October occurs during the work window, the overall risk to adults is also expected to be minimized due to the temporary and localized nature of dredging. NMFS expects that the increased sediment effects of dredging at the NDD intake site will adversely affect a small proportion of juvenile and very small proportion of adult fall-run Chinook salmon.

Late Fall-run Chinook Salmon

Juvenile late fall-run Chinook salmon are present in the Delta from July through January, with a peak in December. Adult late fall-run Chinook salmon enter the San Francisco Bay in October and may be present through March (Vogel and Marine 1991).

Juvenile late fall-run Chinook salmon will be exposed to increased sediment concentration and turbidity caused by PA dredging at the NDD intake locations from July through September. This conclusion is based on the temporal overlap between Sacramento trawl catches of fall-run Chinook salmon juveniles (July through September; November through January) and the June through October NDD pile driving work window.

Late fall-run Chinook salmon adults will not be exposed to increased sediment concentration and turbidity caused by PA dredging at the NDD intake locations, except for the very end of the immigration period. NDD dredging will occur from June 15 through October 31. Therefore, adult late fall-run Chinook salmon will overlap in time and space with NDD pile driving only during the end of October.

Exposed late fall-run Chinook salmon will be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress. Reduced fitness due to stress related to turbidity plumes from the pulsed sediment plumes is expected. Given that there is a three-month period in which late fall-run Chinook salmon juveniles will be exposed to increased sediment concentration and turbidity caused by PA dredging at the NDD intake locations, an adverse effect to individuals of this life stage is expected. Additionally, adverse effects to adults are expected, but the risk is minimal given the limited exposure. NMFS expects that the increased sediment effects of dredging at the NDD intake site will adversely affect a small proportion of juvenile and adult late fall-run Chinook salmon.

2.5.1.1.2.4.2 Clifton Court Forebay

Dredging at CCF during construction is likely to result in increased sediment mobilization and turbidity, which has the potential to adversely affect listed fish. Construction at CCF includes dredging the existing CCF area, as well as excavating the expanded CCF (590 acres to the southeast) to design depths of negative 8 feet for north CCF (NCCF) and negative 10 feet for south CCF (SCCF). Although the in-water work window is restricted to July 1 through October 31 of each year of construction, according to the current schedule, the partition sheet pile dike will close off the NCCF in the summer of 2026, which will then isolate the NCCF from the rest of the fish bearing waters in the CCF. Because water temperatures will be too warm for salmonids in the summer months, they are not expected to be present in the NCCF while it is being isolated from the rest of the forebay. Fish capture and relocation will then take place in the NCCF. The NCCF will be dewatered completely following the fish removal and excavation of earth to design elevations will take place in the dry behind the sheet pile cofferdam using construction equipment; therefore, listed fish are not expected to be adversely affected by suspended sediment in the NCCF.

As with current operations, fish will continue to be entrained into the existing portion of SCCF throughout the years of construction via the radial gates at Old River. As described in the PA and information provided by DWR, the existing portion of SCCF will begin to be systematically dredged within a silt curtain enclosure isolating an area of approximately 200 acres and thus containing any increased suspended sediment and turbidity from the rest of the forebay. This method of dredging is expected to greatly minimize adverse effects of mobilized sediment and increased turbidity to fish, although any fish present may experience some disturbance or injury. Dredging will only occur within the in-water work window each year of construction, which will greatly minimize the risk of listed salmonid presence. Fish may, however, enter the area as water temperatures start to cool (especially October). Green sturgeon may be present year-round. The expanded area of SCCF south of the existing earthen berm will be excavated to design depth in the dry prior to breaching the existing berm to connect with the existing SCCF portion.

Recognizing that design of these modifications is still in an early stage, DWR, Reclamation, NMFS, CDFW, and USFWS have agreed to ongoing collaborative efforts to ensure that the final design and construction procedures for CCF minimize adverse effects to listed species to the extent practicable. Accordingly, representatives from each of these agencies will participate in a Clifton Court Forebay Technical Team (CCFTT). Additionally, the proposed construction at CCF includes implementation of the appropriate BMPs and AMMs identified in BA Appendix 3.F, which are expected to minimize adverse effects to species.

2.5.1.1.2.4.2.1 Chinook Salmon Exposure and Risk

The timing and spatial occurrence of all salmonids has been described in Section 2.5.1.1 Construction Effects.

Limiting dredging activities within CCF to the July 1 through October 31 work window is expected to minimize exposure to Chinook salmon species because:

- Juvenile winter-run Chinook salmon are present in the CCF from November to April. Adult winter-run are present in the Delta between November and June, but are unlikely to be found in CCF because it is outside of their main upstream migratory route.
- Juvenile spring-run Chinook salmon are expected to be present in CCF from February to June, while adult spring-run are present in the Delta between January and March.

- Juvenile fall- and late fall-run Chinook salmon are expected to be present in CCF from January through June. Juvenile late fall-run Chinook salmon will be present during July to November. Although adult fall-run will be migrating through the action area from July through December, only a small portion of the Central Valley population is expected to pass near CCF. Adult late fall-run Chinook salmon are not expected to be present during construction activities.

Continued operation of CCF throughout the construction period, however, increases the risk of potential entrainment of listed fish species into CCF during construction, creating a potential for adverse effects to listed fish from dredging activities. With implementation of the AMMs and in-water work window, the in-water construction activities would result in mostly temporary, localized increases in turbidity and suspended sediment, but any fish present may be subject to behavioral modifications as described in Section 2.5.1.1.6 Increased Predation Risk. The effects on all adult and juvenile salmonids would likely be limited to harassment of individuals that encounter turbidity plumes.

Given the extension of the work window into October and potential presence of juvenile winter- and spring-run Chinook salmon in the area, NMFS expects the increased sediment concentration effects of dredging at CCF to adversely affect a small proportion of juvenile winter- and spring-run Chinook salmon. Given that late fall-run Chinook salmon juveniles will be present during the July through October work window, NMFS expects that the increase in sediment concentration and turbidity caused by dredging activities at CCF will adversely affect a small proportion of juvenile late fall-run Chinook salmon. Exposed Chinook salmon will be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress such as reduced fitness due to stress related to turbidity plumes.

2.5.1.1.2.4.2.2 Steelhead Exposure and Risk

The timing of CCV steelhead at the Clifton Court location has been described in Section 2.5.1.1 Construction Effects.

Less than 1 percent of the annual juvenile emigration is expected to occur at the CCF during the proposed work window (July 1 through October 31). The majority of juvenile steelhead presence in the CCF location will occur from December through March, based on salvage at the CVP and SWP fish collection facilities. It is expected that the timing of adult presence at the CCF location will be later than that observed for the North Delta due to its southern Delta location, and the likelihood that the majority of adult fish present are from the San Joaquin River basin population, which has a later peak in upstream migration compared to the Sacramento River basin population. Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta in September, with the majority of the population passing through the Delta from November to January. This slightly later upstream migration for San Joaquin River basin CCV steelhead overlaps from September through October with the proposed in-water work window.

Because the dredging of CCF will occur only during the in-water work window (July 1 through October 31), it is expected that adult steelhead will be the predominant life stage affected by dredging in CCF due to the overlap in the dredging work window and the upstream migration of adult steelhead. Few juvenile CCV steelhead are expected to be affected by the dredging actions in CCF due to their later migration period. Exposed steelhead may be subject to physical and behavioral responses identified in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress such as reduced fitness due to stress related to turbidity plumes, or delayed migration. Precautions taken by the applicant include the use of silt curtains. These devices will contain and reduce the exchange of suspended materials from within the silt curtain enclosure with the waterbody surrounding the enclosure. As described previously, the use of a hydraulic cutterhead dredge will substantially reduce the amount of resuspended materials escaping into the surrounding water column by entraining the sediment into a water –sediment slurry and transporting this material via a dredge discharge pipeline to an upland confined disposal site. The combination of silt curtains with the use of hydraulic cutterhead dredges will substantially reduce the amount of sediment escaping into the water column of the surrounding CCF where steelhead may potentially be present.

Because the majority of the juvenile steelhead emigration occurs after the end of the dredging action, NMFS expects that the sediment effects of dredging at the CCF will adversely affect a small proportion of juvenile steelhead. Adult steelhead migration timing overlaps with the work window at CCF, especially given the extension through October for in-water work. Therefore, NMFS expects that the sediment effects of dredging at the CCF will adversely affect a small proportion of adult steelhead.

2.5.1.1.2.4.2.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1.1.1.1.4 Green Sturgeon Exposure and Risk.

Spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year. NMFS has determined that juvenile, adult, and sub-adult sDPS green sturgeon will be exposed to elevated concentrations of suspended sediment and turbidity in CCF during the in-water construction period due to their widespread and year-round presence in the waters of the Delta.

Limiting dredging activities to the in-water work window of July 1 through October 31 will avoid the peak upstream migration period of adult green sturgeon transiting the action area (late February to early May) to upstream spawning habitats, although post-spawning adults returning to the ocean, sub-adults, and juveniles may be present in the Delta during the late summer and fall months. They are therefore potentially exposed to increases in turbidity and suspended sediment in CCF during the in-water work window. Historically, salvage of juvenile green sturgeon generally peaked in the summer, indicating presence in CCF and the Old River channel adjacent to the SWP radial gates to CCF, although few green sturgeon have been salvaged in recent years (NMFS 2015b). A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon owing to their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats through the waters of the Delta. (NMFS 2015b).

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids by having their feeding behavior disrupted, although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because they are a benthically oriented species evolutionarily adapted for life in turbid flowing waters. They may rely on biomagnetic electroreception or olfactory cues more consistently than vision to locate prey. Any reductions in the availability of foraging habitat and food due to sedimentation of benthic habitat would likely have little or no effect on growth or survival due to the temporary, localized nature of these effects and the low quality of existing habitat in CCF and adjacent south Delta channels.

Given the known presence of juvenile and sub-adult green sturgeon in the Delta during the in-water work window, NMFS expects that the sediment effects of dredging at the CCF will adversely affect a small proportion of juvenile and sub-adult green sturgeon. Because adult green sturgeon are not present at the CCF from August through October, NMFS expects that the sediment effects will not adversely affect adult green sturgeon.

2.5.1.1.2.4.3 HOR Gate

Dredging activities are associated with constructing and installing the HOR gate as proposed in the PA. Dredging to prepare the channel for construction of the HOR gate will occur along 500 feet of channel, from 150 feet upstream to 350 feet downstream of the proposed gate location. A total of up to 1,500 cubic yards of material is expected to be dredged. Dredging will last approximately 15 days and will be performed within the August 1 through October 31 in-water work window for this location. Sediment mobilization and increased turbidity in Old River and the San Joaquin River downstream of the activity is likely and therefore any fish present may be adversely affected.

As described in Section 2.5.1.1.2.4.1 North Delta Intake Locations, implementation of the appropriate BMPs and AMMs is proposed to minimize potential adverse effects to fish because of dredging activities.

2.5.1.1.2.4.3.1 Winter-run Exposure and Risk

The timing and spatial occurrence of juvenile and adult winter-run Chinook salmon has been described in Section 2.5.1.1 Construction Effects.

Juveniles are present in the Delta from October through April, while adults are present in the Delta from November through June. Because the HOR gate is on a distributary of the San Joaquin River far from the main winter-run Chinook salmon migration corridor (i.e., the Sacramento River), it is highly unlikely that winter-run Chinook salmon would be found in the vicinity of the gate. Additionally, the in-water work window for the HOR gate is August 1 through October 31, so the potential for dredging-induced turbidity is not expected to coincide with winter-run Chinook salmon presence. Given the timing and location of winter-run Chinook salmon presence and migration compared to the proposed in-water work window, NMFS expects that the sediment concentration and turbidity effects of construction dredging at the HOR gate will not adversely affect winter-run Chinook salmon.

2.5.1.1.2.4.3.2 Spring-run Exposure and Risk

The timing and spatial occurrence of juvenile and adult spring-run Chinook salmon has been described in Section 2.5.1.1 Construction Effects.

Both San Joaquin River basin spring-run Chinook salmon adults and any straying adults from the Sacramento River basin will most likely already be staging for spawning in upriver locations by

August and are not expected to be migrating through the vicinity of the HOR during the August 1 through October 31 work window. Although there is some uncertainty due to lack of monitoring data regarding the timing of outmigrating juvenile spring-run Chinook salmon in the San Joaquin River basin, NMFS assumes that these fish exhibit similar emigration patterns to the Sacramento River basin populations, and, therefore, yearling smolt spring-run Chinook salmon may be present in the vicinity of the HOR gate in October, though likely in very few numbers. NMFS therefore expects that the sediment concentration and turbidity effects of construction dredging at the HOR gate will adversely affect a very small proportion of spring-run Chinook salmon. Adverse effects are likely limited to behavioral modifications, which could result in increased risk of predation (as described in Section 2.5.1.1.6 Increased Predation Risk).

2.5.1.1.2.4.3.3 Steelhead Exposure and Risk

The timing of CCV steelhead at the HOR gate location has been described in Section 2.5.1.1 Construction Effects.

In summary, juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Because dredging activities are limited to August 1 through October 31, a minimal amount of temporal overlap with the presence of juvenile CCV steelhead is expected. Less than 1-2 percent of the annual juvenile emigration from either the Sacramento or San Joaquin River basin is expected to occur during the proposed work window. San Joaquin River basin juvenile CCV steelhead presence is expected to peak in April and May, but their abundance is considerably lower than that of steelhead originating from the Sacramento River basin. It is not expected that juvenile steelhead from the Sacramento River basin will be present at the location of the HOR gate.

Adult CCV steelhead from the Sacramento River basin are not expected to be present at the HOR gate location. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January. Because dredging at the HOR gate occurs during August through October, only adult steelhead migrating into the San Joaquin River basin during these months will be affected. It is anticipated that only a small proportion of the annual adult upriver migration will overlap with the dredging associated with the HOR gate installation.

Because of the timing of the dredging activities at the HOR gate location and the presence of only a small percentage of the juvenile population at this time, NMFS expects that increased sediment will adversely affect a small proportion of juvenile steelhead. Adverse effects are likely limited to behavioral modifications, which could result in increased risk of predation (as described in Section 2.5.1.1.6 Increased Predation Risk), or delayed migration. Because adult steelhead from the San Joaquin River basin begin migration in September or October and generally peak in presence in November, NMFS expects that increased sediment will adversely affect a small proportion of adult San Joaquin River steelhead. Adverse effects are likely to be limited to behavioral effects such as route avoidance or short term delays on the order of a day until passage can be completed during the night when dredging operations have ceased.

2.5.1.1.2.4.3.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving.

Despite the uncertainty and variability associated with Delta residence time by life stage, juvenile and sub-adult sDPS green sturgeon may be present throughout the Delta during every month of the year, whereas spawning and post-spawn adults are unlikely to migrate through the waters of the south Delta because their principal migratory route between the ocean and upstream spawning habitats lies primarily in the Sacramento River and the channels of the north Delta. Because of the widespread and year-round presence of juvenile and sub-adult sDPS green sturgeon in the waters of the Delta, these life stages could be present in the vicinity of the HOR gate and could be exposed to increased suspended sediment concentrations and turbidity from dredging operations associated with construction during the August 1 through October 31 in-water construction period.

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids by having their feeding behavior disrupted, although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because they are a benthically oriented species evolutionarily adapted for life in turbid flowing waters. They may rely on biomagnetic electroreception or olfactory cues more consistently than vision to locate prey. Any reductions in the availability of foraging habitat and food due to sedimentation of benthic habitat may affect growth and survival. Given the potential presence of several life stages of green sturgeon at the HOR gate location during the work window, NMFS expects that the increased sediment effects of dredging at the HOR gate site will adversely affect a small proportion of juvenile and sub-adult green sturgeon but not affect adult green sturgeon.

2.5.1.1.2.4.3.5 Fall/Late Fall-run Exposure and Risk

Fall-run Chinook Salmon

The timing and spatial occurrence of juvenile and adult fall-run Chinook salmon has been described in Section 2.5.1.1.1.1 Pile Driving.

Juvenile fall-run Chinook salmon do not occur in the Delta during the August through October construction window and are not are likely to be exposed to increased sediment concentration and turbidity.

Adult fall-run Chinook salmon from the San Joaquin basin will be immigrating to their natal spawning grounds from September through December (Williams 2006). Given that the HOR gate construction site will be adjacent to the San Joaquin River, some immigrating adults will likely be in the construction area during the August through October construction period. Fall-run Chinook salmon adults are likely to be exposed to increased sediment concentration and turbidity due to PA dredging at the HOR gate.

Adult Sacramento River fall-run Chinook salmon, particularly hatchery-origin fish, may be present at the HOR gate location. Naturally produced Chinook salmon adults have low stray rates relative to hatchery-produced fish, particularly when hatchery releases are made off site (Keefer and Caudill 2014). As such, fall-run Chinook salmon adults produced naturally in the Sacramento River basin have a low probability of straying into the HOR gate area, whereas fish produced at Coleman National Fish Hatchery, Feather River Hatchery, and Nimbus Hatchery on the American River are more likely to stray into Old River and experience HOR gate dredging stressors.

Because juvenile fall-run Chinook salmon are not present during dredging activities, NMFS expects that the increased sediment concentrations will not adversely affect juvenile fall-run Chinook salmon. Given the temporal and spatial overlap between fall-run Chinook salmon adults and the short-term duration of dredging activities, NMFS expects that increased sediment concentrations due to dredging at HOR gate will adversely affect a small proportion of fall-run Chinook salmon adults. Adverse effects are likely limited to behavioral modifications, which could result in increased risk of predation (as described in Section 2.5.1.1.6 Increased Predation Risk), or delayed migration.

Late Fall-run Chinook Salmon

Late fall-run Chinook salmon occur in the Sacramento River basin, but not the San Joaquin River basin. Juvenile late fall-run Chinook salmon occur in the Delta from July through January, which overlaps with the August through October construction window. Therefore, any juveniles that stray to the San Joaquin River near the HOR gate location are expected to be exposed to the effects of dredging activities at the HOR gate location.

While stray late fall-run Chinook salmon adults occur occasionally in the San Joaquin River near the HOR gate location, the likelihood of occurrence is low and very difficult to predict. Nearly all Coleman National Fish Hatchery late fall-run Chinook salmon immigrate to the Sacramento River basin where they originated (Kormos et al. 2012). Additionally, the October through April timing of adult immigration only slightly overlaps with the window for dredging activities at HOR gate. Therefore, there is a very low probability that adult late fall-run Chinook salmon will overlap in time and space with stressors produced by dredging at the HOR gate.

Given the temporal overlap between late fall-run Chinook salmon juveniles and the possible, although short-term duration of spatial overlap with dredging activities, NMFS expects that the increased sediment concentrations associated with dredging activities at the HOR gate will adversely affect a very small proportion of juvenile late fall-run Chinook salmon. Adverse effects are likely limited to behavioral modifications, which could result in increased risk of predation (as described in Section 2.5.1.1.6 Increased Predation Risk), or delayed migration. Given the low probability of occurrence of late fall-run Chinook salmon adults at the HOR gate location, NMFS expects that the increased sediment will not adversely affect adult late fall-run Chinook salmon.

2.5.1.1.2.4.4 Barge Routes and Landings

Dredging associated with barge operations can be expected during the construction activity period of the proposed action. Barge landings are distributed over a broad area of the Sacramento-San Joaquin Delta. The Sacramento-San Joaquin Delta barge routes will cover nearly 100 miles of waterways from San Francisco to the Port of Stockton and landing locations at the NDD intake location and CCF.

During the 5 to 6 years of construction, barge landing sites (described in Section 2.5.1.1.1.1.4 Barge Landing Locations) and the barge routes themselves (described in Section 2.5.1.1.1.2 Barge Traffic) may need to be periodically dredged of collected sediment to adequate depths to maintain passage and vessel safety. Although dredging at barge landings and along barge routes wasn't initially included in the BA, NMFS and DWR jointly determined the assumptions on frequency for this dredging activity, which are based on professional judgment. The assumptions include initial dredging at barge landings and along barge routes as needed and up to two additional spot dredging actions at barge landings and along barge routes as needed. NMFS also assumes that the in-water work window for dredging activities associated with barge operations will be the same as that used for construction at the barge landings (August 1 through October 31). This work window is expected to minimize exposure to listed fish species under NMFS' authority.

Dredging operations that occur when fish are present are expected to result in exposure to elevated sediment concentrations, which may result in adverse effects to fish. Adverse effects may be limited to fish behavior modifications or may result in direct injury (described in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress). The proposed action includes implementation of BMPs and AMMs, which are expected to minimize the potential for injury during dredging activities (BA Appendix 3.F).

2.5.1.1.2.4.4.1 Winter-run and Spring-run Chinook Salmon Exposure and Risk

Detailed timing and spatial occurrence of winter-run and spring-run Chinook salmon presence in the Delta has previously been described in Section 2.5.1.1 Construction Effects.

Limiting dredging activities of the PA within the Delta to the August 1 through October 31 work window is expected to minimize exposure to these runs of Chinook salmon, because:

- Winter-run Chinook salmon juveniles are present in the Delta from October through April, with about 2 percent of a year's juveniles found in the north Delta in October (DJFMP 2017). Adult winter-run Chinook salmon are present in the Delta from November through June.
- Spring-run Chinook salmon juveniles may be present in the north Delta from November to June, with the majority (greater than 98 percent) of juveniles having emigrated by the end of May. Adult spring-run Chinook salmon are present in the Delta from January to March (with very few in May and early June) as they begin to migrate upstream into the Sacramento River or San Joaquin River basin.

NMFS therefore expects that sediment exposure effects of dredging at barge landings and barge access routes are unlikely to adversely affect individual winter-run and spring-run Chinook salmon throughout the Delta.

2.5.1.1.2.4.4.2 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of CCV steelhead presence in the Delta has previously been described in Section 2.5.1.1 Construction Effects.

The majority of adult steelhead enter the Delta region from June through November, with a peak in September and October. Low levels of adult CCV steelhead continue to emigrate upriver through March. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January. Steelhead smolts begin to enter the northern Delta from the Sacramento River as early as September through December, but do not substantially increase in numbers until February and March. Less than 1 percent of the juvenile population is expected to be present during August, September, and October. Downstream migration of San Joaquin River basin steelhead smolts into the Delta peaks in April and May.

Because of the low potential for juvenile steelhead migrating in August, September, and October to be exposed to dredging activities, NMFS expects that the increased sediment concentration and turbidity effects of dredging at the barge landing locations and along the proposed barge routes will adversely affect a small proportion of individual juvenile CCV steelhead. Adverse effects may be limited to behavioral modifications, which could result in increased risk of predation of juvenile CCV steelhead (described further in Section 2.5.1.1.6 Increased Predation Risk). Although the in-water water work window of August 1 through October 31 overlaps with a substantial proportion of the adult upstream migration, NMFS expects that increases in sediment concentration will adversely affect a small proportion of adult CCV steelhead from both the Sacramento and San Joaquin River basins. Adverse effects are likely to be limited to behavioral effects such as route avoidance or short term delays on the order of a day until passage can be completed during the night when dredging operations have ceased. Most adult steelhead will likely show little effect from the dredging operations and will not experience any prolonged exposures to elevated sediment levels that would result in long term adverse impacts.

2.5.1.1.2.4.4.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving.

Spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year. Because of the widespread and year-round presence of juvenile, adult, and sub-adult sDPS green sturgeon in the Delta, NMFS expects that these life stages would be exposed to turbidity plumes and elevated concentrations of suspended sediment resulting from dredging operations at barge landings and along barge routes during the in-water work window from August 1 through October 31.

The potential for increased sediment concentrations and turbidity because of dredging operations associated with the barge landings and travel routes is expected to have an effect on juvenile, sub-adult and adult sDPS green sturgeon. Multiple barge landings sited in the north, central, and south Delta occur on waterways that are occupied by juvenile and sub-adult life stages of sDPS green sturgeon rearing in the Delta during every month of the year.

Additionally, the annual spawning migrations of adult green sturgeon between the ocean and upstream spawning habitats overlap with the projected routes of barge traffic anticipated between the Golden Gate Bridge in San Francisco and Chipps Island.

Therefore, all juvenile, sub-adult, and spawning or post-spawn adult sDPS green sturgeon will have some level of exposure to increased sediment concentrations resulting from dredging operations at the multiple barge landings and routes located throughout the Delta and San Francisco Estuary. A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon because of their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats.

The adverse effects to fish typically associated with elevated concentrations of suspended sediment in the water column has been generally described in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress, although it is unclear to what extent exposed green sturgeon will be affected. No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. It is possible that higher concentrations of suspended sediment and turbidity in the Delta may interfere with normal sturgeon feeding and migratory behavior, although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because they are a benthically oriented species, evolutionarily adapted for life in turbid flowing waters, and may rely on biomagnetic electroreception or olfactory cues more consistently than vision to locate prey. Any reductions in the availability of foraging habitat and food because of sedimentation of benthic habitat following a dredging episode would likely have little or no effect on growth or survival due to the temporary, localized nature of these effects.

Given the known presence of juvenile, sub-adult, and adult green sturgeon in the Delta during the in-water work window, NMFS expects that the sediment effects of dredging at the barge landings and along barge routes will adversely affect a small proportion of juvenile, sub-adult, and adult green sturgeon.

2.5.1.1.2.4.4.4 Fall/Late Fall-run Exposure and Risk

Fall-run Chinook Salmon

The timing and spatial occurrence of juvenile and adult fall-run Chinook salmon has been described in Section 2.5.1.1.1.1 Pile Driving.

Juvenile fall-run Chinook salmon do not occur in the Delta during the August through October construction window. Therefore, this life stage is not expected to be exposed to increased sediment concentration and turbidity due to dredging at barge landing locations and barge routes.

The fall-run Chinook salmon adult immigration period for both the San Joaquin River basin (September through December) and the Sacramento River basin (July through December) overlap with the August through October dredging period. The multiple barge landing locations in the north, central, and south Delta occur on waterways that are occupied by fall-run Chinook salmon adults from both the Sacramento and San Joaquin river basins. Given the spatial and temporal overlap, fall-run Chinook salmon adults are expected to be exposed to stressors produced by this activity. A higher level of exposure is anticipated for fall-run Chinook salmon originating in the San Joaquin River basin because most barge routes will occur in the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF.

Given the lack of exposure for juvenile fall-run Chinook salmon, NMFS expects that the increased sediment concentration and turbidity caused by dredging at barge landing locations and along barge routes will not adversely affect juvenile fall-run Chinook salmon. Given the temporal and spatial overlap of fall-run Chinook salmon adults and the in-water dredging activity timing, however, NMFS expects that increased sediment concentrations will adversely affect some fall-run Chinook salmon adults. Adverse effects may be limited to behavioral modifications or displacement, which may result in delayed migration.

Late Fall-run Chinook Salmon

Juvenile late fall-run Chinook salmon occur in the Delta from July through January, which overlaps with the August through October in-water work window for dredging. Juveniles are therefore likely to be exposed to increased sediment concentration and turbidity due to dredging at barge landing locations and barge routes.

The timing of adult immigration of late fall-run Chinook salmon (end of October through beginning of April) only slightly overlaps with the window for dredging at barge landings and routes (August through October). Adult late fall-run Chinook salmon at the very beginning of the spawning run (i.e., end of October) are expected to be exposed to dredging at the barge routes and landings.

Given the exposure for the entire migratory period for juvenile late fall-run Chinook salmon, NMFS expects that the increased sediment concentration and turbidity caused by dredging at barge landing locations and along barge routes will adversely affect a large proportion of juvenile late fall-run Chinook salmon. Because early adult migrants may be present during the work window, NMFS expects that the increased sediment concentration will adversely affect a small proportion of adult late fall-run Chinook salmon.

2.5.1.1.3 Contaminant Exposure

The proposed action includes activities that could increase the exposure of fish to harmful contaminants. Chemical forms of water pollution are a major cause of freshwater habitat degradation worldwide. There are many sources of contaminants, and these reflect past and present human activities and land use (Scholz and McIntyre 2015). Contaminants are typically associated with areas of urban development, agriculture, or other anthropogenic activities (e.g., mercury contamination as a result of gold mining or processing). Organic contaminants from agricultural drain water, urban and agricultural runoff from storm events, and high trace element (i.e., heavy metals) concentrations may deleteriously affect early life-stage survival of fish in the Central Valley watersheds (NMFS 2011, 2013).

Many freshwater taxa in the Central Valley are in noticeable decline. This notably includes ESA-listed species and their designated critical habitat, which are susceptible to contaminants, many of which interact with other stressors such as pathogens to cause mortality, reproductive failure, and other losses to individual fitness. Many ESA-listed fish species are highly mobile and traverse hundreds of kilometers of freshwater habitat from the Sacramento-San Joaquin River Delta on their migration path to and from the ocean (Quinn 2005). The degree of sediment mobility and the increased contaminant exposure due to aggregated impacts of pollution from resuspension of sediment by various actions such as large vessel operations (Macneale et al. 2014) within the action area are a particularly important consideration for listed species and their designated critical habitats.

Areas with low human impacts frequently have low contaminant burdens and, therefore, lower levels of potentially harmful toxicants in the aquatic system (Relyea 2009). Legacy contaminants such as mercury, methyl mercury, polychlorinated biphenyls (PCBs), heavy metals, and persistent organochlorine pesticides, however, continue to be found in watersheds throughout the Central Valley. For example, persistent organic pollutants such as PCBs disrupt immune system function in exposed fish, thereby rendering exposed fish more susceptible to disease. PCBs are considered persistent pollutants because they resist degradation in the environment, by processes that are either biotic (e.g., microbial breakdown) or abiotic (e.g., photolysis in response to sunlight). They accumulate in sediments and can be resuspended and redistributed in aquatic habitat by dredging and similar forms of human disturbance.

One of the contaminants potentially present is selenium, which was identified as one of the pollutants in San Francisco Bay and the western Delta on the Clean Water Act section 303(d)

List (State Water Resources Control Board 2011). Within the Delta, there are multiple sources of selenium. Presser and Luoma (2013) identify oil refinery wastewaters from processing crude oils at North Bay refineries and irrigation drainage from agricultural lands in the western San Joaquin Valley (mainly via the San Joaquin River) as the two primary sources. Agricultural drainage in the Sacramento Valley west-side creeks in the Yolo Bypass and non-oil industries and wastewater treatment effluents are minor sources of selenium in the Delta. Selenium can elicit a short- and long-term response from aquatic biota depending on the quantity, quality, and duration of selenium exposure. The primary exposure pathway for fish and other aquatic organisms to selenium is through their diet (Presser and Luoma 2010a, 2010b, 2013; Stewart et al. 2010). Continued exposure of selenium can result in bioaccumulation and/or toxicity to fish in the Delta. Because adult salmon and steelhead do not forage extensively while in the Delta before spawning upstream in the rivers (Sasaki 1966), their exposure is likely to be much less than exposure for juveniles, which spend most of their time in the Delta feeding and foraging for food. Thus, exposures that may affect survival and growth of juvenile salmonids are included below in the analyses of potential selenium effects, due to the timing in which those juveniles occur and feed within the proposed action area. Green sturgeon migrate from major rivers to the Delta and reside within the Delta or in the Pacific Ocean (USFWS 2008). Therefore, all life stages of sturgeon have the potential to be exposed to selenium in the Delta.

Adult salmonid exposure within the Delta is limited and not likely to affect reproduction. However, survival and growth of juvenile salmonids will potentially be affected. In contrast, green sturgeon may remain in or return to the Delta at all life stages such that survival, growth, and reproduction are all important characteristics to consider for green sturgeon. Therefore, the attributes of individual-level survival or growth (all species) and reproduction (sturgeon only) were evaluated for the PA.

Metals, PCBs, and hydrocarbons (typically oil and grease) are common urban contaminants that are introduced to aquatic systems via nonpoint-source stormwater drainage, industrial discharges, and municipal wastewater discharges. Many of these contaminants readily adhere to sediment particles and tend to settle out of solution relatively close to the primary source of contaminants. PCBs are persistent, adsorb to soil and organic matter, and accumulate in the food web. Lead and other metals also will adhere to particulates and can bioaccumulate to levels sufficient to cause adverse biological effects. Mercury is also present in the Sacramento River system and could be sequestered in riverbed sediments. Hydrocarbons biodegrade over time in an aqueous environment and do not tend to bioaccumulate or persist in aquatic systems. This suite of contaminants could pose a risk to listed fish if resuspension of contaminated sediments increases exposure.

Resuspended sediment can expose legacy contaminants that have previously been buried in the waterway's bottom sediment. Sediment is usually considered a sink for anthropogenic contaminants in marine and freshwater environments. Regardless of whether discharges originate from air, rivers, urban or agriculture runoff, or effluents from wastewater treatment plants, contaminants such as heavy metals and organic pollutants are typically scavenged by suspended, fine grained, mineral, and organic particles in the aqueous environment and will eventually settle out of the water column when quiescent hydrodynamic conditions prevail (Lepland et al. 2010, Roberts 2012).

Benthic and infauna species are primarily exposed to these contaminated sediment horizons. When sediment is resuspended, the bound contaminants are remobilized into the water column and become bioavailable to an additional assemblage of aquatic species through chemical processes that change their charge and chemical properties (e.g., oxidation in the aerobic water). While most of the material will likely settle out of suspension in close proximity to the disturbance, some of it may be transported considerable distances from the point of disturbance due to tidal or river currents. The resuspended material can be thought of as a pulsed disturbance resulting in episodic (pulsed) exposures of organisms to the contaminants. To fully understand the responses of exposed organisms, one must know not only the toxicological effects of the contaminant exposure to different organisms and the aquatic community, but also the frequency, magnitude, and duration of the disturbance event (Roberts 2012).

In 2010 the EPA listed the Sacramento River as impaired under Clean Water Act section 303(d) due to high levels of pesticides and heavy metals. The U.S. Army Corps of Engineers has identified polycyclic aromatic hydrocarbons (PAHs), organophosphates, chlorinated herbicides, ammonia, oil, grease, glyphosate, a-amino-3-hydroxy-5-methyl-4-isoxazolepro-pionate (i.e., AMPA), dioxin, heavy metals, and other constituents as potential contaminants within the action area. Some of these contaminants have been found to cause effects of acute and chronic stress that are sublethal and lethal to salmonids (Allen and Hardy 1980). Although most of these contaminants are at low concentrations in the food chain, they continue to work their way into the base of the food web, particularly when sediments are disturbed and previously entombed compounds are released into the water column.

If bioaccumulative contaminants such as organochlorines are released as a result of dredging they biomagnify in aquatic food webs. That is, they become proportionately more concentrated at higher trophic levels. Consequently, they present a greater risk to fish that feed at or near the top of aquatic food webs. Disturbing benthic sediments through dredging and dredge material disposal, as well as through the mechanisms of effluent return flows from dredged material placement sites, is expected to mobilize and redistribute a variety of contaminants in the water column. If contaminants are released during dredging or dredged material disposal activities, their effects may be subtle and difficult to directly observe.

Exposure to contaminated food sources and bioaccumulation of contaminants from feeding on them may create delayed sublethal effects that negatively affect the growth, reproductive development, and reproductive success of listed anadromous fishes, thereby reducing their overall fitness and survival (Laetz et al. 2009). The effects of bioaccumulation are of particular concern as pollutants can reach concentrations in higher trophic level organisms (e.g., salmonids) that far exceed ambient environmental levels (Allen and Hardy 1980).

Bioaccumulation may therefore cause delayed stress, injury, or death as contaminants are transported from lower trophic levels (e.g., benthic invertebrates or other prey species) to predators long after the contaminants have entered the environment or food chain. Many contaminants lack defined regulatory exposure criteria that are relevant to listed salmonids and yet may have effects on salmonids (Ewing 1999). It follows that some organisms may be negatively affected by contaminants while regulatory thresholds for the contaminants are not exceeded during measurements of water or sediments.

Sublethal or nonlethal effects indicate that death is not the primary toxic endpoint. Rand (1995) stated that the most common sublethal endpoints in aquatic organisms are behavioral (e.g., swimming, feeding, attraction-avoidance, and predator-prey interactions), physiological (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes. Some sublethal effects may result in indirect mortality, for example, when a fish already stressed due to toxicity encounters an additional stressor and the combination of those causes death. Changes in certain behaviors, such as swimming or olfactory responses, may diminish the ability of listed fish to find food or escape from predators and may ultimately result in death. Some sublethal effects may have little or no long-term consequences to the fish because they are rapidly reversible or diminish and cease with time. Individual fish of the same species may exhibit different responses to the same concentration of toxicant. In addition, the individual condition of the fish can significantly influence the outcome of the toxicant exposure. Fish with greater energy stores will be better able to survive a temporary decline in foraging ability or have sufficient metabolic stores to swim to areas with better environmental conditions. Fish that are already stressed are more susceptible to the deleterious effects of contaminants and may succumb to toxicant levels that are considered sublethal to a healthy fish.

Exposure to sublethal levels of contaminants has been shown to cause serious implications for salmonid health and survival. Studies have shown that low concentrations of commonly available pesticides can induce significant sublethal effects on salmonids. Scholz et al. (2000) and Moore and Waring (1996) have found that diazinon interferes with a range of physiological biochemical pathways that regulate olfaction, negatively affecting homing, reproductive, and anti-predator behavior of salmonids. Waring and Moore (1997) also found that the carbofuran had significant effects on olfactory mediated behavior and physiology in Atlantic salmon (Salmo salar). Scientific literature on the effects of pesticides on salmonids and identified a wide range of sublethal effects such as impaired swimming performance, increased predation of juveniles, altered temperature selection behavior, reduced schooling behavior, impaired migratory abilities, and impaired seawater adaptation (Sandahl et al. 2000; Baldwin et al. 2009; Laetz et al. 2009; Laetz et al. 2013; McIntryre et al. 2012) are reviewed in Ewing (1999). Other non-pesticide compounds that are common constituents of urban pollution and agricultural runoff also have the potential to negatively affect salmonids.

Pollution risks vary depending on the particular chemical, the amount transported in stormwater, and environmental persistence. Even short-term exposure to aquatic pollutants (i.e., copper) can cause acute lethality or a variety of sub-lethal adverse effects to aquatic species (Baldwin et al. 2003, Hecht et al. 2007, McCarthy 2008). Recent studies in the Pacific Northwest provide insight on the ecological impacts of stormwater, particularly in urban streams, on the growth and survival of listed coho salmon (Sandahl 2007, Feist et al. 2011, Scholz et al. 2011, Spromberg 2011). Exposure to chlorinated hydrocarbons and aromatic hydrocarbons causes immunosuppression and increased disease susceptibility (Arkoosh et al. 1994). In areas where chemical contaminant levels are elevated, disease may reduce the health and survival of affected fish populations (Arkoosh et al. 1994). Environmental stresses as a result of low water quality can lower reproductive success and may account for low productivity rates in fish.

The Southern DPS of North American green sturgeon are expected to be more vulnerable than salmonids to the negative effects of dredging due to their benthic-oriented behavior, which conceivably put them in closer proximity to the contaminated sediment horizon, although it is presently unclear if juveniles exhibit this behavior to the same extent that adults do (Presser and Luoma 2010, 2013). Their “inactive” resting behavior on substrate may potentially put them in dermal contact with contaminated sites, which can lead to lesions and the production of tumors from materials in the substrate. Sturgeon are also benthic invertebrate feeders that forage on organisms that can sequester contaminants at much higher levels than the ambient water or sediment content, such as the Asian clams Corbicula and Potamocorbula that are prevalent in the action area. The great longevity of sturgeons also places them at risk for the bioaccumulation of contaminants to levels that create physiologically adverse conditions within the body of the fish.

As noted above, the literature suggests that certain contaminants may affect the biology of salmonids. At present, regulatory thresholds are likely inadequate to account for these effects because some contaminants do not have established salmonid exposure or bioaccumulation criteria. Therefore, we expect the proposed action to have sublethal effects on listed salmonids as described above. We also anticipate green sturgeon to experience sublethal effects to the same or a greater extent than listed salmonids due to their year-round presence in the action area and dermal contact with sediment because of their benthic lifestyle. Sublethal effects may include behavioral (e.g., swimming, feeding, attraction-avoidance, and predator-prey interactions), physiological (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes.

Because of uncertainties regarding the contaminants present, however, and the concentration at these specific sites, there may be more appropriate specific measures that have not yet been defined. To address these uncertainties, Reclamation and DWR propose to work with NMFS to develop and implement a hazardous materials management plan with specific steps to monitor and measure contaminant level and type, address the containment of contaminants, and describe handling, storing, and disposing of contaminated sediments.

2.5.1.1.3.1 Pile Driving

Pile-driving activities at the north Delta diversion intake locations are described in Section 2.5.1.1.1.1 Pile Driving.

Pile driving has the potential to harm or harass salmonids and green sturgeon within the action area. Resuspension of sediments caused by pile driving may expose species to previously sequestered contaminants in the benthos, resulting in adverse effects to fish.

Although a number of compounds that may be acutely or chronically harmful to salmonids are likely present in the action area, their relative concentration is uncertain. Furthermore, the potential extent of exposure is limited. Observations and analysis of pile driving conducted in an environment similar to the Sacramento San Joaquin Delta indicate that very little resuspended sediment is generated from pile driving activities and that any potential impact is significantly less than background fluctuations in ambient water clarity over time (David Evans and Associates, Inc. 2012). Exposure to contaminants resuspended by pile driving associated with the PA is not expected to manifest as direct injury of or death to fish. Instead, it is likely that the effect of pile-driving-induced contaminant exposure will manifest as sublethal effects. Monitoring during construction activities that resuspend sediment will be important to ensure additional effects are not occurring.

2.5.1.1.3.1.1 North Delta Intake Locations

2.5.1.1.3.1.1.1 Species Exposure and Risk

Although exposure to contaminants as a result of pile driving at the NDD intake locations has potential to impact juvenile salmonids, it is not expected to result in injury or death. Also, even though timing of pile driving at NDDs (June 15 through October 31 – impact pile driving ending

September 15) will expose a much larger proportion of adult CCV steelhead and green sturgeon migrations, the likelihood of this level of sediment disturbance releasing contaminants is extremely unlikely. Any effects of contaminants in resuspended sediment during pile driving is expected to be limited to sublethal effects described above.

For construction at the NDD intake locations, small numbers of juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead are expected to occur at the margins of the in-water work window, which may cause those individuals to be exposed to resuspended contaminants caused by pile driving. In October, about 2 percent of juvenile winter-run-sized Chinook salmon are expected in the vicinity of the NDD intake locations, while in June less than 2 percent of spring-run sized Chinook salmon and about 1-2 percent of steelhead could be migrating past the intake locations. About 0.8 percent of a year's juvenile fall-run sized fish would be found near the NDD intake locations in June through October (DJFMP 2017). Juvenile late fall-run Chinook salmon are present in the Delta from July through January, with a peak in December. An estimate of the percentage of late fall-run juveniles affected has not been affected due to a lack of specific monitoring data on the numbers of late fall-run juveniles in the Delta.

Neither adult winter-run Chinook salmon nor spring-run Chinook salmon would be expected to be found in the vicinity of the NDD intake location during the in-water work window. Adult steelhead and green sturgeon may potentially be found within the Delta during any month of the year, and unlike Chinook salmon, steelhead and sturgeon can spawn more than once, so post-spawn adults have the potential to move back downstream through the Delta after completing their spawning in their natal streams. Typically, adult steelhead moving into the Sacramento River basin begin to enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to November. Adult fall-run Chinook salmon are expected to pass the NDD intake locations between July and December, with the peak of the migration in October. Adult late fall-run Chinook salmon enter the San Francisco Bay in October and may be present through March (Vogel and Marine 1991). The timing of the adult fall-run Chinook salmon, late fall-run Chinook salmon, CCV steelhead, and green sturgeon presence in the Delta has the potential to expose fish destined for the Sacramento River basin to contaminants resuspended during pile driving operations. NMFS therefore expects that increased contaminant exposure due to pile-driving activities at the NDD intake locations would adversely affect a small proportion of juvenile winter-run, spring-run, late fall-run, and fall-run Chinook salmon, steelhead, and green sturgeon.

2.5.1.1.3.1.2 Clifton Court Forebay

2.5.1.1.3.1.2.1 Species Exposure and Risk

Because continued operation of CCF includes potential entrainment of Chinook salmon into CCF during construction activities, there is the potential for adverse effects of resuspended contaminants to fish present during pile driving. With implementation of the AMMs and in-water work window (July 1 through October 31), however, the in-water construction activities would mostly result in temporary, localized increases in turbidity and suspended sediment, which is not likely to adversely affect fish.

Winter-run and spring-run Chinook salmon are not expected to be present during the work window, while less than 1 percent of fall-run Chinook salmon juveniles would be expected to be present July through October. Adult fall-run Chinook salmon will migrate through the action area from July through December. However, the San Joaquin River basin population, which is most likely to be present in waters adjacent to the CCF, represents < 1 percent of the entire Central Valley fall-run population. Juvenile late fall-run Chinook salmon will be present during July to November. Adult late fall-run Chinook salmon are not expected to be present during construction activities and therefore will not be exposed to contaminated sediments resuspended by pile driving.

Juvenile steelhead from both the Sacramento River basin via an open DCC gate and those emigrating downstream from the east side tributaries (Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries during the proposed in-water work window may be present in CCF during pile driving. Less than 1 percent of the annual juvenile emigration is expected to occur in the vicinity of the CCF during pile driving, however, because the majority of juvenile steelhead presence in the CCF location will occur from December through March, based on salvage at the CVP and SWP fish collection facilities.

Adult steelhead may potentially be found within the Delta during any month of the year. Typically, adult steelhead moving into the Sacramento River basin will enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. Steelhead entering the San Joaquin River basin are believed to have a later spawning run, with adults entering the system starting in September and peaking in December and January, indicating presence in the Delta a few weeks earlier. The timing of adult steelhead migration may potentially expose fish destined for either the Sacramento River basin or the San Joaquin River basin to contaminants resuspended by pile driving. Green sturgeon juveniles and sub-adults are also thought to be present in the southern Delta at any time of the year, potentially exposing those life stages to resuspended contaminants. The effects on a small proportion of adult and juvenile fall-run Chinook salmon, steelhead, and green sturgeon as well as juvenile late fall-run Chinook salmon would likely be limited to exposure to resuspended contaminants in the sediment plumes created by pile driving with the potential for sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.1.3 HOR Gate

2.5.1.1.3.1.3.1 Species Exposure and Risk

Contaminants released from resuspended sediment during pile driving at the HOR Gate are not expected to impact juvenile winter-run Chinook salmon, juvenile fall-run Chinook salmon, or juvenile steelhead, but may have a sublethal effect on exposed green sturgeon and those adult fall-run Chinook salmon and steelhead or yearling spring-run Chinook salmon migrating to or from the San Joaquin River basin. Late fall-run Chinook salmon are not expected to be present in the vicinity of the HOR gate because this area is far from any migration routes used by this run.

Construction activities at the HOR Gate will be limited to the in-water work window of August 1 through October 31, which will limit the potential for exposure to contaminants resuspended by pile-driving activities. Winter-run Chinook salmon, adult spring-run Chinook salmon, adult and juvenile late fall-run Chinook salmon, and juvenile fall-run Chinook salmon, and steelhead are not expected to be present during the in-water work window. NMFS assumes that potential San Joaquin River-basin spring-run Chinook salmon would exhibit similar emigration patterns to the Sacramento River basin populations, and, therefore, yearling smolt spring-run Chinook salmon may be present in the vicinity of the HOR gate in October, though likely in very few numbers.

Adult steelhead may potentially be found within the Delta during any month of the year. Adult steelhead from the Sacramento River basin typically will start to enter the Delta during mid to late summer with a peak in September and October. However, steelhead from the Sacramento River basin are not expected to be present in the southern Delta location of the HOR gate on Old River. Steelhead from the San Joaquin River basin typically arrive later and start entering the Delta in September and October with peak migration in December and January. Timing of adult steelhead migration may potentially expose fish destined for the San Joaquin River basin to the physical impacts of pile driving at the HOR gate location.

Rearing green sturgeon juveniles and sub-adults are also thought to be present in the southern Delta at any time of the year, potentially exposing those life stages to contaminants resuspended by pile driving at the HOR Gate. Adult green sturgeon are rare in the waters of the south Delta adjacent to the HOR Gate. Impacts caused by pile driving operations are minimized by the relatively small area influenced by the sediment plume. Therefore, NMFS expects that resuspension of contaminants from pile driving will adversely affect a small proportion of adult fall-run Chinook salmon, adult steelhead, yearling spring-run Chinook salmon, and juvenile, sub-adult, and adult green sturgeon, and would likely be limited to exposure to resuspended contaminants in the sediment plumes created by pile driving with the potential for sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.1.4 Barge Landing Locations

2.5.1.1.3.1.4.1 Species Exposure and Risk

Exposure to contaminants resuspended by pile driving during construction of barge landing locations is not expected to occur for juvenile and adult winter-run and spring-run Chinook salmon, adult late fall-run Chinook salmon, and juvenile steelhead, but may have a sublethal effect on exposed adult fall-run Chinook salmon, adult steelhead, and adult, juvenile, and sub-adult green sturgeon.

There are seven barge landing locations throughout the Delta, with an eighth landing potentially located adjacent to the NDD Intake 2 site if needed by the contractor. Construction at those locations will be limited to the in-water work window of July 1 through August 31, which will limit the potential for exposure to the activity.

At the barge landing locations, adult and juvenile winter-run and spring-run Chinook salmon, adult late fall-run Chinook salmon, and juvenile steelhead are not expected to be present during the in-water work window because it falls outside their migration period through the Delta. Adult steelhead from the Sacramento River basin typically will start to enter the Delta during mid to late summer with a peak in migration in September and October, potentially exposing a small proportion to pile driving activities. Steelhead from the San Joaquin River basin typically arrive later and start entering the Delta in September and October with peak migration in December and January, and therefore potential exposure will mostly be avoided. Adult fall-run Chinook salmon are expected to migrate through the Delta from July through December.

Timing of adult fall-run Chinook salmon and steelhead migrations has the potential to expose fish heading to either the Sacramento River basin or the San Joaquin River basin to contaminants resuspended by pile driving. Green sturgeon adults, juveniles, and sub-adults are potentially present in the Delta at any time of the year, which would expose that species to pile-driving-induced contaminants released from sediment at the barge landing locations. Exposure to contaminants resuspended by pile driving operations will be minimized by the relatively small area of effect.

NMFS expects that the activity will adversely affect a small proportion of adult fall-run Chinook salmon, adult steelhead, and green sturgeon, though likely limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.2 Barge Traffic

Barge operations, routes, and assumptions are described in Section 2.5.1.1.1.2 Barge Traffic. The locations of barge landings are described in Section 2.5.1.1.1.1.4 Barge Landing Locations.

The potential for large vessel operation to cause sediment disturbance and resuspension is described Section 2.5.1.1.3.1.4.1 Species Exposure and Risk.

Within the context of the proposed action, sediment disturbance because of barge operations will occur over a very broad area (San Francisco estuary and the Sacramento-San Joaquin Delta) and over an extended period of time (up to approximately 6 years). For some routes, barges will travel nearly 100 miles from San Francisco to the Port of Stockton and other barge landing locations.

While most of the route will be in open water with fairly deep dredged channels (e.g., shipping channels), barge landing locations in the Delta will require vessels to maneuver in confined, shallow waterways. It is expected that the passage of the barges and tugs coupled with the effects of the propeller jet during normal operations and docking could resuspend a significant amount of sediment material each year. Resuspension of material will occur during each passage of a vessel and barge. The potential for barge traffic to liberate and mobilize previously buried legacy contaminants is greatest in the confined channels of the Delta. Resuspension of sediments provides a mechanism to reintroduce toxic compounds into the current environment and spread them throughout a much larger area due to river and tidal flows. This will expose any fish present to any contaminated sediment existing in those waterways through resuspension.

Likewise, the benthic community, including any prey species for the listed fish species, will be exposed to a chronic source of potentially contaminated sediment, which can lead to enhanced bioaccumulation of the contaminant at higher levels of the food chain. It is anticipated that the entire food chain may exhibit the effects of exposure to contaminated sediments during resuspension ranging from sublethal to lethal responses.

2.5.1.1.3.2.1 Winter-run Exposure and Risk

Detailed timing and spatial occurrence of winter-run Chinook salmon presence has previously been described in Section 2.5.1.1 Construction Effects.

Barge traffic throughout the Delta and San Francisco estuary has the potential to expose the entire population of winter-run Chinook salmon to the resuspended sediments, which may include toxic compounds that can lower reproductive success. Barge traffic will overlap with migrations of juvenile and adult winter-run Chinook salmon throughout the 5 to 6 years of the projected construction schedule. The risk of winter-run Chinook salmon exposure is reduced compared to other species because only one proposed barge landing is located in the north Delta along the main winter-run Chinook salmon migration route and barge traffic is limited to the period between June 1 and October 31. From Chipps Island to the Golden Gate, barge traffic will overlap with the timing of a small proportion of the migratory periods of adult and juvenile winter-run Chinook salmon during June and October. The period between June 1 and October 31, in which barge traffic is allowed throughout the Delta, avoids the majority of winter-run migratory periods. During the main periods of winter-run Chinook salmon migrations, barge traffic is limited to the San Joaquin River between the Port of Stockton and Bouldin Island (November 1 through May 31). Overlap of barge traffic and the presence of winter-run juveniles and adults will occur in a small region of the Delta surrounding the confluence of the Mokelumne River and the San Joaquin River during this period.

The potential for increased contaminant exposure because of increased barge traffic will act as a stressor on winter-run Chinook salmon. Both adult and smolting juvenile winter-run Chinook salmon will be exposed to this stressor because of the spatial and temporal overlap of the increased barge traffic with winter-run migration at the locations and during the periods identified above. Therefore, NMFS expects that the contaminant exposure effects of barge traffic will adversely affect a small proportion of Sacramento River winter-run Chinook salmon though likely limited to sublethal effects of released contaminants, or through consumption of contaminated prey during their Delta migratory phase, particularly zooplankton or small invertebrates that reside in the areas affected by the barge traffic, described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.2.2 Spring-run Exposure and Risk

Detailed timing and spatial occurrence of spring-run Chinook salmon presence have previously been described in Section 2.5.1.1 Construction Effects.

Exposure of juvenile spring-run Chinook salmon in the Sacramento River migratory corridor will occur at the very beginning and end of the June 1 through October 31 period for early or late running fish when barge traffic is permitted on the Sacramento River. Exposure of both adult and juvenile spring-run will occur during the November 1 through May 31 period when barge traffic is limited to the San Joaquin River between the Port of Stockton and Bouldin Island. Spring-run Chinook salmon originating from the Sacramento River basin will have overlap with the barge traffic in the region adjacent to the confluence of the Mokelumne River and the San Joaquin River during this period when they are migrating. Adult and juvenile spring-run Chinook salmon from the San Joaquin River basin (progeny of the experimental population introduction) will overlap with barge traffic along the entire river reach from the Port of Stockton to Bouldin Island during the period from November 1 through May 31. If juvenile spring-run are present in June as young of the year or in October as yearlings, they could potentially overlap with barge traffic throughout the southern and central Delta.

The potential for increased contaminant exposure because of construction-related barge traffic will act as a stressor on spring-run Chinook salmon at the locations and during the periods described above. NMFS expects that the contaminant exposure effects of barge traffic will adversely affect a small proportion of spring-run Chinook salmon, though likely limited to sublethal effects of released contaminants, or through consumption of contaminated prey during their Delta migratory phase, particularly zooplankton or small invertebrates that reside in the areas affected by the barge traffic, as described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.2.3 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of juvenile and adult CCV steelhead presence has previously been described in Section 2.5.1.1 Construction Effects.

Because the barge traffic occurs long-term for the duration of the construction period, all emigrations of juvenile CCV steelhead and upstream and downstream migrations of adult CCV will overlap with the projected barge traffic operations during the 5 to 6 years of the projected construction schedule. The multiple barge landing locations are in the north Delta, central Delta, and south Delta, and thus occur on waterways that are occupied by both juvenile and adult life stages of CCV steelhead from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, adult life stages of CCV steelhead overlap with projected routes of the barge traffic from San Francisco.

Adult steelhead entering the Sacramento or San Joaquin River basins from June 1 through October 31 will overlap with barge traffic throughout the Delta and also within the waters of San Francisco Bay, San Pablo Bay, and Suisun Bay. Adult steelhead arriving in the Delta after November 1 will overlap with barge traffic only on the San Joaquin River between the Port of Stockton and Bouldin Island. Adult Sacramento River basin fish will have the potential to be exposed to barge traffic in the waters adjacent to the confluence of the Mokelumne River while moving upriver into the Georgiana Slough channel to access the Sacramento River. Adult fish destined for tributaries in the San Joaquin River basin will overlap with barge traffic in the mainstem portion of the river during the November 1 through May 31 period. The vast majority of juvenile steelhead from the Sacramento River basin will avoid barge traffic in the Sacramento River between June 1 and October 31 as few fish will be emigrating during this time period. There will be some overlap with barge traffic at the junction of the Mokelumne River and San Joaquin River between November 1 and May 31 for juveniles emigrating through the Georgiana Slough route to the western Delta. Juvenile steelhead from the San Joaquin River basin will overlap with barge traffic from the Port of Stockton to Bouldin Island during their emigration to the ocean since barge traffic operates year-round on this reach of river.

The potential for increased contaminant exposure due to increased barge traffic will act as a stressor on steelhead at the locations and during the periods described above. NMFS expects that the contaminant exposure effects of barge traffic will adversely affect a small proportion of CCV steelhead throughout the Delta, though likely limited to sublethal effects of released contaminants, or through consumption of contaminated prey during their Delta migratory phase, particularly zooplankton or small invertebrates that reside in the areas affected by the barge traffic, as described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.2.4 Green Sturgeon Exposure and Risk

The timing and spatial occurrence of sDPS green sturgeon presence has been generally described in Section 2.5.1.1.1.1 Pile Driving and characterized in further detail with specific regard to the exposure of green sturgeon to stressors emanating from long-term barge traffic throughout the action area in Sections 2.5.1.1.1.2.1.4 Green Sturgeon Exposure and Risk and 2.5.1.1.2.2.4 Green Sturgeon Exposure and Risk.

Because of the planned year-round frequency and extent of planned barge operations in the Delta, all juvenile sDPS green sturgeon rearing in the Delta and the annual migration of all spawning adult sDPS green sturgeon through the Delta will potentially be exposed to increased concentrations of contaminants released into the aquatic environment by barge traffic and the potential introduction of these contaminants into the food chain.

The degree to which any individual fish may be adversely effected by the increased exposure to contaminants, including selenium, resuspended by the movement of barges throughout the action area is difficult if not impossible to ascertain with any precision. Because of the frequency and duration of the expected exposure, however, and the probability of bioaccumulation through normal rearing and feeding behavior throughout the waters of the Delta, NMFS expects that a high proportion of spawning adult and rearing juvenile sDPS green sturgeon will be adversely affected by increased exposure to contaminants resuspended and released into the aquatic environment by way of continuous barge traffic moving throughout the action area for the duration of the construction period. Adverse effects are likely limited to sublethal effects, including reproductive effects, reduced survival, and stunted growth from released contaminants as described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.2.5 Fall/Late Fall-run Exposure and Risk

Detailed timing and spatial occurrence of fall and late fall-run Chinook salmon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving.

Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, while adult fall-run Chinook salmon enter the San Francisco Bay in June and immigrate through the north Delta from July through December (Vogel and Marine 1991), with a peak in October. Juvenile late fall-run Chinook salmon are present in the Delta from July through January. Adult late fall-run Chinook salmon emigrate through the Delta from October through March (Vogel and Marine 1991).

Exposure of juvenile fall-run Chinook salmon in the Sacramento River migratory corridor will occur at the very beginning of the June 1 through October 31 period (June through August) for late emigrating fish when barge traffic is permitted on the Sacramento River. Adult fall-run are expected to overlap with barge traffic in the Sacramento River from July through October, when barge traffic is permitted on the Sacramento River. Exposure of both adult and juvenile fall-run will occur during the November 1 through May 31 period when barge traffic is limited to the San Joaquin River between the Port of Stockton and Bouldin Island. This occurs due to the movements of some Sacramento River basin fish through the Georgiana Slough migratory route between the Sacramento River and the lower San Joaquin River. Fall-run Chinook salmon originating from the Sacramento River basin will have overlap with the barge traffic in the region adjacent to the confluence of the Mokelumne River and the San Joaquin River during this period when they are migrating. Adult and juvenile fall-run Chinook salmon from the San Joaquin River basin will overlap with barge traffic along the entire river reach from the Port of Stockton to Bouldin Island during the period from November 1 through May 31. During the remainder of the year, adult fall-run from the San Joaquin River basin will overlap with barge traffic from the Port of Stockton to the Golden Gate from July through October, including waters of the central and southern Delta surrounding the proposed barge landing sites.

Barge traffic will overlap with juvenile late fall-run in the Sacramento River migratory corridor from July through October, including the waters of the San Francisco Bay estuary. Starting in November, this overlap with barge traffic will be limited to the area surrounding the confluence of the Mokelumne River and the lower San Joaquin River. Adult late fall-run Chinook salmon will overlap in October with barge traffic on the Sacramento River and in the bays of the San Francisco estuary from Chipps Island to the Golden Gate. Starting in November, any barge traffic overlap with migrating adult late fall-run Chinook salmon will occur at the confluence of the Mokelumne River and San Joaquin River. Currently, there are no late fall-run populations known to exist in the San Joaquin River basin. Consequently, there should be no late fall-run Chinook adults moving upriver through the Delta into the San Joaquin River tributaries.

The potential for toxic compounds to become resuspended with disturbed sediment will increase due to barge traffic, providing an additional stressor to fall and late fall-run Chinook salmon. Because barges will be operating in locations that all Central Valley fall and late fall-run Chinook salmon adults and juveniles must pass through, the entirety of both adult and juvenile life stages may be exposed to increased contaminant concentrations caused by the PA barge traffic for the 5- to 6-year construction period.

A higher level of exposure is anticipated for fall-run Chinook salmon originating in the San Joaquin River basin because most barge traffic will use the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the main landing locations at Bouldin Island and CCF.

NMFS expects that the contaminant exposure effects of barge traffic will adversely affect a small proportion of fall-run and late fall-run Chinook salmon populations throughout the Delta due to the majority of juvenile emigrations occurring in the Sacramento River basin and at times when the barge traffic activity is limited to the San Joaquin. Any effects related to contaminant resuspension are likely limited to sublethal effects due to exposure, or through consumption of contaminated prey during their Delta migratory phase, particularly zooplankton or small invertebrates that reside in the areas affected by the barge traffic, described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.3 Geotechnical Analysis

Activities related to the geotechnical analysis proposed in and required for the PA are described in Section 2.5.1.1.2.3 Geotechnical Analysis.

Activities associated with geotechnical analysis can increase exposure to contaminants by multiple pathways. Sediments disturbed by the activities can potentially resuspend contaminated sediments that had been latent in settled sediments. The closed circulating system employed in the rotary drilling method and sampling protocols described in Section 2.5.1.1.2.3 Geotechnical Analysis, however, will reduce the likelihood that any contaminants potentially present in the soil horizons below the channel bottom would be introduced into the aquatic environment as a result of these operations. Also, during these activities, contaminants may be introduced to the aquatic environment from accidental spills of oil, gas, or hydraulic fluids associated with operating a barge or boat during overwater geotechnical investigations. Implementation of the following AMMs is expected to minimize the potential for introduction of contaminants to surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials.

- AMM1 Worker Awareness Training
- AMM2 Construction Best Management Practices and Monitoring
- AMM3 Stormwater Pollution Prevention Plan

- AMM4 Erosion and Sediment Control Plan
- AMM14 Hazardous Material Management
- AMM5 Spill Prevention, Containment, and Countermeasure Plan
- AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material
- AMM7 Barge Operations Plan
- HMMP Hazardous Materials Management Plan

2.5.1.1.3.3.1 Species Exposure and Risk

As described in Section 2.5.1.1.2.3 Geotechnical Analysis, during construction of the NDD, CCF, HOR, and barge landings, small numbers of juvenile salmonids (juvenile winter-run Chinook salmon, spring-run Chinook salmon, late fall- and fall-run Chinook salmon, and steelhead) are expected to occur at these locations during the margins of the in-water work windows, which may cause those individuals to be exposed to contaminants that are exposed or introduced during geotechnical exploration. Juvenile green sturgeons rearing in the Delta waters where these surveys are occurring will have a greater risk of exposure due to their year-round presence of the juveniles which overlaps with the planned period of geotechnical analyses (August 1 through October 31). No adult winter-run or spring-run Chinook salmon are expected to be present during these surveys, however adult steelhead and fall-run are expected to be present as the peaks of their upriver spawning migrations are occurring during the August 1 through October 31 in-water work window for geotechnical surveys. Few adult late fall-run Chinook salmon are expected to be present as the surveys are ending as their upstream migration is beginning. Small numbers of adult and sub-adult green sturgeon may be present during the August through October time period.

While there is potential for contaminants to be introduced to the aquatic environment from either the borings themselves or accidental spills of oil, gas, or hydraulic fluids, several measures—including AMMs, the closed circulating system of the rotary drilling method, and sampling protocols—make it highly unlikely that any contaminants potentially present in the soil horizons below the channel bottom would be introduced into the aquatic environment as a result of geotechnical analysis operations.

NMFS therefore expects that the contaminant exposure effects of geotechnical analysis will adversely affect a small proportion of juvenile steelhead and winter-, spring-, late fall-run and fall-run Chinook salmon. Adult winter- and spring-run Chinook salmon are not expected to be present and therefore the resuspension of contaminants due to geotechnical analysis will not adversely affect these fish. Few adult and sub-adult green sturgeon are expected to be present near the borings and only a small proportion of adult and sub-adult green sturgeon are expected to be exposed and adversely affected. NMFS expects that the exposure to resuspended contaminants due to geotechnical analyses will adversely affect a small proportion of adult steelhead, fall-run Chinook salmon adults, and juvenile green sturgeon due to the small amount of materials that might escape into the water column adjacent to any borings. Adverse effects would likely be limited to sublethal effects of released contaminants, or through consumption of contaminated prey during their Delta migratory phase, particularly zooplankton or small invertebrates that reside in the areas affected by the barge traffic, described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4 Dredging

As noted in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress, the proposed action includes dredging activities within the project construction area that can cause sediment disturbance.

Section 2.5.1.1.3 Contaminant Exposure indicates that disturbed sediment can mobilize and redistribute contaminants that were previously latent, exposing listed fish species. Measured sediment plumes from hydraulic dredging operations (Hayes et al. 2000) suggest that less than 0.1 percent of disturbed sediments and associated contaminants would likely be re-suspended during cutterhead dredging operations. Using a suction dredge in particular is expected to minimize to the point of insignificance any dispersion of resuspended contaminants released through the dredging process. Also, the potential release of contaminants from suspended sediment is expected to be limited because many of the chemical constituents preferentially adsorb or attach to organically enriched or fine particles of sediment. These heavier sediments are also expected to resettle to the bottom relatively quickly. Additionally, using a suction dredger will keep much of the re-suspended sediment and turbidity plume contained.

Implementation of BMPs and the following AMMs are expected to minimize the potential for introduction of contaminants to surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials:

- AMM2 Construction Best Management Practices and Monitoring;
- AMM4 Erosion and Sediment Control Plan;
- AMM5 Spill Prevention, Containment, and Countermeasure Plan;
- AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material.
- HMMP Hazardous Materials Management Plan

2.5.1.1.3.4.1 North Delta Diversion Intake Locations

Dredging activities associated with construction of the north Delta intakes and the potential for sediment disturbance at the NDD intake locations are described in Section 2.5.1.1.2.4.1 North Delta Intake Locations.

Not only can such disturbance potentially increase localized turbidity levels, but sediment resuspension can also expose latent contaminants. Proposed intake sites are downstream of the City of Sacramento where sediments have been affected by historical and current urban discharges from the city. No information on sediment contaminants at these sites is currently available.

It is assumed that after construction at the NDD intake locations is complete, the area in front of each intake will need to be dredged to provide appropriate flow conditions at the intake entrance. Current estimates indicate that total dredging and channel disturbance would affect 12.1 acres of dredging outside the cofferdams. If required, dredging will occur during the in-water work window of June 15 through October 31.

2.5.1.1.3.4.1.1 Chinook Salmon Exposure and Risk

The timing of the Chinook salmon presence has been described in Section 2.5.1.1 Construction Effects.

Limiting construction-related dredging activities at the NDD intake locations to the June 15 through October 31 work window is expected to minimize exposure to Chinook salmon species because:

- Juvenile winter-run Chinook salmon are expected to be present in the Delta from October to April, while adult winter-run are present in the Delta between November and June.
- Juvenile spring-run Chinook salmon are expected to be present in the Delta from November through May, with adult spring-run presence between January and March, with very few occurring in May and June.
- Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, with only small numbers present in July and August. Adults are present from July to December.
- Juvenile late fall-run Chinook salmon are expected to be present from July through September. Adult late fall-run Chinook salmon are expected to be present in the Delta from November through April.

Given the timing and location of in-water construction activities and that in some years a small proportion of the population may be migrating through the action area and be exposed, NMFS expects a very small proportion of juvenile winter- and spring-run and adult winter-run Chinook salmon, a small proportion of juvenile and adult fall-run Chinook salmon, and a small proportion of juvenile late-fall run Chinook salmon would be adversely affected. Any adverse effects are expected to be limited to sublethal effects of released contaminants, or through consumption of contaminated prey during their Delta migratory phase, particularly zooplankton or small invertebrates that reside in the areas affected by the barge traffic, described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.1.2 Steelhead Exposure and Risk

The timing of CCV steelhead at the NDD location has been described in Section 2.5.1.1 Construction Effects.

The in-water water work window overlaps with a substantial proportion of the adult upstream migration because adult steelhead start to enter the Delta region as early as June and peak presence is in September. Small numbers of adult CCV steelhead may continue to emigrate upriver through March.

Data from northern and central Delta fish monitoring programs (https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm), indicate that steelhead smolts begin to enter the northern Delta as early as September through December, but do not substantially increase in numbers until February and March. It is estimated that less than 1 percent of the annual juvenile steelhead population will pass during September and October.

Because construction-related dredging activities will overlap with most of the adult steelhead upstream migration period, NMFS expects that the increased contaminant exposure caused by dredging will adversely affect a small proportion of adult steelhead. Because most of the juvenile steelhead emigration occurs after the end of the dredging period, NMFS expects that increased contaminant exposure will only adversely affect a very small proportion of juvenile steelhead. Any adverse effects are expected to be limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.1.3 Green Sturgeon Exposure and Risk

Timing of green sturgeon presence has been described in Section 2.5.1.1.1 Acoustic Stress.

The in-water work window of June 15 through October 31 will avoid the peak upstream migration period of spawning adult green sturgeon (late February to early May), although both post-spawn adults and rearing juveniles may potentially be present in the vicinity of the north Delta near the proposed intake structures on the Sacramento River during any month of the year. Juvenile and post-spawn adult sDPS green sturgeon could therefore be present at the NDD location during the in-water work window and subject to exposure to any contaminants released to the aquatic environment by way of dredging throughout the construction period.

NMFS expects a few post-spawn adults and juvenile sDPS green sturgeon migrating or rearing in the Sacramento River during dredging activities to be exposed to slightly higher concentrations of contaminants. It is presently uncertain what specific contaminants might be exposed and resuspended as a result of dredging activities in the vicinity of the NDD locations. A more detailed analysis of potential constituents of concern will be possible following the proposed geotechnical investigations preceding actual dredging and construction activities at the NDD locations, but all evidence suggests that selenium will not be among the more prevalent and readily available contaminants for exposure and resuspension at these locations compared to other locations in the southern and western Delta. It is therefore unlikely that the reproductive fitness of spawning adults migrating past the NDD locations will be impaired as a result of increased selenium concentrations in the aquatic environment or the prey they consume. Juvenile green sturgeon are more vulnerable to the physiological effects associated with selenium exposure as they will be regularly feeding and in frequent contact with the bottom substrate as they emigrate through and rear in these areas, but because most of the contaminants released through dredging, including selenium, will be removed with the dredged material or otherwise contained, adverse effects will likely be limited to a small proportion of juvenile and post-spawn adult green sturgeon and limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.2 Clifton Court Forebay

Dredging activities associated with the construction at CCF and the potential for sediment disturbance are described in Section 2.5.1.1.2.4.2 Clifton Court Forebay.

Not only can such disturbance potentially increase localized turbidity levels, but sediment resuspension can also expose latent contaminants.

To minimize adverse effects of sediments releasing contaminants, dredged material will likely require disposal. Any sediments found to be suitable for use in constructing the new embankments within the modified CCF will be stockpiled within the construction area limits and reused. Unsuitable material will be disposed as described in AMM 6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material. In addition, the use of silt curtains to enclose the dredging operations is proposed. This action will minimize the amount of resuspended sediments released into the larger CCF waterbody by dredging operations, and thus reduce the exposure to contaminants associated with the resuspended materials.

Recognizing that design of these modifications is still in an early stage, DWR, Reclamation, NMFS, CDFW, and USFWS have agreed to ongoing collaborative efforts to ensure that final design and construction procedures for CCF minimize adverse effects to listed species to the extent practicable. Accordingly, representatives from each agency will participate in a Clifton Court Forebay Technical Team.

2.5.1.1.3.4.2.1 Chinook Salmon Exposure and Risk

Because continued operation of CCF includes potential entrainment of Chinook salmon into CCF during construction activities, there is the potential for adverse effects of resuspended contaminants to Chinook salmon present during the dredging component. This is limited, however, by the ambient water temperatures found in the south Delta during the majority of the in-water construction window, typically exceeding 20°C from July through September in most water years. Furthermore, the use of silt curtains to contain any resuspended sediment during dredging operations will minimize the movement of this material within the forebay and contain it within the silt curtain enclosure.

Extending in-water dredging activities into October results in the potential presence of juvenile spring-run Chinook salmon (yearling smolts), winter-run Chinook salmon (young-of-the year) and juvenile late fall-run Chinook salmon during dredging operations if upstream precipitation events stimulate early downstream migrations. San Joaquin River-basin spring-run Chinook salmon juveniles may also be present in October, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations. Less than 1 percent of fall-run Chinook salmon juveniles would be expected to be present during the work window. As stated previously, exposure is minimized by the use of silt curtains to contain the contaminated sediments should these materials be present and resuspended by dredging. Although there is some potential for exposure to contaminants, the adverse effects on a small proportion of adult and juvenile Chinook salmon would likely be limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.2.2 Steelhead Exposure and Risk

The timing of CCV steelhead at the Clifton Court location has been described in Section 2.5.1.1 Construction Effects.

It is expected that this water body will be accessible to both CCV steelhead juveniles from the Sacramento River basin via an open DCC gate and to fish emigrating downstream from the east side tributaries (Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries during the proposed in-water work window. The likelihood of fish from the Sacramento River being present, however, diminishes with distance from the main stem of the San Joaquin River.

Less than 1 percent of the annual juvenile emigration is expected to occur at the CCF during the proposed work window (July 1 through October 31). The majority of juvenile steelhead presence in the CCF location will occur from December through March, based on salvage at the CVP and SWP fish collection facilities. It is expected that the timing of adult presence at the CCF location will be later than that observed for the North Delta because of its southern Delta location and the likelihood that the majority of adult fish present are from the San Joaquin River basin population, which has a later peak in upstream migration compared to the Sacramento River basin population. Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta starting in September, with most of the population passing through the Delta from November to January. This slightly later upstream migration for San Joaquin River basin CCV steelhead overlaps from September through October with the proposed in-water work window.

Because dredging of CCF will occur only during the in-water work window (July 1 through October 31), it is expected that adult steelhead will be the predominant life stage affected by dredging in CCF due to the overlap in the dredging work window and the upstream migration of adult steelhead. Few juvenile CCV steelhead are expected to be affected by the dredging actions in CCF due to their later migration period.

Because most juvenile steelhead emigration occurs after the end of the dredging action, NMFS expects that the contaminant exposure effects of dredging at the CCF will adversely affect a small proportion of juvenile steelhead. Adult steelhead migration timing overlaps with the work window at CCF, especially given the extension to November for in-water work. Therefore, NMFS expects that the sediment effects of dredging at the CCF will adversely affect a small proportion of adult steelhead. The effects on adult and juvenile fish would likely be limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.2.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1.1.1.1.4 Green Sturgeon Exposure and Risk.

Although there is some uncertainty and variability associated with Delta residence time by life stage, spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year. Historical salvage records of green sturgeon at the Skinner and Tracy salvage facilities indicate a general peak in the summer months, although very few sturgeon have been encountered there in recent years (NMFS 2015a).

Adherence to the July 1 through October 31 in-water construction period will avoid the peak upstream migration period of adult green sturgeon transiting the action area (late February to early May) to upstream spawning habitats. Post-spawning adults, sub-adults, and juveniles may be present in the Delta during the late summer and fall months, however, and could therefore become exposed to increasing concentrations of contaminants released by dredging operations conducted in the CCF during the in-water construction period. A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon owing to their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats through the waters of the Delta.

Of particular concern to sDPS green sturgeon is the potential availability of the contaminant selenium to be released into the aquatic environment and bioaccumulated through the consumption of invertebrate prey species. Available evidence suggests that selenium may be more readily available in the vicinity of the CCF, but the degree to which this particular contaminant actually poses a threat in this regard won’t be entirely clear until after geotechnical investigations have been conducted to infer a profile of the sediment horizon prior to dredging and construction activities.

NMFS expects a small portion of post-spawning adults, sub-adult and juvenile sDPS green sturgeon migrating or rearing in the vicinity of CCF to be exposed to potential contaminants released from disturbed sediment during dredging activities conducted at the CCF. Most of those fish exposed will be sub-adult or juvenile life stages due to their prolonged rearing in the Delta, compared to the transitory use of Delta waters by post-spawning adults. However, since most of the contaminants released through dredging, including selenium, will be removed with the dredged material or otherwise contained, adverse effects are likely limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.3 HOR Gate

Dredging at HOR gate during construction is likely to result in mobilization of contaminants settled into the sediment into the water column, which may potentially adversely affect listed fish.

Dredging to prepare the channel for construction of the HOR gate will occur along 500 feet of channel, from 150 feet upstream to 350 feet downstream of the proposed gate location. A total of up to 1,500 cubic yards of material is expected to be dredged. Dredging will last approximately 15 days and will be performed within the August 1 through October 31 in-water work window for this location. Sediment mobilization may redistribute bound contaminants into Old River and the San Joaquin River downstream of the activity, and therefore any fish present may be exposed.

As described in Sections 2.5.1.1.2.4.1 North Delta Intake Locations and 2.5.1.1.3.4.1 North Delta Diversion Intake Locations, implementation of the appropriate BMPs and AMMs is proposed to minimize potential adverse effects on fish due to dredging.

2.5.1.1.3.4.3.1 Winter-run Exposure and Risk

The timing and spatial occurrence of juvenile and adult winter-run Chinook salmon has been described in Section 2.5.1.1 Construction Effects.

Juveniles are present in the Delta from October through April, while adults are present in the Delta from November through June. Because the HOR gate is on a distributary of the San Joaquin River far from the main winter-run Chinook salmon migration corridor (i.e., the Sacramento River), it is highly unlikely that winter-run Chinook salmon would be found in the vicinity of the gate. Also, the in-water work window for the HOR gate is August 1 through October 31, so the potential for dredging-induced release of contaminants is not expected to coincide with winter-run Chinook salmon presence. Given the timing and location of winter-run Chinook salmon presence and migration compared to the proposed in-water work window, NMFS expects that the potential for contaminant release from construction dredging at the HOR gate would not adversely affect winter-run Chinook salmon.

2.5.1.1.3.4.3.2 Spring-run Exposure and Risk

The timing and spatial occurrence of juvenile and adult spring-run Chinook salmon has been described in Section 2.5.1.1 Construction Effects.

Both San Joaquin River basin spring-run Chinook salmon adults and any straying adults from the Sacramento River basin will most likely already be staging for spawning in upriver locations by August and are not expected to be migrating through the activity area during the August 1 through October 31 work window. Although there is some uncertainty due to lack of monitoring data regarding the timing of outmigrating juvenile spring-run Chinook salmon in the San Joaquin River basin, NMFS assumes that these fish exhibit similar emigration patterns to the Sacramento River basin populations, and, therefore, yearling smolt spring-run Chinook salmon may be present in the vicinity of the HOR gate in October, though likely in very few numbers. NMFS therefore expects that any contaminants released in the resuspension of sediment and turbidity from construction-related dredging at the HOR gate will adversely affect a small proportion of spring-run Chinook salmon. Adverse effects are likely limited to sublethal effects of released contaminants (described above in Section 2.5.1.1.3 Contaminant Exposure).

2.5.1.1.3.4.3.3 Steelhead Exposure and Risk

The timing of CCV steelhead at the HOR gate location has been described in Section 2.5.1.1 Construction Effects.

In summary, juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Because dredging associated with constructing the HOR gate occurs from August 1 through October 31, and is expected to be completed over a 2-year period, only a minimal amount of temporal overlap with the presence of juvenile CCV steelhead is expected.

Based on regional monitoring data and salvage data from the SWP and CVP fish collection facilities (Reclamation 2017 (https://www.usbr.gov/mp/cvo); CDFW 2017 (ftp://ftp.dfg.ca.gov/salvage), less than 1-2 percent of the annual juvenile emigration from either basin is expected to occur during the proposed work windows. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location ((DJFMP found at: https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm), but their numbers appear to be considerably lower than those fish originating in the Sacramento River basin. It is not expected that juvenile steelhead from the Sacramento River basin will be present at the location of the HOR gate, even though juvenile CCV steelhead from this basin are present at the CVP and SWP salvage facilities.

Adult CCV steelhead from the Sacramento River basin begin to migrate upriver from the Delta in June, with increasing numbers of fish arriving from August through September, before tapering off in October and November. Peak migration (approximately 69 percent of annual run) occurs in September and October. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January; therefore, a small proportion may be exposed to dredging activities. Because most juvenile steelhead emigration occurs after the end of the dredging action, a small proportion of juvenile steelhead will potentially be exposed to resuspended contaminants, resulting in adverse effects. Adverse effects are likely limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.3.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving.

Although there is some uncertainty and variability associated with Delta residence time by life stage, juvenile and sub-adult sDPS green sturgeon may be present throughout the Delta during every month of the year, whereas spawning and post-spawn adults are unlikely to migrate through the waters of the south Delta because their principal migratory route between the ocean and upstream spawning habitats lies primarily in the Sacramento River and the channels of the north Delta. Because of the widespread and year-round presence of juvenile and sub-adult sDPS green sturgeon in the waters of the Delta, these life stages could be present in the vicinity of the HOR gate and could be exposed to resuspended contaminants in the water column during dredging operations conducted during the August 1 through October 31 in-water construction period.

As described in Section 2.5.1.1.3 Contaminant Exposure, green sturgeon are expected to be more vulnerable than salmonids to the negative effects of contaminants released during dredging activities because of their benthic-oriented behavior, which conceivably put them in closer proximity to the contaminated sediment horizon. Adverse effects could include physical injury, or physiological effects due to bioaccumulation of contaminated prey. Of particular concern to sDPS green sturgeon is the potential availability of the contaminant selenium to be released into the aquatic environment and bioaccumulated through the consumption of invertebrate prey species. Available evidence suggests that selenium may be more readily available in the vicinity of the HOR, but the degree to which this particular contaminant actually poses a threat in this regard won’t be entirely certain until after geotechnical investigations have been conducted to infer a profile of the sediment horizon prior to dredging and construction activities.

Given the likely presence of juvenile and sub-adult life stages of green sturgeon at the HOR gate location during the work window, NMFS expects that contaminants released during dredging at the HOR gate site, including selenium, will potentially expose a large proportion of juvenile and sub-adult green sturgeon. However, since most of the contaminants released through dredging, including selenium, will be removed with the dredged material or otherwise contained, adverse effects are likely limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure. Uncertainty as to which contaminants would be released, however, and at what levels, creates uncertainty as to the level of effect associated with this activity. Conducting geotechnical investigations before construction of the HOR gate, and monitoring as per the HMMP, is expected to provide up-to-date and site-specific contaminant profile information.

2.5.1.1.3.4.3.5 Fall/Late Fall-run Exposure and Risk

Fall-run Chinook Salmon

The timing and spatial occurrence of juvenile and adult fall-run Chinook salmon has been described in Section 2.5.1.1.1.1 Pile Driving.

Juvenile fall-run Chinook salmon do not occur in the Delta during the August through October construction window and are not likely to be exposed to contaminants released during construction-related dredging at the HOR gate location and are, therefore, unlikely to be adversely affected.

Adult fall-run Chinook salmon from the San Joaquin basin, or strays from the Sacramento River basin, will be immigrating to their natal spawning grounds from September through December. Given that the HOR gate construction site will be adjacent to the San Joaquin River, some immigrating adults will likely be in the construction area during the August through October construction period. Fall-run Chinook salmon adults are likely to be exposed to any increases of contaminants in the resuspended sediment because of PA dredging at the HOR gate.

Based on the temporal and spatial overlap between fall-run Chinook salmon adults and the short-term duration of dredging activities, NMFS expects that a small proportion of adult fall-run would experience any adverse effects from contaminants released into the water column during dredging at HOR gate. Any adverse effects would likely be limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

Late Fall-run Chinook Salmon

The timing and spatial occurrence of juvenile and adult late fall-run Chinook salmon has been described in Section 2.5.1.1.1.1 Pile Driving.

Late fall-run Chinook salmon occur in the Sacramento River basin, but are not currently known to occur in the San Joaquin River basin. While late fall-run Chinook salmon adult strays from the Sacramento River basin occur occasionally in the San Joaquin River near the HOR gate location, the likelihood of occurrence is low. Juvenile late fall-run Chinook salmon occur in the Delta from July through January, which overlaps with the August through October construction window at HOR gate. Any juveniles that move into the Old River may be adversely affected by any releases of contaminants due to dredging activities at the HOR gate, but numbers are likely very low. Any adverse effects would likely be limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.4 Barge Routes and Landings

As discussed previously in Section 2.5.1.1.2.4.4 Barge Routes and Landings, dredging associated with barge operations can be expected during the construction activity period of the proposed action.

Barge landings are distributed over a broad area of the Sacramento-San Joaquin Delta and thus will have a wide source of sediment and contaminant inputs. These will range from natural background sources based on local geology to inputs from agricultural sources or heavy industrialized port operations.

Sacramento-San Joaquin Delta barge routes will cover nearly 100 miles of waterways from San Francisco to the Port of Stockton and landing locations at the NDD intake location and CCF. While barge landings are in operation, it is assumed that precautionary spot dredging will occur to provide safe passage through the proposed routes to the barge landing sites and that these sites will be maintained to provide safe operating depths for barges and tug boats.

NMFS also assumes that the in-water work window for dredging activities associated with barge operations will be the same as that used for construction at the barge landings (July 1 through August 31). This work window is expected to minimize dredging exposure to fish. Furthermore, NMFS assumes that the suite of AMMs proposed for minimizing dredging impacts will be beneficial in reducing the exposure to dredging-related contaminant resuspension.

NMFS believes that the level of potential contaminants is related to the frequency of dredging operations in the location of future barge landing sites, as well as the nature of flushing flows found at those sites. In areas such as the NDD intake sites, strong riverine flows will flush most fine sediment and organic materials away from the site, leaving heavier mineral substrates such as sand. These larger sized particulate, mineral-based substrates have less propensity to sequester contaminants, particularly organic compounds, because they have less surface-area-to-volume ratios than finer sized materials such as silt and clays.

Conversely, in areas such as the central and south Delta barge landing locations, as well as Snodgrass Slough, where flushing flows are not as strong and sediment has accumulated along the banks, there is more potential for contaminants to have been sequestered in the sediment over time. These sediment deposits are typically comprised of fine-sized particulate matter such as silt, clays, or decayed organic matter. These sediments tend to have higher organic carbon levels than those areas where sand is the predominant sediment constituent and have much greater surface-area-to-volume ratios to which contaminants can undergo sorption to the surface of the sediment particle (Rand 1995). These areas often require frequent dredging due to accumulation of sediments as a result of quiescent hydraulics conditions. Such areas are at greater risk of contaminant deposition.

2.5.1.1.3.4.4.1 Chinook Salmon Exposure and Risk

Detailed timing and spatial occurrence of winter-run, spring-run, and fall/late fall-run Chinook salmon presence in the Delta has previously been described in Section 2.5.1.1 Construction Effects.

Limiting dredging activities of the PA within the Delta to the July 1 through August 31 work window is expected to minimize exposure to Chinook salmon, because:

- Winter-run Chinook salmon juveniles are present in the Delta from October through April, with about 2 percent of a year’s juveniles found in the north Delta starting in October (https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm). Based on the in-water work window and migration timing, juvenile winter-run are not expected to be present in the Delta during dredging and are not expected to be adversely affected. Adult winter-run Chinook salmon are present in the Delta from November through June, and, therefore, are not expected to be adversely affected.
- Spring-run Chinook salmon juveniles may be present in the north Delta from November to June. Adult spring-run Chinook salmon are present in the Delta from January to March, with very few occurring in May and June, as they begin to migrate upstream into the Sacramento River or San Joaquin River basin. Therefore, spring-run Chinook salmon are not expected to be adversely affected during dredging activities.
- Juvenile fall-run Chinook salmon occur in very low numbers in the Delta during the July through August construction window. Therefore, a very small proportion of this life stage expected to be exposed to dredging activities at barge landing locations and barge routes. The fall-run Chinook salmon adult immigration period for the Sacramento River basin (July through December) overlaps with the July through August dredging period. The San Joaquin River Basin fall-run Chinook salmon population has a slightly later migration period (September through December) and has little if any overlap in August with the proposed work window. Exposure to the Sacramento River fall-run Chinook

population occurs due to the alternative migratory pathways through the central Delta which include the Georgiana Slough migratory route to the Sacramento River, and the Mokelumne River migratory route through an open DCC gate near Walnut Grove to move upriver in the mainstem Sacramento River.

- Juvenile late fall-run Chinook salmon occur in the Delta from July through January, which overlaps with the July through August in-water work window for dredging. Juveniles are therefore likely to be exposed to dredging activities at barge landing locations and barge routes. The timing of adult immigration of late fall-run Chinook salmon (end of October through beginning of April) is not expected to overlap with the window for dredging at barge landings and routes.

NMFS therefore expects that exposures to contaminated sediments associated with dredging at barge landings and barge access routes are likely to occur for a small proportion of juvenile fall-run Chinook salmon, a large proportion of fall-run Chinook salmon adults, and a large proportion of late fall-run Chinook salmon juveniles. Adverse effects are likely limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.4.2 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of CCV steelhead presence in the Delta has previously been described in Section 2.5.1.1 Construction Effects.

The in-water water work window of July 1 through August 31 overlaps with a small proportion of the adult CCV steelhead upstream migration in the Sacramento River. As previously described for pile driving, adult steelhead start to enter the Delta region as early as June (0.2 percent of annual total based on catch per 100 trap hours) increasing to 1.8 percent in July and 12.1 percent in August for a cumulative total of ~14 percent for the in-water work window proposed for dredging. Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January; therefore, very few would be present as early as August in the central and southern Delta.

Data from the northern and central Delta fish monitoring programs (DJFMP found at: https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm) indicate that steelhead smolts begin to enter the northern Delta from the Sacramento River as early as September through December, but do not substantially increase in numbers until February and March. It is estimated that less than 1 percent of the annual juvenile steelhead population will pass through the Delta during September and October. The downstream migration of San Joaquin River basin steelhead smolts into the Delta peaks in April and May. Therefore, NMFS expects very few if any juvenile steelhead will be present in the Delta during the proposed in-water work window of July 1 to August 31 for dredging barge landings.

NMFS expects that a small proportion of adult CCV steelhead would be exposed to dredging activities during the July 1 to August 31 in-water work window. Although exposure is likely, adverse effects are likely limited to sublethal effects of released contaminants described above in Section 2.5.1.1.3 Contaminant Exposure.

2.5.1.1.3.4.4.3 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1.1.1 Pile Driving.

Spawning adults migrate through the Delta during the early spring, summer, and fall months, whereas juvenile and sub-adult sDPS green sturgeon are present throughout the Delta during every month of the year. Therefore, NMFS expects these life stages to be broadly exposed to any contaminants released from resuspended sediment during dredging operations (July 1 to August 31) associated with the barge landings and barge routes.

As described in Section 2.5.1.1.3 Contaminant Exposure, green sturgeon are expected to be more vulnerable than salmonids to the negative effects of contaminants, particularly selenium, released during dredging activities because of their benthic-oriented behavior, which conceivably put them in closer proximity to the contaminated sediment horizon. However, since most of the contaminants released through dredging, including selenium, will be removed with the dredged material or otherwise contained, adverse effects are likely limited to sublethal effects of released contaminants, but may also result in physical injury or physiological effects due to bioaccumulation of toxic compounds from the consumption of contaminated prey after dredging has occurred. Uncertainty as to which contaminants would be released, and at what levels, creates uncertainty as to the level of effect that might be associated with this exposure. Conducting geotechnical investigations at the barge landing locations and along routes is expected to provide up-to-date, site-specific contaminant profile information.

2.5.1.1.4 Increased Temperature

Water temperatures can be affected by a number of factors, including air temperatures, elevation, flow and velocity, and presence of riparian vegetation. Loss of riparian vegetation is likely to occur during clearing and grubbing activities at construction sites, including the NDD intake sites, barge landings, CCF, and HOR. It may also occur as an indirect effect of creating temporary access points to the river for construction.

Riparian vegetation, specifically shaded riverine aquatic (SRA) habitat, provides overhead cover, which results in shade and protection, increases large woody material recruitment, provides slower flow velocities for resting spots, and provides substrate for food production (such as aquatic and terrestrial invertebrates) for anadromous fish (Anderson and Sedell 1979; Pusey and Arthington 2003).

A vibrant riparian corridor provides important water temperature cooling, especially in smaller streams. The loss of riparian vegetation can therefore increase predation rates (see Section 2.5.1.1.6 Increased Predation Risk) and reduce food production and feeding rates for juveniles (see Section 2.5.1.1.5 Reduced Prey Availability). Also, anadromous fish juveniles may be exposed to increased water temperatures when the riparian corridor has been degraded, which may result in decreased growth and survival (Michel 2010; Michel et al. 2012; USFWS 1992).

2.5.1.1.4.1 Clearing and Grubbing at Construction Sites

Because loss of riparian vegetation is likely to occur during clearing and grubbing activities at construction sites, including the NDD intake sites, barge landings, CCF, and HOR, adverse effects to species may occur. Decreased riparian vegetation may also occur as an indirect effect of creating temporary access points to the river for construction. Some locations of cleared or cut riparian vegetation will be replaced with angular rock or a structure or facility and, therefore, will result in permanent loss. Other locations may be left to recolonize once construction activity has been completed, which may take one to five growing seasons depending on best management measures taken.

Although construction of the proposed project is likely to reduce riparian vegetation in the footprint of each new facility, the Sacramento River and Delta are wider, faster moving migration corridors for Central Valley anadromous fish, which are less likely to experience warming of water temperatures due to limited decreases in riparian vegetation. As the river channels become wider, a smaller fraction of the channel is affected by shading and the narrow riparian corridor found along those river banks. The volume of water present in the river channel will act as a thermal sink, having great inertia to temperature changes caused by shading along a narrow riparian zone. Temperature changes are more influenced by the greater surface area of exposed open water in the river channel, ambient air temperatures over those exposed areas, solar irradiation, and the influence of water layers mixing within the main river channel. Because any water temperature increases as a result of decreased riparian vegetation in these locations would be difficult to detect, fish species will likely not be adversely affected by changes in riparian vegetation coverage.

The acreage of effect for each structure, including areas located in designated critical habitat that could be affected by placement of permanent in-water structures, and the temporary areas of effect (i.e., areas that will only be affected during construction activities) were calculated and will be mitigated for through channel margin and tidal perennial habitat creation/restoration in the appropriate areas (see Appendix A2 Proposed Action).

Given the relative scale of permanent loss of riparian vegetation compared to the total abundance of vegetation in the immediate area, coupled with the habitat mitigation proposed as part of the PA, it is unlikely that the resultant loss of shading will lead to significant adverse impacts to listed species.

2.5.1.1.5 Reduced Prey Availability

One of the most important habitat attributes of the riverbed to listed anadromous fish species in the action area is the production of food resources for rearing and migrating juveniles, such as drifting and benthic invertebrates, forage fish, and fish eggs. Benthic invertebrates, such as oligochaetes and chironomids (dipterans), are the predominant juvenile salmonid and sDPS green sturgeon food items produced in the silty and sandy substrates of the action area. Although specific information on food resources for green sturgeon within freshwater riverine systems is lacking, they are presumed to be generalists and opportunists that feed on similar prey to other sturgeons (Israel and Klimley 2008), such as the population of white sturgeon present and coexisting with green sturgeon in the Sacramento basin. Seasonally abundant drifting and benthic invertebrates have been shown to be the major food items of white sturgeon in the lower Columbia River (Muir et al. 2000). As sturgeons grow, they begin to feed on oligochaetes, amphipods, smaller fish, and fish eggs as represented in the diets of white sturgeon (Muir et al. 2000).

Contaminants may impact food sources, which can result in bioaccumulation of contaminants from feeding on them, adversely affecting anadromous fish (see previous discussion in

Section 2.5.1.1.3 Contaminant Exposure). In this section, we discuss how disturbance of the riverbed is likely to occur during construction of the PA through pile-driving activities, barge traffic, geotechnical analysis, dredging, and clearing and grubbing, which has the potential to reduce prey availability for anadromous fish species in the action area. The activity resulting in the largest disturbance is through dredging, which has the potential to entrain and thereby remove populations of small demersal fish and benthic invertebrates from the channels within the action area, which represents a loss of the forage base to outmigrating juvenile salmonids and rearing green sturgeon.

The loss of benthic food resources, such as amphipods or isopods, could reduce fish growth rates and increase the energy expended searching for food, depending on the density of the animal assemblages on the channel bottom and the benthic invertebrate population recovery rate, which can be months to years (McCauley et al. 1976; Oliver et al. 1977; Currie and Parry 1996; Tuck et al. 1998; Watling et al. 2001).

Impacts from loss of food resources within the action area are more likely to occur to green sturgeon, which are specialized benthic feeders, but also may affect juvenile salmon and steelhead. NMFS expects that small invertebrates—such as annelids, crustaceans (amphipods, isopods), and other benthic fauna—would be unable to escape the suction of a hydraulic dredge and be lost to the system. Also, many benthic invertebrates have pelagic, surface-oriented larvae. Therefore, the loss of these benthic invertebrates may reduce the abundance of localized zooplankton populations in the upper regions of the water column where juvenile salmonids migrate through the Delta.

The time needed to fully recolonize the disturbed channel bottom is unknown and further complicated by the variable frequency and timing of channel bottom disturbances, as well as the various reach locations where these disturbances are likely to occur. The variable cycles of channel bottom disturbances in the particular activity area between June 15 and October 31 in any given year may preclude replacement of the forage base through recruitment from surrounding areas before the onset of the following winter and spring migration period of anadromous fishes through the action area (Nightingale and Simenstad 2001) and will likely pose a barrier to the re-establishment of a natural climax of benthic invertebrate assemblage in any specific reach, throughout the construction period.

As these organisms occupy habitat types that are prone to disturbance under natural conditions, however, they would likely recolonize these areas fairly rapidly by drifting and crawling from adjacent non-disturbed areas (Mackay 1992; Nichols and Pamatmat 1988). There are no indications as to what the species richness or diversity of the recolonizing community might be within the action area, however, or the proportion of native to invasive species in the resulting community structure and the nutritional value of those prey resources to listed anadromous fish species.

Overall, reduced prey availability in the migration and rearing habitats of listed anadromous fishes may impact the viability of those populations by increasing stress and reducing the overall fitness of individuals migrating through or rearing in the Delta. Furthermore, nutritional deficiencies and reduced fitness of individuals may result in an abbreviated residence time in the waters of the Delta, stunted growth rates, and diminished resiliency for survival in the ocean, in addition to the potential for increased susceptibility to disease, contaminants, predation, entrainment, and other project-related effects that are likely to be compounded by exposure to multiple stressors during their residence in and migration through the action area.

2.5.1.1.5.1 Pile Driving

Pile driving has the potential to harm or harass salmonids and green sturgeon within the action area. The ways in which pile driving can affect species are through pile-driving-induced acoustic stress (see Section 2.5.1.1.1 Acoustic Stress), the resuspension of sediments and associated turbidity (see Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress), the exposure to contaminants previously sequestered in the benthos (see Section 2.5.1.1.3 Contaminant Exposure), and the increased exposure to potential predators (see Section 2.5.1.1.6.1 Pile Driving). The disturbance to the environment (benthos and water column) caused by pile driving may also impact fish through a reduction in the availability of prey species.

Overall, there is little evidence to suggest that pile-driving activities will affect the availability of anadromous fish prey species in the short term. And while it has been shown that hydraulic pile driving used in dock construction has the potential to significantly alter the long-term sediment grain size composition, which may in turn affect epibenthic faunal assemblages, stomach content analysis of juvenile salmon caught in Puget Sound indicate that most fish continue to feed successfully near pile driving operations (Feist et al. 1996). Furthermore, the effect of pile driving on prey availability is expected to manifest in a way similar to that of other anthropogenic waves where chronic, long-term disturbance would be expected to have a negative impact (Bishop 2004), but short-term disturbances could have a beneficial effect of increasing prey availability (Gabel et al. 2011) through resuspension. Lastly, the potential extent of exposure is expected to be limited as observations and analyses of pile driving conducted in an environment similar to the Sacramento San Joaquin Delta indicate that very little sediment, resuspended by pile driving, is observable (Dave Evans and Associates 2012), meaning any potential impact to prey availability would be expected to be minimal as well.

2.5.1.1.5.1.1 Species Exposure and Risk

The spatial extent of listed species occurring contemporaneously with pile driving operations has been described previously (see Section 2.5.1.1 Construction Effects) and, for the most part, Chinook salmon are not expected to be present during pile driving operations. Species that have the potential to be present year-round (for example, steelhead and green sturgeon) and small numbers of Chinook salmon found at either end of the in-water work window in some years could be present during pile driving operations. Given the extremely small spatial extent of effect, however, with regard to prey availability, NMFS expects that pile-driving operations effect on prey species will not adversely affect—and may even have a minor, short-term beneficial effect—on winter-run Chinook salmon, spring-run Chinook salmon, fall/late fall-run Chinook salmon, CCV steelhead, and green sturgeon.

2.5.1.1.5.2 Barge Traffic

Vessel traffic and the associated wake will act to resuspend infauna and detach invertebrates from hard surfaces and aquatic flora (Fleit et al. 2016), which have been shown to have a varying degree of effect on prey availability. Chronic disturbance caused by long-term exposure to anthropogenic waves will result in decreasing assemblages of macrobenthic infauna and altered community structure (Bishop 2004), which may result in decreased growth and survival of anadromous fish. Alternatively, the proximate effect, immediately post-disturbance, will be to increase prey accessibility and foraging success as benthic invertebrate prey species are exposed and resuspended in the water column (Gabel et al. 2011).

2.5.1.1.5.2.1 Species Exposure and Risk

The spatiotemporal extent of barge traffic is described in Section 2.5.1.1.1.2 Barge Traffic.

In summary, over the course of the 5 to 6 years of construction of the tunneled conveyance and other facilities, it is projected that up to 9,400 barge trips (18,800 one way trips) may be added to the daily vessel traffic over a very broad area (San Francisco estuary and the Sacramento-San Joaquin Delta). Considering that this increase in barge traffic will be long-term, all salmonids and green sturgeon utilizing the Delta are expected to be exposed to the increased vessel traffic and its effect on prey availability.

Because most of the barge traffic will be using the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the primary landing sites at Bouldin Island and the CCF, those species or runs originating in the Sacramento River basin will have a reduced exposure compared to those entering the Delta from the San Joaquin River.

That said, all species must pass through the western Delta and the waterways leading to the ocean where they will have some level of exposure to increased barge traffic through the Delta and San Francisco Estuary, as well as within the main river channels of the Sacramento and San Joaquin Rivers for populations that originate in those respective river basins or utilize them during parts of their life history. With regard to prey availability, NMFS expects that barge traffic will not adversely affect and may even have a minor, short-term beneficial effect on winter-run Chinook salmon, spring-run Chinook salmon, fall/late fall-run Chinook salmon, and steelhead. Juvenile, sub-adult, and spawning adult green sturgeon are expected to also benefit from short term increases in prey accessibility due to anthropogenic disturbances related to increased barge traffic. Finally given the large area of the Delta overall, as compared to the areas that will have demonstrable impacts from increased vessel traffic and vessel induced disturbances of the sediment and shorelines where prey communities might be altered, adverse effects are not anticipated as fish can move short distances to find areas with undisturbed prey communities to support their foraging.,.

2.5.1.1.5.3 Geotechnical Analysis

Activities associated with the geotechnical analysis to be conducted as part of the PA are described in detail in Section 2.5.1.1.2.3 Geotechnical Analysis.

These activities include approximately 90 to 100 overwater geotechnical borings and cone penetration tests to be drilled in the Delta waterways during the designated in-water work window over several years. By their nature, these activities will disturb and remove a small portion of the river bed and, therefore, have the potential to effect the benthic infauna, including species common in the diet of salmonids and sturgeon. The extent and area of effect is expected to be extremely small, however, because the conductor casing of each boring will only be about 8 in. in diameter. Multiplied by the number of cores taken (90-100), the total area of sediment removal is expected to be at most 17.5 square feet. And although the drill operates by pumping fluid through the material to be removed, the effect to the surrounding environment will be minimal as the drilling fluid remains within the closed system of the conductor casing and recirculation tank.

2.5.1.1.5.3.1 Species Exposure and Risk

The spatial and temporal extent of species has been described previously (see Section 2.5.1.1 Construction Effects) and, for the most part, Chinook salmon are not expected to be present during geotechnical analysis operations. Species that have the potential to be present year-round (for example, steelhead and green sturgeon) and small numbers of Chinook salmon found at either end of the in-water work window in some years could be present during the geotechnical analysis. Given the extremely small area of effect and the small likelihood of disturbance outside of the removal area, however, NMFS expects that there would not be an appreciable reduction in prey availability caused by the geotechnical analysis and that it will not have an adverse effect on winter-run Chinook salmon, spring-run Chinook salmon, fall/late fall-run Chinook salmon, CCV steelhead, and green sturgeon.

2.5.1.1.5.4 Dredging

As noted in Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress, the proposed action includes dredging activities within the project construction area that can cause sediment disturbance. Section 2.5.1.1.2.4 Dredging describes the extent of the activity.

As noted in Section 2.5.1.1.5 Reduced Prey Availability, dredging may potentially reduce the benthic forage base to listed fish species. Reine and Clark (1998) estimated that the mean entrainment rate of a typical benthic invertebrate, represented by the grass shrimp, when the cutterhead of the dredge was positioned at or near the bottom, was 0.69 shrimp per cubic yard, but rose sharply to 3.4 shrimp per cubic yard when the cutterhead was raised above the substrate to clean the pipeline and cutterhead assembly. Likewise, benthic infauna, such as clams, would be entrained by a suction dredge in rates equivalent to their density on the channel bottom because they have no ability to escape (Larson and Moehl 1990; McGraw and Armstrong 1990).

Dredging activities associated with the PA are expected to have an effect on benthic prey availability and, to a lesser extent, prey availability in the water column. This disturbance could have an appreciable impact on the prey base at any given location, but the effect will be experienced over a limited area relative to the available habitat. Additionally, this effect is expected to occur for a short duration in a given year due to recolonization from locations in close proximity to the area of disturbance.

2.5.1.1.5.4.1 Salmonids Exposure and Risk

The spatial extent of listed species occurring contemporaneously with the dredging activities has been described previously (see Section 2.5.1.1 Construction Effects) and, for the most part, Chinook salmon are not expected to be present during dredging operations. Small numbers of Chinook salmon could be present, however, at either end of the in-water work window in some years. A larger proportion of steelhead would be present during dredging and could, therefore, be exposed to habitat that contains reduced prey. Given the extent of the activity, NMFS expects that the reduced prey availability caused by dredging will adversely affect a small proportion of winter-run Chinook salmon, spring-run Chinook salmon, fall/late fall-run Chinook salmon, and CV steelhead.

2.5.1.1.5.4.2 Green Sturgeon Exposure and Risk

The timing of green sturgeon presence has been described in Section 2.5.1.1.1 Acoustic Stress.

The in-water work windows avoid the peak upstream migration period of green sturgeon (late February to early May) although both post-spawn adults and rearing juveniles may be present in the action area throughout the year.

Dredging activities associated with in-water construction of all PA components are expected to have an effect on benthic prey availability for green sturgeon. The loss of benthic food resources, such as amphipods or isopods, could reduce fish growth rates and increase the energy expended searching for food, depending on the density of the animal assemblages on the channel bottom. This would be more likely to occur to sturgeon, which are specialized benthic feeders. NMFS believes that small invertebrates—such as annelids, crustaceans (amphipods, isopods), and other benthic fauna—would be unable to escape the suction of the hydraulic dredge and be lost to the system.

Radtke (1966) inspected the stomach contents of juvenile green sturgeon (range: 200–580 mm) in the Delta and found food items to include mysid shrimp (*Neomysis awatschensis*), amphipods (*Corophium* sp.), and other unidentified shrimp. In the northern estuaries of Willapa Bay, Grays Harbor, and the Columbia River, green sturgeon have been found to feed on a diet consisting primarily of benthic prey and fish common to the estuary. For example, burrowing thalassinid shrimp (mostly *Neotrypaea californiensis*) were important food items for green sturgeon taken in Willapa Bay, Washington (Dumbauld et al. 2008). Populations of these organisms would be entrained by the hydraulic suction dredge, particularly small demersal fish and benthic invertebrates.

Repeated activities throughout the multi-year construction period may also delay or impair recruitment from surrounding areas before the following winter and spring migration periods through the action area. As these organisms occupy habitat types that are prone to disturbance under natural conditions, however, they would likely rapidly recolonize dredged areas by drifting and crawling from adjacent non-disturbed areas (Mackay 1992).

Dredging activities are expected to affect prey availability for green sturgeon throughout the Delta. This disturbance could have a significant impact to the prey base at any given location, but the effect will be experienced in a limited area relative to the available habitat surrounding each identified dredging location and for a relatively short duration. Additionally, suitable alternative feeding locations are likely within close proximity to the area of disturbance. Dredging activity occurrence and the associated disturbance of the existing benthic community, however, will cause an adverse effect to green sturgeon. Given the certainty and extent of the activity, NMFS therefore expects that the reduced prey availability caused by dredging will adversely affect a medium proportion of green sturgeon.

2.5.1.1.5.5 Clearing and Grubbing at Construction Sites

Clearing and grubbing at construction sites is expected to result in some loss of riparian vegetation, including the NDD intake sites, barge landings, CCF, and HOR gate. Loss of riparian vegetation may also occur as an indirect effect of creating temporary access points to the river for construction. Some locations of cleared or cut riparian vegetation will be replaced with angular rock, or a structure or facility, and therefore will result in permanent loss of riparian vegetation. Other locations may be left to recolonize once construction activity has been completed, which may take one to five growing seasons depending on best management measures taken.

Riparian vegetation, specifically shaded riverine aquatic (SRA) habitat, provides overhead cover, resulting in shade and protection, slower flow velocities for resting spots as well as providing substrate for food production such as aquatic and terrestrial invertebrates for anadromous fish. A vibrant riparian corridor provides important water temperature cooling, especially in smaller streams. The loss of riparian vegetation can therefore increase predation rates (see Section 2.5.1.1.6 Increased Predation Risk) and increase water temperatures, which may result in decreased survival (see section 2.5.1.1.4 Increased Temperature). Additionally, a degraded riparian corridor may reduce food production and feeding rates for juvenile and adult anadromous fish.

The acreage of effect for each structure, including areas located in designated critical habitat that could be affected by placement of permanent in-water structures, and the temporary areas of effect (i.e., areas that will only be affected during construction activities) were calculated and will be mitigated for through channel margin and tidal perennial habitat creation/restoration in the appropriate areas (see Appendix A2 Proposed Action).

Given the relative scale of permanent loss of riparian vegetation compared to the total abundance of vegetation in the immediate area, coupled with the habitat mitigation proposed as part of the PA, NMFS expects that construction-related riparian vegetation removal resulting in reduced prey in these areas will adversely affect a small proportion of juvenile salmonids and green sturgeon.

2.5.1.1.5.5.1 Species Exposure and Risk

Species spatial and temporal extent has been described previously in Section 2.5.1.1 Construction Effects. Although loss of riparian vegetation at construction sites may reduce food inputs of aquatic or terrestrial invertebrates for fish, the extent is expected to be minimal. Because all migrating fish feed during their transition through the Delta, they rely on a forage base for sustaining their migration. Additionally, benthic production relies in part on terrestrial and nearshore riparian production for nutrients which form part of the food web for scrapers, collectors, and filter feeders in the benthic invertebrate assemblage. NMFS expects that construction-related riparian vegetation removal resulting in reduced prey in these areas will adversely affect a small proportion of juvenile salmonids and green sturgeon.

2.5.1.1.6 Increased Predation Risk

Predator-prey interactions can be broken down into several fundamental steps between the prey and the predator. These steps include the rates of encounters between the predator and the prey, the rate at which the predator decides to pursue and attack the prey when detected, the rate at which the predator successfully captures the prey, and, ultimately, the rate at which the prey is consumed by the predator.

Each one of these steps is influenced by biological and physical factors in the surrounding environment such as prey abundance, spatial and temporal overlap of prey with the predator, habitat complexity, turbidity, and behavioral, physiological, and morphological adaptations that facilitate (predator success) or inhibit (prey avoidance) the predation process (Grossman et al. 2013, Grossman 2016). Although predation is frequently the proximate cause of mortality, the ultimate cause of mortality is often related to alterations in the physical or biological parameters of the habitat that prey occupy that enhance the rate of predation.

Predators and prey are affected by the habitat they occupy, which in turn influences the predator-prey interaction. First, predators and prey both partition habitat, which affects the rate of contact between predator and prey (the search and encounter rate). Secondly, habitat characteristics exert a direct effect on predator-prey behavior and interaction, primarily by reducing prey detection and improving the ability of prey to escape attack once detected by the predator (pursuit and attack rate) (Monroe 1997). Species partition the available habitat according to their intrinsic needs in response to their ability to use a variety of environmental conditions. Such environmental conditions include (Monroe 1997):

- Food availability for both predator and prey,
- Spawning habitat conditions,
- Availability of cover,
- Bottom substrate,
- Water depth,
- Distribution based on time of day and light conditions,
- Temperature and salinity preferences, and
- Water quality conditions (i.e., dissolved oxygen, pH, etc.).

Habitat also influences the behavior and survival of predators. Monroe (1997) states that habitat affects the behavior of predators primarily by:

- Separating predators and prey (habitat partitioning),
- Limiting visual contact between predator and prey, and
- Making a successful attack more difficult for predators than a successful escape by prey.

Locating prey appears to be primarily a visual function in most piscine predators (Dunbrack and Dill 1984), although there are other sensory forms that have been observed in prey detection (for example, olfaction in catfish, electrosensory detection in sharks). Because prey detection, particularly for predators common in the Delta and Central Valley waterways—such as striped bass, pike minnow, and largemouth bass—is most often a function of visual contact, any habitat characteristics that affect vision could be considered “cover” for prey species (Monroe 1997). Therefore, cover may include:

- Turbidity and shade, which limit light penetration,
- Vegetation and other physical structures that interrupt the line-of-sight from predator to prey, and
- Background color or texture that “masks” or conceals the prey from detection by the predator.

Because predators also vary in their physiology, protection conferred by one form of habitat may make prey vulnerable to another predator species. For example, avoiding heavily vegetated channel margins (e.g., Egeria beds) and remaining in open water may confer protection on prey species from ambush predators (e.g., largemouth bass), but makes them more vulnerable to attacks by a chase predator suited for open water habitat (e.g., striped bass).

Just as habitat affects the ability of prey to survive, habitat qualities also affect the success of predators to detect or capture prey and may include (Monroe 1997):

- Density and extent of structures that affect both detection and success of predator attacks,
- Presence of barriers—such as dams with fish ladders, gates, or other structures—that can concentrate prey and predators and thus increase predator-prey contact rates,
- Light, which affects prey detection,
- Turbidity, which affects detection distance of prey,
- Prey behavior such as schooling, swimming speed, or choice of habitat,
- Temperature, which affects the activity level of both predator and prey, and
- Stressors, such as contaminants, that can reduce prey growth rate (which keeps prey at a more vulnerable size for a longer period of time) or slows the response time and swimming speed of prey (and therefore reduces the ability of prey to escape).

Finally, because fish are highly adaptable, the response to habitat changes and quality are not always straightforward and linear and thus may not always be completely predictable, particularly on a shorter time scale. In general, though, habitat that is complex and offers a multitude of different niches provides for a more diverse biological community (Grossman et al. 2013, Grossman 2016).

In a stable, undisturbed, functioning habitat, multiple species can occupy the same general area by each species occupying a particular ecological niche, thereby minimizing direct competition between species and having a balanced predator-prey interaction. This is particularly true in habitats where predators and prey have co-evolved with each other. This relationship does not exist or is compromised when habitat is altered or nonnative species invade a new habitat, causing a loss of equilibrium among the species inhabiting it.

The Delta and Central Valley waterways are currently highly altered and disturbed habitats. In the aquatic ecosystems of the Central Valley and Delta waterways, widespread habitat alteration has occurred over the last 150 years including (Vogel 2010, Cloern and Jassby 2012, Demetras et al. 2010, Sabal el al. 2016, Wiens et al. 2016):

- Numerous invasions by non-native species that alter physical habitat and food webs,
- Alterations of hydrologic regimes, temperature regimes, and turbidity levels,
- Loss of wetlands and riparian areas,
- Anthropogenic changes in regional waterways due to physical structures such as levees, dams, channelized waterways, and water diversions, which in combination result in changed hydrodynamics and ambient flows,
- Discharge of toxins, nutrients, and other contaminants, and
- Changes in climate affecting precipitation patterns and temperatures.

The PA will create numerous alterations to the local aquatic habitat that will modify the predator–prey interaction in favor of the predator. The PA will modify existing hydrodynamics, turbidity, riparian and littoral areas at the construction sites and introduce novel elements such as noise and vibration into the adjacent waterways.

Examples of habitat modification created by the PA actions include the following:

- Reduction in sediment load in the Sacramento River due to the NDDs, which will impact turbidity levels farther downstream in the tidally mixed area, thus increasing the detection distance of prey by predators,
- Increased noise and activity along the margins of the river channels due to construction activities that may force prey to abandon the shoreline habitat and occupy the open water habitat in the construction areas, thus making them more vulnerable to predators,
- Increases in ambient noise levels due to construction activities that may mask the approach of predators, reducing the ability of prey to avoid attacks,
- Increases in local turbidity levels to high levels due to bank construction activities or dredging that may force prey from their preferred habitat into more risky environments, increasing the vulnerability to predator detection,
- Construction of large in-water structures as part of the PA that may attract predators or concentrate prey and predators into confined spaces, thereby increasing the likelihood and duration of predator-prey interactions,
- Alterations of ambient flows or circulation patterns that may increase the length of predator-prey interactions due to slower migration rates or disorient prey thereby making them more vulnerable to attack, and
- Reduction of shoreline cover, riparian areas, and submerged vegetation, thereby increasing the vulnerability to detection by predators.

2.5.1.1.6.1 Pile Driving

Pile driving is expected to create environmental conditions that may cause fish to be:

- Injured due to barotrauma brought on by high levels of sound pressure related to the pile-driving actions, thereby altering the fish's swimming ability and behavior and making them more noticeable to predators and less likely to successfully avoid predator attacks.
- Less able to detect the approach of a predator by masking the sounds of the predator with elevated ambient noise levels directly related to the pile-driving actions.
- Distracted and direct its attention away from the approach of a predator in its surroundings and thus compromise its ability to successfully avoid a predatory attack.
- More likely to avoid nearshore areas adjacent to pile-driving activities and migrate through areas of deeper water with less areas of refugia from predators, thereby increasing their visibility to predators and increasing their risk of predatory attacks by open water predators.

2.5.1.1.6.1.1 North Delta Intake Locations

Pile driving and associated anthropogenic noise at the NDD locations (see Section 2.5.1.1.1.1.1 North Delta Intake Locations for details) are expected to increase predation risks to juvenile salmonids and green sturgeon present during the in-water work window, June 15 through October 31.

2.5.1.1.6.1.1.1 Chinook Salmon Exposure and Risk

Pile driving and associated anthropogenic noise at the NDD locations is expected to increase predation risk to juvenile salmonids. Small numbers of juvenile SR winter-run Chinook salmon, CV spring-run Chinook salmon, and fall-run Chinook salmon may be present at either end of the in-water work window in some years, in addition to a large number of late fall-run Chinook salmon, which may delay the migrations of those individuals and which may expose individuals to pile-driving-induced noise and an associated increase in predation risk.

In October, less than 2 percent of juvenile SR winter-run Chinook salmon are expected to be found in the vicinity of the NDDs, while in June less than 1 percent of juvenile CV spring-run Chinook salmon could be migrating past the NDD locations. Beach seine and trawl data from the last 10 years (2006 through 2015 found at: https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm) indicate that less than 1 percent of juvenile fall-run Chinook salmon would be found near the NDD project sites in June through October. A small proportion of winter-run, spring-run, and fall-run Chinook salmon juveniles, and a large proportion of late fall-run Chinook salmon juveniles present are expected to be adversely effected through the increased risk of predation caused by pile driving in the vicinity of the NDD locations.

Exposure of adult Chinook salmon to the effects of pile driving will only occur for fall-run and late fall-run Chinook salmon due to the overlap in their upstream migration timing with the in-water work window (see Section 2.5.1.1.1.1.1.5 Fall/Late Fall-run Exposure and Risk). No adult SR winter-run Chinook salmon or CV spring-run Chinook salmon are expected to be present during the in-water work window for the NDD location. Furthermore, NMFS does not anticipate that larger sized Chinook salmon (adult life stage) would experience any changes in predation risks to fish predators, due to their exposure to elevated sound pressure levels related to the pile-driving actions. Therefore, adverse effects to adult Chinook salmon are not expected.

2.5.1.1.6.1.1.2 Steelhead Exposure and Risk

The timing of CCV steelhead at the NDD locations has been described in Section 2.5.1.1 Construction Effects.

The in-water water work window overlaps with a substantial proportion of the adult upstream migration. As previously assessed for adult Chinook salmon, however, NMFS anticipates that there will be no changes in the predation risks for adult fish due to exposure to elevated sound pressure levels related to pile-driving actions. There is a high certainty that adult steelhead will experience little if any increased predation risk due to pile-driving actions at the NDD locations.

There is little overlap between the timing of juvenile steelhead migration and the in-water work window for the NDD location. NMFS estimates that less than 1-2 percent of the juvenile population will be moving past the NDD locations during pile-driving actions. While there is some increased risk of predation because of fish being exposed to the pile-driving stressors described above, the larger size of emigrating steelhead smolts compared to Chinook salmon will provide some minimization in this risk. Overall, a small proportion of juvenile steelhead are expected to be exposed to the pile-driving actions, which is likely to increase predation risk. Therefore, a small proportion of juvenile steelhead are likely to be adversely affected.

2.5.1.1.6.1.1.3 Green Sturgeon Exposure and Risk

The overlap of green sturgeon presence with the occurrence of pile driving activity has been previously described in Section 2.5.1.1.1.1 Pile Driving as it pertains to the acoustic effects experienced by green sturgeon encountering pile driving activity during the in-water work windows.

Generally speaking, juvenile sDPS green sturgeon are much more likely to experience increased predation throughout the Delta than adults or sub-adults owing to the difference in size. It is also worth noting, however, that juvenile green sturgeon may be inherently less susceptible to predation than other species of fish because of the deterrence afforded them by the presence of protective scutes on their skin (once over 200 mm). Nevertheless, juvenile green sturgeon have the potential to be present in all waters of the Delta during every month of the year, and the protective scutes on the individual fish migrating past the NDD locations in particular may still be developing as they transition from their natal riverine habitat to the rearing habitat in the Delta; therefore, a medium proportion will be exposed to an increased risk of predation during the pile driving in-water work window at the NDD locations. However, green sturgeon do not appear to be a preferentially selected prey species relative to other available prey species in general (unpublished data, UC Davis 2016). Based on that factor coupled with the consideration of the limited period of time during which juvenile sturgeon may still be developing better formed protective scutes and growing in size as they migrate past the NDD locations, combined with the unlikelihood of adult or sub-adult green sturgeon being preyed upon in this portion of their habitat, NMFS expects only a small proportion of green sturgeon is likely to be adversely affected by increased predation through displacement from nearshore habitat and cover, injury as a result of barotrauma, or otherwise compromised by acoustic-related stress from anthropogenic noise associated with pile driving as described earlier in this section.

2.5.1.1.6.1.2 Clifton Court Forebay

The construction in-water work window for the CCF is proposed from July 1 to October 31. Pile driving and associated anthropogenic noise at the CCF location is expected to create environmental conditions that are likely to increase predation risks to juvenile salmonids and green sturgeon that are present and exposed to the sound field. The stressors related to the increase in predation risks have been described above for the NDD locations and will also apply to the CCF location. The acoustic effects of pile driving are described in Section 2.5.1.1.1 Acoustic Stress.

In summary, the extent of the 150-dB RMS threshold will cover the vast majority of the CCF waterbody when pile-driving actions are taking place in the forebay. The extent of the forebay that will exceed the 187-dB SEL threshold is approximately 25 percent of the width of the forebay when the cofferdams are installed along the perimeter of the forebay and approximately 45 percent of the width of the forebay when the sheet piles are driven along the partition dike separating the forebay into two waterbodies.

Fish exposed to sound pressure in excess of the 150-dB RMS threshold are expected to be vulnerable to masking sounds of approaching predators and to be distracted by the additional noise in the surrounding environment. Fish within the threshold of 187-dB SEL are more likely to suffer injuries due to barotrauma and, therefore, become more susceptible to predation through reduced fitness and their ability to escape predation attacks.

2.5.1.1.6.1.2.1 Chinook Salmon Exposure and Risk

Because continued operation of CCF includes potential entrainment of Chinook into CCF during construction activities, there is the potential for adverse effects from increased risk of predation. Extending in-water construction activities through October results in negligible potential for exposure of juvenile spring-run Chinook salmon (yearling smolts) and winter-run Chinook salmon (young-of-the year) as they are expected to be in the vicinity of the CCF from February through June (spring-run Chinook salmon) and December through April (winter-run Chinook salmon), respectively. Less than 1 percent of fall-run Chinook salmon juveniles would be expected to be present during the work window.

Although salvage data from 1993 through 2011 indicate very little to no winter-run and spring-run Chinook salmon would be present in the CCF during the in-water work window, there is a very low likelihood that a few may be present towards the very end of the work window (late October) particularly if large fall storms have increased Sacramento River flows and exports are increased to take advantage of these increased flows into the Delta. Although the in-water work window will greatly reduce the exposure of juvenile fall-run and late fall-run Chinook salmon to pile-driving-induced predation effects, NMFS expects a small proportion of juvenile fall-run and late fall-run will be adversely affected. NMFS does not expect there to be any adverse effects to juvenile winter-run or spring-run Chinook salmon due to their expected absence in the CCF during the in-water work window.

Exposure of adult Chinook salmon to the effects of pile driving will only occur for fall-run and late fall-run due to the overlap in their upstream migration timing with the in-water work. No adult SR winter-run Chinook salmon or CV spring-run Chinook salmon are expected to be present during the in-water work window for the CCF location. Furthermore, NMFS does not anticipate that larger sized Chinook salmon (adult life stage) would experience any changes in predation risks, due to their exposure to elevated sound pressure levels related to pile-driving actions. Therefore, adverse effects to adult Chinook salmon are not expected.

2.5.1.1.6.1.2.2 Steelhead Exposure and Risk

Pile driving in CCF is not expected to appreciably increase the predation risk for juvenile steelhead present in the forebay. Although this water body will be accessible to both CCV steelhead juveniles from the Sacramento River basin via an open DCC gate and to fish emigrating downstream from the east side tributaries (Mokelumne and Calaveras rivers) and the San Joaquin River basin tributaries during the proposed in-water work window, it will likely be in low numbers. Based on monitoring data from the Delta (DJFMP data available at: https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm) and salvage data from the SWP and CVP fish collection facilities (Reclamation 2017) (https://www.usbr.gov/mp/cvo); CDFW 2017 (ftp://ftp.dfg.ca.gov/salvage), less than 1 percent of the annual juvenile emigration is expected to occur during the proposed work window. Most juvenile steelhead presence in the CCF location will occur from December through March, based on salvage at the CVP and SWP fish collection facilities. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location. As a few individual juvenile steelhead are likely to be present during the in-water work window due to the timing of emigration, they would enter the forebay and be exposed to increased predation risks due to pile driving. A small proportion of juvenile steelhead are likely to be adversely affected.

The CCF location on Old River is accessible to adult CCV steelhead populations from the Sacramento River basin, east side tributaries, and the San Joaquin River Basin. The likelihood of fish from the Sacramento River being present, however, diminishes with distance from the main stem of the San Joaquin River. It is expected that the timing of adult presence at the CCF location will be later than that observed for the North Delta due to its southern Delta location and the likelihood that the majority of adult fish present are from the San Joaquin River basin population, which has a later peak in upstream migration compared to the Sacramento River basin population.

Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta starting in September, with most of the population passing through the Delta from November to January based on data from the Stanislaus River fish weir. This slightly later upstream migration for San Joaquin River basin CCV steelhead overlaps from September through October with the proposed in-water work window. As previously assessed for adult Chinook salmon, however, NMFS anticipates that there will be no changes in the predation risks for adult fish due to exposure to the elevated sound pressure levels related to pile-driving actions. There is a high certainty that adult steelhead will experience little, if any, increased predation risk due to pile-driving actions at the CCF locations.

2.5.1.1.6.1.2.3 Green Sturgeon Exposure and Risk

The risk of predation to adult and sub-adult sDPS green sturgeon is practically non-existent throughout the action area because of the relative size of these fish to the common predatory species typically found in the Delta, as well as the presence of protective scutes on their skin that act as a natural deterrent to being preyed upon in general. Regarding the potential for increased exposure of juvenile green sturgeon to the risk of predation as a result of pile driving activity at CCF, NMFS expects that a very small proportion, if any, juvenile green sturgeon will be adversely affected by this particular stressor.

2.5.1.1.6.1.3 HOR Gate

The construction in-water work window for the HOR Gate is proposed from August 1 to October 31. Pile driving and associated anthropogenic noise at the HOR gate location is expected to create adverse environmental conditions that will increase predation risks to juvenile salmonids and green sturgeon that are present and exposed to the sound field. The stressors related to the increase in predation risks have been described above for the NDD locations and will also apply to the HOR gate location.

The acoustic effects of pile driving are described in Section 2.5.1.1.1.1 Pile Driving above.

In summary, the extent of the 150-dB RMS threshold and the 187-dB SEL threshold overlap and will cover the entire width of the Old River channel at the HOR gate location and extend up to 1,500 feet up and down river until the alignment of the river channel blocks further propagation of the sound path. Thus, any fish moving through Old River past the gate location will likely be injured or killed due to the magnitude of the sound pressure field that exists in this confined space.

Fish moving upstream in the mainstem channel of the San Joaquin River will also be exposed to the high sound levels as they pass the Head of Old River junction, but the distance that this intense field is present in the San Joaquin River is relatively short, and fish are expected to pass through relatively quickly. Fish within the threshold of 187-dB SEL are more likely to suffer injuries because of barotrauma and, therefore, become more susceptible to predation through reduced fitness and their ability to escape predation attacks.

2.5.1.1.6.1.3.1 Chinook Salmon Exposure and Risk

Pile driving at the Head of Old River Gate is not expected to increase predation on juvenile SR winter-run Chinook salmon, juvenile CV spring-run Chinook salmon, or juvenile fall-run Chinook salmon due to a lack of overlap in the timing of juvenile migrations and pile driving at the HOR gate location.

Exposure of adult Chinook salmon to the effects of pile driving will only occur for fall-run Chinook salmon because of the overlap in their upstream migration timing with the in-water work window (see Section 2.5.1.1 Construction Effects). No adult SR winter-run Chinook salmon or CV spring-run Chinook salmon are expected to be present during the in-water work window for the HOR gate location. Furthermore, NMFS does not anticipate that larger sized Chinook salmon (adult life stage) would experience any changes in predation risks to fish predators, due to their exposure to elevated sound pressure levels related to the pile-driving actions. Therefore, adverse effects to adult Chinook salmon are not expected.

2.5.1.1.6.1.3.2 Steelhead Exposure and Risk

Pile driving in Old River at the HOR gate location is not expected to appreciably increase the predation risk for juvenile steelhead (see Section 2.5.1.1.6.1.3.2 HOR Gate). Juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Therefore, exposure is unlikely. A few may be present, however, at the very end of the work period in October.

Based on regional monitoring data and salvage data from the SWP and CVP fish collection facilities, less than 1-2 percent of the annual juvenile emigration from either basin is expected to occur during the proposed work windows in 2020 and 2021. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location. It is not expected that juvenile steelhead from the Sacramento River basin will be present at the location of the HOR gate, even though juvenile CCV steelhead from this basin are present at the CVP and SWP salvage facilities. There is a medium to high certainty that few individual juvenile steelhead will be present during the in-water work window due to the timing of emigration. Therefore, a small proportion of juvenile steelhead are likely to be adversely affected.

The HOR gate location on Old River is accessible to adult CCV steelhead populations from the Sacramento River basin, east side tributaries, and the San Joaquin River Basin. As previously assessed for adult Chinook salmon, however, NMFS anticipates that there will be no changes in the predation risks for adult fish due to the exposure to the elevated sound pressure levels related to pile-driving actions. There is a high certainty that adult steelhead will experience little if any increased predation risk due to pile-driving actions at the CCF locations.

2.5.1.1.6.1.3.3 Green Sturgeon Exposure and Risk

As discussed in the previous Sections 2.5.1.1.6.1.3 HOR Gate and 2.5.1.1.6.1.3.3 Green Sturgeon Exposure and Risk, the probability of juvenile sDPS green sturgeon experiencing increased rates of predation is limited by the presence of bony scutes on their skin, which makes them a less desirable prey species than other fish. There is little evidence to suggest that the density of their numbers in the vicinity of the HOR would result in an increased risk of predation during the in-water work window. In addition, by the time juvenile green sturgeon will have transited the Delta to be in the vicinity of the HOR and the south Delta in general, they will be larger in size and have better formed protective scutes affording them greater protections from predation than they had when they initially dispersed from their upstream spawning habitat and began migrating downstream. For these reasons, NMFS expects the risk of increased predation to sDPS green sturgeon as a result of pile driving activity at the HOR gate will not result in adverse effects.

2.5.1.1.6.1.4 Barge Landings Locations

Barge landings will be constructed at each TBM launch shaft site for loading and unloading construction equipment, materials, fill, and tunnel spoils. A total of seven barge landings are currently proposed throughout the Delta in the PA. The locations are described in Section 2.5.1.1.1.1.4 Barge Landing Locations. However, an additional barge landing location was identified by the applicant during consultation and may be built at the contractor’s discretion at Intake 2 at the NDD locations.

Each barge landing will require pile driving 107 steel pilings to support overwater dock structures during the proposed in-water work window of July 1 and August 31 when most listed species are least likely to occur in the action area. Pile driving and associated anthropogenic noise at the barge landing locations are expected, however, to create adverse environmental conditions that will increase predation risks to juvenile salmonids and green sturgeon that are present and exposed to the sound field.

Stressors related to the increase in predation risks have been described above for the NDD locations. It is expected that the diverse locations of barge landings will increase the potential for exposure to migrating fish because the sites are on main distributaries of the Delta in locations that serve as migratory corridors for listed salmonids and green sturgeon. The only exception is Snodgrass Slough, which is situated off of the main migratory corridors in a dead-end slough.

The extent of the sound pressure fields at each of the barge landing locations is given in Section 2.5.1.1.1.1.4 Barge Landing Locations. In general, the distance to the 187-dB SEL threshold will block channels within several hundred to several thousand feet at each landing location, creating areas where barotrauma injuries are likely. Reductions in fitness and swimming ability will enhance the vulnerability of affected fish to predation.

Similarly, the distance to the 150-dB RMS threshold for behavioral modifications will affect a greater area of the Delta channels surrounding the barge landing locations and create conditions in which the environmental sounds of approaching predators are masked or the prey are distracted from detecting approaching predators. This will lead to increased vulnerability to predation.

2.5.1.1.6.1.4.1 Chinook Salmon Exposure and Risk

Pile driving during construction of the barge landing locations is not expected to cause increased predation to juvenile CV spring-run Chinook salmon, but may expose a small proportion of SR winter-run, late fall-run, and fall-run Chinook salmon to increased predation. Presence of juvenile Chinook salmon is expected as follows:

- Juvenile winter-run Chinook salmon are generally expected to be present in the Delta from November to April, but with very small numbers possible in September and October (~1-2 percent of the annual population). Winter-run Chinook salmon exposure is also minimized compared to other runs because six of the seven landings in the BA are located on or near the San Joaquin River, which is not the main migratory corridor for winter-run Chinook salmon. The eighth proposed barge landing (Snodgrass Slough) is located on a dead-end channel located off any main migratory routes used by winter-run juveniles.
- Juvenile spring-run Chinook salmon are expected to be present in the Delta from November through May, which is outside the proposed in-water work window.
- Juvenile late fall-run Chinook salmon may be present between July and January, with peaks in December and January.
- Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, with only small numbers present in July and August.

Therefore, NMFS expects that a small proportion of winter-run, late fall-run, and fall-run Chinook salmon juveniles will experience an adverse effect of increased risk of predation caused by pile driving in the vicinity of the barge landing location.

Exposure of adult Chinook salmon to the effects of pile driving will only occur for fall-run and late fall-run because of the overlap in their upstream migration timing with the in-water work window (see Section 2.5.1.1 Construction Effects).

No adult SR winter-run Chinook salmon or CV spring-run Chinook salmon are expected to be present during the in-water work window for the barge landing locations. Furthermore, NMFS does not anticipate that larger sized Chinook salmon (adult life stage) would experience any changes in predation risks to fish predators due to their exposure to elevated sound pressure levels related to the pile-driving actions. Therefore, adverse effects to adult Chinook salmon are not expected.

2.5.1.1.6.1.4.2 Steelhead Exposure and Risk

The majority of juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March. Therefore, it is expected that very little overlap will occur, resulting in exposure to pile driving activities.

Based on regional monitoring data (DJFMP 2017) and salvage data from the SWP and CVP fish collection facilities (Reclamation 2017; CDFW 2017), less than 1-2 percent of the annual juvenile emigration from either basin is expected to occur during the proposed in-water work windows. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location. NMFS expects a small proportion of juvenile CCV steelhead will be adversely effected.

The various locations of the barge landings throughout the Delta waterways are accessible to adult CCV steelhead populations from the Sacramento River basin, east side tributaries, and the San Joaquin River Basin. The in-water water work window overlaps with a sizeable proportion (~14 percent) of the adult upstream migration for the Sacramento River basin population. Adult CCV steelhead from the San Joaquin River basin are expected to start migrating into the Delta starting in September, with most of the population passing through the Delta from November to January based on data from the Stanislaus River fish weir; therefore, very few would be present as early as August in the central and southern Delta. As previously assessed for adult Chinook salmon, however, NMFS anticipates no changes in the predation risks for adult fish because of the exposure to elevated sound pressure levels related to pile-driving actions. There is a high certainty that adult steelhead will experience little, if any, increased predation risk due to pile-driving actions at the barge landing locations in the Delta.

2.5.1.1.6.1.4.3 Green Sturgeon Exposure and Risk

Although juvenile green sturgeon have the potential to be present in all waters of the Delta during every month of the year, as described in the preceding sections characterizing the exposure and risk of sDPS green sturgeon to the threat of increased predation, the threat of increased predation as a result of exposure to anthropogenic noise from pile driving associated with the construction of barge landings is unlikely to occur. Any potential exposure to pile driving activities is not expected to result in adverse effects to sDPS green sturgeon related to increased predation risk.

2.5.1.1.6.2 Barge Traffic

Details on the Barge Traffic component of the PA were described in Section 2.5.1.1.1.2 Barge Traffic.

2.5.1.1.6.2.1 Species Exposure and Risk

A description of the exposure and risk to species from increased predation as a result of increased barge traffic may be found in Section 2.5.1.1.1.2.1 Acoustic Effects of Barge and Tugboat Traffic.

In summary, all anadromous fish will potentially be exposed to increased predation caused by barge-induced acoustic stress owing to a long-term increase in barge traffic and the multiple waterways associated with the project’s barge traffic routes. Because most of the barge traffic will be utilizing the Stockton DWSC and waterways associated with the lower San Joaquin River to reach the primary landing sites at Bouldin Island and the CCFB, those species or runs originating in the Sacramento River basin will have reduced exposure compared to those entering the Delta from the San Joaquin River. Moreover, restrictions of barge traffic on the Sacramento River migratory corridor to the period between June 1 and October 31, further reduce exposure to listed anadromous fish, particularly juvenile Chinook salmon and steelhead originating in the Sacramento River basin. All species must pass through the western Delta and the waterways leading to the ocean. However due to restrictions on barge travel in these waters, which limits barges to operations from June 1 to October 31 there will be reductions in the level of exposure to increased predation resulting from the noise generated by the barge tows during their movements through the Delta and San Francisco Estuary. Juvenile Chinook salmon and steelhead will benefit greatly from this schedule restriction due to the lack of overlap between their emigrations to the ocean and barge operations in these waters.

All juvenile salmonids and green sturgeon from the Central Valley will have the potential to be exposed to some level of increased predation caused by the acoustic response effects of increased barge traffic sound. Fish within the San Joaquin River basin will have barge traffic operating year-round from the Port of Stockton to Bouldin Island on their main emigration route. Other waters of the central and south Delta leading to the barge landings located in this region will have barge operations from June 1 to October 31. Listed fish from both the Sacramento River basin and the San Joaquin River basin will have year-round overlap with barge traffic in the waters adjacent to the confluence of the Mokelumne River and the lower San Joaquin near Bouldin Island. Thus, juvenile salmonids from the Sacramento River basin that emigrate to the ocean via Georgiana Slough to the lower San Joaquin River will have the potential to be exposed to barge traffic noise and the risk of increased predation.

The increased level of anthropogenic noise will act as an additional stressor on the aquatic community, which in turn will expose salmonids and green sturgeon to an increased level of predation. Smolting juvenile salmonids from the Sacramento River basin will be primarily exposed to increased predation due to the spatial and temporal overlap of the acoustic stressors (i.e., increased barge traffic) with salmonid migrations at the junction between the Mokelumne River and lower San Joaquin River adjacent to Bouldin Island. All San Joaquin River basin salmonids will also pass through this area, as well as a high proportion through the main channel of the San Joaquin River between the Port of Stockton and Bouldin Island. Some juvenile salmonids will migrate through the waters of the southern Delta via Old and Middle rivers. Adverse effects to a small proportion of salmonids are expected to occur. As described earlier (Section 2.5.1.1.6.1 Pile Driving), the probability of juvenile sDPS green sturgeon experiencing increased rates of predation is limited by the presence of bony scutes on their skin, which makes them a less desirable prey species than other fish. Therefore, the likelihood of adverse effects to green sturgeon as a result of increased exposure to the risk of predation from increased barge traffic is considerably lower than for salmonids, such that a very small proportion may be adversely affected, if any at all. NMFS does not expect any adult fish species to be adversely affected by the increase in barge traffic noise due to predation.

2.5.1.1.6.3 Interim In-water Structures (Present During Construction)

The PA has numerous interim structures that have a high potential to increase the vulnerability of anadromous fish to predation because of their presence in the Delta's waterways. The PA will require the construction of multiple structures that will last for a finite period of time while the overall project is under construction. Following completion of the proposed project's infrastructure, these interim structures will either be removed completely from the water or modified to have a benign presence in the aquatic environment (i.e., cutting off pilings or sheet piles at the mudline).

The PA has several interim structures that can be separated into two main categories for in-water structures: cofferdams constructed with sheet piles and pilings to support docks. Each category will have specific effects related to their structures. The effects of bulkheads, piers, pilings, and other over- and in-water structures on salmonids in the northwest were reviewed by Kahler et al. (2000) and Carrasquero (2001).

Cofferdams

Cofferdams will be constructed at all three North Delta intakes to isolate the construction area from the Sacramento River for the construction of the fish screens. Likewise, cofferdams will be constructed at the HOR gate location to isolate work areas to construct the gates, boat lock, and fish ladder within the live river channel of Old River. Several cofferdam structures will be constructed in the CCF to allow for construction of earthen embankments around the perimeter of the forebay and to separate the NCCF from the SCCF, construction of the NCCF siphon underneath the inlet to the intake channel, and the construction of the channel through the currently existing southern embankment to allow flooding of the newly constructed expansion area of the SCCF.

Cofferdams are typically built by pile driving steel interlocking sheet piles into the substrate, creating a vertical wall (a bulkhead) with little complexity or features into areas below the waterline and away from the bank.

There are no refugia for small prey size fish to hide from predators adjacent to the vertical steel wall. Kahler et al. (2000) and Carrasquero (2001) described the effects of vertical bulkhead or retaining walls such as cofferdams. These structures tend to be in deeper water, primarily because the structures are usually placed below the ordinary high water mark and the space behind them dewatered for construction purposes. This effectively pushes the shoreline out from its original location resulting in a corresponding increase in water depth along the face of the structure outside of the shallow littoral zone.

Given that out-migrating juvenile salmonids (particularly Chinook salmon) use shallow-water habitats for rearing, foraging, and migration, retaining walls may potentially disrupt juvenile salmonid migration. In turn, the cumulative impact of this migration disruption may be an overall reduction in survival rate because forcing juveniles into deeper water potentially affects their survival by limiting prey resource availability along the shoreline (shallow littoral zone), thereby decreasing their feeding success and growth rate, and also by increasing their exposure to predators in deeper water, hence increasing the predation rate.

Vertical bulkheads or retaining walls also lack habitat complexity, which offers little critical refuge from predators along the face of the structure. In the case of Delta waters, this increases the exposure to predators such as striped bass, which are visual predators that cruise in the open waters of mid channel and will opportunistically prey on fish forced out into the mid-channel open water by the shoreline cofferdam structures.

Furthermore, the hard vertical walls associated with the cofferdams have indentations in them created by the design of the sheet piles. The PA describes the type of sheet piles to be used as AZ-28-700 sheet piles. These piles are interlocking and create a depression that is approximately 18 in. deep by 40 in. wide. The depressions are large enough for larger predators such as black bass, pikeminnows, or catfish to hide in and ambush small fish such as salmonids passing along the face of the vertical sheet pile wall.

In addition to these depressions, the vertical structure allows for some level of shading along the face of the wall, which further camouflages predators holding there from prey moving along the wall in waters lit by the sun. Such shaded areas create hiding areas for predators and prey that conceal them from fish in the lighted zone outside of the area impacted by the shaded area. Such behavior by fish creates a temporal and spatial overlap of predators and prey in the shaded zone, as well as enhancing the success of predator ambush attacks on prey outside of the shaded zone (Kahler et al. 2000, Carrasquero 2001).

Pilings

Each piling will provide both structure and shade in an offshore environment. This will likely attract both predators and prey. The vertical pilings will provide alterations to the local flow field by disrupting the flow and creating eddies downstream of the piling (Carrasquero 2001). In the review by Carrasquero (2001), it was reported that fish such as northern pikeminnow preferentially held in the backside eddies created by pilings in a riverine system. These pilings also attracted juvenile salmonids trying to avoid the local river currents and increased the overlap of predator and prey in a localized area, thus increasing the vulnerability of the prey to the co-occurring predator.

As noted previously for bulkheads and retaining walls, pilings are structurally simple and do not provide the necessary habitat complexity to function as prey refugia. Kahler et al. (2000) and Carrasquero (2001) also reported that bass were attracted to these structures. Largemouth bass appeared to be attracted to the shade produced by these structures, while male smallmouth bass appeared to use the structures (pilings) as a reference point for locating nests for spawning. The pilings will also support a large dock area that will provide thousands of square feet of shade per a landing dock structure for an extended period of time (years until the completion of the project construction). Increased shading of submerged aquatic plants can reduce the primary productivity, which may eventually cause the loss of any submerged aquatic plants beneath the dock structure. Loss of hiding spots for juveniles may increase risk of predation.

Altered Hydraulics Due to Structures

The PA includes construction of cofferdams at both the HOR gate location and at the NCCF siphon structure. These structures have the capacity to alter the flow conditions in the waterways they occupy by decreasing the cross-sectional area of the channel, resulting in higher flow velocities and increased turbulence as water flows through the narrowed channel and around the structures. These hydraulic changes will create adverse conditions for any listed fish present in those areas and will increase vulnerability to predation. The higher velocity and increased turbulent flow field will disorient smaller fish, making them more susceptible to predators. The structures themselves, as well as the flow shears between different velocities, will create eddies and holding areas for predators to lie in wait for passing prey. These elements associated with the altered hydraulic conditions will adversely affect the survival of listed salmonids passing through these channels.

Because the cofferdams and barge landings with their multiple pilings and large deck structure will be left in place for at least a year (and typically for multiple years during the construction of the PA's infrastructure) they will overlap with both juvenile and adult salmonid and green sturgeon presence in the Delta waterways during their migrations through the Delta waterways.

Based on the spatial locations of the proposed cofferdams and barge landings and the 5.5- to 6-year duration of construction of the PA, all Central Valley populations of salmonids and green sturgeon will be exposed to interim structures during some portion of their life histories, many potentially several times during their life span.

The presence of the multiple interim structures in the Delta associated with the PA have a high likelihood of creating hotspot habitats for predators, which will in turn adversely affect salmonids and green sturgeon that come into contact with them.

2.5.1.1.6.3.1 North Delta Intakes

2.5.1.1.6.3.1.1 Species Exposure and Risk

Spatial occurrence for juvenile and adult salmonids and green sturgeon has been described previously in Section 2.5.1.1.6.1.1 North Delta Intake Locations. In summary, all adult and juvenile salmonids as well as green sturgeon must pass through the Sacramento–San Joaquin Delta waterways and the San Francisco Bay Estuary on their way to or from the ocean. The multiple cofferdams and barge landing locations are located in the North Delta, Central Delta, and south Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of salmonids and green sturgeon that may originate from both Sacramento and San Joaquin river basins.

The North Delta Diversions will have three large, temporary cofferdams built in front of the locations of the future fish screens and diversion points.

The cofferdam associated with Intake 2 is currently scheduled to be built in 2025 and mostly removed (cutoff near the mudline) in 2029, a period of 5 years. A portion of the cofferdam will remain as the training wall leading to the fish screens, and along the leading edge of the future screen structure forming the sill to the foundation for the screens. This cofferdam will have a linear length of 1,969 feet.

The cofferdam associated with Intake 3 will be built in 2024 and removed in 2027, a period of 4 years and will have a linear length of 1,497 feet. Most of it will be removed as described for Intake 2.

The cofferdam associated with Intake 5 will be built in 2022 and removed in 2026, a period of 5 years. It will have a linear length of 1,901 feet. This cofferdam will be removed in the same fashion as the previous two intake cofferdams. The total length of cofferdams present is 5,367 feet, and all three cofferdams will be present concurrently for at least 2 years (2025 and 2026) based on the proposed schedule.

The presence of the three cofferdams will have adverse effects on the survival of downstream emigrating salmonids (juveniles) in the Sacramento River. Impacts to adult migrants are less certain as they are less vulnerable to predation from resident predators in the Delta system. As described in the introduction to this section, cofferdams will reduce the available habitat for smaller migrating fish to use as refugia from predators. This will include salmonid smolts as they move downstream in the Sacramento River past the location of the three intakes.

It is expected that the presence of the intake cofferdams will increase the vulnerability of the emigrating juvenile salmonids to predation and ultimately lead to a higher mortality rate in this reach of their downstream emigration to the Delta over baseline conditions without the cofferdam structures. Because the majority of juvenile salmonids must use this reach of the Sacramento River to reach the Delta except during flood conditions and passage through the Yolo Bypass, it is expected that all Sacramento River basin salmonids will be adversely impacted by these structures while they are in place, a period of up to 8 years (2022 to 2029).

The impact on the different life history stages of green sturgeon is less certain. Fine-scale habitat use by juvenile green sturgeon is unclear based on our current knowledge of the species. Whether individual green sturgeon juveniles will be forced away from the shoreline towards deeper waters by the cofferdams will depend on how these juveniles utilize nearshore habitat in the first place.

Predation on juvenile green sturgeon also has a large degree of uncertainty associated with it. It is likely that smaller individuals and more immature life history stages are vulnerable to predation by native and non-native piscine predators in the Delta system. It is possible that smaller individuals in the vicinity of the NDD, making the transition from upstream riverine habitat to the brackish waters and rearing habitat of the Delta, will still be growing in size and have less formed protective scutes, which are believed to protect these fish from predatory attacks. The presence of interim in-water structures associated with the NDD will expose any individual green sturgeon juvenile passing through this reach of the river to a local predator field that is attracted to the in-water structures. It is expected that the density of predators associated with the structures will be greater than the surrounding area.

NMFS expects that increased predator-prey overlap in time and space associated with the NDD interim structures will adversely affect a medium proportion of juvenile winter-run Chinook salmon, spring-run Chinook salmon, late-fall-run, and fall-run Chinook salmon, as well as steelhead smolts given the multiple years of exposure to the interim structures and the documented presence at the NDD location during their downstream migrations to the Delta.

NMFS also expects that the increased presence of predators at the NDD interim structures will adversely affect juvenile green sturgeon. NMFS does not expect that the increased presence of predators associated with the NDD interim structures will adversely affect adult winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, steelhead, or green sturgeon.

2.5.1.1.6.3.2 Clifton Court Forebay

Construction activities at CCF are described in Section 2.5.1.1.1.1.2 Clifton Court Forebay.

2.5.1.1.6.3.2.1 Species Exposure and Risk

The effects of interim in-water structures on predation risk is described in the NDD section above. Because these structures are in place year-round for multiple years, all anadromous fish that become entrained into the forebay will potentially be exposed to any adverse effects of the structure during their migratory movements.

Cofferdam structures associated with the NCCF siphon construction are expected to create predator habitat, which will expose fish to increased risk of predation as they enter the inlet to the intake channel leading to the Skinner Fish Protection Facility. Predation of listed salmonids—including juvenile steelhead, winter-run, and spring-run Chinook, as well as juvenile green sturgeon and the unlisted fall-run and late-fall run Chinook salmon—is expected to increase. NMFS expects that not only will there be elevated predation related to the physical structure itself (vertical walls and loss of habitat refugia), but that the altered hydraulics associated with a structure blocking the flow of water in an export influenced channel will greatly benefit predator hunting efficiency. Predators such as black bass, pikeminnows, and striped bass can use holding areas in back eddies and hydraulic cushions created by the cofferdam structure and prey on the smaller fish disoriented by the increased velocities and turbulence present in the water flowing through the narrowed channel. These cofferdam structures will create adverse conditions in the inlet channel for at least two years and will affect that proportion of migrating juvenile fish entering this channel on their way to the Skinner Fish Protection Facilities.

The cofferdam channel associated with the southern embankment to allow flooding of the expanded southern forebay is also expected to create predator habitat, exposing fish to increased risk of predation. Although a relatively short section of cofferdam will be built, the channel will have altered hydraulic conditions associated with it that are expected to enhance the predation of salmonids and green sturgeon.

As water levels increase and decrease in the main forebay due to export and radial gate operations, water will flow into and out of the newly created southern expansion area through the cofferdam lined channel. This will create the same scenario for increased flow velocities and turbulence as described above for the NCCF siphon locations. This condition is expected to last up to 2 years as the southern embankment is degraded and removed to form one continuous southern waterbody (the SCCF). During this period, this interim structure is expected to increase the vulnerability of listed salmonids and juvenile green sturgeon to predation and increase the magnitude of loss associated with the operations of the SWP through its CCF operations.

Cofferdams that will form the cross forebay partition dike and the eastern and western embankment cofferdams are also expected to provide habitat for predators, which will increase predation risk of fish moving through CCF. The cumulative length of these three cofferdams is over 20,000 linear feet and will provide only vertical walls with no refugia for smaller fish to utilize.

As stated previously, the only features in these cofferdam walls are the large indentations created by the design of the interlocking sheet piles. These indentations are better suited for larger predators to hold in and hide from prey moving along the face of the cofferdam wall than for small fish to take refuge in.

In addition, the partition wall across the forebay will have two, 100-foot-wide gaps in its alignment during its first year of installation to allow water flow and circulation to occur while the southern earthen embankment is being removed. These channels will create their own localized velocity and turbulence conditions that will enhance the vulnerability of listed salmonids and green sturgeon to predation. The adverse effects of these hydraulic alterations are described above for the NCCF siphons.

Finally, the partition dike cofferdam will act as a “fence” intercepting fish moving within the forebay and guiding them towards the intake channel to the west. This condition is likely to concentrate listed salmonids and green sturgeon in areas with increased predator concentrations, leading to higher predation rates than currently experienced in the forebay. It is expected that the eastern and western embankment cofferdams will be in place for two construction seasons (2027 and 2028). The partition dike cofferdam will be in place for up to 4 years (2025 to 2028) while the cross forebay earthen embankment is constructed to separate the forebay into the NCCF and SCCF.

After the final earthen embankments are constructed, the sheet pile cofferdams are expected to be removed or cutoff at the mudline. During the period that the interim cofferdams are in place, the overall predation rate in the forebay is expected to increase due to the adverse habitat conditions created by the cofferdams.

NMFS expects that increased predator-prey overlap in time and space associated with the CCF interim structures will adversely affect a small proportion of juvenile salmonids given the multiple years of exposure to the interim structures and the presence at the CCF location during their downstream migrations through the Delta. NMFS expects that the increased predator-prey overlap in time and space at the CCF interim structures will also adversely affect a small proportion of juvenile green sturgeon. NMFS does not expect that the increased presence of predators associated with the CCF interim structures will adversely affect adult salmonids or green sturgeon.

2.5.1.1.6.3.3 HOR Gate

Construction of the HOR gate is expected to take 2 years. The HOR gate will be constructed in two phases using cofferdams to isolate and dewater half the channel during the first phase and the other half during the second phase.

All in-water construction work, including cofferdam installation, riprap placement, dredging, and barge operations, would be restricted to August 1 through October 31 to minimize or avoid potential effects on listed fish species. In addition, all pile driving requiring using an impact pile driver in or near open water (cofferdams and foundation piles) will be restricted to the in-water work period to avoid or minimize exposure of listed species to potentially harmful underwater noise levels. AMM 9 will be implemented to minimize impacts.

2.5.1.1.6.3.3.1 Species Exposure and Risk

The effects of interim in-water structures on predation risk is described in the NDD section above. Because these structures are in place year-round for multiple years, all fish that migrate past the interim structure may potentially be exposed to any adverse effects of the structure during their migratory movements.

The presence of the cofferdams associated with the HOR gate construction will adversely affect salmonids originating in the San Joaquin River basin or any fish that stray from the Sacramento River basin. This includes steelhead, spring-run Chinook salmon, and fall-run Chinook salmon.

It is also possible that juvenile and adult green sturgeon will be present in these waters of the Delta. The two proposed cofferdams will be constructed in such a manner as to block one half of the Old River channel while that half of the gate structure is being built and then the other half when the remaining half of the gate is constructed in the subsequent year.

Each cofferdam installation is expected to last an entire year and will overlap with both adult salmonid upstream migrations and juvenile downstream migrations as smolts to the Delta. Green sturgeon may be present in the area year-round. As described above, these cofferdams are expected to increase the vulnerability of emigrating salmonid smolts and rearing juvenile green sturgeons to local predators. Adverse effects to adult migrants are not expected to occur as they are less vulnerable to predation from resident predators in the Delta system.

NMFS also expects that not only will there be elevated predation related to the physical structure itself (vertical walls and loss of habitat refugia), but that the altered hydraulics associated with a structure blocking the flow of water in a tidally influenced channel will greatly benefit predator hunting efficiency. Predators such as black bass, pikeminnows, and striped bass can use holding areas in back eddies and hydraulic cushions created by the cofferdam structure and prey on the smaller fish disoriented by the increased velocities and turbulence present in the water flowing through the narrowed channel. Furthermore, because this is a tidally influenced channel, flow may potentially be bi-directional, creating these adverse conditions on both sides of the structure. These cofferdam structures will create adverse conditions in the Old River corridor for at least two years and will affect that proportion of migrating juvenile fish entering this channel on their downstream migration.

NMFS expects that increased predator-prey overlap in time and space associated with the HOR gate interim structures will adversely affect a small proportion of juvenile spring-run and fall-run Chinook salmon, as well as steelhead smolts given the multiple years of exposure to the interim structures and their presence at the HOR gate location during their downstream migrations to the Delta.

NMFS expects that the increased presence of predators at the HOR gate interim structures will also adversely affect juvenile green sturgeon present at that location. NMFS does not expect that the increased presence of predators associated with the NDD interim structures will adversely affect adult salmonids or green sturgeon.

2.5.1.1.6.3.4 Barge Landings

Construction of barge landings throughout the Delta will result in the degradation of nearshore habitat and increase the vulnerability of salmonids and green sturgeon to predation.

The PA describes at least eight potential locations for barge landings in the Delta, requiring over 800 pilings being placed into Delta waters to support these structures (107 pilings per barge landing). These pilings will create vertical structural habitat that is anticipated to create both velocity breaks and shade. Both predators and small fish such as salmonids are attracted to these habitat features created by the pilings, producing a potential overlap in their spatial occurrence. Pilings have little habitat complexity to offer refuge to small fish from co-occurring predators, and therefore the overlap in spatial occurrence is expected to increase predation vulnerability.

Additionally, the large overwater dock structures will create tens of thousands of square feet of shaded water that will adversely affect nearshore habitat as described previously, enhancing the vulnerability to predation and potentially reducing productivity by shading submerged aquatic vegetation.

The barge landings are scheduled to be built early in the project construction schedule to accommodate the off-loading of vital construction materials and equipment for the project. The barge landings are currently scheduled to be constructed in 2018 and 2019. They are expected to remain in place through the end of the project in 2029 when they are scheduled to be removed. Thus, the habitat alterations created by the pilings and over-water dock structures will affect 10 to 11 years of salmonid and green sturgeon populations moving through the Delta.

All but one of these proposed barge landings are on waterways frequented by salmonids and green sturgeon. The one landing that is located in waters not expected to be frequented by salmonids is Snodgrass Slough near the Intermediate Forebay location. All other locations are on significant waterways that serve as migration corridors or are immediately adjacent to such waterways. Therefore, it is highly likely that each year, salmonids and green sturgeon will pass through the waterways containing these barge landings and experience the adverse habitat conditions associated with the pilings and overwater structures.

2.5.1.1.6.3.4.1 Species Exposure and Risk

There is more uncertainty in how green sturgeon juveniles will respond to the barge landings. It is unknown whether juvenile green sturgeon will be attracted to the dozens of vertical pilings associated with each landing or will seek out the shaded waters under the dock platform.

Because green sturgeon juveniles are found in the waterways upon which the barge landings will be constructed, there will be some level of exposure to the predator field associated with each structure. The increased exposure is likely to enhance predation risk due to increased overlap in time and space with the increased density of predators associated with the structures.

NMFS expects that increased predator-prey overlap in time and space associated with the barge landing interim structures will adversely affect a small proportion of juvenile salmonids, given the multiple years of exposure to the interim structures and the presence at the various barge landing locations in the Delta during their downstream migrations through the Delta.

NMFS expects that the increased presence of predators at the barge landing interim structures will adversely affect a smaller proportion of juvenile green sturgeon than compared to salmonids. NMFS does not expect that the increased presence of predators associated with the barge landing interim structures will adversely affect adult salmonids or green sturgeon.

2.5.1.1.6.4 Clearing and Grubbing

Loss of riparian vegetation is likely to occur during clearing and grubbing activities at construction sites, including the NDD sites, barge landings, CCF, and HOR. It may also occur as an indirect effect of creating temporary access points to the river for construction.

Some locations of cleared or cut riparian vegetation will be replaced with angular rock, or a structure or facility, and therefore will result in permanent loss. Other locations may be left to recolonize once the construction activity has been completed, which may take one to five growing seasons depending on best management measures taken. Regardless if the loss is temporary or permanent, the loss of habitat that is necessary for the survival of emigrating juvenile salmonids is likely to result in an adverse effect to juvenile salmonids present in the Delta.

Riparian vegetation, specifically shaded riverine aquatic (SRA) habitat, provides vital overhead cover, resulting in shade and protection from predators. A vibrant riparian corridor provides habitat for juveniles to rest and hide from large predators. A degraded riparian corridor, especially one replaced with unnatural rock, cement, or metal, can adversely affect fish by increasing the risk of being eaten by predators (described in Section 2.5.1.1.6.3 Interim In-water Structures). Furthermore, removed riparian vegetation, particularly SRA, will reduce the already diminished quality of delta waterways for the rearing, foraging, and migration of anadromous fish. This continuing loss of SRA, and riparian habitat in general, perpetuates the poor quality of Delta waterway, which further reduces the ability of emigrating salmonids to successfully transit the Delta to the marine environment. The risk of predation is elevated due to a lack of nearshore refugia where smaller anadromous fish can hide and successfully forage in the face of predator presence in the affected waterways. Increasing the spatial and temporal overlap of predators and prey, and reducing the fitness of juvenile anadromous fish by reducing foraging success, may decrease the survival of emigrating fish through the Delta.

Construction of the proposed project is likely to reduce riparian vegetation in the footprint of each new facility, and anadromous fish utilize these areas of the Sacramento River and Delta as a migratory corridor. However, the likely impact at each location is expected to be so minimal that detection of changes in the rates of predation will be difficult to observe. Nevertheless, adverse effects of predation as a result of the loss of riparian vegetation are expected to occur to all life stage of anadromous fish in these areas, particularly when viewed as a combined effect of all the construction sites together.

The acreage of effect for each structure, including areas located in designated critical habitat that could be affected by placement of permanent in-water structures, and the temporary areas of effect (i.e., areas that will only be affected during construction activities) were calculated and will be mitigated for through channel margin and tidal perennial habitat creation/restoration in the appropriate areas (see Appendix A2 Proposed Action).

Given the relative scale of permanent loss of riparian vegetation compared to the total abundance of vegetation in the immediate area, coupled with the habitat mitigation proposed as part of the PA, NMFS expects that adverse effects of predation as a result of the loss of riparian vegetation are expected to occur to all life stage of anadromous fish in these areas, particularly when viewed as a combined effect of all the construction sites together.

2.5.1.1.7 Physical Impacts to Fish

Physical disturbance may occur during PA construction activities such as pile driving, geotechnical boring, dredging, and cofferdam installation. The physical disturbance may be through displacement or disruption of normal behaviors. Displacement may temporarily expose juvenile fish to a greater risk of predation. Some adult and juvenile anadromous fish may experience up to 12 hours of migration delay due to construction activities. Repeated disturbance may potentially increase stress levels, which could result in lower reproductive success in adults and reduced growth in juveniles.

Direct injury or death may occur during instream construction activities if listed anadromous fish are present. Adult listed salmonids more easily avoid disturbance, although green sturgeon may approach an active construction area. Adults are especially vulnerable to injury from propellers on barges (strikes and entrainment) during barge traffic related to construction of the PA. Listed juvenile fish are especially vulnerable to crushing by construction equipment that enter the water for dredging and can become entrained into the dredger, geotechnical boring, cofferdam installation, and placement of nearshore riprap. Additionally, inside isolated cofferdams, the PA includes a “Fish Rescue Plan” to occur before dewatering, which will involve capture, transport, and release of fish present. Fish may be injured or killed during this process. Any fish not captured may become stranded and perish.

2.5.1.1.7.1 Pile Driving

Pile driving, as described in the PA, may potentially harm or harass salmonids and green sturgeon in the action area. The ways in which pile driving can affect species include:

- Through pile-driving-induced acoustic stress (see Section 2.5.1.1.1 Acoustic Stress),

- The concentration and contaminant composition of resuspended sediments (see Sections 2.5.1.1.2.1 Pile Driving and 2.5.1.1.3.1 Pile Driving),
- The reduction of prey availability (see Section 2.5.1.1.5.1 Pile Driving), and
- The increased exposure to potential predators (see Section 2.5.1.1.6.1 Pile Driving).

Pile driving may also result in physical impacts to fish (described here) that include direct injury or death through contact with driven piles as well as the displacement or disruption of normal behaviors.

It is expected that the effect of pile-driving-induced physical impacts to fish will not manifest in any substantial way as direct injury or death considering the extreme proximity required (physical contact) and that any effect at greater distance would be considered an acoustic stressor (see Section 2.5.1.1.1 Acoustic Stress). What is far more likely is that the effect of pile-driving-induced physical impacts to fish will occur as displacement or disruption of migration behaviors.

All pile driving is proposed to occur within the in-water work window. For species with migrations contemporaneous with the in-water work window for a particular location, those species may experience up to 12 hours of migration delay due to construction activities. Repeated disturbance may potentially increase stress levels, which could result in lower reproductive success in adults and reduced growth in juveniles.

2.5.1.1.7.1.1 North Delta Intake Locations

Section 2.5.1.1.3.1.1 North Delta Intake Locations describes pile driving activities at these locations.

2.5.1.1.7.1.1.1 Salmonids Exposure and Risk

Pile driving at the NDD locations has the potential to cause physical impacts to juvenile salmonids (as described in this section). Small numbers of Chinook salmon and steelhead juveniles may be present at either end of the in-water work window in some years, which may delay their migrations. Exposure is expected to occur to a much larger proportion of adult CCV steelhead due to migration timing.

In October, about 2 percent of juvenile SR winter-run Chinook salmon are expected to be found in the vicinity of the NDD. Less than 1 percent of CV spring-run Chinook salmon and less than 1 percent of the annual juvenile fall-run Chinook salmon population would be found near the NDD sites in June through October, and about 1-2 percent of CCV steelhead could be migrating past the NDD locations. Additionally, a large proportion of late fall-run Chinook salmon juveniles are likely to be exposed.

A large proportion of adult fall-run, and a small proportion of adult late fall-run, are expected to be found in the vicinity of the NDD during the in-water work window, though adult winter-run and spring-run Chinook salmon are not expected to be present. Adult CCV steelhead may potentially be found within the Delta during any month, and, unlike Chinook salmon, steelhead can spawn more than once, so post-spawn adults (typically females) have the potential to move back downstream through the Delta after completing their spawning in their natal streams.

Typically, adult steelhead moving into the Sacramento River basin begin to enter the Delta during mid to late summer, with fish entering the Sacramento River system from July through November. The timing of the adult CCV steelhead migration may potentially expose fish returning to the Sacramento River basin to the physical impacts of pile driving. Larger fish are more physically able to move away from any disturbance and are less likely to be injured. Because of the potential exposure of a small proportion juvenile salmonids, adult CCV steelhead, late fall-run and fall-run Chinook salmon to pile-driving-induced physical impacts (as described in this section), some adverse effects are likely. Adverse effects, however, would likely be limited to stress, displacement, or delay.

2.5.1.1.7.1.1.2 Green Sturgeon Exposure and Risk

Juvenile sDPS green sturgeon are potentially present throughout the Delta every month in small numbers, whereas spawning and post-spawn adults primarily migrate past the NDD locations during the spring and fall months, respectively. Because of the widespread and year-round potential presence of juvenile sDPS green sturgeon in the waters of the Delta, this life stage could be present in the vicinity of the NDD locations and could be exposed to physical impacts of pile-driving activities. Adverse effects to those present are expected to be limited to stress, displacement, or disruption of normal behavior for a small proportion of green sturgeon.

2.5.1.1.7.1.2 Clifton Court Forebay

Section 2.5.1.1.6.1.2 Clifton Court Forebay describes pile driving activities at this location.

2.5.1.1.7.1.2.1 Salmonids Exposure and Risk

Pile driving at the CCF may result in physical impacts to salmonids (as described in this section). Pile driving actions within the CCF overlap with the presence of adult and juvenile steelhead, adult and juvenile fall-run Chinook salmon, juvenile late fall-run Chinook salmon, and potentially adult late-fall run Chinook salmon. It is not expected that adult or juvenile winter-run or spring-run Chinook salmon, will be present in the CCF during pile driving.

A small proportion of salmonids will be adversely affected by physical impacts from pile driving activities at the CCF. As described above in Section 2.5.1.1.7 Physical Impacts to Fish, however, any adverse effects are expected to be limited to stress, displacement, or disruption the normal behavior.

2.5.1.1.7.1.2.2 Green Sturgeon Exposure and Risk

Post-spawning adults, sub-adults, and juveniles may be present in the Delta during the late summer and fall months and could therefore become exposed to physical impacts of pile driving activities in the CCF during the in-water construction period. A higher level of exposure is anticipated for the juvenile and sub-adult life stages of green sturgeon owing to their extended temporal occurrence while rearing in the waters of the Delta compared to the relatively short transit time of spawning adults migrating between the ocean and upstream spawning habitats through the waters of the Delta. Adverse effects to those present are expected to be limited to stress, displacement, or disruption of normal behavior for a small proportion of green sturgeon.

2.5.1.1.7.1.3 HOR Gate

Section 2.5.1.1.6.1.3 HOR Gate describes pile driving activities at this location.

2.5.1.1.7.1.3.1 Salmonids Exposure and Risk

Pile driving at the Head of Old River Gate has the potential to cause physical impacts (as described in this section) to juvenile and adult salmonids. Although injury is not likely to occur, impacts may include displacement or disruption to their normal behavior.

During the in-water work window, adult CCV steelhead may be exposed to pile-driving activities at the HOR gate as they come from or go to the San Joaquin River. This also applies to less than 1-2 percent of the juvenile steelhead emigration from either basin.

Sacramento River winter-run Chinook salmon and CV spring-run Chinook salmon are not expected to be present during the in-water work window, although a few individual spring-run Chinook salmon juveniles may be exposed in October (progeny of the experimental population introduced to the San Joaquin River basin).

Adult late fall-run Chinook salmon are not expected to be present in the Delta during the in-water work window and are not typically present in the San Joaquin River basin except as strays from the Sacramento River basin. Juvenile fall-run Chinook salmon may be exposed to activities during the July through August work window, though likely only in small numbers.

Therefore, physical impacts of pile-driving activities at the Head of Old River Gate are expected to adversely affect a small proportion of juvenile and adult CCV steelhead, as well as a small proportion of individual juvenile spring-run and fall-run Chinook salmon.

2.5.1.1.7.1.3.2 Green Sturgeon Exposure and Risk

Juvenile and sub-adult sDPS green sturgeon may be present throughout the Delta every month, whereas spawning and post-spawn adults are unlikely to migrate through the waters of the south Delta because their principal migratory route between the ocean and upstream spawning habitats lies primarily in the Sacramento River and the channels of the north Delta.

Because of the widespread and year-round presence of juvenile and sub-adult sDPS green sturgeon in the waters of the Delta, these life stages could be present in the vicinity of the HOR gate and could be exposed to physical impacts of pile-driving activities. Adverse effects to those present are expected to be limited to stress, displacement, or disruption of normal behavior for a small proportion of green sturgeon.

2.5.1.1.7.1.4 Barge Landing Locations

Section 2.5.1.1.6.1.4 Barge Landings Locations describes pile driving activities at these locations.

2.5.1.1.7.1.4.1 Salmonids Exposure and Risk

Pile driving during construction of the barge landing locations is not expected to cause direct physical injury to juvenile and adult salmonids, but those present may experience displacement or disruption to normal behavior. Contact with the piles as they are driven into the substrate is not anticipated to occur with either juvenile or adult salmonids, as the impact is a small concentrated area, and salmonids are likely to avoid the activity.

There will be seven barge landing locations throughout the Delta as described in the BA for the Project. However, an eighth location was identified by the applicants at the location of Intake 2 of the NDD and will be constructed if the construction contractor deems it necessary. For their construction, the action agency has proposed a reduced in-water work window of July 1 to August 31, which will further minimize salmonid exposure. Exposure of Chinook salmon is expected as follows:

- Juvenile winter-run Chinook salmon are generally expected to be present in the Delta from November to April, but with small numbers possible in September and October; while adult winter-run are present in the Delta between November and May. Winter-run Chinook salmon exposure is also minimized compared to other runs because six of the seven landings are located on or near the San Joaquin River, which is not the main migratory corridor for winter-run Chinook salmon.
- Juvenile spring-run Chinook salmon are expected to be present in the Delta from November through May, with adult spring-run presence between January and June.
- Adult late fall-run Chinook salmon are expected to be present in the Delta from October through March, peaking in December and January. However, juvenile late fall-run Chinook salmon may be present between July and January.
- Adult fall-run Chinook salmon may be present July through December, peaking in October. Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, with only small numbers present in July and August.

Given the timing and location of in-water construction activities, NMFS expects that the physical impacts related to the effects of pile-driving at the barge landing locations will not adversely affect juvenile or adult winter-run or spring-run Chinook salmon. The in-water work window will reduce the exposure of juvenile and adult fall-run and adult late fall-run Chinook salmon to pile-driving-induced physical effects. NMFS expects adverse effects to a small proportion of adult and juvenile late fall-run Chinook salmon to occur, as reduced exposure is expected, as they are generally not found in the San Joaquin River basin. NMFS also expects adverse effects will occur to a small proportion of juvenile fall-run, and a large proportion of adult fall-run Chinook salmon. NMFS believes that physical impacts to exposed fish will take the form of displacement or disruption of normal behavior of those fish.

Adult steelhead may potentially be found within the Delta during any month of the year. Typically, adult steelhead moving into the Sacramento River basin will start entering the Delta during mid to late summer, with the majority of fish entering the Sacramento River system from August through November. Steelhead bound for the San Joaquin River basin enter the system starting in September and with immigration peaking in December and January.

Risk of injury caused by pile-driving operations are somewhat minimized by the relatively small area of effect. NMFS expects that increased exposure to pile driving at the barge landing locations would not adversely affect adult or juvenile winter-run or spring-run Chinook salmon, adult late fall-run Chinook salmon, and juvenile steelhead. NMFS expects that increased physical impacts from pile driving will adversely affect a small proportion of adult fall-run Chinook salmon, adult steelhead, and juvenile fall-run and late fall-run Chinook salmon during the in-water work window.

With respect to physical impacts (as described in this section), the adverse effects to salmonids present during pile driving activities at barge landings are expected to be limited to stress, displacement, or disruption of normal behaviors, which could lead to increased predation of juveniles (see Section 2.5.1.1.6 Increased Predation Risk) or decreased spawning success for adults.

2.5.1.1.7.1.4.2 Green Sturgeon Exposure and Risk

Displacement or disruption of normal behavior of exposed green sturgeon may occur. Green sturgeon are potentially present in the Delta at any time of the year, exposing that species to pile-driving-induced injury at the barge landing locations. NMFS expects that increased physical impacts from pile driving will adversely affect a small proportion of juvenile, sub-adult, and adult green sturgeon, because of their likely presence at the barge landing locations during the in-water work window.

Although exposure is likely, direct injury is not likely, with adverse effects limited to stress, displacement, or disruption of normal behavior for a small proportion of green sturgeon that may be rearing or sheltering near shore in the vicinity of the barge landing locations during the in-water work window as they migrate through the waters of the Delta.

2.5.1.1.7.2 Dredging Entrainment

It is anticipated that most construction-related dredging will be done by hydraulic cutterhead dredges. The hydraulic cutterhead dredge operates by pulling water through the cutterhead assembly, upwards through the intake pipeline, past the hydraulic pump, and down the outflow pipeline to the dredge material placement site. The suction creates a field of entrainment around the head of the dredge intake pipe, which can result in adverse effects to fish. The size of the field of entrainment surrounding the cutterhead depends on the diameter of the pipeline, the power of the pump, and how deep the cutterhead is extended into the sediment layer.

In previous consultations regarding large-scale dredging projects for the Sacramento and Stockton DSC (NMFS 2005: Port of Stockon, West Complex Dredging Project Biological Opinion, NMFS 2006: Stockton DWSC Maintenance Dredging and Levee Stabilization Project Biological Opinion), NMFS calculated the flow fields surrounding a cutterhead with either half the cutterhead exposed above the sediment surface or a quarter of the cutterhead exposed above the sediment surface. Using a dredger with a 15-feet/second inlet pipe velocity (approximately equivalent to the dredger used for the DWSC maintenance dredging projects), the flows surrounding the cutterhead for the hemisphere exposure will have a velocity of 38 cm/sec at 0.5 m from the intake. At 1.5 m from the cutterhead, flow velocities are reduced to 4.2 cm/sec.

Assuming that the average size steelhead smolt is approximately 250 mm in length, based on data from the DJFMP Chipps Island trawls and Sacramento Trawls, as well as salvage data from the CVP and SWP fish protection facilities, then the flow velocity, even within 0.5 m of the cutterhead, is still below the burst swimming speed of 10 body lengths (BL)/sec for steelhead (i.e., 250 cm/sec burst speed). Similarly, a winter-run Chinook salmon juvenile with an average length of 85 mm would still have sufficient burst speed capacity to overcome the intake velocity of the dredge (85 cm/sec burst speed) at the 0.5-meter distance.

The modeling conducted for those maintenance dredging projects using a quarter hemisphere flow field for a deeper entrenched cutterhead calculated that flow velocities will be 76 cm/sec at

0.5 m and 8.4 cm/sec at 1.5 m. Velocities within 0.5 m of the cutterhead are still below the critical 10 BL/sec burst swimming speed for steelhead smolts, but are approaching the burst speed limits for smaller salmonids (Webb 1995).

It is therefore unlikely that either a steelhead smolt or a winter-run Chinook salmon juvenile that detects the presence of the cutterhead would be unable to escape its field of influence, unless its swimming ability was in some way compromised. Furthermore, most dredging will take place during the day and at times of the year (summer/fall) when juvenile salmonids are least likely to be present in the Delta. In addition, the NDD intake locations are in areas that are deeper than approximately 3 m and frequently deeper (6–7 m). It is not anticipated that steelhead or Chinook salmon smolts would be at this depth during the day while on their seaward migration, preferring to migrate in the upper reaches of the water column, thus further insulating them from the effects of the flow fields surrounding the cutterhead. Adult salmonids that may encounter the hydraulic dredge would likewise be able to avoid and escape entrainment due to their greater swimming speed.

Modeling indicates that smaller salmonids may be at risk because the flow velocities may exceed the burst swimming capabilities of the fish. Earlier Corps studies of juvenile salmonid entrainment in the lower Fraser River, British Columbia, Canada indicated that dredging in confined waters, such as narrow constricted channels where fish occupied the entire channel, could result in substantial entrainment rates of salmon (Dutta and Sookachoff (1975) as cited in Reine and Clarke 1998). Estimates of entrainment rates by hydraulic dredging ranged from 0.00004 to 0.4 percent of the total out-migration of fry and smolts (Arsenault (1981) in Reine and Clark 1998). The Corps report (Reine and Clark 1998) estimated that for chum salmon (O. keta), entrainment rates for hydraulic pipeline dredging were 0.008 fish/cubic yard of dredged material. The Corps report also concluded that for upland confined dredging material disposal, as is proposed for this project, entrainment mortality would be 100 percent.

In addition to salmonids, other organisms would be entrained by the hydraulic suction dredge, particularly small demersal fish, and benthic invertebrates. The Corps report (Reine and Clark 1998) estimated that the mean entrainment rate of a typical benthic invertebrate represented by the grass shrimp when the cutterhead was positioned at or near the bottom, was 0.69 shrimp/cubic yard, but rose sharply to 3.4 shrimp/cubic yard when the cutterhead was raised above the substrate to clean the pipeline and cutterhead assembly.

Similarly, benthic infauna, such as clams, would be entrained by the suction dredge in rates equivalent to their density on the channel bottom because they have no ability to escape. The loss of benthic food resources, such as amphipods or isopods, could reduce fish growth rates and increase the energy expended searching for food, depending on the density of the animal assemblages on the channel bottom. This would be more likely the case for sturgeon, which are specialized benthic feeders, but also could affect juvenile salmon and steelhead. (See Section 2.5.1.1.5.4 Dredging for more discussion.)

It is likely that small invertebrates—such as annelids, crustaceans (amphipods, isopods), and other benthic fauna—would be unable to escape the suction of the hydraulic dredge and be lost to the system. Also, many benthic invertebrates have pelagic, surface-oriented larvae. The loss, therefore, of these benthic invertebrates may reduce the abundance of localized zooplankton populations in the upper regions of the water column where juvenile salmonids migrate through the DWSC. The timing of the dredging cycle (summer-fall) may preclude forage base replacement by recruitment from surrounding populations prior to the following winter and spring migration period of juvenile steelhead and Chinook salmon through the dredging action area (Nightingale and Simenstad 2001).

2.5.1.1.7.2.1 Salmonids Exposure and Risk

Based on the timing of juvenile and adult Chinook salmon migration through the Delta from both the Sacramento and San Joaquin river basins described in Section 2.5.1.1 Construction Effects:

- Juvenile winter-run Chinook salmon are expected to be present in the Delta in very small numbers in September and October, and in higher numbers from November to April, while adult winter-run are present in the Delta between December and May.
- Juvenile spring-run Chinook salmon are expected to be present in the Delta from November through May. Adult spring-run presence is expected between January and March, with a few occurring in May and June.
- Juvenile fall-run Chinook salmon are expected to be present in the Delta from December through August, with only small numbers present in July and August. Adults are present from July to December.
- Juvenile late fall-run Chinook salmon are expected to be present from July through January. Adult late fall-run Chinook salmon are expected to be present in the Delta from October through April.

Although the timing and location of in-water activities such as dredging are designed to minimize overlap with the majority of migrating listed juvenile and adult Chinook salmon, in some years, small proportions of the different populations may still be migrating through the action area during the in-water work window. NMFS expects that a very few individual juvenile winter- and spring-run and adult winter-run Chinook salmon, some juvenile and adult fall-run Chinook salmon, and some juvenile late-fall run Chinook salmon present would be exposed to entrainment into the dredger cutterheads during dredging activities. Therefore, although some adverse effects are likely to occur, as explained above, this risk is considered to be low because:

- Very few to no winter-run or spring-run juveniles or adults are expected in the south Delta barge landing locations or the HOR locations during the in-water work windows;
- If present, few juvenile fish are expected to be near the bottom where the dredger is operating;
- If present, juvenile fish should be able to avoid and escape the inflow velocity to the cutterhead based on their burst speed swimming velocities; adults should be able to easily avoid the inflow velocity based on their size;

Based on the timing of juvenile and adult steelhead migration through the Delta from both the Sacramento and San Joaquin river basins described in Section 2.5.1.1 Construction Effects:

- Juvenile steelhead will begin to enter the northern Delta as early as September through December, but do not substantially increase in numbers until February and March.
- San Joaquin River basin juvenile steelhead occur throughout the winter and spring, but peak emigration occurs in April and May.

- Adult steelhead may begin to enter the Sacramento River from the Delta as early as June, but most immigration occurs from August through November, with a peak in September and October.
- Adult steelhead from the San Joaquin River basin enter the Delta starting in September, but peak in November through January.

NMFS expects that there will be a minor overlap of juvenile steelhead emigration with dredging activities in the fall and June, but that only a few individuals will be adversely effected. There is a substantial overlap of dredging activities with adult steelhead migration into the Sacramento River basin during the summer and fall period. The overlap of dredging activities with the adults from the San Joaquin River basin is considerably less because of the expected later timing of that upstream migration peak. Adverse effects to adult steelhead are not expected to occur. Adults should be able to easily avoid the inflow velocity to the cutterhead based on their size. Few individuals are anticipated in September and October when dredging activities are expected to be concluding. NMFS expects that the risk of entrainment for juvenile steelhead will be low due to the low likelihood of juvenile presence during the work window and the following factors:

- If present, few juvenile steelhead are expected to be near the bottom where the dredger is operating.
- Juvenile fish should be able to avoid and escape the inflow velocity to the cutterhead based on their burst speed swimming velocities.

2.5.1.1.7.2.2 Green Sturgeon Exposure and Risk

Although there is some uncertainty as to how sturgeon react to an approaching dredge, considering their benthic orientation there is a relatively high probability that some interactions between sturgeon and the suction head of the dredge will occur.

The Corps (2008) concluded the potential for entrainment of green sturgeon may be higher than for salmonids. Entrainment monitoring conducted during maintenance dredging operations in the Sacramento and Stockton DWSC, however, showed that very few sturgeon were ever entrained by the dredge. Recent laboratory studies of sturgeon behavior have demonstrated that green sturgeon have higher entrainment rates than salmonids, and do not exhibit avoidance behavior typical of salmonids near unscreened diversions, and that they may not be as adept at detecting disturbances in water velocity and altering their swimming direction to avoid them (Mussen et al. 2014).

Those findings suggest that sturgeon may also be more susceptible to entrainment into the suction head of the dredge. Adult and sub-adult sturgeon are expected to be able to swim away from the suction head of the dredge because of their size and corresponding swimming strength and speed, but juvenile green sturgeon are less likely to be able to overcome the sudden change in water velocities in the area immediately surrounding the suction head of the dredge and will likely become entrained and killed if they are in close proximity to it during operation.

Because of their year-round presence in the waters of the Delta, some juvenile sDPS green sturgeon will be present in the action area during the in-water work windows when dredging is scheduled to occur and could therefore be adversely affected by entrainment into the suction dredge. The rate of entrainment is difficult to ascertain, but will likely have a higher probability of occurring at the NDD and barge landings on the Sacramento River than at CCF, the HOR gate, or the south Delta in general, since a greater proportion of the population, and particularly the smaller individuals that are still growing as they transit from upstream riverine habitat to the Delta, will be present in the waters of their principal migratory pathway between the ocean and their upstream spawning habitat than might be found in the other parts of the Delta.

2.5.1.1.7.3 Barge Propeller Injury and Entrainment

Barge operations, routes, and assumptions are described in Section 2.5.1.1.1.2 Barge Traffic.

As noted in Section 2.5.1.1.1.2 Barge Traffic, Reclamation and DWR indicated that the assumed length of tug boats will be 65 to 100 feet (19.8 to 30.5 m) with a beam of approximately 35 feet (10.7 m) and a draft of approximately 6 to 8 feet (1.8 to 2.4 m).

To estimate the potential effects of increased barge traffic on listed species because of direct injury from propellers, NMFS assumed that propeller disc diameter is approximately 70 percent of the draft, or 50 to 70 inches (1.3 to 1.8 m) in diameter. This corresponds to dimensions for typical tug boats operating in the Delta and San Francisco Bay. Tugs in the Bay and Delta typically use shrouded propellers (e.g., Kort nozzles). Three sizes of propellers that span the middle range of diameters were used for the effects assessment (1.3-, 1.5-, and 1.8-meter diameter). These sizes correspond to ships with drafts from 1.86 to approximately 2.6 m.

The increase in barge traffic to the multiple barge landing sites in the Delta will concurrently increase the number of salmonids and green sturgeon that will have encounters with the propellers of the tugboats pushing the barges.

Although the exact numbers of fish entrained into the propeller’s zone of influence are impossible to determine, certain assumptions and modeling of the propeller entrainment zone can be made to give ranges for the numbers of affected fish. In order to make a simple assessment of the number of juvenile anadromous salmonids subject to propeller entrainment, NMFS determined the length of the route transited by ships in the San Joaquin River and Sacramento River channels, the range of ship propeller sizes, and then applied the recorded density of Chinook salmon or steelhead in the Delta from published data provided by the USFWS to characterize the juvenile salmonid entrainment numbers for vessel traffic within the different routes. NMFS assumes that densities in the lower Sacramento DWSC downstream of Rio Vista would be similar to those seen at Chipps Island. Currently, there are no catch per unit effort densities calculated for green sturgeon as very few green sturgeon are ever captured in monitoring efforts; therefore, no analyses for green sturgeon can be completed using this methodology. Similarly, capture of adult salmon or steelhead is very rare in the juvenile fish monitoring trawls conducted by USFWS, therefore catch per unit effort densities cannot be calculated for these life stages.

NMFS calculated the volume of water that is swept through the propeller disc during three different legs of the transit distance between the Port of Pittsburgh and the barge landings at Bouldin Island and CCF. Table 2-35 describe the miles contained within each reach of the barge routes assessed. The route analyses for the San Joaquin River portion of the barge landings start at the Port of Pittsburg at river mile 4 (RM 4) of the San Joaquin River and at the Port of Stockton at RM40. The Sacramento River route starts at Chipps Island for barges moving upriver to the NDD #2 location.

Table 2-35. Distances of Barge Routes for the Proposed Action.

San Joaquin River				
Reach	**Description**	**SJR River Miles (RM)**	**Miles**	**Kilometers**
Reach 1	Port of Pittsburgh to Blind Point	RM 4 to RM 10	6	9.7
Reach 2	Blind Point to Sevenmile Slough (Marker 42)	RM 10 to RM 20	10	16.1
Reach 3	Sevenmile Slough to Port of Stockton	RM 20 to RM 40	20	32.2
Sacramento River				
Reach	**Description**	**Sacramento River Miles (RM)**	**Miles**	**Kilometers**
Reach 1	Chipps Island to DWSC Channel Marker 37 (RM 14)	RM -4.5 to RM 14	18.5	29.8
Reach 2	Mouth of Sacramento River Channel/DWSC to NDD #2	RM 14 to RM 41.1	27.1	43.6

In order to calculate the final route mileages in the third reach to the final barge landing destinations in the San Joaquin River portion of the barge landings, the distance within the San Joaquin River from RM 20 or the Port of Stockton to the channel junction leading to the barge landing site is determined. This distance is then added to the distance within the new channel to the barge landing site for the cumulative distance the barge travels in reach 3 to the barge landing site. Barge traffic from the Port of Pittsburg is labeled as from the "West" while barge traffic originating from the Port of Stockton is labeled as from the "East".

Table 2-36. Barge Landing Locations.

Barge traffic from the West (Port of Pittsburg/ San Francisco)			
Barge Landing	**River Mile of Junction**	**Cumulative Miles to Landing**	**Cumulative kilometers to Landing**
Bouldin Island	RM 22.5	4.1	6.6
Clifton Court Forebay	RM 23	20	32.2
Barge Traffic from the East (port of Stockton)			
Barge Landing	**River Mile of Junction**	**Cumulative Miles to Landing**	**Cumulative kilometers to Landing**
Bouldin Island	RM 22.5	19.1	30.7
Clifton Court Forebay	RM 23	34	54.7

The volumes were simplified to be equivalent to the diameter of the propeller times the distance of each leg. The model calculating the volume had to be simplified because specific information for the pitch of the propeller, the revolutions per minute of the propeller disc, the area of water in front of the shrouded propeller entrained into the propeller, and the variability of the speed of the engine during the tug's maneuvering of barges was unavailable.

NMFS also assumes that there are twin propellers on each tugboat, thus the volume swept by a single propeller disc is multiplied by two to give the cumulative volume per tugboat transit. These volumes were then multiplied by the different Chinook salmon and steelhead densities, as measured by the USFWS during their monitoring efforts at Chipps Island, Jersey Point, Prisoners Point, and Sherwood Harbor (Speegle 2016; Cadrett 2005).

The products of these calculations were then adjusted for the projected rate of mortality for smolting salmonids between 85 and 250 mm long passing through the blades of a propeller or turbine (Gutreuter et al. 2003; Killgore et al. 2001; Dubois and Gloss 1993; Cada 1990; Holland 1986; Giorgi et al. 1988; Gloss and Wahl 1983) to derive the number of salmon mortalities for 1 year's volume of barge traffic in the San Joaquin DWSC going to Bouldin Island or the CCF barge landings and the volume of barge traffic using the Sacramento River route to the NDD Intake 2 construction site.

NMFS used a mortality value of 40 percent for Chinook salmon, which would represent smolts between 85 and 120 mm, and 80 percent mortality for steelhead smolts that encountered the propeller resulting in direct death because of being struck by the propeller blade, death from the cavitation surrounding the blade, or delayed death shortly following the encounter with the propeller. Other results for entrained fish include injury, but survivable wounds that do not result in immediate death; injuries that result in infections, but not immediate death; injuries that compromise swimming ability; and disorientation and temporary loss of swimming abilities. Any of these other results may also increase the vulnerability to predation post entrainment. However, the current model cannot account for these other results and thus other these results were not included in the model's outcome.

Additional assumptions for calculating propeller entrainment are:

- Barge traffic follows the schedule provided by the applicant,
    - June 1 to October 31 barges may travel to any one of the eight barge landing locations;
    - November 1 to May 31 barges may only travel between the Port of Stockton and the Bouldin Island barge landing, sailing in the San Joaquin River;
- That each point of origin for barge traffic accounts for one third of the trips to Bouldin or the CCF barge landing site during the June 1 to October 31 period, and only from the Port of Stockton from November 1 to May 31.
- Barges only travel on week days during the week, not on weekends for a cumulative 260 work days per year.
- Barge traffic to the NDD #2 intake location will only occur once per week (once every 5 work days) from June 1 to October 31 (110 work days).
- Number of estimated barge trips to Bouldin Island is 3,344 trips over 6 years, 557.3 trips per year, 2.14 trips per day (one way) and 4.3 round trips per day over a 260-work-day year.
- Number of estimated one-way barge trips to CCF is 2185 trips over 6 years, 364.2 trips per year, 3.33 trips per day one way and 3.67 trips per day round trip over a 110-work-day year (barge traffic limited to June 1 to October 31).
- Chipps Island fish densities were used for the Sacramento River leg from Chipps Island to RM 14. Sherwood Harbor fish densities were used from RM 14 to RM 41 on the Sacramento River route to NDD Intake 2.

- Chipps Island fish densities were used for the San Joaquin River route from RM 4 to RM 10.
- RM 10 to RM 20 on the San Joaquin River used estimated fish densities determined from the ratio of Jersey Point fish densities to Chipps Island fish densities to determine monthly densities throughout the year.
- RM 20 to barge landings sites on the San Joaquin River used estimated fish densities determined from the ratio of Prisoners Point fish densities to Chipps Island fish densities to determine monthly densities throughout the year.

The zones of effects for water entrainment by the propellers (inflow zone) are calculated only for the diameter of a given set of propeller along the length of the ship channel from Pittsburgh or Stockton to the Bouldin Island or CCF barge landings or Chipps Island to NDD Intake 2. Studies by Maynord (2000) indicated that the inflow zone for barge tows on the Mississippi River extend slightly beyond the beam of the tow (about 20 percent wider than the beam of the tow from centerline). Therefore, NMFS calculations may be underestimating the true volume of water entrained by the tugboat's propeller during its transit to the barge landings.

Similarly, NMFS does not have any data for potential avoidance of juvenile and adult salmonids to oncoming barge traffic. Data gathered by the USFWS trawls, however, should represent a reasonable approximation of fish density that a tug and barge would encounter in the channel. The trawling activities involve motorized vessels dragging a net through the channel's waters, which creates a substantial disturbance within the water column. The speed of the trawl is quite slow, generally less than 5 mph, providing ample opportunity for fish to escape the net by either moving laterally or vertically in the water column. Oncoming barge traffic would be moving at a faster rate (5 to 8 miles per hour) than the trawl vessels and would take up a greater percentage of the channel's cross section. The draft of the barge tow would be similar to that of the trawl (approximately 3 m), but would have a greater beam (15 to 17 m) than the width of the mouth of the trawl net (maximum of 9.14 m), which would necessitate moving greater lateral distances to avoid the oncoming barge compared to the mouth of the mid-water or Kodiak trawl net.

The following table portrays the physical assumptions for the barges and tug boats used in the analyses.

Table 2-37. Assumed Physical Properties of Barges and Tugboats for Analyses.

Vessels	Beam	Length	Draft
Barge	45–50 ft (13.7-15.2 m)	200–250 ft (61-76 m)	6–10 ft (1.8-3.0 m)
Tug boat	35 ft 10.7 m)	65–100 ft (19.8–30.5 m)	6–8 ft (1.8–2.4 m)
Assumed entrainment zone (CL beam+ 20%)	30 ft (9,100 mm)		
	Number/tug boat	**Diameters**	
Propeller	2	50–70 in. (1.3–1.8 m)	
Vessel speed	5–8 mph	2,200 mm–3,600 mm/sec	

The maximum burst swimming speed for juvenile salmonids is approximately 10 times their body length (Webb 1995) or 900 mm/sec per second for Chinook salmon and 2200 mm/sec for steelhead smolts.

The following table portrays the physical information for salmonid swimming characteristics used in the analyses.

Table 2-38. Assumed Properties for Chinook Salmon and Steelhead Analyses.

Properties	Chinook Salmon	Steelhead
Average body length (BL)	90 mm	220 mm
Assumed burst speed = 10 BL/sec	900 mm/sec	2,200 mm/sec
Assumed maximum duration of burst speed swimming	15 sec	15 sec
Relative ratio of vessel speed to BL	24-40 times BL	10-16 times BL
Time to swim out of entrainment zone	~10.1 sec	~4.5 sec
Vessel distance travelled	22,000-36,000 mm (22-36 m)	10,000-16,200 (10-16.2 m)

Although a salmonid would easily be able to detect the ship's propulsion system at these distances, data is lacking as to the critical distances at which a salmonid would exhibit escape responses as a result of the increasing noise levels. At 40 m in front of the bow of an oncoming barge, the propulsion unit of a ship and its propeller will be an additional 75 to 80 m further distant from this point because of the length of the barge and tug. Therefore, the noise source as detected by the fish 40 m in front of the ship is actually about 120 m distant. This distance is shorter for steelhead and is less than 100 m.

2.5.1.1.7.3.1 Winter-run Exposure and Risk

Because the barge traffic occurs long-term for the duration of the construction period, all migrations of juvenile and adult winter-run Chinook salmon will overlap with the projected barge traffic operations during the 5 to 6 years of the projected construction schedule.

The multiple barge landing locations are located in the north Delta, central Delta, and south Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of winter-run Chinook salmon from the Sacramento River basin. From Chipps Island to the Golden Gate, all juvenile and adult life stages of winter-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco.

Estimates for annual propeller entrainment and mortality of winter-run Chinook salmon passing through the propellers of the tugboats are based on the densities of winter-run sized Chinook salmon captured in the fish monitoring efforts at Chipps Island and Sherwood Harbor over the course of a year, using data from 1996 through 2016. The year-round implementation of the fish monitoring efforts accounts for the differences in local presence and migratory behavior and timing as detected in the changes in observed fish densities. Data from Jersey Point (1997-1998) and Prisoners Point (1999) monitoring efforts were used to construct ratios with the more extensive Chipps Island data to account for months not sampled at these locations.

Table 2-39 below provides estimates for the annual entrainment of juvenile winter-run Chinook salmon to the three different barge landings over the course of 1 year for the three different propeller diameters. Estimates of adult entrainment are not possible due to a lack of information regarding fish density in the different barge routes, and the ability of adult fish to avoid the barge and tugboat as it approaches. It is expected that some adult fish would be entrained as there are rare catches of adult Chinook salmon in the Chipps Island trawl.

Table 2-39. Estimated Annual Winter-run Juvenile Propeller Entrainment for Three Barge Landing Sites.

Propeller Diameter	Barge Landing Site						
	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake [2]	Annual sum Entrainment	Annual Mortality
1.3 m	0	32	0	0	0	32	13
1.5 m	0	43	0	0	0	43	17
1.8 m	0	61	0	0	1	62	25

[1] Barge traffic from either Antioch or San Francisco point of origin is "west"

[2] Barge traffic from the Port of Stockton point of origin is "east"

NMFS expects that the proposed barge traffic will adversely affect a small proportion of winter-run Chinook salmon over the course of the proposed construction of the PA.

2.5.1.1.7.3.2 Spring-run Exposure and Risk

Because the barge traffic occurs long-term for the duration of the construction period, all migrations of juvenile and adult spring-run Chinook salmon will overlap with the projected barge traffic operations during the 5 to 6 years of the projected construction schedule.

The multiple barge landing locations are located in the north Delta, central Delta, and south Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of spring-run Chinook salmon from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of spring-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco.

The estimates for annual propeller entrainment and mortality of spring-run Chinook salmon passing through the propellers of the tugboats are based on the densities of spring-run-sized Chinook salmon captured in the fish monitoring efforts at Chipps Island and Sherwood Harbor over the course of a year, using data from 1996 through 2016. The year-round implementation of the fish monitoring efforts accounts for the differences in local presence and migratory behavior and timing as detected in the changes in observed fish densities.

Data from Jersey Point (1997-1998) and Prisoners Point (1999) monitoring efforts were used to construct ratios with the more extensive Chipps Island data to account for months not sampled at these locations.

Table 2-40 below provide estimates for the annual entrainment of juvenile spring-run Chinook salmon to the three different barge landings over the course of 1 year for the three different propeller diameters. Estimates of adult entrainment are not possible due to a lack of information regarding fish density in the different barge routes, and the ability of adult fish to avoid the barge and tugboat as it approached. It is expected that some adult fish would be entrained as there are rare catches of adult Chinook salmon in the Chipps Island trawl.

Table 2-40. Estimated Annual Spring-run Juvenile Propeller Entrainment for Three Barge Landing Sites.

Propeller diameter	Barge Landing Site						
	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake [2]	Annual sum Entrainment	Annual Mortality
1.3 m	3	204	5	2	0	214	86
1.5 m	3	272	7	3	0	285	114
1.8 m	5	391	10	4	0	410	164

[1] Barge traffic from either Antioch or San Francisco point of origin is "west"

[2] Barge traffic from the Port of Stockton point of origin is "east"

NMFS expects that the proposed barge traffic will adversely affect a small proportion of spring-run Chinook salmon over the course of the proposed construction of the PA.

2.5.1.1.7.3.3 Steelhead Exposure and Risk

Because the barge traffic occurs long-term for the duration of the construction period, all emigrations of juvenile CCV steelhead and upstream and downstream migrations of adult CCV will overlap with the projected barge traffic operations during the 5 to 6 years of the projected construction schedule.

The multiple barge landing locations are in the north Delta, central Delta, and south Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of CCV steelhead from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of CCV steelhead overlap with projected routes of the barge traffic from San Francisco.

Estimates for annual propeller entrainment and mortality of steelhead passing through the propellers of the tugboats are based on the densities of steelhead captured in the fish monitoring efforts at Chipps Island and Sherwood Harbor over the course of a year, using data from 1998 through 2016.

The year-round implementation of the fish monitoring efforts accounts for the differences in local presence and migratory behavior and timing as detected in the changes in observed fish densities. Data from Jersey Point (1997-1998) and Prisoners Point (1999) monitoring efforts were used to construct ratios with the more extensive Chipps Island data to account for months not sampled at these locations.

Table 2-41 and Table 2-42 below provide estimates for the annual entrainment of juvenile CCV steelhead to the three different barge landings over the course of 1 year for the three different propeller diameters similar to those constructed for winter-run and spring-run Chinook salmon using densities of unclipped steelhead and clipped steelhead. Estimates of adult entrainment are not possible due to a lack of information regarding fish density in the different barge routes, and the ability of adult fish to avoid the barge and tugboat as it approaches. It is expected that some adult fish would be entrained as there are rare catches of adult steelhead in the Chipps Island trawl.

Table 2-41. Estimated Annual Unclipped California Central Valley Steelhead Juvenile Propeller Entrainment for Three Barge Landing Sites.

Propeller diameter	Barge Landing Site						
	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake [2]	Annual sum Entrainment	Annual Mortality
1.3 m	6	5	12	4	1	28	22
1.5 m	8	6	16	6	1	37	30
1.8 m	11	9	23	8	2	53	43

[1] Barge traffic from either Antioch or San Francisco point of origin is “west”

[2] Barge traffic from the Port of Stockton point of origin is “east”

Table 2-42. Estimated Annual Clipped California Central Valley Steelhead Juvenile Propeller Entrainment for Three Barge Landing Sites.

Propeller diameter	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake [2]	Annual sum Entrainment	Annual Mortality
1.3 m	0	32	1	0	0	34	27
1.5 m	0	43	1	0	0	45	36
1.8 m	1	62	1	0	0	64	52

[1] Barge traffic from either Antioch or San Francisco point of origin is “west”

[2] Barge traffic from the Port of Stockton point of origin is “east”

NMFS expects that the proposed barge traffic will adversely affect a medium proportion of steelhead over the course of the proposed construction of the PA.

2.5.1.1.7.3.4 Green Sturgeon Exposure and Risk

Green sturgeon can become entrained by the flow field generated by propellers on large ships, barges, tugs, or dredges. Because of their size, adult sturgeon that are unable to swim away and escape entrainment are likely to be struck by the propeller blades and either injured or killed. Juvenile sturgeon will likely have a more difficult time swimming away from the propeller’s flow field and evading entrainment, but they might be small enough to become entrained in the flow field and pass through the propeller’s wake without being struck by any of the blades. Even if a juvenile fish did become entrained and escape direct injury from being struck by a propeller blade, the fish would nevertheless be disoriented, and possibly more susceptible to predation, from having been caught in the vortex of turbulent flow trailing the propeller.

The probability of propeller entrainment will vary depending on the draft of the vessel and the size, orientation, and behavior of the fish. Because of their benthic orientation, sturgeon may be less vulnerable to propeller entrainment of shallow draft vessels and, conversely, more so to deep draft vessels.

Based on the planned operation of barges throughout the action area where juvenile green sturgeon may be present during any month of the year, and through which spawning adults annually migrate between the ocean and their upstream spawning habitat, NMFS has determined that many, if not all, juvenile and spawning adult sDPS green sturgeon will be exposed to a higher risk of propeller entrainment from increased barge traffic in the channels of the Delta over the 6-year period of barge operations. Even though there is a high level of overlap with green sturgeon distribution in the Delta, and thus potential exposure to barge traffic and associated propeller entrainment, the behavior of sturgeon to stay out of the upper portion of the water column reduces their actual exposure to the propellers of the shallow draft tugboats. This is likely to result in adverse effects to only a medium proportion of juvenile and adult sDPS green sturgeon.

2.5.1.1.7.3.5 Fall/Late Fall-run Exposure and Risk

Because barge traffic occurs long-term for the duration of the construction period, all migrations of juvenile and adult fall/late fall-run Chinook salmon will overlap with the projected barge traffic operations during the 5 to 6 years of the projected construction schedule.

The multiple barge landing locations are in the north Delta, central Delta, and south Delta and thus occur on waterways that are occupied by both juvenile and adult life stages of fall/late fall-run Chinook salmon from both Sacramento and San Joaquin river basins. From Chipps Island to the Golden Gate, all juvenile and adult life stages of fall/late fall-run Chinook salmon overlap with projected routes of the barge traffic from San Francisco.

Estimates for annual propeller entrainment and mortality of fall/late fall-run Chinook salmon passing through the propellers of the tugboats are based on the densities of fall/late fall-run-sized Chinook salmon captured in the fish monitoring efforts at Chipps Island and Sherwood Harbor over the course of a year, using data from 1996 through 2016.

The year-round implementation of the fish monitoring efforts accounts for the differences in local presence and migratory behavior and timing as detected in the changes in observed fish densities. Data from Jersey Point (1997–1998) and Prisoners Point (1999) monitoring efforts were used to construct ratios with the more extensive Chipps Island data to account for months not sampled at these locations.

Table 2-43 and Table 2-44 below provide estimates for the annual entrainment of fall/late fall-run Chinook salmon to the three different barge landings over the course of 1 year for the three different propeller diameters similar to those constructed for winter-run and spring-run Chinook salmon using densities of fall-run and late fall-run Chinook salmon. Estimates of adult entrainment are not possible due to a lack of information regarding fish density in the different barge routes, and the ability of adult fish to avoid the barge and tugboat as it approaches. It is expected that some adult fish would be entrained as there are rare catches of adult Chinook salmon in the Chipps Island trawl.

Table 2-43. Estimated Annual Fall-run Chinook Salmon Juvenile Propeller Entrainment for Three Barge Landing Sites.

Propeller diameter	Barge Landing Site						
	Bouldin Island (west)[1]	Bouldin Island (east)[2]	CCF (west)	CCF (east)	NDD Intake 2	Annual Sum Entrainment	Annual Mortality
1.3 m	561	738	1,133	411	104	2,947	1,179
1.5 m	747	983	1,508	548	138	3,924	1,570
1.8 m	1076	1415	2172	789	199	5,651	2,260

[1]Barge traffic from either Antioch or San Francisco point of origin is “west”

[2]Barge traffic from the Port of Stockton point of origin is "east"

Table 2-44. Estimated Annual Late Fall-run Chinook Salmon Juvenile Propeller Entrainment for Three Barge Landing Sites.

Propeller diameter	Barge Landing Site						
	Bouldin Island (west)1	Bouldin Island (east)2	CCF (west)	CCF (east)	NDD Intake 2	Annual sum Entrainment	Annual Mortality
1.3 m	9	12	18	6	2	47	19
1.5 m	12	16	24	9	3	63	25
1.8 m	17	23	34	12	5	91	36

[1]Barge traffic from either Antioch or San Francisco point of origin is "west"

[2]Barge traffic from the Port of Stockton point of origin is "east"

NMFS expects that the proposed barge traffic will adversely affect a medium proportion of fall/late fall-run Chinook salmon over the course of the proposed construction of the PA.

2.5.1.1.7.4 Dewatering Capture/Release

Cofferdams at the NDDs, CCF, and HOR gate will be installed before construction of the PA infrastructure begins. Depending on the specific location, the in-water work window will begin as early as June and may extend through the end of October (Table 2-9).

Cofferdam installation begins with sheet pile installation. Once the cofferdam area is isolated, the action agency/applicant will implement AMM 8, Fish Rescue and Salvage Plan (Appendix 3.F of BA), which involves removing any fish remaining in the isolated cofferdam area before dewatering. Any fish present will be adversely affected, either by capture, transfer, and release, or, if capture was avoided, by becoming stranded during dewatering. Some portion of fish within the cofferdam area will be expected to die during the dewatering process.

2.5.1.1.7.4.1 North Delta Intake Locations

Construction of each intake is projected to take approximately 4 to 5 years and will require approximately 42 days to construct and close the cofferdam structure at each NDD intake location (BA Appendix 3.E).

Portions of the cofferdam will become permanent components of the intake structure when construction is completed. All in-water activities will be restricted to June 15 through October 31 to minimize exposure of listed fish species to construction-related impacts on water quality and other hazards.

Initial construction activities at each intake will involve installing a sheet pile cofferdam in the river during the first construction season, which will isolate the waterside portion of the PA infrastructure during the remaining years of construction. During the period of sheet pile installation, fish may be able to escape from the area behind the cofferdam and the adjacent bank through open gaps in the sheet pile alignment that have not yet undergone sheet pile installation. Fish that do not escape are likely to be injured or killed by the subsequent day's sheet pile installation. NMFS expects that the final days of sheet pile installation will have the highest risk of entrapping fish behind the cofferdam as the final gaps in the cofferdam alignment are closed off. Fish that are entrapped behind the cofferdam will be the subject of fish capture and relocation. The capture and relocation efforts are unlikely to be completely effective, and some fish will avoid capture and die behind the cofferdam as it is dewatered. Other fish that are captured during the dewatering process may not survive this action and die immediately or at some time afterwards due to latent injuries or stress. It is expected that the methods of capture to rescue fish can and will result in injury or death due to entanglement in seine nets or injury due to electrofishing efforts. Furthermore, water quality conditions are expected to deteriorate during the dewatering process, leading to elevated risk of stress, injury, or death of fish trapped behind the cofferdam.

2.5.1.1.7.4.1.1 Chinook Salmon Exposure and Risk

The timing of cofferdam installations at the NDD sites will greatly minimize exposure to Chinook salmon. Winter-run Chinook salmon adults are expected to be in the activity area November through June, while juveniles are expected to be outmigrating past the area October through April. Therefore, there is some likelihood that adults or juvenile winter-run Chinook salmon could be in the area during the final closing of the cofferdams and become entrapped behind the cofferdams. These fish would be vulnerable to the effects of the dewatering activities.

Adult spring-run Chinook salmon are not expected to be in the area during in-water work because most of them will have moved upstream between January and March; very few may be migrating through the area in May and June. In some years, juvenile spring-run Chinook salmon migrating through the NDD locations may occur as late as June. This is likely to only occur in some years, and in small proportions (less than 2 percent) of the total number of outmigrating juvenile spring-run Chinook salmon. Thus, these late emigrating fish could be present during the final closing of the cofferdam and become entrapped behind the cofferdam. These fish would be vulnerable to the effects of dewatering activities.

Fall-run Chinook salmon adults are expected to be in the area July through December, and juveniles from December through August, therefore potentially exposing both life stages to dewatering activities if they are present during the final closing of the cofferdams and become entrapped behind the sheet piles. Late-fall Chinook salmon adults are expected to be in the area October through April, and juveniles July through September, and again November through January. Therefore, potential exposure will occur to both adult and juvenile life stages.

If construction takes several weeks to complete, it is expected that most fish will find their way out through gaps in the sheet pile wall. This ability to escape will diminish as the ratio of gap length to cofferdam wall length also diminishes, making it harder for fish to find the gap in the wall to escape. Those fish unable to escape will become entrapped behind the cofferdam wall and be subject to dewatering activities. Adverse effects to Chinook salmon are expected to occur because of the overlap in cofferdam closure and Chinook salmon migration timing. Adult Chinook salmon migrating through the construction area, however, are not expected to be as adversely affected as juveniles due to their ability to actively swim out of the open end of the cofferdam before it is closed. When pile driving activity begins, they will be expected to leave the area behind the cofferdam through one of the gaps in the sheet piles in the cofferdam wall. Nevertheless, some adults are also expected to become entrapped behind the cofferdam wall and NMFS expects there will be a small proportion of the adult population adversely affected. NMFS also expects a small proportion of the Chinook salmon juveniles to be adversely affected, primarily late migrants.

2.5.1.1.7.4.1.2 Steelhead Exposure and Risk

Installation of the cofferdams at the NDD intake sites has the potential to entrap both juvenile and adult CCV steelhead during construction. Adult steelhead are migrating upstream throughout the in-water work window of June 15 to October 31. If cofferdam construction is initiated in June and finished quickly, then juvenile CCV steelhead may be entrapped behind cofferdam structures during their downstream emigration. If construction takes several weeks to complete, it is expected that most fish will find their way out through gaps in the sheet pile wall. This ability to escape will diminish as the ratio of gap length to cofferdam wall length also diminishes, making it harder to find the gap in the wall to escape.

Similarly, if the cofferdam installation continues into the end of summer and early fall, then increasing numbers of upstream migrating adult CCV steelhead are subject to entrapment behind the cofferdam structure. Although adult steelhead have a higher likelihood and ability than juveniles to leave the cofferdam before it is closed, there may be a small proportion that remain who will be subject to fish capture or relocation as described for adult Chinook salmon. NMFS expects adverse effects to a small proportion of both juvenile and adult CCV steelhead to occur as a result of these activities.

2.5.1.1.7.4.1.3 Green Sturgeon Exposure and Risk

The in-water work window will minimize the exposure of adult green sturgeon migrating to upstream spawning habitat since the majority of those fish will have already passed by the action area at the NDD before the end of May each year. Similarly, most post spawn adults will migrate back out to the ocean either before or after over summering in upstream spawning habitat depending on the strategy adhered to by each individual. Juvenile green sturgeon have the greatest potential to be exposed to the effects of dewatering in association with coffer dam installation during the in-water construction period because they have the potential to be present in the action area during any month of the year. Green sturgeon that become stranded behind the sheet pile walls during cofferdam installation will likely be captured for removal and relocation before dewatering of the isolated area behind the cofferdam is completed due to their larger size which makes them more visible. Those individual fish that are captured by seining will be subject to handling stress during the relocation efforts. Those individual fish that are able to evade capture in a seine may instead be subject to the stress of electrofishing and then handling afterwards.

The size of adult green sturgeon makes it unlikely that they would be able to evade detection or capture in the confined area behind the cofferdam before dewatering, so NMFS does not expect any adult green sturgeon to become exposed to the adverse effects of complete dewatering. Some juvenile sturgeon, however, could conceivably evade capture and suffer declining water quality conditions during the dewatering process. NMFS expects that implementation of the fish rescue and salvage plan (AMM 8) will sufficiently minimize the risk of stranding so that very few sDPS green sturgeon will experience the adverse effects associated with dewatering. A small proportion of juveniles and adults will be adversely affected from capture and handling stress during relocation efforts.

2.5.1.1.7.4.2 Clifton Court Forebay

Adverse effects to salmonid species would be minimized by restricting all in-water construction to July 1 through October 31, limiting the duration of these activities to the extent practicable, and implementing AMM8.

The installation of cofferdams in the CCF work area will include installing the siphon infrastructure in the future NCCF (two work seasons), the partition dike cofferdam across the width of the existing CCF (two work seasons), and the east and west dikes adjacent to the existing levee embankments to facilitate construction of the new SCCF embankments (one season).

The siphon structure will require installing a cofferdam enclosure to isolate half of the inlet channel to the Skinner Fish Protection Facility in each of two consecutive work seasons. The east and west embankment dikes will require that the space between the cofferdam and existing levee embankments be dewatered and fish capture or relocation operations carried out per AMM 8 when the cofferdams are fully installed.

The partition dike across the width of the existing CCF will be constructed in one season, except for two, 100-foot-wide gaps in the eastern and western ends of the cofferdam wall. These gaps will be closed the following work season when the new expansion area to the south of the existing CCF is flooded and the existing earthen embankment removed to design elevation. Once the gaps are closed off with sheet piles, the entire NCCF area will be dewatered and a fish capture or relocation operation conducted per AMM 8.

2.5.1.1.7.4.2.1 Salmonid Exposure and Risk

The timing of the in-water work window is expected to minimize the exposure of salmonids to entrapment behind the cofferdams during construction. Typically, salvage of listed salmonids at the CVP and SWP fish collection facilities ends in June, and by July water temperatures in the CCF are consistently in excess of thermal preferences for Chinook salmon or steelhead (greater than 22°C). This typically indicates environmental conditions that are inhospitable to salmonids and minimizes the potential for salmonids to be present in the forebay during the start of in-water construction in July.

The projected duration of cofferdam installation is 85 days for the eastern and western embankment cofferdams, 72 days each work season for the NCCF siphon, 86 days to install the partition cofferdam across the CCF, and 30 days to close the partition dike in the second construction season.

If in-water work starts for the cofferdams on July 1, then completion of the work should be no later than the end of September if work is continuous and approximately the end of October if limited to a 5-day work week. The risk of salmonids entering the cofferdam structures at the end of the work window increases by the end of October, but is still considered low based on historical salvage records at the CVP and SWP projects. Therefore, it is still unlikely that more than a few individual salmonids would be present in the areas behind the cofferdams during the dewatering process and be the subject of a fish rescue and salvage. NMFS expects, however, that there may be adverse effects to a small proportion of salmonids.

2.5.1.1.7.4.2.2 Green Sturgeon Exposure and Risk

As described for the NDD intake locations in Section 2.5.1.1.7.4.1 North Delta Intake Locations, very few individual green sturgeon, if any, will be exposed to the adverse effects associated with dewatering at the CCF, and only a small proportion of juveniles, sub-adults, and adults will experience the stress of capture and handling during relocation efforts. This potential for exposure to dewatering in relation to the CCF location is likely even further reduced because of how far removed in the south Delta the site is from the main migratory path of green sturgeon between the ocean and the Sacramento River and the relatively low numbers and density of sturgeon expected to occur in this area.

2.5.1.1.7.4.3 HOR Gate

Construction of the HOR gate is expected to take 2 years. The HOR gate will be constructed in two phases using cofferdams to isolate and dewater half the channel of Old River during the first phase and the other half during the second phase. All in-water construction work, including cofferdam installation, will be restricted to August 1 through October 31 to minimize or avoid potential effects on listed fish species. AMM 8 will be implemented to minimize impacts to fish during dewatering and implementation of the fish capture and relocation plan.

2.5.1.1.7.4.3.1 Chinook Salmon Exposure and Risk

Limiting in-water work at the HOR Gate to the August 1 through October 31 work window is expected to minimize exposure to Chinook salmonid species because:

- Winter-run Chinook salmon are not expected to be present near the HOR Gate because it is far from their migration routes. Furthermore, the winter-run Chinook salmon-sized juveniles that have been found in the area of the HOR Gate have only been found there in March and April.
- Juvenile spring-run Chinook salmon originating from the Sacramento River basin are not expected to be present near the HOR Gate because it is far from their migration routes. San Joaquin River basin spring-running fish and those from the reintroduced experimental population have been found in the area of the HOR Gate in April and May.
- Late fall-run Chinook salmon are not expected to be present in the vicinity of the HOR Gate because this area is far from any migration routes used by this run. While late fall-run Chinook salmon adult strays from the Sacramento River basin could end up near the HOR gate location, the likelihood of occurrence is very low and impossible to predict. Juvenile late fall-run Chinook salmon occur in the Delta from July through January, which may include the HOR gate location, and which overlaps with the August through October construction window.
- Juvenile fall-run Chinook salmon are expected to be present in the vicinity of the HOR Gate from April through June. And while adult fall-run will be migrating through the action area July through December, only a small proportion of the Central Valley population is expected to pass near the HOR Gate.

It is also expected that the methods of fish capture will result in injury or death to a small percentage of fish (less than 10 percent), due to entanglement in seine nets or injury due to electrofishing efforts. Furthermore, water quality conditions are expected to deteriorate during the dewatering process, leading to elevated risk of stress, injury, or death of fish trapped behind the cofferdam.

A small proportion of Chinook salmon are expected to be adversely effected as a result of HOR construction activities.

2.5.1.1.7.4.3.2 Steelhead Exposure and Risk

Juvenile CCV steelhead are likely to be present in the HOR Gate construction area during cofferdam installation in very low numbers based on their emigration timing. The construction of the cofferdam structures in Old River will occur from August through October, when few juvenile steelhead have been observed in either regional monitoring or in fish salvage at the CVP and SWP facilities (Reclamation 2017; DJFMP 2017).

Based on regional monitoring data and salvage data from the SWP and CVP fish collection facilities, less than 1-2 percent of the annual juvenile emigration from either basin is expected to occur during the proposed work windows in 2020 and 2021. The presence of juvenile CCV steelhead from the San Joaquin River basin is expected to peak in April and May based on historical data from the Mossdale trawl location.

Adult CCV steelhead from the San Joaquin River basin migrate into the Delta beginning in September and October, with peak migration occurring between November and January. Because the cofferdam installation at the HOR gate occurs August through October, coupled with the location of the HOR Gate, only those adult steelhead migrating into the San Joaquin River basin during these months will be affected. No steelhead from the Sacramento River basin are anticipated to be present at this location at any time.

It is anticipated that only a small proportion of the annual adult upriver migration will overlap with pile driving associated with the cofferdam installation. It is expected that only fish migrating past the cofferdam during the final installation of the sheet piles will be at risk for entrapment within the cofferdam before dewatering. Earlier arriving fish will have either had time to escape the cofferdam enclosure through openings in the wall or will have died or been injured during the sheet pile-driving actions while partially trapped in the enclosure.

Fish that are entrapped behind the completed cofferdam will be the subject of fish capture and relocation per AMM 8. The capture or relocation effort is unlikely to be completely effective. Some fish will avoid capture and die behind the cofferdam as it is dewatered. Other fish that are captured during the dewatering process may be stressed or injured and die immediately or at some time afterwards.

It is expected that the methods of fish capture will result in injury or death to a small percentage of fish (less than 10 percent), due to entanglement in seine nets or injury due to electrofishing efforts. Furthermore, water quality conditions are expected to deteriorate during the dewatering process, leading to elevated risk of stress, injury, or death of fish trapped behind the cofferdam. Although unlikely, there is some possibility a few individual juvenile steelhead will be exposed and adversely effected. Adult steelhead would more likely be exposed, but more likely to leave the area of activity. However, a small proportion of adult steelhead may nonetheless be subject to adverse effects.

2.5.1.1.7.4.3.3 Green Sturgeon Exposure and Risk

Very few green sturgeon, if any, will be exposed to dewatering activities at the HOR gate. The risk of exposure is low because of the distance from the main migratory path of green sturgeon (between the ocean and the Sacramento River), which results in relatively low numbers and density of green sturgeon expected to occur in this area. Therefore, a very small proportion of juvenile green sturgeon will experience the stress of capture and handling during relocation efforts.

2.5.1.2 Operations Effects

Water facility operations are described in the BA Section 3.3 Operations and Maintenance of New and Existing Facilities. Modeling methods and results simulating operations of the PA and NAA are provided in BA Appendix 5.A CALSIM II Modeling and Results and Appendix 5.B DSM2 Modeling and Results. For ease of reference, the proposed North Delta Diversion bypass rules, the proposed operating criteria for the existing south Delta facilities, and existing Delta regulatory requirements that guided modeling and analysis of the proposed operations are in Appendix A2. The North Delta Diversion bypass rules, as modified during the consultation process to include unlimited pulse protections for juvenile migrating Chinook salmon, will not result in modifications to upstream operations beyond what is evaluated here.

As stated in the BA, for the purpose of analyzing “upstream” operational effects, “upstream” refers to waterways upstream of the legal Delta where flows, reservoir storage, and water temperatures and, as a result, listed fish species or critical habitat for such species may be affected by implementation of the PA.

A preliminary screening analysis was conducted for the BA using model outputs of exceedance plots and mean reservoir storage, monthly flows, and water temperatures, where available, in the Trinity, Sacramento, American, San Joaquin, and Stanislaus Rivers and Clear Creek to determine whether modeled flows, storage, and water temperatures in any of these waterways would be clearly not affected by the PA and, therefore, no further analyses of effects on listed aquatic species or critical habitat for such species would be necessary in the waterway.

This preliminary analysis indicated that there is the potential for changes as a result of the PA in reservoir operations, instream flows, and water temperatures in the Sacramento River and American River. Therefore, this section assesses potential effects of those changes on listed aquatic species and critical habitat in the American River and Sacramento River upstream of the Delta.

2.5.1.2.1 Increased Upstream Temperature

Coldwater Pool

Salmonids cannot access historical spawning grounds above the Shasta Dam and are now dependent on cold water pool releases to successfully spawn during the summer and fall. Shasta reservoir stores water for several purposes including flood control, irrigation, and water releases in dry months to prevent salt intrusion into the Delta. Reclamation is also responsible for providing adequate in-stream temperatures so that ESA-listed salmonids below Keswick Dam can successfully spawn each year. A temperature control device was installed in 1997 to improve downstream temperatures for ESA-listed salmonids by releasing epilimnetic waters in the winter/spring and hypolimnetic waters in the summer/fall. Management and timely distribution of the cold water stratified at the bottom of the reservoir is a critical component of temperature management of instream flows during the salmonid spawning season.

The amount of cold water pool available for instream temperature management depends on carry-over storage, reservoir water temperature, and the amount, timing, and water temperature of inflows to and outflows from Shasta Reservoir. End of September storage targets of 1.9 MAF are part of the NMFS RPA actions for the CVP/SWP long-term operations intended to sustain cold water supply for winter-run and spring-run Chinook salmon each year (NMFS 2009). This

RPA has not been met during some years (Swart 2016). As described in Section 1.3.1.1 Existing Biological Opinions on the Long-Term Operations of the CVP and SWP, NMFS and Reclamation are considering modifications to the RPA relating to Shasta Reservoir operations. Dry winters reduce the likelihood temperature compliance points needed for successful spawning can be met. Cold water pool (CWP) availability involves many management decisions, so it is essential that appropriate monitoring occurs to inform when and how much water to release to protect spawning salmonids. Meeting predetermined storage targets is a tool to help ensure that enough cold water will be available, but does not take into account day-to-day operations that can compromise meeting predetermined geographic temperature compliance points in the upper Sacramento River.

Under dual conveyance of the Proposed Action (PA), reservoir water releases and, therefore, CWP availability may be changed from existing conditions for optimization of exports in the north and south Delta. If CWP storage and management is improved or degraded it could have effects on the viability of listed salmonids.

Temperature

Chinook salmon depend on suitable water temperatures for spawning and essentially all life functions. Chinook salmon in California are at the southern end of their range within North America. Additionally, historical habitat in the Central Valley that provided suitable summer temperatures for adult holding, spawning, and early life stages is now blocked by dams.

Anadromous salmonids in the Sacramento River are now dependent on cold water temperature management in the upper Sacramento River below Keswick Dam. Winter-run and spring-run Chinook salmon in particular are sensitive to Keswick Reservoir water releases because they either spawn or hold in the upper Sacramento River during the summer months.

Based on several studies on Central Valley Chinook salmon, as well as more northern races of Chinook salmon, temperatures between 43°F and 54°F (6°C and 12°C) appear best suited to Chinook salmon egg and larval development (Myrick and Cech 2004). Several studies indicated that daily temperatures over 56°F (13.3°C) would lead to sub-lethal and lethal effects to incubating eggs (Seymour 1956; Boles 1988; USFWS1998; U.S. Environmental Protection Agency 2003). A 56°F (13.3°C) temperature compliance program was included in the NMFS 2009 BiOp to protect the sensitive life-stages of listed Chinook salmon (NMFS 2009). Consequently, the extent of habitat cold enough for spawning and early life stage survival changes every year in relation to where in the Sacramento River the upper temperature threshold of 56°F (13.3°C) can be maintained from May to October. Keswick and Shasta dams block salmon and steelhead from their historical habitat, confining them to a limited amount of thermally suitable habitat that varies in spatial extent within and between years.

Recently, a succession of dry years with low precipitation highlighted how difficult the upper river spawning area is to manage for successful spawning and embryo incubation. High mortality (greater than 95%) in the youngest life-stages (eggs, yolk-sac fry) resulted when temperature compliance points were not maintained under 56°F (13.3°C) for the spawning and embryo incubation season (Swart 2016).

Recent investigations into causes of mortality upstream also revealed that the 56°F (13.3°C) daily average temperature criteria mandated in the National Marine Fisheries Service (2009) biological opinion on the long-term operations of the CVP/SWP was not adequate to protect the earliest life stages (Swart 2016). Most of the egg/fry temperature studies relied on for this threshold were conducted in a laboratory with constant temperatures. In the river, managing for a daily average temperature of 56°F (13.3°C) can still result in a maximum daily temperature of greater than 60°F (15.5°C).

The U.S. Environmental Protection Agency (2003) provided comprehensive water temperature guidance concluding that a temperature criteria based on a seven-day average of daily maximum temperatures (7DADM) was better at accounting for diel water temperature fluctuations than a daily average criteria, and thus was better at determining suitable spawning and rearing temperatures for salmonids (U.S. Environmental Protection Agency 2003). The Shasta RPA actions in the National Marine Fisheries Service (2009) BiOp on the long-term operations of the CVP/SWP and the associated 2011 amendments are being adjusted because of the unprecedented mortality for two consecutive winter-run Chinook salmon brood years (2014 and 2015), the availability of new studies and models, including the River Assessment for Forecasting Temperature (RAFT) model, and the SWFSC's temperature-dependent Chinook salmon egg mortality model (Martin et al. 2016), and the poor status of winter- and spring-run Chinook salmon. The RAFT model more accurately predicts temperatures to better manage reservoir releases to maintain suitable instream temperatures in the upper Sacramento River (Pike et al. 2013).

The Martin et al. (2016a) egg mortality model found strong evidence that significant thermal mortality occurs during the embryonic stage in some years because of a >5°F reduction in thermal tolerance in the field compared to laboratory studies, suggesting that the 56°F (13.3°C) daily temperature criteria mandated in the NMFS 2009 BiOp is likely not sufficiently protective. To improve Sacramento River water temperature management for Chinook salmon, the criterion was adjusted in 2016 to the U.S. Environmental Protection Agency (2003) recommendation of 55°F 7DADM metric and applying it to the Bonneyview Bridge temperature control point (Swart 2016).

Every salmonid life stage is dependent on suitable temperatures. Besides spawning and egg incubation, juvenile rearing also occurs in the upper Sacramento River. Salmonids with a stream life history, such as spring-run Chinook salmon and steelhead, need suitable spawning and rearing temperatures to be maintained year round. The larger salmonid juvenile life stages are less sensitive to temperature than the alevins and yolk-sac fry, but will suffer lethal and sub-lethal effects when not in optimal instream temperatures. EPA guidelines recommend water temperatures do not exceed 61°F (16°C) 7DADM for juvenile rearing salmonids in the upper basin of natal rivers and do not exceed 64°F (18°C) in the lower basin of natal rivers (U.S. Environmental Protection Agency 2003). Potential sub-lethal temperature effects on juvenile salmonids include slowed growth, delayed smoltification, desmoltification, and extreme physiological changes, which can lead to disease and increased predation.

Myrick and Cech (2004) reviewed the published information on Central Valley salmon and steelhead temperature tolerance and growth and noted that several studies suggest that the optimal temperature for Chinook salmon growth lies within the 63°F to 68°F (17 to 20°C) range, provided that food is not limiting, and other factors, such as disease, predation, and competition have a minimal effect (Brett et al. 1982; Clarke and Shelbourn 1985, 1988; Myrick and Cech 2002; Marine and Cech 2004 as cited by Myrick and Cech 2004). It is unlikely that Chinook salmon in field conditions will feed at 100% satiation, however, and the effects of disease, competition, and predation should also be taken into account.

Green sturgeon have different temperature requirements than salmonids in the upper Sacramento River. The majority of green sturgeon spawn above Red Bluff Diversion Dam. Suitable spawning temperatures must remain below 63°F (17.5°C) to reduce sub-lethal and lethal effects. Temperatures in the range of 57° to 62°F (14 to 17°C) appear to be optimal for embryonic development (Van Eenennaam et al. 2005). Juvenile sturgeon can tolerate higher temperatures and optimal bioenergetics performance was found to be between 59 to 66°F (15 to 19°C) (Mayfield and Cech 2004).

Reservoir releases from Keswick Reservoir influence flows and temperatures in the upper and lower Sacramento River, which is critical habitat for several ESA-listed species, including two runs (winter and spring) of Chinook salmon, Central Valley steelhead, and green sturgeon. Any change in seasonal, monthly, and daily water releases out of Shasta Dam under the PA have been analyzed for potential effects on critical habitat. Changes in release patterns expected and modeled under the dual conveyance capabilities of the PA are addressed in this Opinion.

2.5.1.2.1.1 Winter-run Exposure and Risk

Sacramento River winter-run Chinook salmon exposure and risk to warm water temperatures occurring in the upper reaches of the Sacramento River under the PA are discussed below by life stage in the following order: (1) spawning, egg incubation and alevins, (2) fry and juvenile rearing and outmigration, and (3) adult immigration and staging.

Spawning, Egg Incubation, Alevins

Winter-run Chinook salmon eggs and alevins occur in the Sacramento River from the time when spawning begins in April, through October, with a peak during June through September (Vogel and Marine 1991). CDFW aerial redd surveys from 2003 through 2014 show that the vast majority (99.3%) of SR winter-run Chinook salmon spawning occurs upstream of Airport Road Bridge (RM 284) (CDFW 2014).

NMFS' evaluation of upstream temperature effects on spawning, egg incubation and alevins of winter-run Chinook salmon relied on several models and analysis presented in the BA (Monthly Temperatures and Exceedance Plots, temperature threshold analysis, SALMOD), as well as NMFS' Southwest Fisheries Science Center egg mortality model.[1]

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures during the April through October spawning and incubation period for SR winter-run Chinook salmon are presented in the BA, Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, and Table 5.C.7-8.

Overall, the analysis in the BA demonstrates that the PA would result in a marginal increase in mean water temperatures (predominantly less than one °F) throughout the spawning reach of Keswick Dam to Red Bluff in all months of the spawning and incubation period and water year

[1] The egg mortality model developed by Reclamation that is used in the BA has not been incorporated into this biological opinion because it is based on thermal tolerance studies conducted in the laboratory which substantially underestimate egg mortality in natural conditions (e.g., a salmon redd in the Sacramento River) (Martin et al. 2016). The SWFSC's egg mortality model is based on a relationship between temperature and egg survival derived from field data, providing a more reliable tool for estimating thermal effects on salmon eggs than Reclamation's egg mortality model.

types. The largest increase in mean monthly water temperatures under the PA relative to the NAA would be 0.6°F, and would occur at Red Bluff in above normal water years during August and in above- and below-normal years during September; and at Bend Bridge in below normal years during September. These largest increases would occur during the period of peak presence of spawners, eggs, and alevins.

The BA also examined exceedance plots of monthly mean water temperatures during each month throughout the spawning and incubation period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). As described in the BA in Appendix 5A, the probability of exceedance plots provide the frequency of occurrence of values of a parameter that exceed a reference value. For example, for Shasta storage end of September exceedance plot, Shasta storage values at the end of September for each simulated year are sorted in ascending order. The smallest value would have a probability of exceedance of 100% since all other values would be greater than that value; and the largest value would have a probability of exceedance of 0%. All the values are plotted with probability of exceedance on the x-axis and the value of the parameter on the y-axis. Following the same example, for one scenario, Shasta end of September of 2,000 TAF corresponds to 80% probability; it implies that Shasta end-of September storage is higher than 2,000 TAF in 80% of the years under the simulated conditions. The BA shows that the values for the PA in these exceedance plots generally track those of the NAA. Further examination of above normal water years during August (Figure 2-12) and September (Figure 2-13) at Red Bluff, below normal years during September at Red Bluff (Figure 2-14), and in below normal years during September at Bend Bridge (Figure 2-15) where the largest increases in mean monthly water temperatures were modeled reveals that there is a general trend towards marginally higher temperatures under the PA.

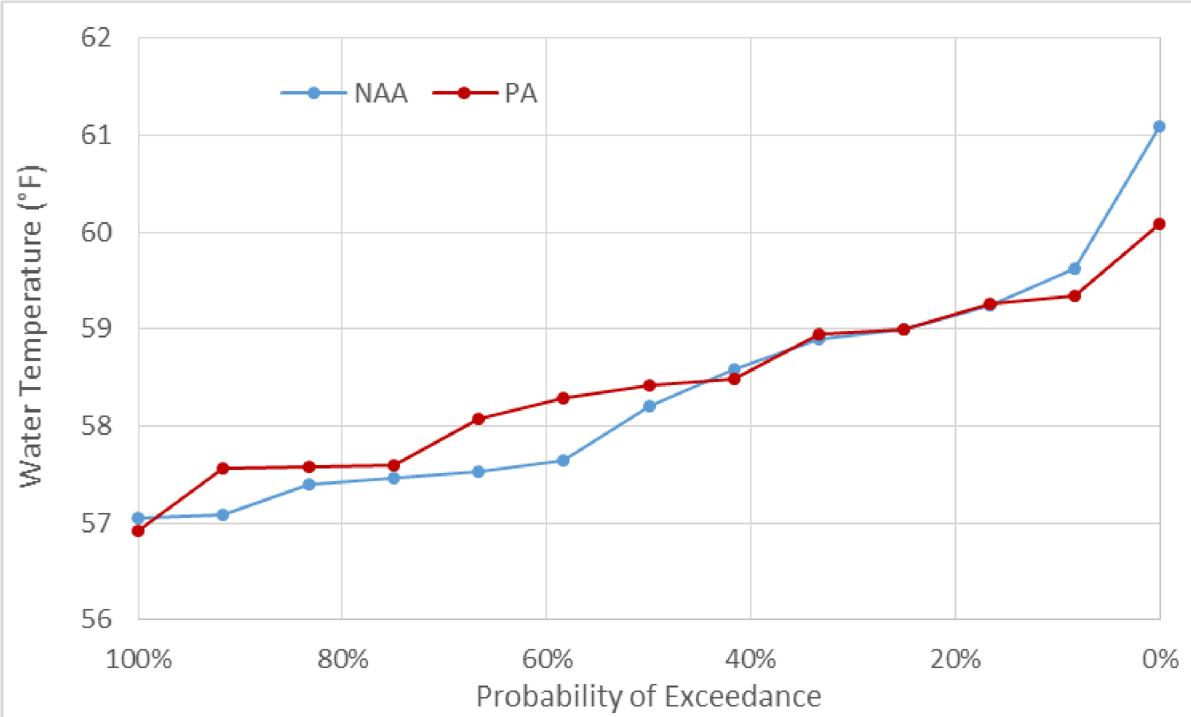


Figure 2-12. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Above Normal Water Years.

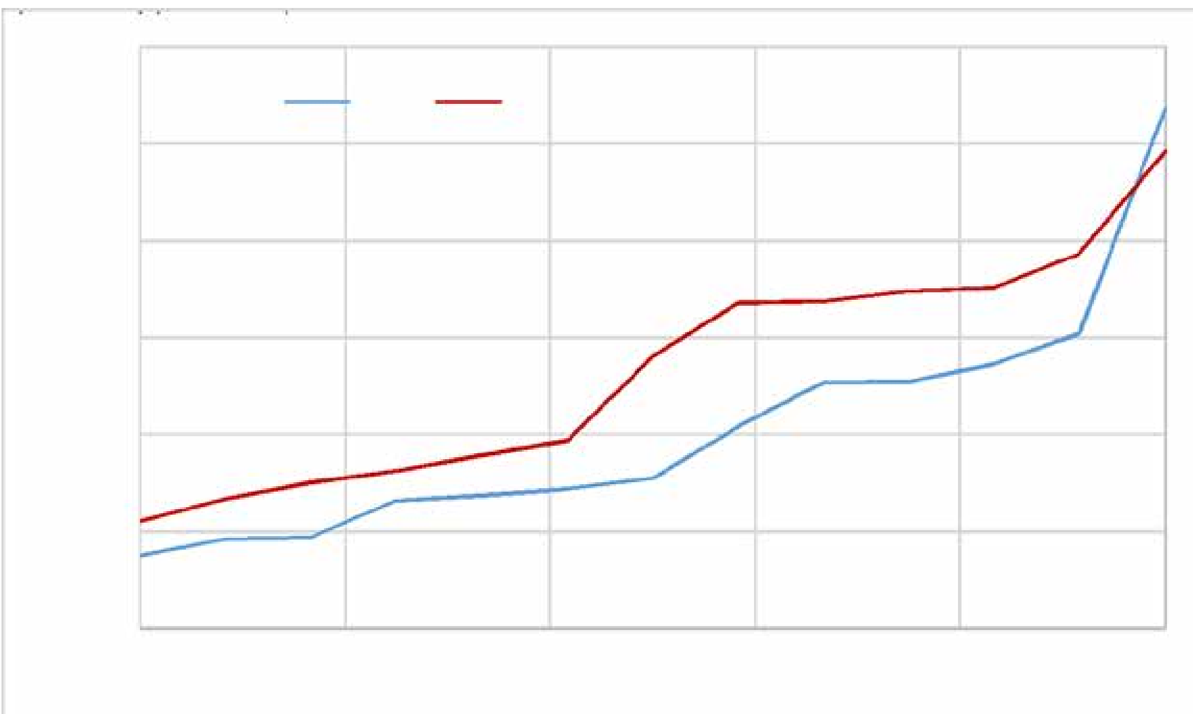


Figure 2-13. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years.

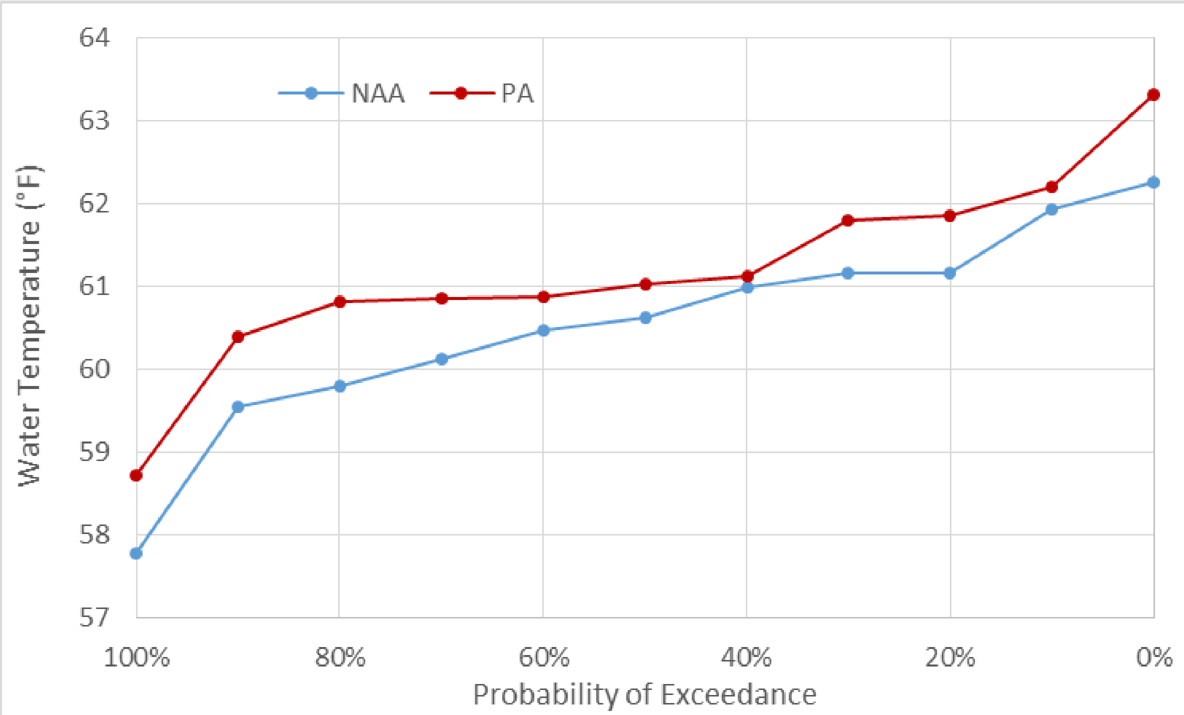


Figure 2-14. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years.

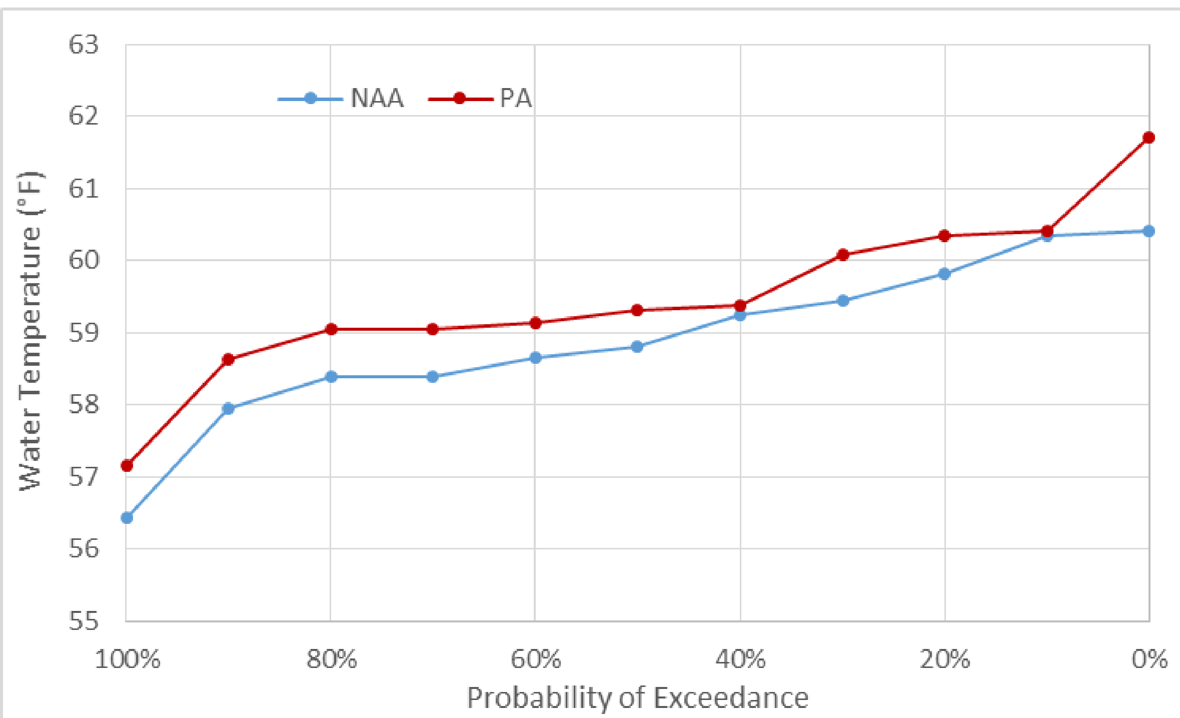


Figure 2-15. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in September of Below Normal Water Years.

Water Temperature Thresholds Analysis

The water temperature thresholds analysis presented in the BA indicates that water temperatures under the PA are not expected to have a biologically meaningful effect on winter-run Chinook salmon spawning, egg incubation, and alevin development when compared to the NAA. Results of the water temperature thresholds analysis may be found in the BA, Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-63 through Table 5.D-67. In the BA, a biologically meaningful effect for the water temperature threshold analysis was defined as the months and water year types in which water temperature results met two criteria: (1) the difference between NAA and PA in frequency of exceedance of the threshold was greater than 5%, and (2) the difference between NAA and PA in average daily exceedance was greater than 0.5°F. The 5% criterion was based on best professional judgment of fisheries biologists from NMFS, CDFW, DWR, and Reclamation. As described in the BA, the 0.5°F criterion was based on: (1) a review of the water temperature-related mortality rates for steelhead eggs and juveniles and (2) a reasonable water temperature differential that could be resolved through real-time reservoir operations.

Overall, the thresholds analysis presented in the BA indicates that there would be more exceedances (5% or greater) above the threshold (i.e., 55.4 7DADM) under the PA in certain months and water year types compared to the NAA. In all but two cases, the difference between NAA and PA in average daily exceedance would not result in biologically meaningful (as defined in the BA) water temperature-related effects on winter-run spawning, egg incubation, and alevins. The two cases where modeled water temperatures under the PA would be considered biologically meaningful (as defined in the BA) compared to the NAA (May of below normal water years at Clear Creek and Balls Ferry) appear to be the result of an anomalous CALSIM output from a single year (1923) in which water temperature would be substantially higher than expected (approximately 2 to 3°F). A high proportion of developing embryos are expected to parish from exposure to lethal water temperatures in critically dry water years.

SALMOD Model

The BA also provides SALMOD model results that predict a beneficial effect of the PA, relative to the NAA, related to the water-temperature-related mortality of SR winter-run Chinook salmon spawning, eggs, and alevins in the Sacramento River. SALMOD differentiates the water-temperature-related mortality of winter-run spawning, eggs, and alevins between pre-spawn (in vivo, or in the mother before spawning) and egg (in the gravel) mortality (see BA Attachment 5.D.2, SALMOD Model, for a full description).

BA Table 5.4-38 (Appendix C) presents results for water-temperature-related mortality of spawning, eggs, and alevins, in addition to other sources of flow-related mortality for SR winter-run Chinook salmon predicted by SALMOD and discussed in section 2.5.1.2.2 Redd Dewatering and 2.5.1.2.3 Redd Scour.

These results indicate that, combining all water year types, there would be no increase in temperature-related mortality of winter-run Chinook salmon spawning, eggs, and alevins under the PA relative to the NAA and, in fact, average annual mortality would decrease by 31,755 fish, or 7%, under the PA. For individual water year types, only the below normal water years show an increase in pre-spawn and egg temperature-related mortality under the PA. For all other year types, average annual mortality is found to decrease under the PA compared to the NAA. In absolute terms, most of the temperature-related mortality (greater than 95%) is predicted to occur in critical years. In this water year type, mortality would average 203,180 fish (7%) lower under the PA relative to the NAA.

NMFS Southwest Fisheries Science Center Temperature Dependent Egg Mortality Model

Besides the two biological analyses presented in the BA, the water temperature thresholds analysis and SALMOD, NMFS' Southwest Fisheries Science Center has developed a novel egg mortality model (Martin et al. 2016) to discern how water temperatures are expected to affect Chinook salmon egg survival. The SWFSC's egg mortality model is a temperature-dependent mortality model for Chinook salmon embryos that differs from previous models in that thermal tolerance parameters were estimated using field egg-to-fry survival data, rather than assuming thermal tolerance (the level of temperature under which an egg can survive to produce a healthy hatched fry) parameters measured in laboratory studies hold in the field. Based on their analysis for field data, Martin et al. (2016) found strong evidence that significant thermal mortality occurred during the embryonic stage in some years due to a >5°F reduction in thermal tolerance in the field compared to laboratory studies. Martin et al. (2016) used a biophysical model of oxygen supply and demand to demonstrate that such discrepancies in thermal tolerance could arise to differences in oxygen supply in lab and field contexts. Because oxygen diffuses slowly in water, as embryos consume oxygen they deplete the concentration of oxygen in the surrounding water, reducing their rate of oxygen supply. This is exacerbated in warm waters because oxygen demand increases exponentially with temperature. Flowing water replenishes oxygen through convective transfer, and thereby increases oxygen supply. Thus, higher flows deliver more oxygen to embryos than low flows allowing for higher thermal tolerance. The egg survival-temperature relationships found in laboratory studies likely overestimate thermal tolerance of eggs developing in the river by roughly 3°C because those studies typically take place at relatively high flows compared to flows experienced by eggs in spawning gravels in the river (Martin et al. 2016). To account for this, the SWFSC's egg mortality model uses 53.6°F as the temperature below which there is no mortality due to temperature.

In laboratory studies, Chinook salmon embryos have been allowed to develop in highly oxygenated, fast flowing water (approximately 0.15 cm/s) (Beacham and Murray 1989; Jensen and Groot 1991; USFWS 1999), while in nature, embryos are embedded in gravel where flow velocities are lower [~0.04 cm/s; (Zimmermann and Lapointe 2005)]. By accounting for oxygen supply and demand in the relationship between egg survival and water temperature, the SWFSC's egg mortality model represents the best available tool for estimating the thermal risk to Chinook salmon eggs under the PA. Using the SWFSC egg mortality model linked with a 1-dimensional temperature model of the Sacramento River at 1 km spatial resolution (Pike et al. 2013), survival probabilities are estimated for eggs exposed to water temperatures under the PA and NAA.

The SWFSC's egg mortality model shows the winter-run Chinook salmon egg survival probability under the PA and NAA for all water years combined and by individual water year type (Figure 2-16). These results show the influence of temperature on survival independent of other sources of mortality. Other factors affecting egg and alevin survival such as physical disturbance from redd superimposition would lower the overall survival, beyond that which is described as water temperature dependent survival shown in Figure 2-16. The mean water temperature dependent survival probability under the PA ranged from 20% in critical years to

95% in above normal years; and the mean for all water years combined was 76%. This means that in critical years 80% of egg and alevin mortality is attributable to temperatures, while only 5% of egg and alevin mortality is expected to be caused by temperatures in above normal years.

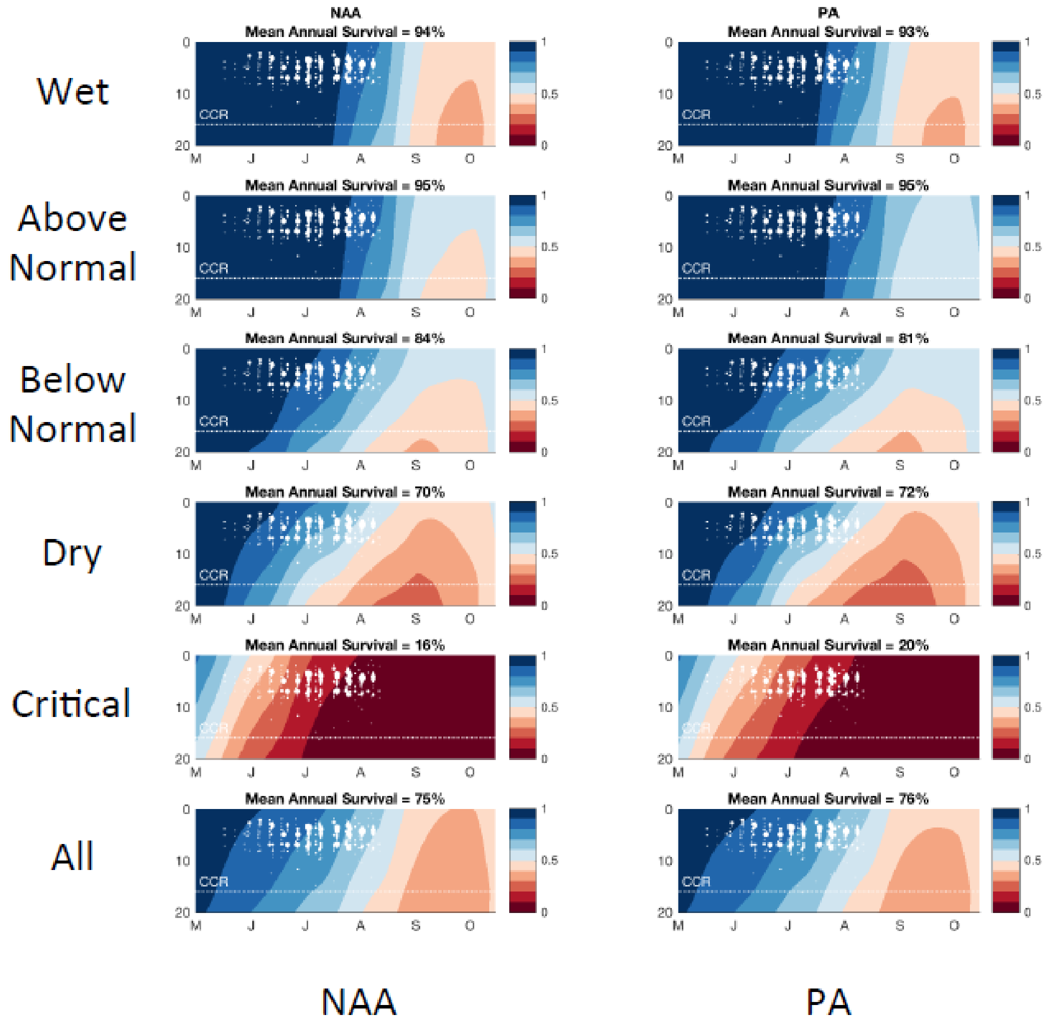


Figure 2-16. Winter-run Chinook Salmon Egg Survival Landscape from the SWFSC's Temperature Dependent Egg Survival Model. Primary Y-axis is distance in km downstream from Keswick Dam. The color key is the probability of survival. Winter-run redds during the 2012-2015 spawning seasons (white marks) were used to calculate mean annual survival under the NAA and PA.

A comparison of temperature dependent egg survival between the PA and NAA shows little to no difference between the alternatives. Mean annual temperature-dependent survival would decrease under the PA by 1% in wet years and 3% in below normal years. For the other water year types and for all water years combined, the SWFSC's model showed no difference in mean annual temperature-dependent survival between the PA and NAA or slightly higher survival under the PA. All differences in mean annual temperature-dependent survival are likely within the margin of error of the model and are not significant.

The SWFSC model results suggest that winter-run Chinook salmon egg survival will largely be the same under the NAA and PA operations.

Overall, the certainty of the three biological tools' respective ability to accurately estimate thermal impacts to eggs and alevins in the Sacramento River under the PA is low[2] because all three models utilize daily (thresholds analysis and the SWFSC' egg/alevin mortality model) or weekly (SALMOD) water temperatures downscaled from the same modeled monthly values. Eggs and alevins developing in the Sacramento River spawning gravels experience a thermal regime that varies between day and night and from one day to the next. The downscaled water temperature modeling utilized in all the biological models does not capture that level of thermal variation. Nevertheless, the biological models are useful qualitative indicators of potential thermal impacts under the PA.

Overall, the monthly temperature modeling results, exceedance plots and biological tools all indicate that thermal impacts on the winter-run Chinook salmon spawning and egg incubation life stage will largely be the same with implementation of either the NAA or PA operations. Adverse thermal effects on these life stages resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in substantial water temperature-related mortality in critically dry years.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5 Real-Time Operations Upstream of the Delta, and Section 3.3.3 Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

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[2] Additional key assumptions and data limitations that influence the reliability of results from SALMOD are highlighted in NRC (2010).

Additionally, the modeling results do not reflect new measures that will be taken to protect winter-run Chinook salmon through science-based adaptive management under the 2009 biological opinion on the long-term operations of the CVP/SWP (section 11.2.1.2). On August 2, 2016, Reclamation requested using the adaptive management provision in the 2009 biological opinion related to Shasta Reservoir operations. The basis for this request included recent, multiple years of drought conditions, new science and modeling, and data demonstrating the low population levels of endangered Sacramento River winter-run Chinook salmon and threatened Central Valley spring-run Chinook salmon. As a necessary step in the science-based adaptive management process, NMFS, in consultation with Reclamation, developed a draft proposed amendment to the NMFS' 2011 amendment to the 2009 RPA (NMFS 2017). The draft proposed amendment describes the proposed changes, lays out a phased approach, and states that a pilot approach to water temperature management will be implemented in 2017. The 2017 pilot approach applies new science on the thermal tolerance of Chinook salmon eggs (Martin et al. 2016) and is designed to efficiently utilize Shasta Reservoir limited supply of cold water by basing the spatial distribution of protective temperatures on the within-season spatial distribution of winter-run Chinook salmon redds. The intent is to provide daily average water temperatures of 53°F or less to the furthest downstream redds. The existing requirement is a daily average temperature of 56°F or less at compliance locations between Balls Ferry and Bend Bridge, which are not based on the within-season redd distribution. The science-based, within season management under the 2017 pilot approach, and additional adjustments to the NMFS' 2011 amendment to the 2009 RPA included in the draft proposed amendment intended to protect winter-run Chinook salmon are expected to result in improved survival over what is reflected in the modeling results.

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Fry and Juvenile Rearing and Outmigration

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures during the July through November juvenile rearing period for winter-run Chinook salmon in the Sacramento River upstream of the Delta show a marginal difference between the NAA and the PA (see BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10). Overall, the PA would change mean water temperatures very little (less than 1°F) throughout the juvenile rearing reach of Keswick Dam to Knights Landing in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F and would occur at Knights Landing in below normal years during August.

Further examination of below normal water years in August at Knights Landing, where the largest increase in mean monthly water temperature was seen, indicates that water temperatures under the PA would be higher than those under NAA for most of the exceedance range by up to approximately 2.2°F, particularly in the colder end of the range (Figure 2-17).

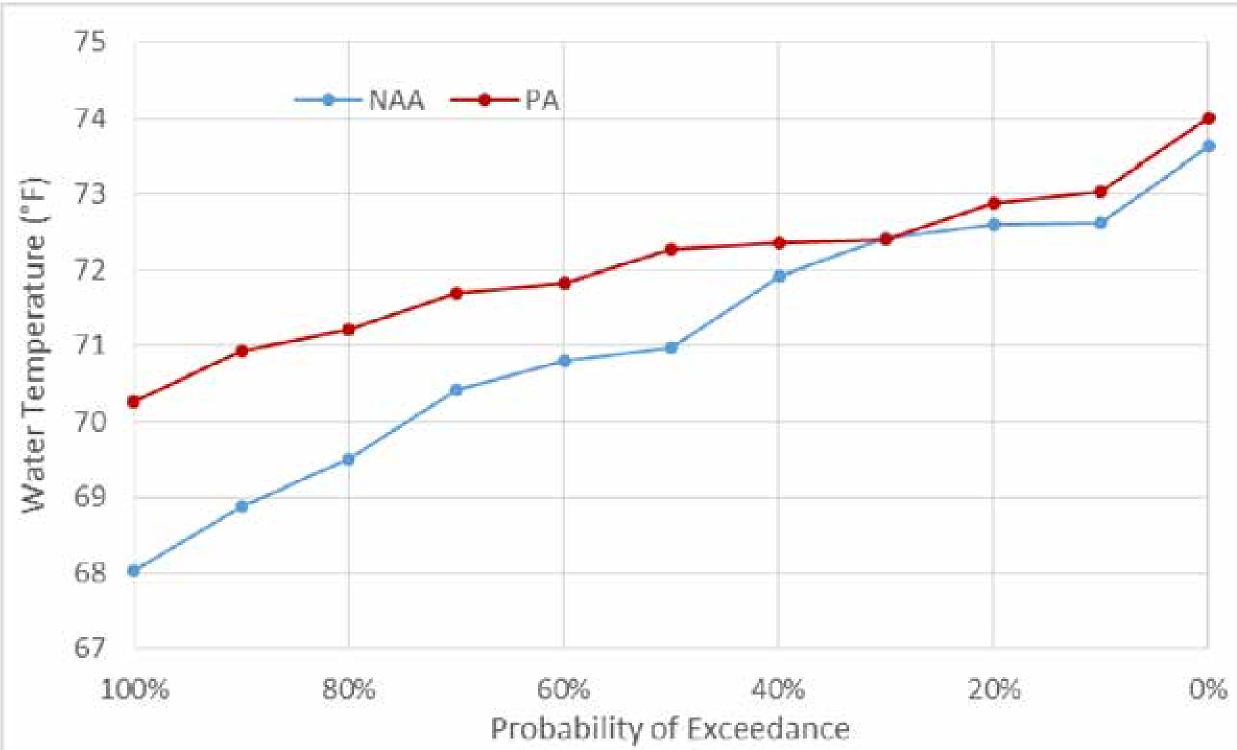

Figure 2-17. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Wilkins Slough/Knights Landing in August of Below Normal Water Years.

Temperature Threshold Analysis

The temperature threshold analysis results predict that temperatures for Knights Landing during August of below normal water years would be greater than the 64°F 7DADM threshold on 100% of days under both the NAA and PA. These results suggest that water temperatures are expected to be unsuitably warm for winter-run Chinook salmon fry and juvenile rearing under the NAA and PA. The changes in exceedance of the water temperature thresholds as a result of the PA compared to the NAA are described in greater detail below.

For the water temperature thresholds analysis in the BA, the period of July through March was evaluated. The threshold used was the USEPA's 7DADM value of 61°F for the core juvenile rearing reach from Keswick Dam to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing (see BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49). The 7DADM values were converted by month to function with daily model outputs (see BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51).

Table 2-45. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Fry and Juvenile Rearing and Emigration, Sacramento River at Keswick, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.3	0.0	-0.3	0	0	0	0.00	NA	NA
	All	0.0	0.0	0.0	0	0	0	0.00	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	32.8	32.5	-0.3	245	269	24	2.01	2.22	0.21
	All	4.8	4.8	0.0	245	269	24	2.01	2.22	0.21
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	64.4	60.0	-4.4	857	909	52	3.69	4.21	0.51
	All	9.4	8.8	-0.7	857	909	52	3.69	4.21	0.51
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	52.7	49.5	-3.2	450	407	-43	2.30	2.21	-0.08
	All	7.8	7.3	-0.5	450	407	-43	2.30	2.21	-0.08
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.6	0.0	-0.6	1	0	-1	0.50	NA	NA
	All	0.1	0.0	-0.1	1	0	-1	0.50	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-46. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Fry and Juvenile Rearing and Emigration, Sacramento River at Clear Creek, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	3.0	3.2	0.3	10	9	-1	0.91	0.75	-0.16
	All	0.4	0.5	0.0	10	9	-1	0.91	0.75	-0.16
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	41.1	39.2	-1.9	543	565	22	3.55	3.87	0.32
	All	6.0	5.7	-0.3	543	565	22	3.55	3.87	0.32
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	73.1	66.4	-6.7	1,458	1,484	26	5.54	6.21	0.67
	All	10.7	9.7	-1.0	1,458	1,484	26	5.54	6.21	0.67
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	79.8	68.0	-11.8	903	801	-102	3.04	3.17	0.13
	All	11.8	10.1	-1.8	903	801	-102	3.04	3.17	0.13
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	5.8	4.2	-1.7	13	9	-4	0.62	0.60	-0.02
	All	0.9	0.6	-0.2	13	9	-4	0.62	0.60	-0.02
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-47. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Fry and Juvenile Rearing and Emigration, Sacramento River at Balls Ferry, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	9.7	12.1	2.4	54	65	11	1.50	1.44	-0.06
	All	1.4	1.8	0.4	54	65	11	1.50	1.44	-0.06
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	2.3	0.2	-2.1	4	0	-4	0.29	0	-0.29
	C	46.0	42.5	-3.5	799	802	3	4.67	5.08	0.40
	All	7.3	6.3	-1.0	803	802	-1	4.34	5.04	0.70
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	3.9	6.1	2.1	6	13	7	0.46	0.65	0.19
	D	12.2	11.0	-1.2	52	37	-15	0.71	0.56	-0.15
	C	83.9	73.9	-10.0	1,667	1,658	-9	5.52	6.23	0.71
	All	15.8	14.3	-1.5	1,725	1,708	-17	4.45	4.85	0.41
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.2	0.2	0	0	0	NA	0	NA
	C	76.6	62.6	-14.0	827	742	-85	2.90	3.18	0.28
	All	11.4	9.3	-2.0	827	742	-85	2.90	3.17	0.27
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	4.4	4.2	-0.3	8	7	-1	0.50	0.47	-0.03
	All	0.7	0.6	0.0	8	7	-1	0.50	0.47	-0.03
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-48. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Fry and Juvenile Rearing and Emigration, Sacramento River at Bend Bridge, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	3.3	3.7	0.4	7	7	0	0.26	0.23	-0.03
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	1.2	0.6	-0.6	1	0	-1	0.25	0	-0.25
	D	1.3	1.1	-0.2	1	1	0	0.13	0.14	0.02
	C	56.2	64.0	7.8	332	384	52	1.59	1.61	0.02
	All	9.8	10.9	1.1	341	392	51	1.38	1.42	0.04
Aug	W	4.1	3.8	-0.2	21	22	1	0.64	0.71	0.07
	AN	2.7	0.5	-2.2	6	0	-6	0.55	0	-0.55
	BN	0.6	6.5	5.9	1	8	7	0.50	0.36	-0.14
	D	33.1	24.7	-8.4	206	118	-88	1.00	0.77	-0.23
	C	77.2	65.6	-11.6	1,107	1,090	-17	3.86	4.47	0.61
	All	21.2	17.8	-3.4	1,341	1,238	-103	2.49	2.74	0.25
Sep	W	0.8	0.5	-0.3	4	1	-3	0.67	0.25	-0.42
	AN	0.8	0.0	-0.8	1	0	-1	0.33	NA	NA
	BN	26.1	41.8	15.8	85	159	74	0.99	1.15	0.16
	D	46.8	54.8	8.0	469	517	48	1.67	1.57	-0.10
	C	93.9	92.2	-1.7	1,897	1,882	-15	5.61	5.67	0.06
	All	29.0	32.6	3.6	2,456	2,559	103	3.44	3.19	-0.25
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	1.8	1.3	-0.5	5	4	-1	0.45	0.50	0.05
	C	69.6	58.6	-11.0	757	685	-72	2.92	3.14	0.22
	All	10.8	9.0	-1.8	762	689	-73	2.82	3.05	0.23
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	1.7	1.9	0.3	2	2	0	0.33	0.29	-0.05
	All	0.2	0.3	0.0	2	2	0	0.33	0.29	-0.05
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-49. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Fry and Juvenile Rearing and Emigration, Sacramento River at Red Bluff, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	8.4	8.4	0.0	46	46	0	0.68	0.68	0
	AN	0.5	0.2	-0.2	1	1	0	0.50	1.00	0.50
	BN	5.0	2.9	-2.1	7	4	-3	0.41	0.40	-0.01
	D	10.5	9.5	-1.0	28	19	-9	0.43	0.32	-0.11
	C	66.1	72.6	6.5	470	548	78	1.91	2.03	0.12
	All	15.7	16.1	0.4	552	618	66	1.39	1.51	0.13
Aug	W	18.0	15.9	-2.1	134	117	-17	0.92	0.91	-0.01
	AN	12.7	9.7	-3.0	47	20	-27	0.92	0.51	-0.41
	BN	15.2	24.6	9.4	22	53	31	0.42	0.63	0.21
	D	57.7	51.6	-6.1	519	391	-128	1.45	1.22	-0.23
	C	85.5	79.0	-6.5	1,363	1,311	-52	4.29	4.46	0.17
	All	36.3	34.0	-2.3	2,085	1,892	-193	2.26	2.19	-0.07
Sep	W	3.5	2.7	-0.8	32	22	-10	1.19	1.05	-0.14
	AN	9.0	16.7	7.7	37	51	14	1.06	0.78	-0.27
	BN	74.8	85.2	10.3	503	669	166	2.04	2.38	0.34
	D	87.5	93.0	5.5	1,462	1,606	144	2.78	2.88	0.09
	C	97.5	97.8	0.3	2,504	2,513	9	7.13	7.14	0.01
	All	48.2	51.9	3.7	4,538	4,861	323	3.83	3.81	-0.02
Oct	W	0.7	2.0	1.2	2	7	5	0.33	0.44	0.10
	AN	1.6	2.2	0.5	2	4	2	0.33	0.50	0.17
	BN	4.7	3.8	-0.9	10	7	-3	0.63	0.54	-0.09
	D	12.1	10.3	-1.8	72	60	-12	0.96	0.94	-0.02
	C	80.9	81.2	0.3	1,123	1,043	-80	3.73	3.45	-0.28
	All	16.1	16.0	0.0	1,209	1,121	-88	2.99	2.78	-0.21
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	4.7	4.4	-0.3	12	11	-1	0.71	0.69	-0.02
	All	0.7	0.7	0.0	12	11	-1	0.71	0.69	-0.02
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-50. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Fry and Juvenile Rearing and Emigration, Sacramento River at Knights Landing, 64°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	100.0	100.0	0.0	7,366	7,265	-101	9.14	9.01	-0.13
	AN	100.0	100.0	0.0	3,022	3,025	3	7.50	7.51	0.01
	BN	100.0	100.0	0.0	2,684	2,631	-53	7.87	7.72	-0.16
	D	100.0	100.0	0.0	5,472	5,535	63	8.83	8.93	0.10
	C	100.0	100.0	0.0	4,034	4,189	155	10.84	11.26	0.42
	All	100.0	100.0	0.0	22,578	22,645	67	8.88	8.91	0.03
Aug	W	100.0	100.0	0.0	7,777	7,697	-80	9.65	9.55	-0.10
	AN	100.0	100.0	0.0	3,588	3,642	54	8.90	9.04	0.13
	BN	100.0	100.0	0.0	2,856	3,201	345	8.38	9.39	1.01
	D	100.0	100.0	0.0	6,423	6,282	-141	10.36	10.13	-0.23
	C	100.0	100.0	0.0	4,372	4,303	-69	11.75	11.57	-0.19
	All	100.0	100.0	0.0	25,016	25,125	109	9.84	9.88	0.04
Sep	W	82.6	84.1	1.5	2,229	2,272	43	3.46	3.46	0.00
	AN	99.7	100.0	0.3	1,815	2,149	334	4.67	5.51	0.84
	BN	100.0	100.0	0.0	2,886	3,144	258	8.75	9.53	0.78
	D	100.0	100.0	0.0	6,001	6,128	127	10.00	10.21	0.21
	C	100.0	100.0	0.0	4,223	4,261	38	11.73	11.84	0.11
	All	94.4	95.0	0.5	17,154	17,954	800	7.38	7.69	0.30
Oct	W	27.3	34.2	6.9	217	337	120	0.99	1.22	0.23
	AN	31.5	33.1	1.6	250	292	42	2.14	2.37	0.24
	BN	49.3	41.3	-7.9	444	406	-38	2.64	2.88	0.24
	D	57.1	52.7	-4.4	1,004	961	-43	2.84	2.94	0.10
	C	89.8	88.2	-1.6	1,545	1,558	13	4.63	4.75	0.12
	All	47.5	47.6	0.1	3,460	3,554	94	2.90	2.97	0.07
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	2.2	1.7	-0.6	6	5	-1	0.75	0.83	0.08
	All	0.3	0.2	-0.1	6	5	-1	0.75	0.83	0.08
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.5	0.5	0.0	1	1	0	0.33	0.33	0
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.1	0.1	0.0	1	1	0	0.33	0.33	0

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

The general pattern is that daily occurrences of threshold exceedances under the PA decrease from Keswick Dam to Bend Bridge, especially during critical years early in the rearing season (September through October). As such, the frequency of adverse effects to winter-run Chinook salmon juveniles is not found to increase under the PA; however, when temperatures are exceeded, the exceedance level tended to be more severe.

From Bend Bridge downstream to Red Bluff, the percent of days exceeding the 61°F 7DADM threshold under the PA would be more than 5% higher in certain months of critical, dry, and below normal water years. For this reach and for these months, however, there was not a corresponding more-than-0.5°F difference in the magnitude of average daily exceedance under the PA. This means that while the frequency of exceedance is expected to increase, the magnitude is expected to be minor relative to the NAA.

From Red Bluff to Knights Landing, the percent of days exceeding the 64°F 7DADM threshold for non-core rearing and emigration habitat under the PA would be more than 5% higher than under the NAA in certain months and water year types. For this reach and for these months, however, there was not a corresponding more-than-0.5°F difference in the magnitude of average daily exceedance under the PA. This means that while the frequency of exceedance is expected to increase, the magnitude is expected to be minor relative to the NAA.

Overall, adverse thermal effects on winter-run Chinook salmon juveniles resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of juveniles during drier water year types, but those effects would likely be small in magnitude (Table 2-2 through Table 2-7).

SALMOD Model

The SALMOD model provides predicted water-temperature-related fry and juvenile winter-run Chinook salmon mortality, which is a combination of mortality of the fry, pre-smolt, and immature smolt life stages (see BA Attachment 5.D.2, SALMOD Model, for a full description). Results for water temperature-related mortality of these life stages are presented in BA Table 5.4-108 in Appendix C of this Opinion and the annual exceedance plot for all water year types combined is presented in Figure 2-18.

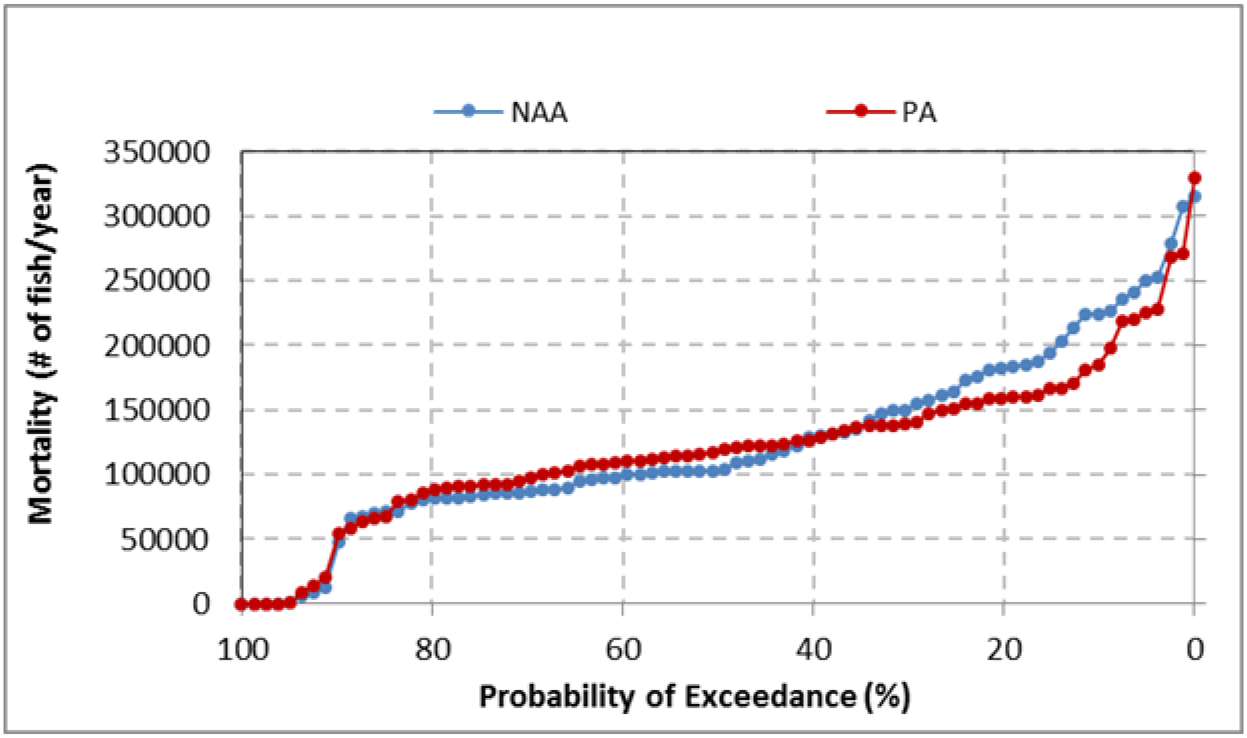

Figure 2-18. Exceedance Plot of Annual Flow-Based Mortality (# of Fish/Year) of Winter-run Chinook Salmon Fry and Juveniles.

These results indicate that differences under the PA in temperature-related mortality relative to the NAA would generally be insignificant. The mean annual temperature-induced mortality for all water years and for the NAA is about 7,734 fish (or 5.9% of total fry and juvenile rearing mortality). The mean annual temperature-induced mortality for all water years and for the PA is about 7,620 fish (or 5.9% of total fry and juvenile rearing mortality). These results indicate that the PA would not increase water temperature-related mortality of fry and juvenile winter-run Chinook salmon relative to the NAA, but that temperatures play a significant role in fry and juvenile rearing mortality.

Overall, the monthly water temperature modeling results, exceedance plots, and biological tools all indicate that thermal impacts on the winter-run Chinook salmon fry and juvenile rearing and outmigration life stage will largely be the same with implementation of either the NAA or PA operations. Adverse thermal effects on winter-run fry and juveniles resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of juveniles during drier water year types, but those effects would likely be small in magnitude.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for

CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Adult Immigration and Holding

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures were evaluated in the BA for the Sacramento River at Keswick, Bend Bridge, and Red Bluff during the December through August adult immigration period for winter-run Chinook salmon. Overall, the PA would change mean water temperatures very little (less than 1°F) at these locations in all months and water year types in the period (see BA Appendix *5.C*, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.3.7-7, Table 5.C.7-8).

The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F and would occur at Red Bluff in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration and holding period (see BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. For below normal water years in August at

Red Bluff, where the largest increases in mean monthly water temperatures were seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 2-19).

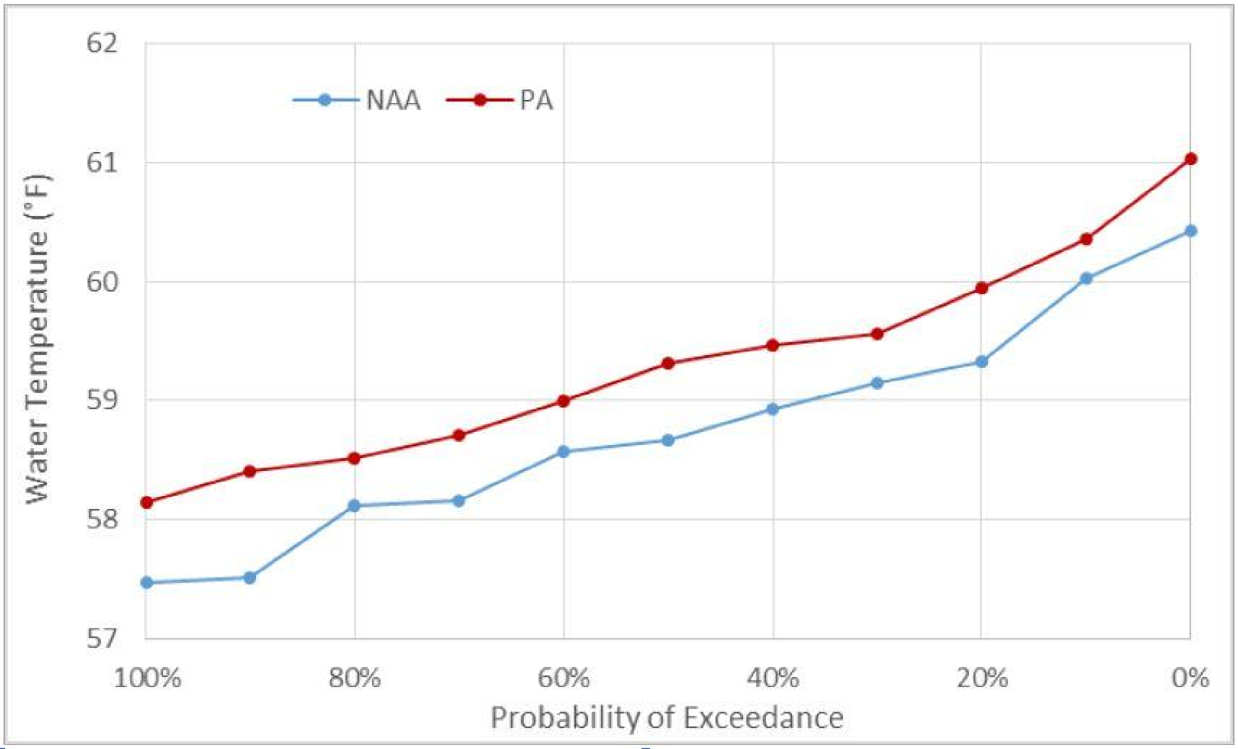

Figure 2-19. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Below Normal Water Years.

Temperature Threshold Analysis

The USEPA's 7DADM threshold value of 68°F was used to evaluate water temperature threshold exceedance during the winter-run Chinook salmon adult immigration life stage at Keswick Dam, Bend Bridge, and Red Bluff (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49). Water temperatures predicted at all three locations would be lower than the 68°F 7DADM for all days in both the NAA and PA, except for August of critically dry years at Bend Bridge and Red Bluff (Table 2-51 through Table 2-53).

Those limited, extreme cases could have lethal or sublethal effects on adult immigrants. Sub-lethal effects on adults exposed to warm temperatures during their upstream migration include: (1) delay in migration and spawning, (2) depletion of energy stores through heightened respiration, (3) deformation of eggs and decreased viability of gametes, and (4) increased incidence of debilitating diseases (McCullough et al. 2001).

Table 2-51. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Adult Immigration, Sacramento River at Keswick, 68°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-52. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Adult Immigration, Sacramento River at Bend Bridge, 68°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	11.6	16.7	5.1	56	81	25	1.30	1.31	0
	All	1.7	2.4	0.7	56	81	25	1.30	1.31	0

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-53. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Adult Immigration, Sacramento River at Red Bluff, 68°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	21.0	21.2	0.3	101	129	28	1.29	1.63	0.34
	All	3.1	3.1	0.0	101	129	28	1.29	1.63	0.34

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

To evaluate water temperature threshold exceedance during the adult holding life stage at Keswick Dam, Balls Ferry, and Red Bluff, the USEPA's 7DADM threshold value of 61°F was used (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49) (U.S. Environmental Protection Agency 2003). At all three locations, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and no more-than a 0.5°F difference in the magnitude of average daily exceedance (Table 2-54 through Table 2-56). Therefore, it was concluded that there would be no biologically meaningful effect of the PA relative to the NAA. The water temperature thresholds analysis indicates that adverse thermal effects on this life stage resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of holding adults in drier years. For example, exceedances over the 61°F threshold under the PA do occur at Keswick Dam and Balls Ferry in drier water waters, and exceedances are prevalent at Red Bluff in most holding months and all water years, suggesting adverse effects that are primarily sub-lethal given the small amount in which the threshold is exceeded (e.g., typically less than 2°F per day). Lethal water temperatures for salmon adults are at least several degrees warmer than the 61°F 7DADM threshold value (McCullough N. 2001).

Table 2-54. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Adult Holding, Sacramento River at Keswick, 61°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.3	0.0	-0.3	0	0	0	0.00	NA	NA
	All	0.0	0.0	0.0	0	0	0	0.00	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	32.8	32.5	-0.3	245	269	24	2.01	2.22	0.21
	All	4.8	4.8	0.0	245	269	24	2.01	2.22	0.21

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-55. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Adult Holding, Sacramento River at Balls Ferry, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.7	0.7	0.0	3	3	0	0.50	0.50	0
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.2	0.2	0	0	0	NA	0	NA
	C	1.1	1.1	0.0	2	1	-1	0.50	0.25	-0.25
	All	0.4	0.4	0.0	5	4	-1	0.50	0.36	-0.14
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.6	0.3	-0.3	0	0	0	0	0	0
	All	0.1	0.0	0.0	0	0	0	0	0	0
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	9.7	12.1	2.4	54	65	11	1.50	1.44	-0.06
	All	1.4	1.8	0.4	54	65	11	1.50	1.44	-0.06
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	2.3	0.2	-2.1	4	0	-4	0.29	0	-0.29
	C	46.0	42.5	-3.5	799	802	3	4.67	5.08	0.40
	All	7.3	6.3	-1.0	803	802	-1	4.34	5.04	0.70

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-56. Water Temperature Threshold Analysis Results, Winter-run Chinook Salmon, Adult Holding, Sacramento River at Red Bluff, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.5	0.5	0.0	2	2	0	0.50	0.50	0
	AN	0.5	0.5	0.0	1	1	0	0.50	0.50	0
	BN	0.0	0.3	0.3	0	0	0	NA	0	NA
	D	2.7	2.8	0.2	11	11	0	0.69	0.65	-0.04
	C	1.7	1.7	0.0	6	6	0	1.00	1.00	0
	All	1.1	1.2	0.1	20	20	0	0.71	0.67	-0.05
May	W	15.8	15.9	0.1	162	162	0	1.28	1.27	-0.01
	AN	14.6	12.2	-2.5	81	76	-5	1.37	1.55	0.18
	BN	5.3	8.8	3.5	10	24	14	0.56	0.80	0.24
	D	19.0	14.8	-4.2	181	150	-31	1.53	1.63	0.10
	C	25.3	23.7	-1.6	127	118	-9	1.35	1.34	-0.01
	All	16.4	15.2	-1.1	561	530	-31	1.35	1.37	0.02
Jun	W	12.7	12.4	-0.3	103	103	0	1.04	1.06	0.02
	AN	10.8	9.0	-1.8	39	37	-2	0.93	1.06	0.13
	BN	7.0	6.1	-0.9	23	21	-2	1.00	1.05	0.05
	D	4.3	2.8	-1.5	20	11	-9	0.77	0.65	-0.12
	C	46.7	40.8	-5.8	238	186	-52	1.42	1.27	-0.15
	All	14.6	12.8	-1.7	423	358	-65	1.18	1.13	-0.05
Jul	W	8.4	8.4	0.0	46	46	0	0.68	0.68	0
	AN	0.5	0.2	-0.2	1	1	0	0.50	1.00	0.50
	BN	5.0	2.9	-2.1	7	4	-3	0.41	0.40	-0.01
	D	10.5	9.5	-1.0	28	19	-9	0.43	0.32	-0.11
	C	66.1	72.6	6.5	470	548	78	1.91	2.03	0.12
	All	15.7	16.1	0.4	552	618	66	1.39	1.51	0.13
Aug	W	18.0	15.9	-2.1	134	117	-17	0.92	0.91	-0.01
	AN	12.7	9.7	-3.0	47	20	-27	0.92	0.51	-0.41
	BN	15.2	24.6	9.4	22	53	31	0.42	0.63	0.21
	D	57.7	51.6	-6.1	519	391	-128	1.45	1.22	-0.23
	C	85.5	79.0	-6.5	1,363	1,311	-52	4.29	4.46	0.17
	All	36.3	34.0	-2.3	2,085	1,892	-193	2.26	2.19	-0.07

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Overall, the monthly water temperature results, exceedance plots, and threshold analysis collectively indicate that thermal impacts on the winter-run Chinook salmon adult immigration and holding life stage will largely be the same with implementation of either the NAA or PA operations. Adverse thermal effects on this life stage resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of individuals for this life stage, particularly in drier water years and at the more downstream locations during late spring and summer months.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

2.5.1.2.1.2 Spring-run Exposure and Risk

CV spring-run Chinook salmon exposure and risk to warm water temperatures occurring in the upper Sacramento River under the PA are discussed below by life stage in the following order: (1) spawning, egg incubation, and alevin development; (2) fry and juvenile rearing and outmigration; and (3) adult immigration and holding.

Spawning, Egg Incubation, and Alevin Development

Aerial redd surveys in September have identified likely spring-run Chinook salmon spawning in the upper Sacramento River (CDFW unpublished data 2016). Total redds by reach from 2001 to 2016 are shown in Table 2-57 below. The eight most recent years of observations (2009 to 2016) were very low, with numbers of redd observations near zero (with the exception of 57 redds in 2013), and in three of the years no surveys were completed. The highest density of spring-run Chinook salmon redds occur between ACID Dam to Airport Road Bridge. Spring-run eggs and alevin remain in the gravel from the time when spawning begins in September through fry emergence in December and January.

Table 2-57. Spatial Distribution of Spawning Redds in the Sacramento River Based on Aerial Redd Surveys in September, 2001–2016 (Source: CDFW, unpublished).

Reach	Mean Annual Percent of Total Redds Sighted	Total Redds
Keswick to ACID Dam	12.4	56
ACID Dam to Highway 44 Bridge	32.8	108
Highway 44 Bridge to Airport Road Bridge	27.7	141
Airport Rd. Bridge to Balls Ferry Bridge	10.9	48
Balls Ferry Bridge to Battle Creek	7.3	29
Battle Creek to Jelly’s Ferry Bridge	1.5	35
Jelly’s Ferry Bridge to Bend Bridge	2.6	10
Bend Bridge to Red Bluff Diversion Dam	0.8	2
Below Red Bluff Diversion Dam	4.1	21

ACID: Anderson-Cottonwood Irrigation District

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures during the August through December spawning, egg incubation, and alevins period for spring-run Chinook salmon are presented in the BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. As stated in the BA, the PA would change mean water temperatures very little (predominantly less than 1°F) from Keswick Dam to Red Bluff in all months of the period and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, and would occur at Red Bluff in above normal years during August, and above- and below-normal years during September, and at Bend Bridge in below normal years during September. The increases during September would occur during the period of peak presence of spawners, eggs, and alevins.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (BA Appendix 5.C, Upstream Water

Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7).

The values for the PA in these exceedance plots generally overlap those of the NAA. Further examination of above normal water years during August (Figure 2-20) and September (Figure 2-21) at Red Bluff, below normal years during September at Red Bluff (Figure 2-22), and below-normal years during September at Bend Bridge (Figure 2-23), where the largest increases in mean monthly water temperatures were found, reveals that water temperatures under the PA are almost always slightly warmer than under the NAA, with typically less than a degree (°F) difference between the two alternatives.

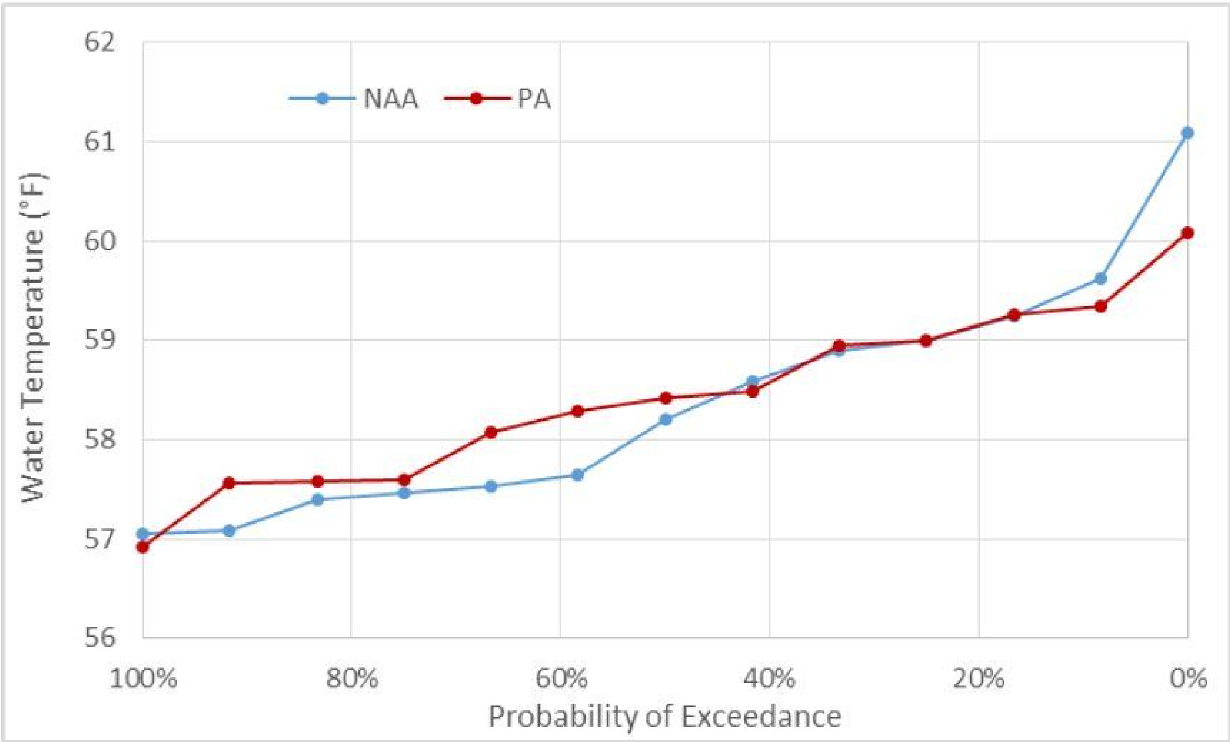

Figure 2-20. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Above Normal Water Years.

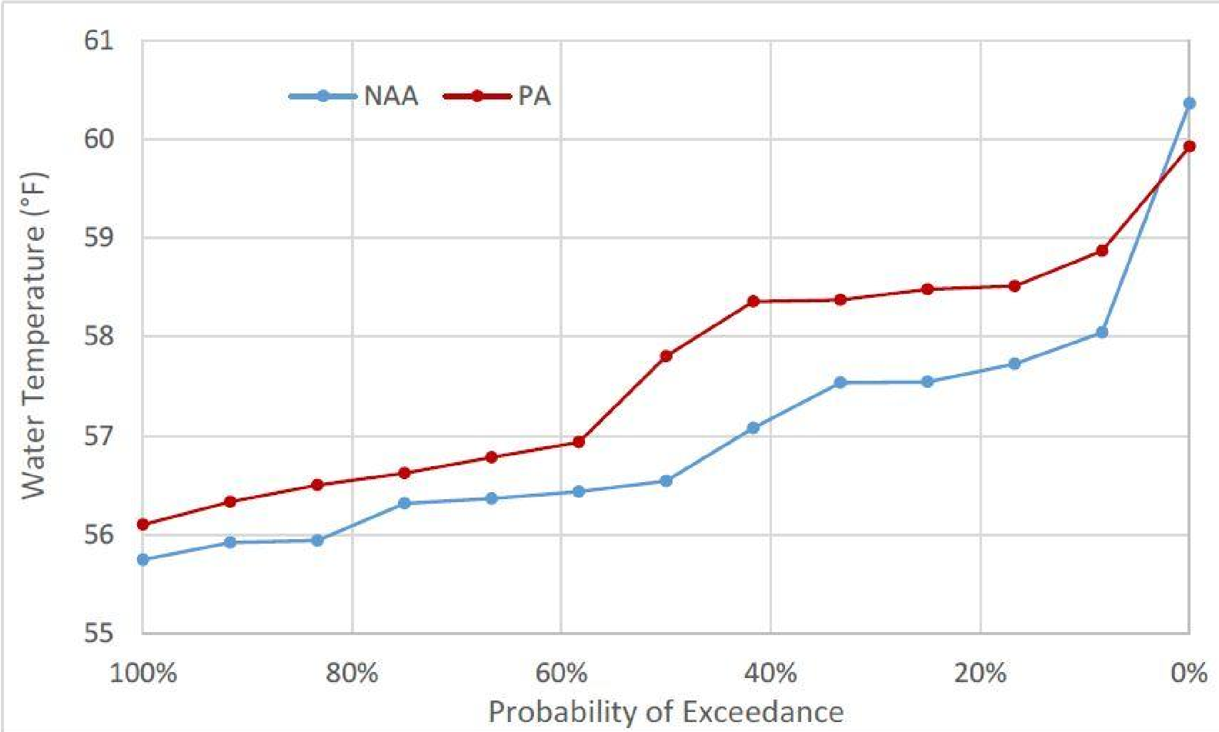

Figure 2-21. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years.

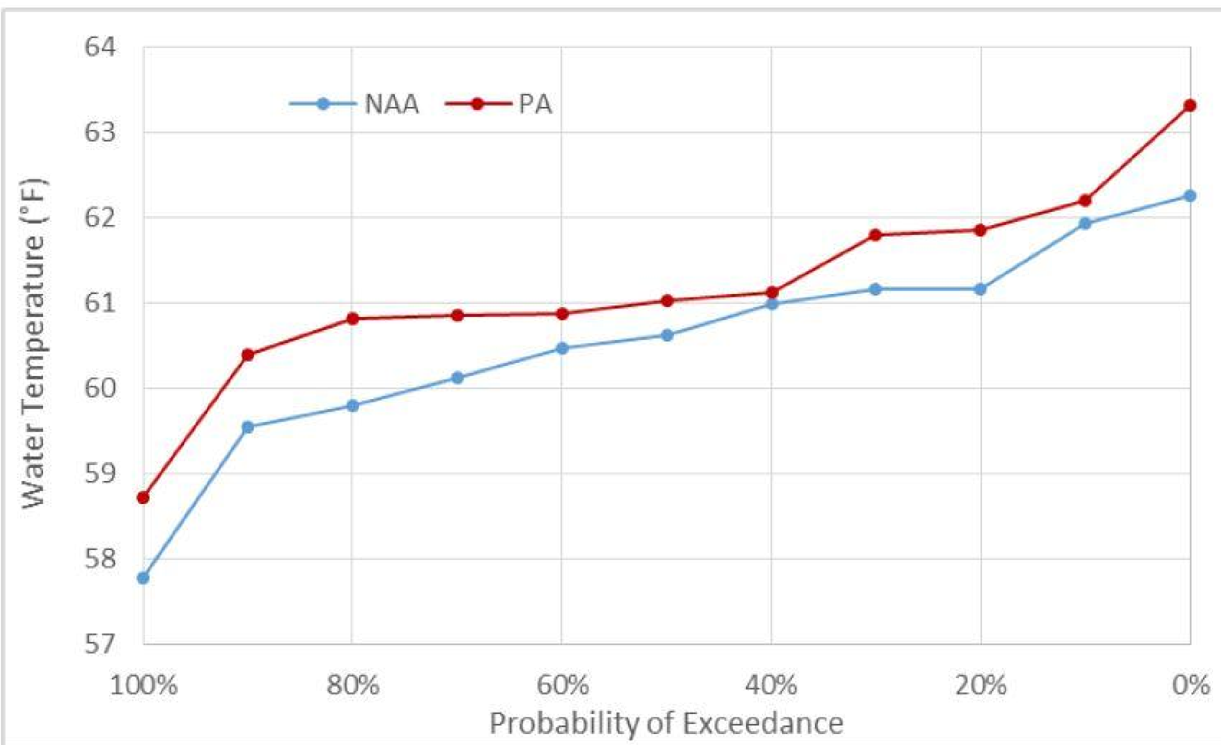

Figure 2-22. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years.

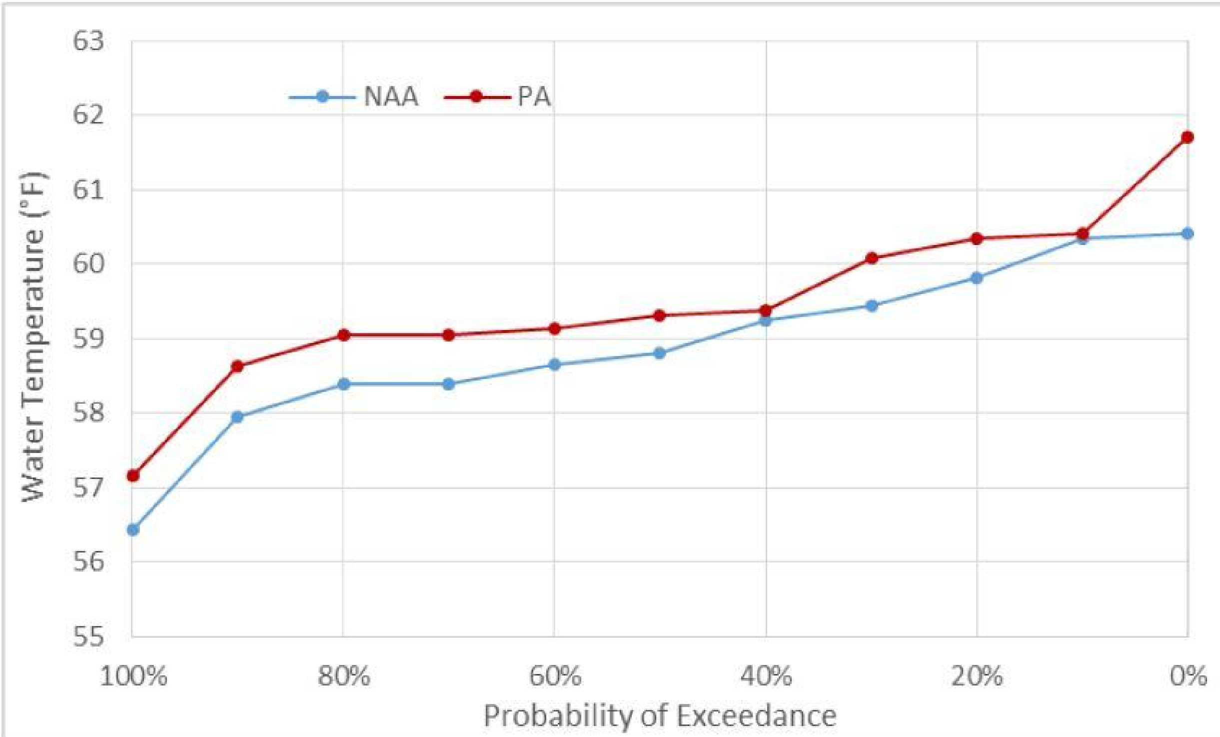

Figure 2-23. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in September of Below Normal Water Years.

The water temperature exceedance plots are useful for assessing whether the PA is expected to make conditions warmer, colder, or have little impact relative to the NAA. The plots clearly show that the latter (little impact) is the case. What the plots do not show is how fish life stages, in this case spring-run Chinook salmon eggs and alevins, will be affected by the PA thermal regime. Three tools were used in this biological opinion to evaluate the expected effects on spring-run Chinook salmon eggs and alevins resulting from the PA thermal regime: a thresholds analysis, the SWFSC's egg mortality model, and SALMOD.

Temperature Threshold Analysis

To evaluate water temperature threshold exceedance during the spawning, egg incubation, and alevin life stages between Keswick Dam and Red Bluff, the USEPA's 7DADM threshold value of 55.4°F was used (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51).

The water temperature thresholds analysis presented in the BA indicates that water temperatures under the PA are not expected to have a biologically meaningful effect on spring-run Chinook salmon spawning, egg incubation, and alevin development when compared to the NAA. In the BA, a biologically meaningful effect for the water temperature threshold analysis was defined as the months and water year types in which water temperature results met two criteria: (1) the difference between NAA and PA in frequency of exceedance of the threshold was greater than 5%, and (2) the difference between NAA and PA in average daily exceedance was greater than

0.5°F. The 5% criterion was based on best professional judgment of fisheries biologists from NMFS, CDFW, DWR, and Reclamation. The 0.5°F criterion was based on: (1) a review of the water temperature-related mortality rates for steelhead eggs and juveniles and (2) a reasonable water temperature differential that could be resolved through real-time reservoir operations. As seen in Table 2-58 through Table 2-62, there are no instances where there is both a 5% change in the frequency of exceeding the water temperature threshold and where the difference between NAA and PA in average daily exceedance is greater than 0.5°F. The water temperature thresholds analysis indicates that adverse thermal effects on this life stage resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of eggs and alevins. For example, exceedances over the threshold are prevalent at all locations and water year types under the PA indicating that lethal or sub-lethal effects on spring-run Chinook salmon eggs and alevins would be expected every spawning season.

Table 2-58. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Spawning, Egg Incubation, and Alevins, Sacramento River at Keswick, 55.4°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	5.5	3.2	-2.3	13	3	-10	0.38	0.15	-0.23
	C	55.1	53.5	-1.6	1,136	1,116	-20	5.54	5.61	0.07
	All	9.4	8.6	-0.8	1,149	1,119	-30	4.81	5.11	0.30
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	9.7	13.6	3.9	17	21	4	0.53	0.47	-0.06
	D	19.7	15.8	-3.8	58	33	-25	0.49	0.35	-0.14
	C	86.7	83.3	-3.3	2,350	2,273	-77	7.53	7.58	0.04
	All	18.8	17.9	-0.9	2,425	2,327	-98	5.25	5.29	0.04
Oct	W	10.7	10.2	-0.5	45	29	-16	0.52	0.35	-0.17
	AN	5.4	3.8	-1.6	5	2	-3	0.25	0.14	-0.11
	BN	27.9	24.0	-3.8	42	20	-22	0.44	0.24	-0.20
	D	40.8	41.5	0.6	139	112	-27	0.55	0.44	-0.11
	C	99.5	100.0	0.5	2,175	2,019	-156	5.88	5.43	-0.45
	All	32.8	32.1	-0.7	2,406	2,182	-224	2.92	2.70	-0.22
Nov	W	67.2	61.3	-5.9	404	360	-44	0.77	0.75	-0.02
	AN	50.8	37.5	-13.3	128	92	-36	0.70	0.68	-0.02
	BN	40.6	37.0	-3.6	138	101	-37	1.03	0.83	-0.20
	D	45.7	48.3	2.7	199	212	13	0.73	0.73	0
	C	86.1	86.1	0.0	625	617	-8	2.02	1.99	-0.03
	All	58.6	54.9	-3.7	1,494	1,382	-112	1.05	1.04	-0.01
Dec	W	8.3	7.8	-0.5	50	39	-11	0.75	0.62	-0.13
	AN	6.2	3.0	-3.2	15	4	-11	0.65	0.36	-0.29
	BN	11.4	7.6	-3.8	23	17	-6	0.59	0.65	0.06
	D	2.6	2.9	0.3	7	9	2	0.44	0.50	0.06
	C	14.0	14.5	0.5	31	32	1	0.60	0.59	0
	All	7.8	6.8	-1.0	126	101	-25	0.64	0.59	-0.05

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-59. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Spawning, Egg Incubation, and Alevins, Sacramento River at Clear Creek, 55.4°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	12.9	12.4	-0.5	60	59	-1	0.58	0.59	0.01
	AN	5.5	1.7	-3.7	3	2	-1	0.14	0.29	0.15
	BN	37.5	45.2	7.6	78	134	56	0.61	0.87	0.26
	D	69.2	71.3	2.1	555	463	-92	1.29	1.05	-0.25
	C	100.0	99.7	-0.3	1,854	1,788	-66	4.98	4.82	-0.16
	All	41.5	42.3	0.7	2,550	2,446	-104	2.42	2.28	-0.14
Sep	W	10.0	10.3	0.3	55	51	-4	0.71	0.64	-0.07
	AN	13.1	15.1	2.1	24	27	3	0.47	0.46	-0.01
	BN	79.7	86.1	6.4	397	497	100	1.51	1.75	0.24
	D	94.5	99.0	4.5	1,123	1,211	88	1.98	2.04	0.06
	C	100.0	100.0	0.0	3,239	3,189	-50	9.00	8.86	-0.14
	All	53.6	56.0	2.4	4,838	4,975	137	3.67	3.61	-0.06
Oct	W	91.9	91.8	-0.1	813	873	60	1.10	1.18	0.08
	AN	85.5	81.7	-3.8	325	302	-23	1.02	0.99	-0.03
	BN	90.3	93.3	2.9	450	395	-55	1.46	1.24	-0.22
	D	89.8	97.1	7.3	1,044	1,022	-22	1.87	1.70	-0.18
	C	100.0	100.0	0.0	2,843	2,700	-143	7.64	7.26	-0.38
	All	91.4	93.0	1.6	5,475	5,292	-183	2.38	2.27	-0.12
Nov	W	89.5	84.7	-4.7	1,035	953	-82	1.48	1.44	-0.04
	AN	73.6	64.7	-8.9	348	272	-76	1.31	1.17	-0.15
	BN	63.9	63.9	0.0	323	281	-42	1.53	1.33	-0.20
	D	67.5	72.8	5.3	560	583	23	1.38	1.33	-0.05
	C	93.6	93.6	0.0	944	934	-10	2.80	2.77	-0.03
	All	78.8	77.3	-1.5	3,210	3,023	-187	1.68	1.61	-0.07
Dec	W	13.6	12.2	-1.5	96	80	-16	0.87	0.82	-0.06
	AN	8.1	5.6	-2.4	27	13	-14	0.90	0.62	-0.28
	BN	15.2	11.1	-4.1	43	30	-13	0.83	0.79	-0.04
	D	5.2	4.8	-0.3	18	20	2	0.56	0.67	0.10
	C	17.5	18.3	0.8	51	53	2	0.78	0.78	-0.01
	All	11.5	10.2	-1.4	235	196	-39	0.81	0.77	-0.04

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-60. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Spawning, Egg Incubation, and Alevins, Sacramento River at Balls Ferry, 55.4°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	89.6	90.0	0.4	974	960	-14	1.35	1.32	-0.02
	AN	76.7	84.1	7.4	315	333	18	1.02	0.98	-0.04
	BN	93.8	97.9	4.1	505	610	105	1.58	1.83	0.25
	D	100.0	100.0	0.0	1,708	1,616	-92	2.75	2.61	-0.15
	C	100.0	100.0	0.0	2,519	2,452	-67	6.77	6.59	-0.18
	All	92.2	94.0	1.8	6,021	5,971	-50	2.57	2.50	-0.07
Sep	W	24.4	26.5	2.2	188	184	-4	0.99	0.89	-0.10
	AN	46.2	62.8	16.7	159	247	88	0.88	1.01	0.12
	BN	98.5	99.1	0.6	881	1,030	149	2.71	3.15	0.44
	D	100.0	99.7	-0.3	2,129	2,258	129	3.55	3.78	0.23
	C	100.0	100.0	0.0	3,573	3,550	-23	9.93	9.86	-0.06
	All	67.3	70.6	3.3	6,930	7,269	339	4.19	4.18	0.00
Oct	W	86.7	89.5	2.7	837	926	89	1.20	1.28	0.09
	AN	84.7	83.6	-1.1	367	349	-18	1.17	1.12	-0.04
	BN	92.1	95.6	3.5	513	438	-75	1.63	1.34	-0.29
	D	92.6	97.6	5.0	1,171	1,135	-36	2.04	1.88	-0.16
	C	100.0	100.0	0.0	2,759	2,638	-121	7.42	7.09	-0.33
	All	90.6	93.0	2.4	5,647	5,486	-161	2.48	2.35	-0.13
Nov	W	75.1	66.7	-8.5	633	550	-83	1.08	1.06	-0.02
	AN	54.7	40.8	-13.9	186	126	-60	0.94	0.86	-0.09
	BN	48.5	47.6	-0.9	220	182	-38	1.38	1.16	-0.22
	D	47.0	49.3	2.3	273	298	25	0.97	1.01	0.04
	C	76.7	76.9	0.3	717	717	0	2.60	2.59	-0.01
	All	61.8	57.5	-4.3	2,029	1,873	-156	1.35	1.34	-0.01
Dec	W	4.8	4.3	-0.5	24	15	-9	0.62	0.43	-0.19
	AN	3.2	1.1	-2.2	7	1	-6	0.58	0.25	-0.33
	BN	4.1	3.8	-0.3	8	6	-2	0.57	0.46	-0.11
	D	0.6	0.6	0.0	1	2	1	0.25	0.50	0.25
	C	2.2	2.4	0.3	2	2	0	0.25	0.22	-0.03
	All	3.1	2.6	-0.5	42	26	-16	0.55	0.40	-0.15

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-61. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Spawning, Egg Incubation, and Alevins, Sacramento River at Bend Bridge, 55.4°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	99.9	99.9	0.0	2,791	2,764	-27	3.47	3.43	-0.03
	AN	99.8	99.5	-0.2	1,165	1,190	25	2.90	2.97	0.07
	BN	100.0	100.0	0.0	1,158	1,317	159	3.40	3.86	0.47
	D	100.0	100.0	0.0	3,063	2,932	-131	4.94	4.73	-0.21
	C	100.0	100.0	0.0	3,107	3,036	-71	8.35	8.16	-0.19
	All	99.9	99.9	0.0	11,284	11,239	-45	4.44	4.43	-0.02
Sep	W	55.8	57.1	1.3	619	639	20	1.42	1.44	0.01
	AN	88.2	96.4	8.2	596	799	203	1.73	2.13	0.39
	BN	100.0	100.0	0.0	1,539	1,730	191	4.66	5.24	0.58
	D	100.0	100.0	0.0	3,392	3,560	168	5.65	5.93	0.28
	C	100.0	100.0	0.0	3,874	3,870	-4	10.76	10.75	-0.01
	All	84.1	85.8	1.7	10,020	10,598	578	4.84	5.02	0.18
Oct	W	89.1	90.7	1.6	1,141	1,268	127	1.59	1.73	0.15
	AN	89.0	86.6	-2.4	544	533	-11	1.64	1.66	0.01
	BN	93.5	96.8	3.2	664	576	-88	2.08	1.75	-0.34
	D	94.4	96.0	1.6	1,476	1,428	-48	2.52	2.40	-0.12
	C	100.0	100.0	0.0	2,674	2,574	-100	7.19	6.92	-0.27
	All	92.6	93.6	1.0	6,499	6,379	-120	2.80	2.71	-0.08
Nov	W	49.5	42.4	-7.1	384	319	-65	0.99	0.96	-0.03
	AN	30.3	18.1	-12.2	85	45	-40	0.78	0.69	-0.09
	BN	38.2	37.0	-1.2	163	128	-35	1.29	1.05	-0.24
	D	25.2	28.3	3.2	122	138	16	0.81	0.81	0.00
	C	56.1	56.9	0.8	464	478	14	2.30	2.33	0.03
	All	40.1	36.7	-3.3	1,218	1,108	-110	1.25	1.24	-0.01
Dec	W	0.5	0.2	-0.2	1	0	-1	0.25	0	-0.25
	AN	0.3	0.0	-0.3	0	0	0	0	NA	NA
	BN	0.3	0.6	0.3	0	0	0	0	0	0.00
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.2	0.2	-0.1	1	0	-1	0.17	0	-0.17

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-62. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Spawning, Egg Incubation, and Alevins, Sacramento River at Red Bluff, 55.4°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	100.0	100.0	0.0	3,651	3,614	-37	4.53	4.48	-0.05
	AN	100.0	100.0	0.0	1,575	1,598	23	3.91	3.97	0.06
	BN	100.0	100.0	0.0	1,467	1,656	189	4.30	4.86	0.55
	D	100.0	100.0	0.0	3,704	3,557	-147	5.97	5.74	-0.24
	C	100.0	100.0	0.0	3,416	3,346	-70	9.18	8.99	-0.19
	All	100.0	100.0	0.0	13,813	13,771	-42	5.43	5.42	-0.02
Sep	W	93.3	95.3	1.9	1,649	1,700	51	2.27	2.29	0.02
	AN	100.0	100.0	0.0	1,300	1,541	241	3.33	3.95	0.62
	BN	100.0	100.0	0.0	2,256	2,470	214	6.84	7.48	0.65
	D	100.0	100.0	0.0	4,755	4,929	174	7.93	8.22	0.29
	C	100.0	100.0	0.0	4,513	4,526	13	12.54	12.57	0.04
	All	97.9	98.5	0.6	14,473	15,166	693	6.01	6.26	0.25
Oct	W	98.9	99.1	0.2	2,178	2,335	157	2.73	2.92	0.19
	AN	98.9	98.4	-0.5	1,047	1,037	-10	2.85	2.83	-0.01
	BN	99.7	100.0	0.3	1,152	1,057	-95	3.39	3.10	-0.29
	D	98.7	99.8	1.1	2,377	2,331	-46	3.88	3.77	-0.12
	C	100.0	100.0	0.0	3,157	3,070	-87	8.49	8.25	-0.23
	All	99.1	99.4	0.3	9,911	9,830	-81	3.98	3.94	-0.05
Nov	W	66.5	56.4	-10.1	647	563	-84	1.25	1.28	0.03
	AN	45.8	34.4	-11.4	160	105	-55	0.97	0.85	-0.12
	BN	46.4	45.5	-0.9	252	218	-34	1.65	1.45	-0.19
	D	39.5	40.7	1.2	256	279	23	1.08	1.14	0.06
	C	65.8	66.1	0.3	610	622	12	2.57	2.61	0.04
	All	54.0	49.2	-4.7	1,925	1,787	-138	1.47	1.49	0.03
Dec	W	1.4	0.4	-1.0	3	1	-2	0.27	0.33	0.06
	AN	0.8	0.0	-0.8	1	0	-1	0.33	NA	NA
	BN	0.9	0.6	-0.3	1	1	0	0.33	0.50	0.17
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.7	0.2	-0.5	5	2	-3	0.29	0.40	0.11

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Southwest Fisheries Science Center's Egg Mortality Model

The SWFSC egg mortality model, described above in the winter-run Chinook salmon section, was linked with a 1-dimensional temperature model of the Sacramento River with one kilometer (km) spatial resolution (Pike et al. 2013) to estimate daily survival probabilities for eggs when exposed to water temperatures under the PA and NAA[3]. Figure 2-24 shows the spring-run Chinook salmon egg survival probability under the PA and NAA for all water years combined and by water year type. These results show the survival after accounting for only the effects of water temperature. Other factors affecting egg and alevin survival such as physical disturbance from redd superimposition would lower the water temperature dependent survival shown in Figure 2-24.

Adverse thermal effects on the spring-run eggs resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of eggs. For example, spring-run Chinook salmon egg survival is expected to be less than 50% throughout much of the first 20 km of spawning habitat in September and early October for all water years combined and in all water year types except for above normal years under the PA. In critical water years, egg survival would be less than 10% throughout the spawning habitat for all of August, September, and the first half of October. These results suggest that Sacramento River water temperatures under the PA when combined with the environmental baseline and modeled climate change impacts will have an adverse effect on a large proportion of incubating spring-run Chinook salmon eggs.

[3] The egg mortality model developed by Reclamation that is used in the BA has not been incorporated into this biological opinion because it is based on thermal tolerance studies conducted in the laboratory which substantially underestimate egg mortality in natural conditions (e.g., a salmon redd in the Sacramento River) (Martin et al. 2016). The SWFSC's egg mortality model is based on a relationship between temperature and egg survival derived from field data, providing a more reliable tool for estimating thermal effects on salmon eggs than Reclamation's egg mortality model.

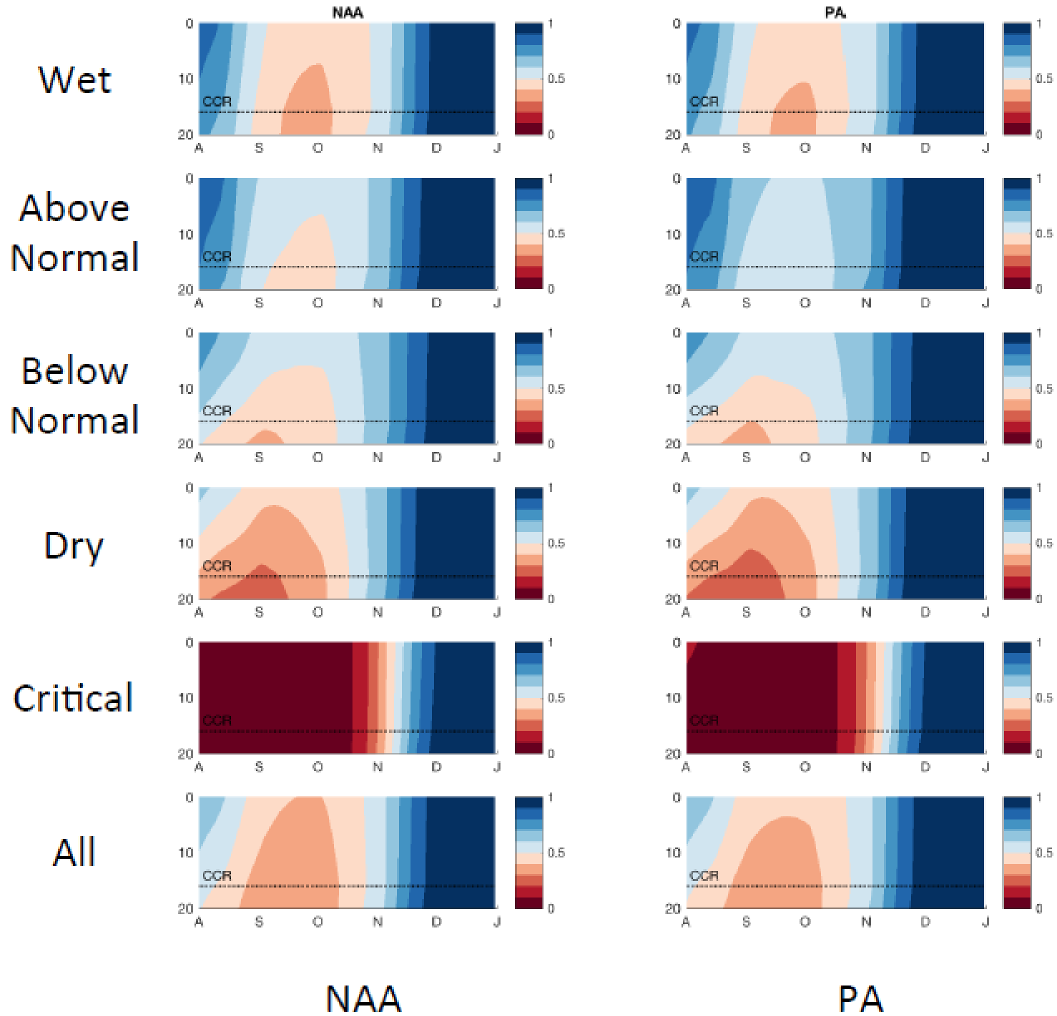

Figure 2-24. Spring-run Chinook Salmon Egg Survival Landscape from the SWFSC's Temperature Dependent Egg Survival Model. Primary Y-axis is distance in km downstream from Keswick Dam. The color key is the probability of survival.

SALMOD Model

The SALMOD model provides predicted water temperature-related mortality of spring-run Chinook salmon spawning, eggs, and alevins the Sacramento River. This water temperature-related mortality of the combined spring-run Chinook salmon "spawning, eggs, and alevins" life stage is split up as *pre-spawn* (in vivo, or in the mother before spawning) and egg (in the gravel) mortality. The annual exceedance plot of temperature-related mortality of spring-run Chinook salmon spawning, eggs, and alevins is presented in Figure 2-25. The model indicates that combining all water year types, water temperature-related mortality of the spawning, egg, and alevin life stage would decrease by 12,110 fish (7%) under the PA relative to the NAA.

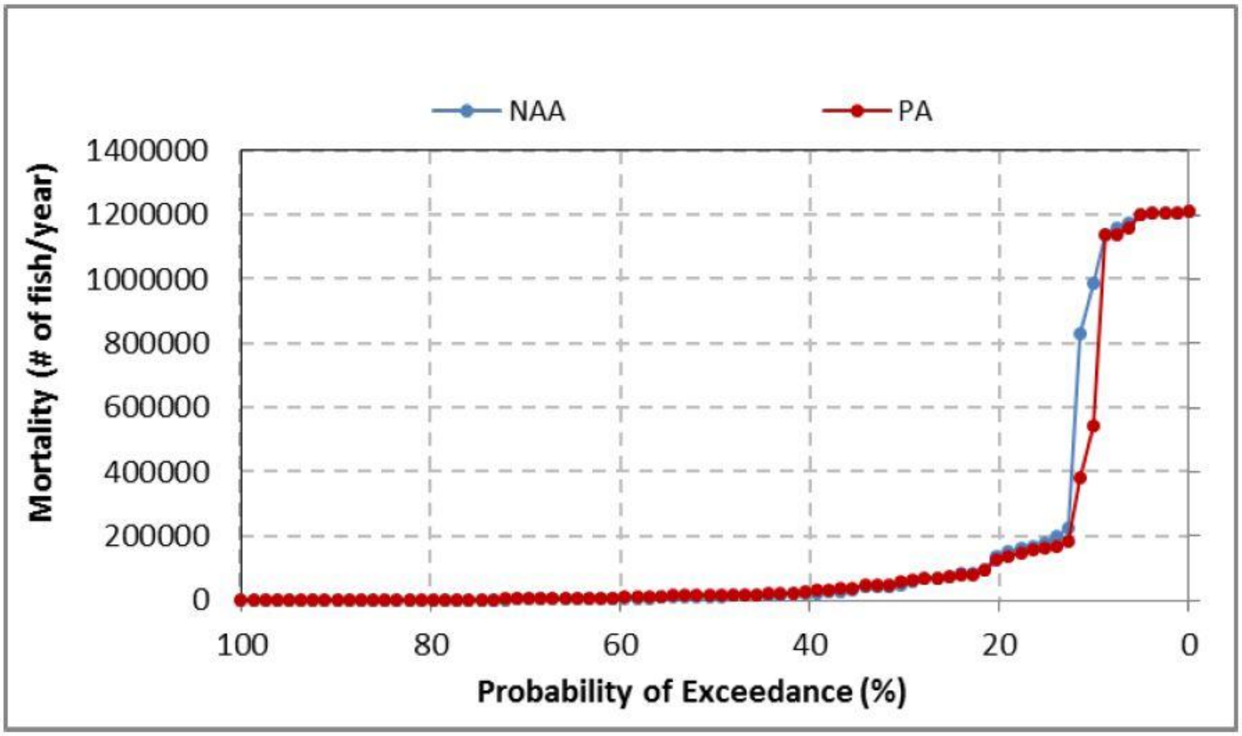

Figure 2-25. Exceedance Plot of Annual Water Temperature-Based Mortality (#of Fish/Year) of Spring-run Chinook Salmon Spawning, Egg Incubation, and Alevins.

Within the combined spawning, egg, and alevin life stages, there would be an increase in prespawn mortality of 4,431 eggs in the mother (10%) under the PA, but a decrease in egg mortality of 16,540 eggs (13%). Water-temperature-related mortality of these combined spawning, egg, and alevin life stages would comprise the large majority (more than 95%) of overall spring-run Chinook salmon mortality and, therefore, can be considered an important source of mortality to early life stages of spring-run Chinook salmon. Individual water year types largely follow the same patterns as for all water year types combined, with few exceptions. Most notably, in below normal years, there would be an overall increase in water-temperature-related mortality under the PA in both pre-spawn (100%) and egg (18%) mortality, and an overall increase in water temperature-related mortality under the PA (18%).

Results of the water temperature threshold analysis, the SWFSC's egg mortality model, and SALMOD all suggest that adverse thermal effects on spring-run spawning, egg, and alevin life stages resulting from changes to upstream operations as a result of the PA are expected to be small. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of spring-run Chinook salmon eggs and alevins.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5 Real-Time Operations Upstream of the Delta, and Section 3.3.3 Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for

CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Fry and Juvenile Rearing and Outmigration

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures during the year-round fry and juvenile rearing period for spring-run Chinook salmon in the Sacramento River upstream of the Delta (BA Table 5.4-27) are presented in BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10.

Overall, the PA would change mean water temperatures very little (predominantly less than 1°F) throughout the juvenile rearing reach of Keswick Dam to Knights Landing in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F, and would occur at Knights Landing in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the juvenile rearing period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results,

Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7).

The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal water years in August at Knights Landing, where the largest increase in mean monthly water temperature was seen, indicates that water temperatures under the PA would be higher than those under NAA for most of the exceedance range by up to approximately 2.2°F, particularly in the colder end of the range (Figure 2-26). This would likely result in adverse effects to juvenile spring-run Chinook salmon as indicated in the following threshold analysis.

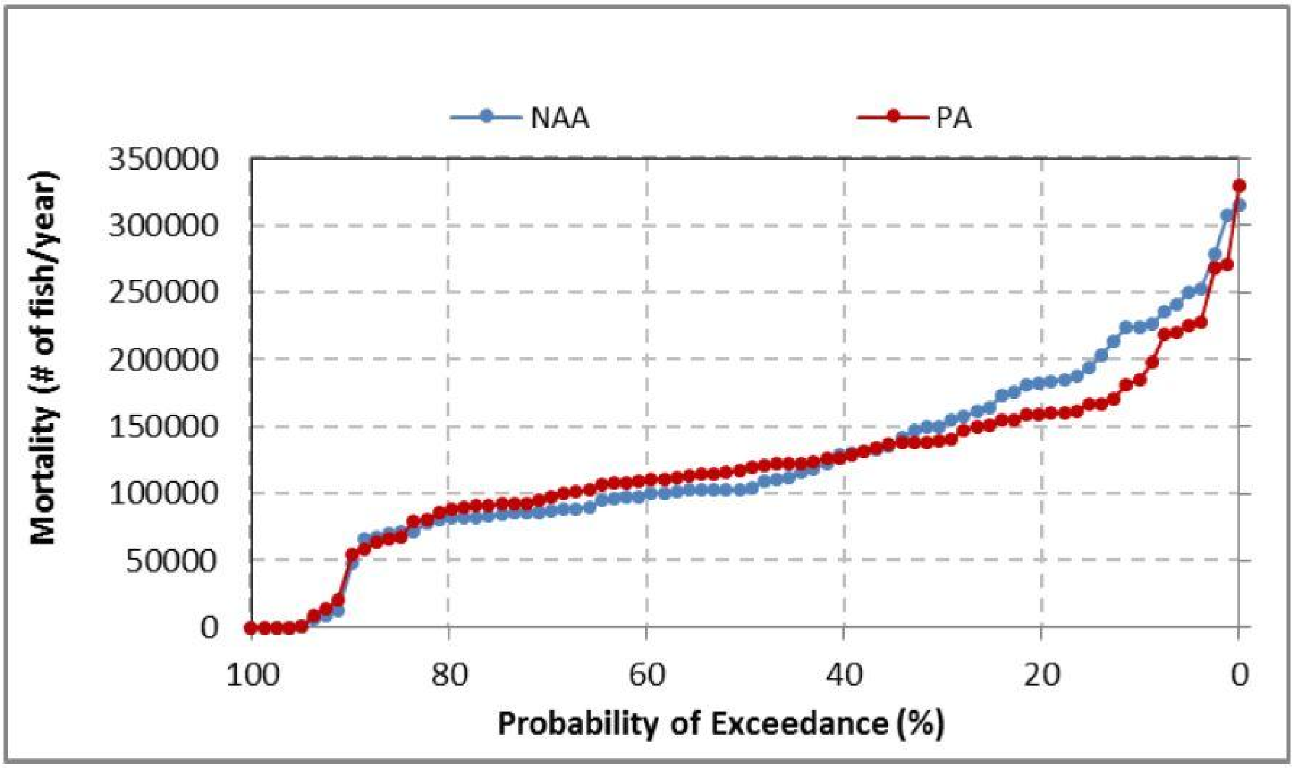

Figure 2-26. Exceedance Plot of Annual Flow-Based Mortality (# of Fish/Year) of Winter-run Chinook Salmon Fry and Juveniles.

Temperature Threshold Analysis

For the water temperature thresholds analysis, juvenile rearing and emigration were combined and the year-round period was evaluated. For juvenile rearing and emigration, the thresholds used were from the USEPA's 7DADM value of 61°F for the core juvenile rearing reach from Keswick Dam to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49). The 7DADM values were converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Tables 5.D-85 through 5.D-90.

At Keswick Dam, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA in which water temperatures would exceed the threshold (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-85 [Table 2-63]). There would be two instances in which average daily exceedance would be 0.5°F: September of critical years and September for all water year types combined (reflecting that the only differences in threshold exceedance among water year types during September would occur during critical years). There would be no concurrent increase, however, in the percent of days exceeding the threshold in these instances. This indicates that the frequency of days above the threshold be would similar under the PA, but exceedances would be higher on average.

Table 2-63. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Fry and Juvenile Rearing and Emigration, Sacramento River at Keswick, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.3	0.0	-0.3	0	0	0	0.00	NA	NA
	All	0.0	0.0	0.0	0	0	0	0.00	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	32.8	32.5	-0.3	245	269	24	2.01	2.22	0.21
	All	4.8	4.8	0.0	245	269	24	2.01	2.22	0.21
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	64.4	60.0	-4.4	857	909	52	3.69	4.21	0.51
	All	9.4	8.8	-0.7	857	909	52	3.69	4.21	0.51
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	52.7	49.5	-3.2	450	407	-43	2.30	2.21	-0.08
	All	7.8	7.3	-0.5	450	407	-43	2.30	2.21	-0.08
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.6	0.0	-0.6	1	0	-1	0.50	NA	NA
	All	0.1	0.0	-0.1	1	0	-1	0.50	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on a large proportion of spring-run Chinook salmon fry and juveniles in critically dry years, although this does not consider real-time operational management described in BA Section 3.1.5 Real-Time Operations Upstream of the Delta and Section 3.3.3 Real-Time Operational Decision-Making Process, that would be used to avoid or minimize any modeled effects. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

SALMOD Model

The SALMOD model provides predicted water temperature-related fry and juvenile spring-run Chinook salmon mortality, which is a combination of mortality of the fry, pre-smolt, and immature smolt life stages (see Attachment 5.D.2, SALMOD Model, for a full description).

Results for water temperature-related mortality of these life stages are presented in the BA in the annual exceedance plot shown in Figure 2-27. These results indicate that there would be very little water-temperature-related mortality to these life stages. Therefore, there would be no biologically meaningful effect of the PA.

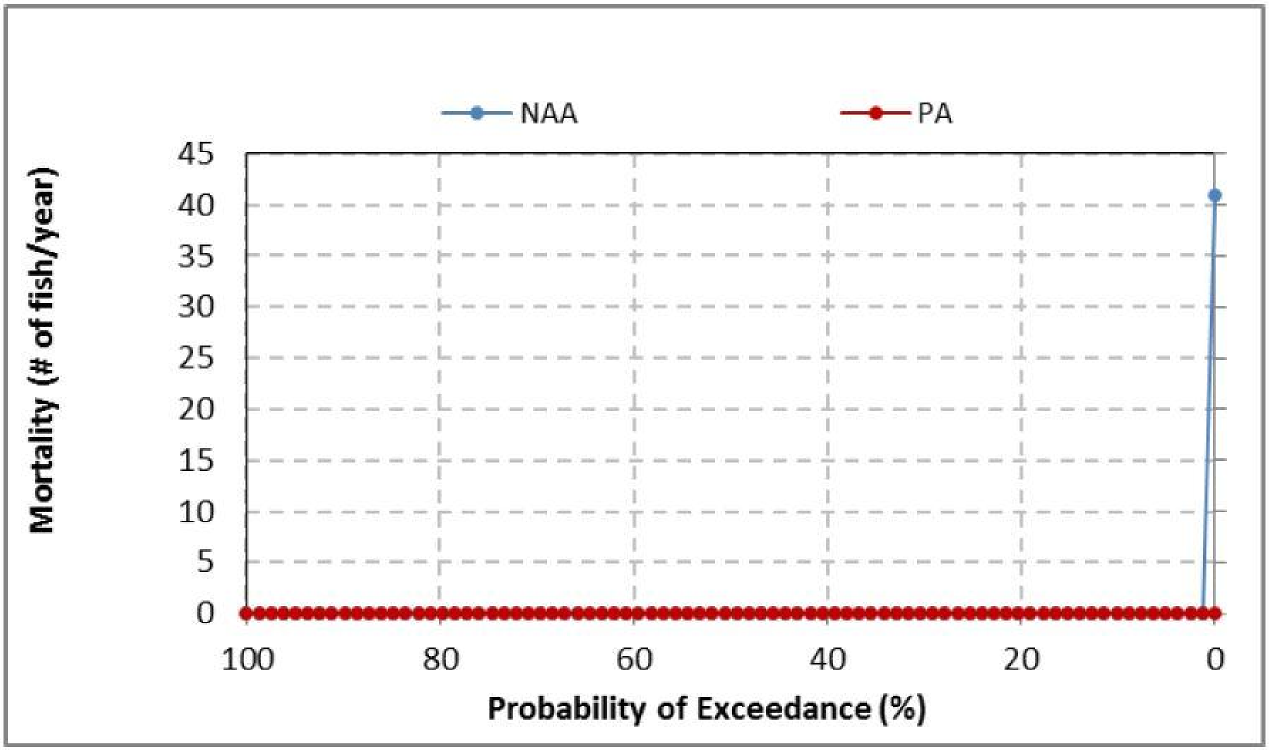

Figure 2-27. Exceedance Plot of Annual Water Temperature-Based Mortality (# of Fish/Year) of Spring-run Chinook Salmon Fry and Juveniles, SALMOD.

Overall, the monthly water temperature results, exceedance plots, and threshold analysis collectively indicate that thermal impacts on the spring-run Chinook salmon fry and juvenile rearing and outmigration life stage will largely be the same with implementation of either the NAA or PA operations. As such, adverse thermal effects on this life stage resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of this life stage in critically dry water years.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Adult Immigration and Holding

Adult Immigration

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Bend Bridge, and Red Bluff during the March through September adult immigration period for spring-run Chinook salmon (BA Table 5.4-27) are presented in the BA Appendix 5.C, Upstream Water Temperature Methods and Results, BA Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, and would occur at Red Bluff in below normal years during August and in above- and below normal water years during September.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The curves for the PA generally match those of the NAA.

For below normal water years in August at Red Bluff, where the largest increase in mean monthly water temperature was seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 2-28). During September of above normal and below normal water years, water temperatures are more variable between the two scenarios, but those under the PA are higher in nearly all years (Figure 2-29, Figure 2-30.)

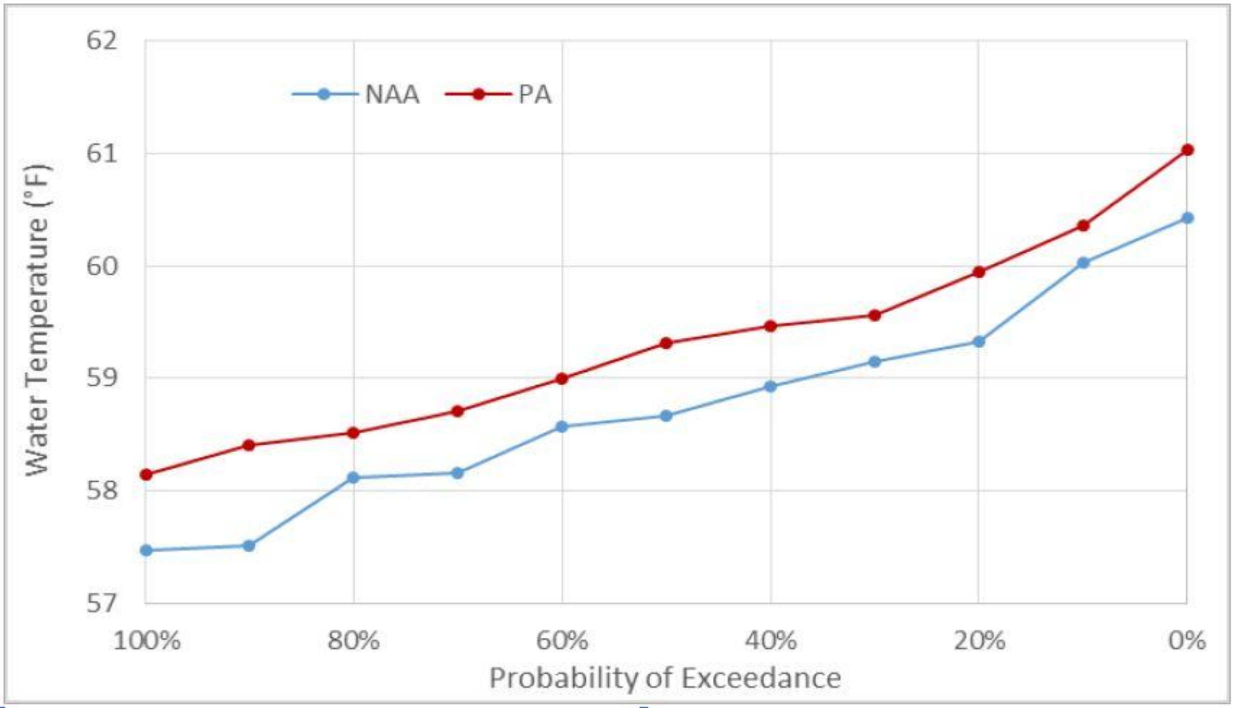

Figure 2-28. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Below Normal Water Years.

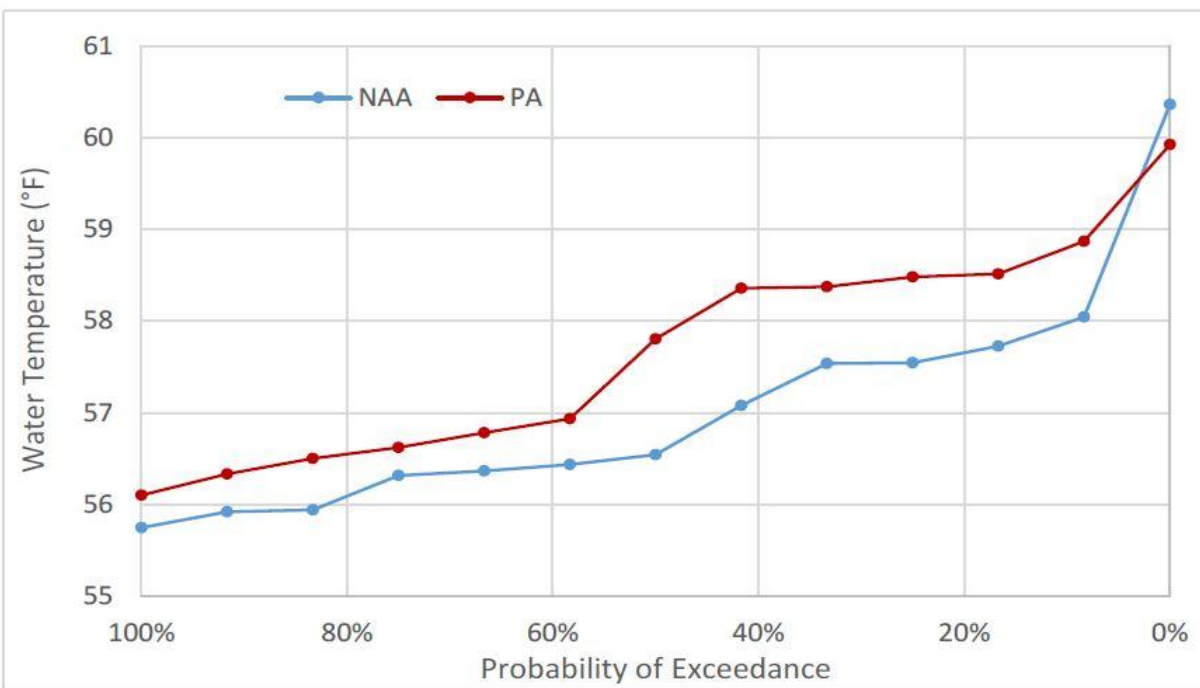

Figure 2-29. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years.

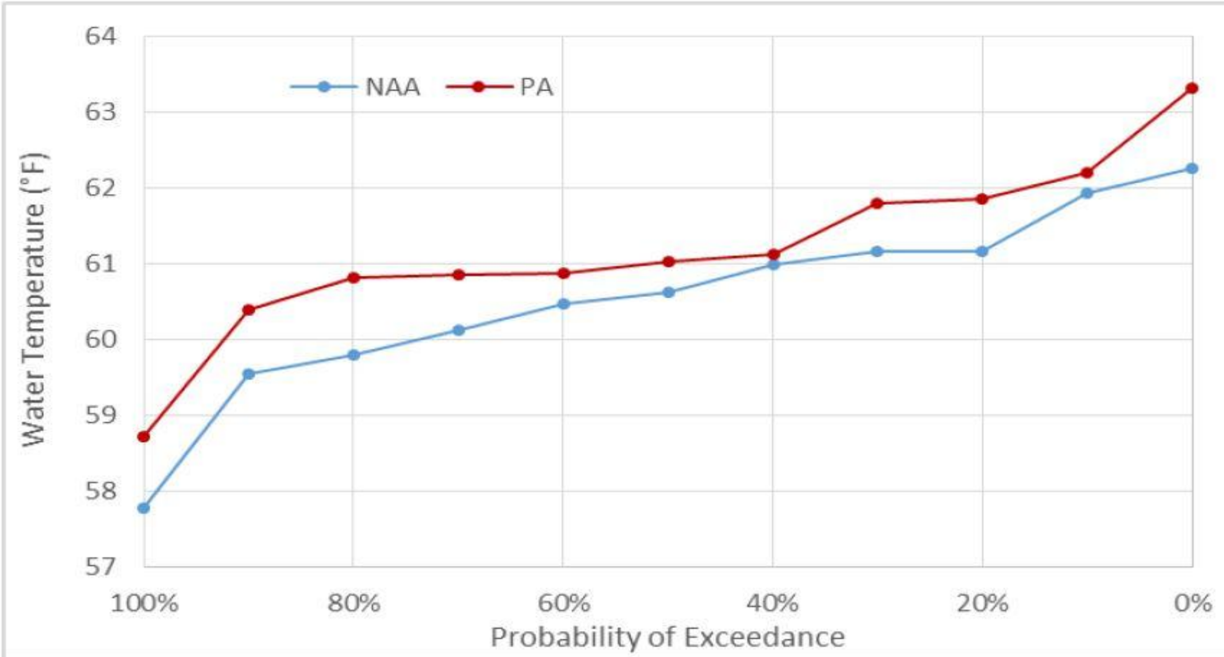

Figure 2-30. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years.

Temperature Threshold Analysis

To evaluate water temperature threshold exceedance during the adult immigration life stage at Keswick Dam, Bend Bridge, and Red Bluff, the USEPA's 7DADM threshold value of 68°F was used (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D.2-49). The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D.2-51). Results of the water temperature thresholds analysis are presented in BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Tables 5.D-91 through 5.D-93 [Table 2-20 through Table 2-22 below].

At Keswick Dam and Red Bluff, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-91 and Table 5.D-93 [Table 2-64 and Table 2-66 below]).

Table 2-64. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Adult Immigration, Sacramento River at Keswick, 68°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	2.2	2.2	0	3	3	NA	0.38	NA
	All	0.0	0.3	0.3	0	3	3	NA	0.38	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-65. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Adult Immigration, Sacramento River at Bend Bridge, 68°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	11.6	16.7	5.1	56	81	25	1.30	1.31	0.004
	All	1.7	2.4	0.7	56	81	25	1.30	1.31	0.004
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	28.1	33.3	5.3	163	203	40	1.61	1.69	0.08
	All	4.1	4.9	0.8	163	203	40	1.61	1.69	0.08

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-66. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Adult Immigration, Sacramento River at Red Bluff, 68°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	21.0	21.2	0.3	101	129	28	1.29	1.63	0.34
	All	3.1	3.1	0.0	101	129	28	1.29	1.63	0.34
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.6	0.6	0	1	1	NA	0.50	NA
	D	0.8	0.5	-0.3	1	1	0	0.20	0.33	0.13
	C	51.1	55.0	3.9	408	476	68	2.22	2.40	0.19
	All	7.7	8.3	0.6	409	478	69	2.16	2.35	0.19

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

At Bend Bridge, there are two instances during which the percent of days exceeding the 68°F 7DADM under the PA would be more than 5% higher than under the NAA: August of critical water years (5.1% higher under the PA) and September of critical water years (5.3% higher) (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-92). However, there would be a less than 0.1°F difference in average daily exceedance in these instances. Therefore, it was concluded that there would be no biologically meaningful effect on spring-run adult immigration.

The thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on a large proportion of immigrating spring-run Chinook salmon adult immigration, although this does not consider real-time operational management described in BA Section 3.1.5 Real-Time Operations Upstream of the Delta, and Section 3.3.3 Real-Time Operational Decision-Making Process, that would be used to avoid or minimize any modeled effects. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see Section BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Adult Holding

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Balls Ferry, and Red Bluff during the April through September adult holding period for spring-run Chinook salmon (BA Table 5.4-27) are presented in BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results. Table 5.C.7-3, Table 5.C.7-5, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, and would occur at Red Bluff in above normal years during August and above- and below normal years during September. This 0.6°F increase during August would occur during the last month of the peak adult holding period (May through August).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.5-7, Figure 5.C.7.8-7). The curves for PA generally match those of the NAA. For below normal water years in August at Red Bluff, where the largest increase in mean monthly water temperature was seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 2-31) (BA Figure 5.4-111).

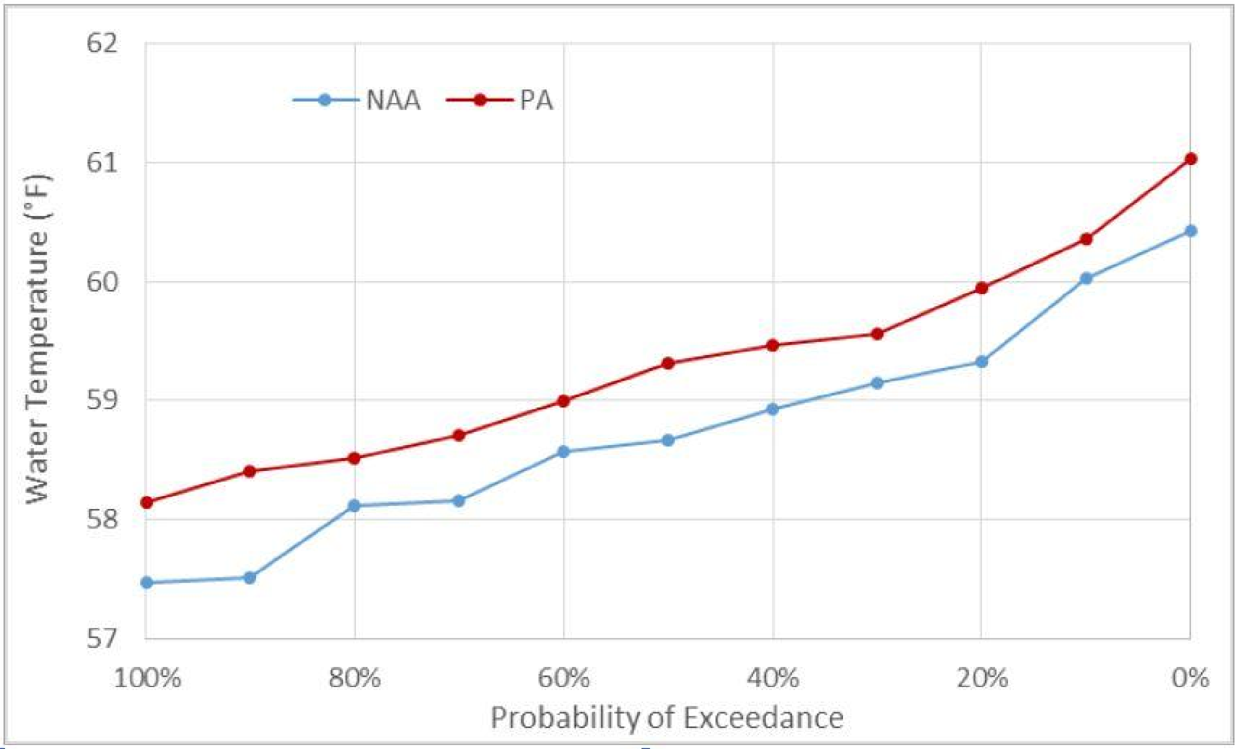

Figure 2-31. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Below Normal Water Years.

Temperature Threshold Analysis

To evaluate water temperature threshold exceedance during the spring-run Chinook salmon adult holding life stage at Keswick Dam, Balls Ferry, and Red Bluff, the USEPA's 7DADM threshold value of 61°F was used (Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51). Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results (Table 2-67 through Table 2-69).

Table 2-67. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Adult Holding, Sacramento River at Keswick, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.3	0.0	-0.3	0	0	0	0.00	NA	NA
	All	0.0	0.0	0.0	0	0	0	0.00	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	32.8	32.5	-0.3	245	269	24	2.01	2.22	0.21
	All	4.8	4.8	0.0	245	269	24	2.01	2.22	0.21
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	64.4	60.0	-4.4	857	909	52	3.69	4.21	0.51
	All	9.4	8.8	-0.7	857	909	52	3.69	4.21	0.51

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-68. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Adult Holding, Sacramento River at Balls Ferry, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.7	0.7	0.0	3	3	0	0.50	0.50	0
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.2	0.2	0	0	0	NA	0	NA
	C	1.1	1.1	0.0	2	1	-1	0.50	0.25	-0.25
	All	0.4	0.4	0.0	5	4	-1	0.50	0.36	-0.14
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.6	0.3	-0.3	0	0	0	0	0	0
	All	0.1	0.0	0.0	0	0	0	0	0	0
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	9.7	12.1	2.4	54	65	11	1.50	1.44	-0.06
	All	1.4	1.8	0.4	54	65	11	1.50	1.44	-0.06
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	2.3	0.2	-2.1	4	0	-4	0.29	0	-0.29
	C	46.0	42.5	-3.5	799	802	3	4.67	5.08	0.40
	All	7.3	6.3	-1.0	803	802	-1	4.34	5.04	0.70
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	3.9	6.1	2.1	6	13	7	0.46	0.65	0.19
	D	12.2	11.0	-1.2	52	37	-15	0.71	0.56	-0.15
	C	83.9	73.9	-10.0	1,667	1,658	-9	5.52	6.23	0.71
	All	15.8	14.3	-1.5	1,725	1,708	-17	4.45	4.85	0.41

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-69. Water Temperature Threshold Analysis Results, Spring-run Chinook Salmon, Adult Holding, Sacramento River at Red Bluff, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Apr	W	0.5	0.5	0.0	2	2	0	0.50	0.50	0
	AN	0.5	0.5	0.0	1	1	0	0.50	0.50	0
	BN	0.0	0.3	0.3	0	0	0	NA	0.00	NA
	D	2.7	2.8	0.2	11	11	0	0.69	0.65	-0.04
	C	1.7	1.7	0.0	6	6	0	1.00	1.00	0
	All	1.1	1.2	0.1	20	20	0	0.71	0.67	-0.05
May	W	15.8	15.9	0.1	162	162	0	1.28	1.27	-0.01
	AN	14.6	12.2	-2.5	81	76	-5	1.37	1.55	0.18
	BN	5.3	8.8	3.5	10	24	14	0.56	0.80	0.24
	D	19.0	14.8	-4.2	181	150	-31	1.53	1.63	0.10
	C	25.3	23.7	-1.6	127	118	-9	1.35	1.34	-0.01
	All	16.4	15.2	-1.1	561	530	-31	1.35	1.37	0.02
Jun	W	12.7	12.4	-0.3	103	103	0	1.04	1.06	0.02
	AN	10.8	9.0	-1.8	39	37	-2	0.93	1.06	0.13
	BN	7.0	6.1	-0.9	23	21	-2	1.00	1.05	0.05
	D	4.3	2.8	-1.5	20	11	-9	0.77	0.65	-0.12
	C	46.7	40.8	-5.8	238	186	-52	1.42	1.27	-0.15
	All	14.6	12.8	-1.7	423	358	-65	1.18	1.13	-0.05
Jul	W	8.4	8.4	0.0	46	46	0	0.68	0.68	0
	AN	0.5	0.2	-0.2	1	1	0	0.50	1.00	0.50
	BN	5.0	2.9	-2.1	7	4	-3	0.41	0.40	-0.01
	D	10.5	9.5	-1.0	28	19	-9	0.43	0.32	-0.11
	C	66.1	72.6	6.5	470	548	78	1.91	2.03	0.12
	All	15.7	16.1	0.4	552	618	66	1.39	1.51	0.13
Aug	W	18.0	15.9	-2.1	134	117	-17	0.92	0.91	-0.01
	AN	12.7	9.7	-3.0	47	20	-27	0.92	0.51	-0.41
	BN	15.2	24.6	9.4	22	53	31	0.42	0.63	0.21
	D	57.7	51.6	-6.1	519	391	-128	1.45	1.22	-0.23
	C	85.5	79.0	-6.5	1,363	1,311	-52	4.29	4.46	0.17
	All	36.3	34.0	-2.3	2,085	1,892	-193	2.26	2.19	-0.07
Sep	W	3.5	2.7	-0.8	32	22	-10	1.19	1.05	-0.14
	AN	9.0	16.7	7.7	37	51	14	1.06	0.78	-0.27
	BN	74.8	85.2	10.3	503	669	166	2.04	2.38	0.34
	D	87.5	93.0	5.5	1,462	1,606	144	2.78	2.88	0.09
	C	97.5	97.8	0.3	2,504	2,513	9	7.13	7.14	0.01
	All	48.2	51.9	3.7	4,538	4,861	323	3.83	3.81	-0.02

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

At Keswick Dam and Balls Ferry, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-94 and Table 5.D-95). Also at Balls Ferry, there would be a 10% reduction under the PA in the percent of days above the threshold in September of critical water years and a concurrent increase in average daily exceedance above the threshold of 0.7°F.

At Red Bluff, the percent of days exceeding the 61°F 7DADM threshold for adult holding habitat under the PA would be more than 5% higher than under the NAA during July (6.5%) of critical water years, August of below normal water years (9.4%), and September of above normal (7.7%), below normal (10.3%) and critical (5.5%) water years (Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-96). There would also be reductions in the percent of days exceeding the threshold in June of critical years (5.8%) and August of dry (6.1%) and critical (6.5%) water years. However, in none of these situations would there also be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect on adult spring-run Chinook salmon holding.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on holding adults, although this does not consider real-time operational management described in BA Section 3.1.5, Real-Time Operations Upstream of the Delta, and BA Section 3.3.3, Real-Time Operational Decision-Making Process, that would be used to avoid and minimize any modeled effects. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

In addition, this analysis does not consider the current revision process to NMFS 2009 BiOp Action Suite 1.2 described in BA Section 3.1.4.5, Annual/Seasonal Temperature Management Upstream of the Delta, to improve Chinook salmon egg-to-fry survival by accounting for new information regarding temperature tolerance during early life stages over the past few years. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates.

Overall, the monthly water temperature results, exceedance plots, and threshold analyses collectively indicate that thermal impacts on the spring-run Chinook salmon adult immigration and holding life stage will largely be the same with implementation of either the NAA or PA operations. As such, adverse thermal effects on this life stages resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of immigrating or holding adults.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5 Real-Time Operations Upstream of the Delta, and Section 3.3.3 Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

2.5.1.2.1.3 Steelhead Exposure and Risk

Sacramento River

Steelhead depend on suitable water temperatures for spawning and essentially all life functions. Like Chinook salmon in California, steelhead in California are at the southern end of their range within North America. Additionally, the majority of historical habitat in the Central Valley that provided suitable areas for spawning, egg incubation, and early life stages are now blocked by dams. Salmonids in the Sacramento River are now dependent on cold water temperature management in the upper Sacramento River (below Keswick Dam) and below Nimbus Dam on the lower American River, relying on cold water releases for their viability. The preferred water temperature for adult steelhead migration is 46°F to 52°F.

(McEwan and Jackson 1996; Myrick 1998; and Myrick and Cech 2000). Thermal stress may occur at temperatures beginning at 66° F and mortality has been demonstrated at temperatures beginning at 70°F. The preferred water temperature for steelhead spawning is 39°F to 52°F, and the preferred water temperature for steelhead egg incubation is 48°F to 52°F (McEwan and Jackson 1996; Myrick 1998; Myrick and Cech Jr 2000).

The United States Environmental Protection Agency (USEPA) issued temperature recommendations for salmon and trout (U.S. Environmental Protection Agency 2003). The USEPA recommends a water temperature range of 39.2°F to 53.6°F for good survival of eggs during incubation studies, with an optimal range of 42.8°F to 50°F. Preferred rearing temperatures for juvenile steelhead in field and lab studies are 50°F to 62.6°F (constant temperature) (Sauter et al. 2001) or less than 64.4°F 7DADM (U.S. Environmental Protection Agency 2003). Optimal growth with limited food supply in lab studies was achieved at temperatures of 50 °F to 61 °F (McCullough et al. 2001).

Steelhead may spend from one to three years (typically two) rearing in freshwater before emigrating to the marine environment as smolts (Moyle 2002). The larger juvenile life-stages are less sensitive to temperature then the alevins and yolk-sac fry but will suffer lethal and sub-lethal effects when not in optimal instream temperatures. USEPA guidelines recommend summer water temperatures do not exceed 61°F (16°C) 7DADM for juvenile rearing salmonids in the upper basin of natal rivers and not exceed 64°F (18°C) in the lower basin of natal rivers (U.S. Environmental Protection Agency 2003). Potential sub-lethal temperature effects on juvenile salmonids include slowed growth, delayed smoltification, desmoltification, and extreme physiological changes which can lead to disease and increased predation.

Spawning, Egg Incubation, and Alevins

Little is known about steelhead spawning locations in the Sacramento River, although it was assumed for this analysis that, because of constraints on water temperature and other habitat features, individuals spawn between Keswick Dam and Red Bluff Diversion Dam, where nearly all Chinook salmon spawn (BA). Identification of steelhead redds is complicated due to the similarity of redds formed by resident rainbow trout and those formed by co-occurring steelhead. CCV steelhead spawning and eggs/alevin incubation occurs from November through April, and water temperatures were modeled for this period from Keswick Dam downstream to Red Bluff.

Monthly Temperatures and Exceedance Plots

In the BA, riverine water temperatures under each operational scenario, PA and NAA, were modeled and the results contrasted to each other in a comparative analysis for each location of interest, and by month and water year type. This comparative analysis noted the frequency and magnitude of differences between the two operational scenarios. Modeled mean monthly water temperatures during the November through April spawning and egg/alevins incubation period for steelhead in the Sacramento River reach of Keswick Dam to Red Bluff are presented in in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the reach in all months and water year types of the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4%, and would occur at Bend Bridge and Red Bluff in critical water years during February. Despite the increase, water temperatures would remain less than 52°F in both locations under both scenarios during this time, which is below the temperature range of concern for spawning and egg/alevin incubation (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7).

The values for the PA in these exceedance plots generally match those of the NAA. For critical years during February at Bend Bridge and Red Bluff, where the largest increase in mean monthly water temperature was seen, curves would be nearly identical between the NAA and PAA, except for 2 years in which the PA would be approximately 1°F higher (Figure 2-32, Figure 2-33). However, water temperatures would not differ in the large majority of years at both locations. These results suggest that the differences in water temperature between NAA and PA in February of critical water years would be very similar at both locations.

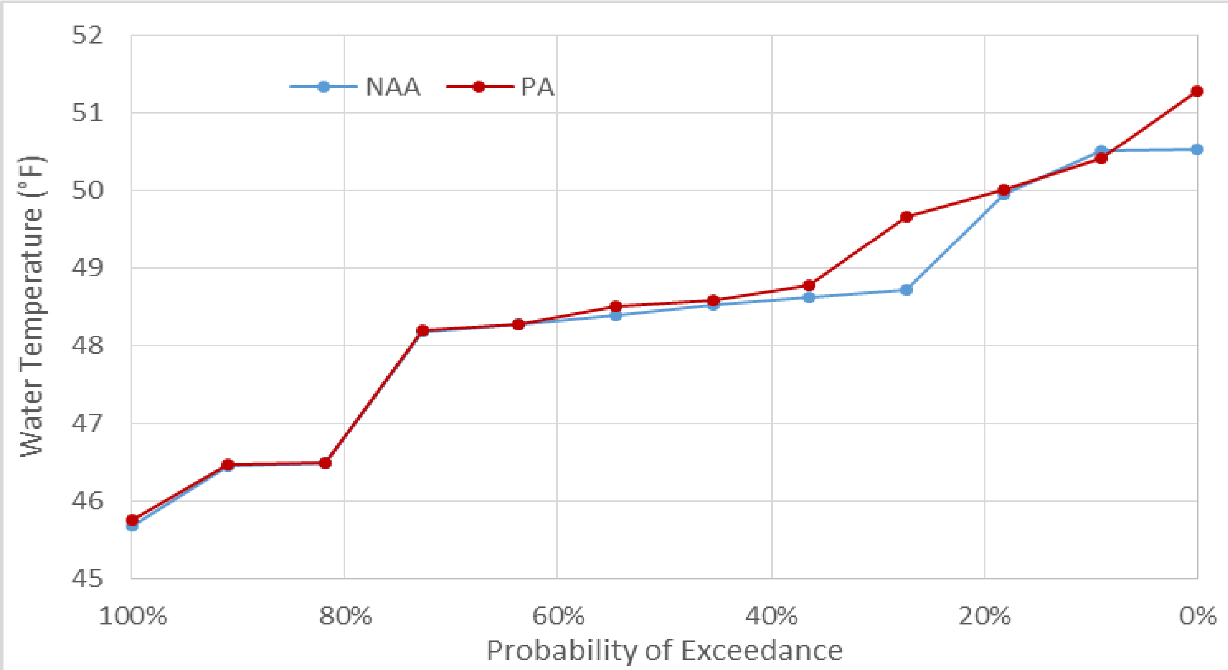

Figure 2-32. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in February of Critical Water Years.

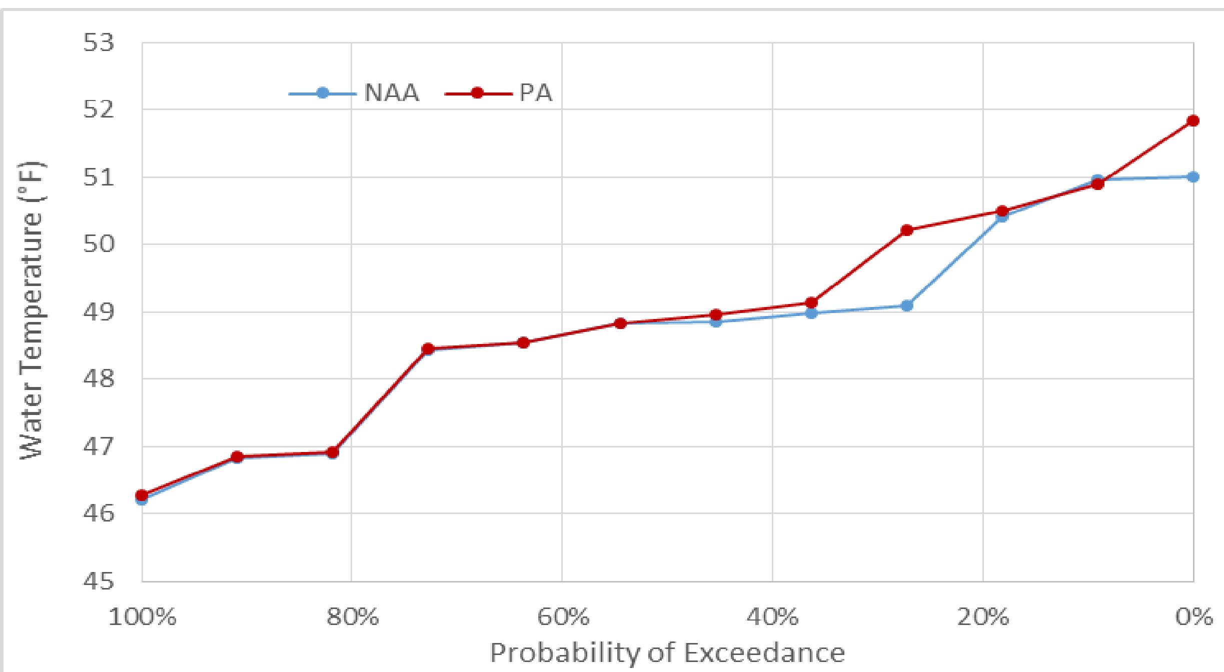

Figure 2-33. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in February of Critical Water Years.

Temperature Threshold Analysis

The exceedance of temperature thresholds in the Sacramento River presented in the BA in Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49 by modeled daily water temperatures was evaluated based on thresholds identified from the literature. For steelhead spawning and egg/alevin incubation, the thresholds used were 53°F (McCullough et al. 2001) and 56°F (McEwan and Jackson 1996) (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods,Table 5.D-51).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-97 through Table 5.D-106. At Keswick Dam, for both temperature thresholds, the modeled daily temperatures have very little difference between the PA and NAA scenarios. There would be no months or water year types in which the modeling results showed 5% more days under the PA scenario compared to the NAA scenario in which daily temperatures would exceed the threshold in a given month or water year type (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-97, Table 5.D-98). There would be one instance in which the percent of days exceeding the 53°F threshold would be lower under the PA relative to the NAA: November of above normal years (8.3% reduction). There would be two instances in which the percent of days exceeding the 56°F threshold would be lower under the PA relative to the NAA: November of above normal (6.7% reduction) and below normal (5.8% reduction) years. However, in no case would there be a more-than-0.5°F difference in the magnitude of average daily exceedance between the PA and NAA values.

At Clear Creek, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-99, Table 5.D-100). There would be 1 month and water year type, November of above normal water years, during which the percent exceedance would be lower under the PA relative to the NAA by 6.9% and 5.8% for the 53°F and 56°F thresholds, respectively. However, there would be no concurrent increase in magnitude of average daily exceedance that is more than 0.5°F for either instance.

At Balls Ferry, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-101, Table 5.D-102). There would be one water year type during November for each threshold during which the percent exceedance would be lower under the PA relative to the NAA by (53°F threshold: above normal water years, 11.7% lower under PA; 56°F threshold: below normal water years, 5.2% lower under PA). However, there would be no increase in magnitude of average daily exceedance that is more than 0.5°F for either instance.

At Bend Bridge, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-103, Table 5.D-104). For the 53°F threshold, there would be two instances, November of wet (8.8% reduction) and above normal (16.1% reduction) water years, in which there would be a reduction in the percent exceedance above the threshold under the PA relative to the NAA. However, there would be no concurrent increase in magnitude of average daily exceedance that is more than 0.5°F for either instance.

At Red Bluff, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-105, Table 5.D-106). For the 53°F threshold, there would be three instances, November of wet (8.3% reduction) and above normal (15.6% reduction) water years and March of below normal water years (6.7% reduction), in which there would be a reduction in the percent exceedance above the threshold under the PA relative to the NAA. However, there would be no concurrent increase in magnitude of average daily exceedance that is more than 0.5°F for any of these three instances.

The water temperature exceedance plots are useful for assessing whether the PA is expected to make conditions warmer, colder, or have little impact relative to the NAA. The plots clearly show that the latter (little impact) is the case. What the plots do not show is how fish life stages, in this case CCV Steelhead eggs and alevins, will be affected by the thermal regimes present under the PA when combined with the environmental baseline and modeled climate change impacts. For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, based on Tables 5.D-97 through 5.D-106 in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, typically more than 90% of the days in November are above the 53°F threshold for egg/alevin incubation for both the Keswick and Clear Creek modeling locations on the Sacramento River. When the more lenient threshold of 56°F is used, the percentage of days above the threshold drops to approximately 20 to 25% for the Keswick and Clear Creek locations. These modeling results would indicate that although there is little difference in the number of water temperature exceedances between the PA and NAA scenarios, the actual water temperature conditions in the river are deleterious to spawning and egg/alevin incubation. The same trend in the results are seen for the month of December, where the average number of days above the 53°F threshold at both the Keswick and Clear Creek locations is approximately 21%, while the more lenient threshold of 56°F averages less than 1%. By January, water temperatures have substantially dropped and the number of days above the 53°F threshold is typically less than 1%. Typically, the PA does slightly better in wetter water year types and slightly worse in drier water year types in providing suitable water temperatures for egg incubation and alevin development. However, given the high number of days in November above the 53°F thermal threshold (approximately 90%), most of the eggs laid in November will perish or have low viability under either operational scenario. Similarly, eggs laid in December will have approximately 20% to 30% of the days exceeding this threshold and thus, an equivalent percentile of eggs laid during this month and surviving eggs from the previous month can be assumed to be lost or have reduced fitness due to excessive temperature conditions.

The trend in water temperature exceeding the two thresholds at sites located downstream of the Clear Creek confluence (Balls Ferry, Bend Bridge, and Red Bluff) shows that water is generally cooler, and there are fewer days in November and December exceeding the thresholds. However, those locations that are farther downstream warm up faster in the spring, and have more days exceeding the two thresholds in March and April, than the Keswick and Clear Creek locations based upon the modeling. The modeling data suggests that steelhead eggs laid in November in the upper Sacramento River below Keswick Dam are at a much higher risk of mortality or developmental abnormalities due to warmer thermal conditions than eggs laid farther downstream. Conversely, eggs laid in the downstream locations (Balls Ferry, Bend Bridge, and Red Bluff) after January are at a higher risk of mortality due to the accelerated warming of the river in March and April compared to the upstream locations. Water temperatures in November and December should be considered at least a high-level stressor for early spawning steelhead in the upper Sacramento River below Keswick Dam. Eggs laid in the more downstream reaches are at risk in March and April. While the two scenarios are essentially equivalent in their effects on water temperature throughout the Keswick to Red Bluff river reaches, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts during November and December, and later in March and April, will adversely affect incubating steelhead eggs and developing steelhead alevins in the gravel during November and December at the Keswick and Clear Creek locations and during March and April farther downstream from Balls Ferry to Red Bluff based on modeling information.

Overall, the water temperature modeling results, exceedance plots, and threshold analyses collectively indicate that thermal impacts on steelhead eggs and alevins will largely be the same with implementation of either the NAA or PA operations. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects, particularly in drier water years. It is important to note that adverse effects for a large proportion of eggs indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process.

NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Kelt Emigration

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures during the February through May kelt emigration period for steelhead in the Sacramento River upstream of the Delta are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F) throughout the kelt emigration reach of Keswick Dam to Knights Landing[4] in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F, and would occur at Knights Landing in below normal water years during August. However, this is outside the anticipated window when kelts are believed to be emigrating back down stream (February through May) and should not affect them.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the kelt emigration period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7). The curves for PA generally match those of the NAA. At Knights Landing[5] in below normal water years during August, where the largest increase in mean monthly water temperature was seen, the difference between PA and NAA would be larger at the lower end of the temperatures range by nearly 2°F in 2 of the 11 years. As mentioned above, however, this is outside the temporal window that is anticipated for kelt emigration.

Temperature Threshold Analysis

There have been no known studies evaluating specific temperature effects on emigrating kelts. Therefore, adult immigration thresholds of 68°F 7DADM and 70°F were used for kelt emigration thresholds, with an assumption that kelts emigrating downstream would be affected by water temperatures similarly to adults immigrating upstream (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49). The 68°F 7DADM threshold was taken from U.S. Environmental Protection Agency (2003) and the 70°F threshold represents the average of the studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range. The 7DADM threshold was converted to function with daily model outputs

[4] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

[5] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

for each month separately (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-107 through Table 5.D-112. At all three locations, Keswick Dam, Bend Bridge, and Red Bluff, there would be no months or water year types with both a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance. This means that the modeling data does not show that in any given month in any one of the water year types modeled both a 5% difference between the exceedance percentiles in the PA and NAA scenarios exists concurrently with a difference in water temperature of more than 0.5°F.

When examining the percentage of days in which water temperatures exceeded the thresholds of 68°F 7DADM or 70°F during the February through May period for kelt emigration, the modeling results show that water temperatures never exceeded the thresholds at Keswick, Bend Bridge, or Red Bluff. Therefore, water temperatures should not affect kelt emigration downstream during the February through May time period, and NMFS concludes that the PA will not adversely affect kelt migration downstream during the February through May emigration period.

Juvenile Rearing

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures during the year-round juvenile rearing period for steelhead in the Sacramento River between Keswick Dam and Red Bluff are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F) throughout the juvenile rearing reach in all months and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, and would occur at Red Bluff in above normal years during August and above- and below normal years during September, and at Bend Bridge in below normal years during September.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the juvenile rearing period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of August (Figure 2-20) (BA Figure 5.4-59) and September (Figure 2-21) (BA Figure 5.4-60) during above normal years at Red Bluff, September of below normal years at Red Bluff (Figure 2-22) (BA Figure 5.4-61), and September during below normal years at Bend Bridge (Figure 2-23) (BA Figure 5.4-62), where the largest increases in mean monthly water temperatures were seen, reveals that there is a general trend towards marginally higher temperatures under the PA but that the difference of 0.6°F in mean monthly temperatures between NAA and PA, the largest throughout the juvenile rearing period, would cause little change to the curves.

Temperature Threshold Analysis

Water temperature thresholds of 63°F mean monthly and 69°F (7DADM) were used to evaluate water temperature threshold exceedances during the steelhead juvenile rearing life stage in the Sacramento River between Keswick Dam and Red Bluff (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49). The 63°F threshold was derived by taking the intermediate value of the ranges of optimal growth from several studies (Grabowski 1973; Wurtsbaugh and Davis 1977; Hokanson et al. 1977; Myrick and Cech 2005; and Beakes et al. 2014). The 69°F 7DADM used was based on Sullivan (2000) and was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in the BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Tables 5.D-113 through 5.D-122. At Keswick Dam, for both thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-113, Table 5.D-114). This means that the modeling data does not show that in any given month in any one of the water year types modeled, that both a 5% difference between the exceedance percentiles in the PA and NAA scenarios exists concurrently with a difference in water temperature of more than 0.5°F. There would be one month and water year type in which the percent of days exceeding the threshold would be 7.8% lower under the PA relative to the NAA, but the magnitude of average daily exceedance above the threshold would be 0.9°F higher under the PA. From January through July, there are no days in which the 63°F threshold is exceeded in either the PA or NAA scenarios. Starting in August, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios (Table 2-70).

Table 2-70. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, Sacramento River at Keswick, 63°F. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	11.8	14.2	2.4	33	51	18	0.75	0.96	0.21
	All	1.7	2.1	0.4	33	51	18	0.75	0.96	0.21
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	53.9	46.1	-7.8	353	450	97	1.82	2.71	0.89
	All	7.9	6.7	-1.1	353	450	97	1.82	2.71	0.89
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	25.8	25.0	-0.8	122	92	-30	1.27	0.99	-0.28
	All	3.8	3.7	-0.1	122	92	-30	1.27	0.99	-0.28
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

The percentage of days exceeding the threshold is higher for the PA in August, but not in September and October. These exceedances occur in critical years, and can reach approximately 50% of the days in September, and 25% of the days in October. The degrees per day above the threshold tend to be higher for the PA in August and September, but not for October. This information from the modeling suggests that water temperature levels in August, September, and October may reach levels that adversely impact steelhead juvenile rearing in the Keswick reach and would negatively impact their viability. If the 7DADM of 69°F is used as the threshold, there are no exceedances during these same summer months and thus the data suggests that there would be no discernable effect based on the threshold temperature criteria.

At Clear Creek, for both thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, BA Table 5.D-115 (Table 2-71 below), BA Table 5.D-116 (Table 2-72 below)). This means that the modeling data does not show that in any given month in any one of the water year types modeled, that both a 5% difference between the exceedance percentiles in the PA and NAA scenarios exists concurrently with a difference in water temperature of more than 0.5°F. There would be one instance in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the 69°F threshold (September of critical water years, 5.3% increase), and two instances in which there would be a more-than-0.5°F increase in the magnitude of average daily exceedance above the 63°F threshold (September of critical years and all water year types combined, 0.6°F for both), but no instances would have both conditions met concurrently.

Table 2-71. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, Sacramento River at Clear Creek, 63°F. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	21.8	22.3	0.5	85	112	27	1.05	1.35	0.30
	All	3.2	3.3	0.1	85	112	27	1.05	1.35	0.30
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	60.8	55.8	-5.0	504	586	82	2.30	2.92	0.61
	All	8.9	8.2	-0.7	504	586	82	2.30	2.92	0.61
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	29.3	28.2	-1.1	167	140	-27	1.53	1.33	-0.20
	All	4.3	4.2	-0.2	167	140	-27	1.53	1.33	-0.20
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Table 2-72. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, Sacramento River at Clear Creek, 69°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	9.7	15.0	5.3	27	40	13	0.77	0.74	-0.03
	All	1.4	2.2	0.8	27	40	13	0.77	0.74	-0.03
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1]7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Starting in August, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios in critical water year types. The percentage of days exceeding the threshold is higher for the PA in August (22.3% versus 21.8%), but not in September and October. These exceedances occur in critical years, and can reach approximately 60% of the days in September, and 29% of the days in October. The degrees per day above the threshold tend to be higher for the PA in August and September, but not for October. This information from the modeling suggests that water temperature levels in August, September, and October of critical years may reach levels that adversely impact steelhead juvenile rearing in the Clear Creek reach and would negatively impact their viability. If the 7DADM of 69°F is used as the threshold, the threshold is exceeded during September of critical water year types for both the PA and NAA, with the PA having a greater percentage of days above the threshold (15.0% versus 9.7%). However, the degrees per day exceedance is slightly lower for the PA than the NAA modeled scenario (0.74 versus 0.77). The data suggests that there would be adverse effects due to temperature during the August through October temporal period at the Clear Creek location during critical water year types for rearing juvenile steelhead based on the threshold temperature criteria. At Balls Ferry, for both thresholds, with one exception, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, BA Table 5.D-117 (Table 2-73 below), BA Table 5.D-118 (Table 2-74 below).

Table 2-73. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, Sacramento River at Balls Ferry, 63°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.5	0.5	0	0	0	NA	0	NA
	All	0.0	0.1	0.1	0	0	0	NA	0	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	31.7	28.5	-3.2	210	234	24	1.78	2.21	0.43
	All	4.6	4.2	-0.5	210	234	24	1.78	2.21	0.43
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	64.2	61.9	-2.2	691	757	66	2.99	3.39	0.40
	All	9.4	9.1	-0.3	691	757	66	2.99	3.39	0.40
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	31.5	30.6	-0.8	208	184	-24	1.78	1.61	-0.16
	All	4.7	4.5	-0.1	208	184	-24	1.78	1.61	-0.16
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Table 2-74. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, Sacramento River at Balls Ferry, 69°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	1.6	3.5	1.9	4	6	2	0.67	0.46	-0.21
	All	0.2	0.5	0.3	4	6	2	0.67	0.46	-0.21
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	14.4	21.1	6.7	58	85	27	1.12	1.12	0
	All	2.1	3.1	1.0	58	85	27	1.12	1.12	0
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1]7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

The one exception would occur under the 69°F 7DADM threshold in September of critical water years (6.7% increase). However, there would not be a concurrent increase of more-than-0.5°F difference in the magnitude of average daily exceedance. Starting in August, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios in critical water year types. The percentage of days exceeding the threshold is higher for the NAA in August (31.7 5 versus 28.5%), September (64.2 versus 61.9%) and October (31.5% versus 30.6%). These exceedances occur only in critical water years. The degrees per day above the threshold tend to be higher for the PA in August and September, but not for October. This information from the modeling suggests that water temperature levels in August, September, and October of critical water year types may reach levels that adversely impact steelhead juvenile rearing in the Balls Ferry reach and would negatively impact their viability under both scenarios. If the 7DADM of 69°F is used as the threshold, the threshold is exceeded during August and September of critical water year types for both the PA and NAA, with the PA having a greater percentage of days above the threshold (3.5% versus 1.6% in August, and 21.1% versus 14.4% in September). However, the degrees per day exceedance is lower for the PA than the NAA modeled scenario (0.46 versus 0.67 in August) and equal in September (1.12). The data suggests that there would be adverse effects due to temperature during the August through September temporal period at the Balls Ferry location during critical water year types for rearing juvenile steelhead based on the threshold temperature criteria.

At Bend Bridge, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-119 (Table 2-75 below), Table 5.D-120 (Table 2-76 below).

Table 2-75. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, Sacramento River at Bend Bridge, 63°F. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.2	0.2	0.0	2	2	0	1.00	1.00	0
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.1	0.1	0.0	2	2	0	1.00	1.00	0
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	2.7	3.8	1.1	11	12	1	1.10	0.86	-0.24
	All	0.4	0.6	0.2	11	12	1	1.10	0.86	-0.24
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.2	0.0	-0.2	0	0	0	0	NA	NA
	C	39.0	38.7	-0.3	434	446	12	2.99	3.10	0.10
	All	5.7	5.7	-0.1	434	446	12	2.97	3.10	0.12
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.9	2.1	1.2	0	7	7	0	1.00	1.00
	D	7.8	6.5	-1.3	28	25	-3	0.60	0.64	0.05
	C	74.2	67.8	-6.4	927	975	48	3.47	4.00	0.52
	All	12.9	11.8	-1.1	955	1,007	52	3.01	3.47	0.46
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	31.7	29.6	-2.2	234	214	-20	1.98	1.95	-0.04
	All	4.7	4.4	-0.3	234	214	-20	1.98	1.95	-0.04
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Table 2-76. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, Sacramento River at Bend Bridge, 69°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	6.5	7.5	1.1	27	39	12	1.13	1.39	0.27
	All	0.9	1.1	0.2	27	39	12	1.13	1.39	0.27
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	18.1	22.5	4.4	82	104	22	1.26	1.28	0.02
	All	2.6	3.3	0.7	82	104	22	1.26	1.28	0.02
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	1.1	0.8	-0.3	1	1	0	0.25	0.33	0.08
	All	0.2	0.1	0.0	1	1	0	0.25	0.33	0.08
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1]7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

There would be one instance for the 63°F threshold in which the percent of days exceeding the threshold would be lower under the PA relative to the NAA, September of critical water years (6.4% reduction), but there would be a 0.5°F increase in the magnitude of average daily exceedance. Starting in July, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios. The percentage of days exceeding the threshold is higher for the PA in July (3.8% versus 2.7%, critical years) and September (2.1% versus 0.9%, below normal years), and higher for the NAA in August (0.2% versus 0.0%, dry years; 39.0% versus 38.7%, critical years), September (7.8% versus 6.5% dry years; 74.2% versus 67.8%, critical years) and October (31.7% versus 29.6%, critical years). The degrees per day above the threshold tend to be higher for the PA in August and September, but not for October. This information from the modeling suggests that water temperature levels in August, September, and October may reach levels that demonstrably impact steelhead juvenile rearing in the Bend Bridge reach and would negatively impact their viability under the PA in drier water year types. If the 7DADM of 69°F is used as the threshold, the threshold is exceeded during August, September, and October for both the PA and NAA, with the PA having a greater percentage of days above the threshold (7.5% versus 6.5% in August, and 22.5% versus 18.1% in September, both in critical years). The NAA has a slightly higher percentage of exceedance days in October (1.1% versus 0.8%, in critical years). The degrees per day exceedance is higher for the PA than the NAA modeled scenario in August (1.39 versus 1.13), September (1.28 versus 1.26) and October (0.33 versus 0.25), all in critical years. The data suggests that there would be adverse effects due to temperature during the August through October temporal period at the Bend Bridge location for rearing juvenile steelhead in drier water year types based on the threshold temperature criteria.

At Red Bluff for both thresholds there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, BA Table 5.D-121 (Table 2-77 below), BA Table 5.D-122 (Table 2-78 below)).

Table 2-77. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, Sacramento River at Red Bluff, 63°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.6	0.6	0.0	8	8	0	1.60	1.60	0
	AN	1.2	1.2	0.0	4	4	0	0.80	0.80	0
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	1.9	1.6	-0.3	6	5	-1	0.50	0.50	0
	C	1.9	1.1	-0.8	2	2	0	0.29	0.50	0.21
	All	1.1	0.9	-0.2	20	19	-1	0.69	0.79	0.10
Jun	W	0.9	1.0	0.1	6	6	0	0.86	0.75	-0.11
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	3.9	1.9	-1.9	8	4	-4	0.57	0.57	0
	All	0.9	0.6	-0.2	14	10	-4	0.67	0.67	0
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	15.1	19.4	4.3	52	69	17	0.93	0.96	0.03
	All	2.2	2.8	0.6	52	69	17	0.93	0.96	0.03
Aug	W	0.4	0.5	0.1	0	1	1	0.00	0.25	0.25

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	6.3	2.1	-4.2	25	5	-20	0.64	0.38	-0.26
	C	43.8	45.7	1.9	634	642	8	3.89	3.78	-0.11
	All	8.1	7.4	-0.7	659	648	-11	3.21	3.47	0.25
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	7.6	12.4	4.8	24	50	26	0.96	1.22	0.26
	D	24.0	28.0	4.0	217	223	6	1.51	1.33	-0.18
	C	85.8	81.9	-3.9	1,260	1,284	24	4.08	4.35	0.27
	All	19.4	20.5	1.1	1,501	1,557	56	3.14	3.09	-0.05
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	35.8	34.4	-1.3	299	276	-23	2.25	2.16	-0.09
	All	5.3	5.1	-0.2	299	276	-23	2.25	2.16	-0.09
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Table 2-78. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, Sacramento River at Red Bluff, 69°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	8.3	11.3	3.0	50	69	19	1.61	1.64	0.03
	All	1.2	1.7	0.4	50	69	19	1.61	1.64	0.03
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	37.8	47.2	9.4	248	290	42	1.82	1.71	-0.12
	All	5.5	6.9	1.4	248	290	42	1.82	1.71	-0.12
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	5.4	3.0	-2.4	19	11	-8	0.95	1.00	0.05
	All	0.8	0.4	-0.4	19	11	-8	0.95	1.00	0.05
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Starting in May, and continuing through October, the 63°F mean monthly threshold is exceeded for both the PA and NAA scenarios. The percentage of days exceeding the threshold is higher for the PA in June (1.0% versus 0.9%, wet years), July (19.4% versus 15.1%, critical years), August (0.5% versus 0.4% wet years, and 45.7 versus 43.8% in critical years) and September (12.4% versus 7.6%, below normal years and 28.0% versus 24.0% in dry years). The percentage of days which exceed the 63°F threshold is higher for the NAA scenario in May (1.9% versus 1.6% in dry years, 1.9 versus 1.1 in critical years), June (3.9% versus 1.9%, critical years), August (6.3% versus 2.1%, dry years), September (85.8% versus 81.9%, critical years), and October (35.8% versus 34.4%, critical years). The degrees per day above the threshold present mixed results, with some months and water years higher for the PA, and in other combinations, the PA is lower than the NAA scenario. This information from the modeling suggests that water temperature levels in July, August, September, and October of critical and dry water year types may reach levels that demonstrably impact steelhead juvenile rearing in the Red Bluff reach and would negatively impact their viability under the PA. If the 7DADM of 69°F is used as the threshold, the threshold is exceeded during August, September, and October for both the PA and NAA, with the PA having a greater percentage of days above the threshold (11.3% versus 8.3% in

August, and 47.2% versus 37.8% in September, both in critical years). The NAA has a slightly higher percentage of exceedance days in October (5.4% versus 3.0%, in critical years). The degrees per day exceedance is higher for the PA than the NAA modeled scenario in August (1.64 versus 1.61) and October (1.00 versus 0.95), both in critical years. The NAA has a higher level in September (1.82 versus 1.71, critical year). The data suggests that there would be adverse effects due to temperature under the PA during the August through October temporal period of critical water year types at the Red Bluff location for rearing juvenile steelhead based on the threshold temperature criteria.

Overall, based on the modeling results discussed above, NMFS concludes that the increase in water temperatures as a result of the PA will adversely affect a large proportion of rearing juveniles during the August through October period from Keswick Dam downstream to Red Bluff. In the farthest downstream reach modeled (Red Bluff), water temperatures under the PA have the potential to adversely affect rearing steelhead in June and July as well.

An additional threshold analysis was conducted to determine how the PA would affect steelhead smoltification. A 54°F threshold was used and was based on an average of temperatures from Zaugg and Wagner (1973), Adams et al. (1975), Zaugg (1981), and Hoar (1988), above which smoltification can be impaired. This analysis was conducted for January through March in the reach from Keswick Dam to Red Bluff.

Results of the water temperature thresholds analysis for steelhead smoltification are presented in the BA (Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, BA Table 5.D-123 through BA Table 5.D-127 (Table 2-79 through Table 2-83 below).

Table 2-79. Water Temperature Threshold Analysis Results, Steelhead, Smoltification, Sacramento River at Keswick, 54°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	6.9	6.9	0.0	42	42	0	1.50	1.50	0
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	1.1	1.1	0.0	42	42	0	1.50	1.50	0
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Table 2-80. Water Temperature Threshold Analysis Results, Steelhead, Smoltification, Sacramento River at Clear Creek, 54°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	6.0	6.0	0.0	29	29	0	1.21	1.21	0
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.9	0.9	0.0	29	29	0	1.21	1.21	0
Feb	W	0.4	0.4	0.0	0	0	0	0	0	0
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.1	0.1	0.0	0	0	0	0	0	0
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Table 2-81. Water Temperature Threshold Analysis Results, Steelhead, Smoltification, Sacramento River at Balls Ferry, 54°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	1.2	1.2	0.0	2	2	0	0.50	0.50	0
	D	1.1	1.3	0.2	5	5	0	0.71	0.63	-0.09
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.4	0.5	0.0	7	7	0	0.64	0.58	-0.05

[1] Only includes days on which temperature exceeded threshold

Table 2-82. Water Temperature Threshold Analysis Results, Steelhead, Smoltification, Sacramento River at Bend Bridge, 54°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.5	0.5	0.0	2	2	0	0.50	0.50	0
	AN	0.7	0.7	0.0	3	3	0	1.00	1.00	0
	BN	8.2	6.5	-1.8	26	24	-2	0.93	1.09	0.16
	D	7.7	7.7	0.0	41	41	0	0.85	0.85	0
	C	9.4	6.2	-3.2	20	13	-7	0.57	0.57	-0.01
	All	4.6	3.9	-0.7	92	83	-9	0.78	0.83	0.05

[1] Only includes days on which temperature exceeded threshold

Table 2-83. Water Temperature Threshold Analysis Results, Steelhead, Smoltification, Sacramento River at Red Bluff, 54°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	1.0	1.0	0.0	10	10	0	1.25	1.25	0
	AN	2.0	1.5	-0.5	6	5	-1	0.75	0.83	0.08
	BN	12.6	9.7	-2.9	59	50	-9	1.37	1.52	0.14
	D	13.2	13.2	0.0	100	100	0	1.22	1.22	0
	C	18.0	16.1	-1.9	68	50	-18	1.01	0.83	-0.18
	All	8.2	7.4	-0.7	243	215	-28	1.17	1.14	-0.03

[1] Only includes days on which temperature exceeded threshold

At all locations analyzed, Keswick Dam, Clear Creek, Balls Ferry, Bend Bridge, and Red Bluff, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA or with a more-than-0.5°F difference in the magnitude of average daily exceedance. However, the modeling showed that in both the PA and NAA, water temperatures exceeded the 54°F threshold in January at Keswick, January and February at Clear Creek, and in March at Balls Ferry, Bend Bridge, and Red Bluff. The percent of days above the threshold was less than 10% at all locations, except Red Bluff. At this location, the percentage of days ranged up to 18.0% (NDD) in March of critical years and was above approximately 10% for both the PA and NAA scenarios in below normal and dry year types. For purposes of the analysis in Section 2.7 Integration and Synthesis section, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impact is expected to result in adverse effects to the smoltification process for a large proportion of steelhead juveniles. Impairment of the smoltification process will occur in January in the Keswick reach, January and February in the Clear Creek reach, and March in the Red Bluff reach due to the effects of operations under the combined effect of PA implementation when added to the environmental baseline and modeled climate change impact, as modeled.

Overall, the water temperature modeling results, exceedance plots, and threshold analyses collectively indicate that thermal impacts on steelhead juveniles and smoltification will largely be the same with implementation of either the NAA or PA operations. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of steelhead juveniles, particularly in drier water years. It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process.

NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Smolt Emigration

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures in the Sacramento River in the reach from Keswick Dam to Red Bluff during the November through June smolt emigration period, which peaks during January through March, are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling

Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F) throughout the Sacramento River upstream of the Delta in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F (0.5 to 0.7%), and would occur at Keswick Dam, above Clear Creek, Balls Ferry, and Bend Bridge in below normal years during May, which is outside the peak period of smolt emigration but within the limits of the entire emigration season. Despite this increase, temperatures would be in the low- to mid-50s range (°F) under both scenarios, which is well below temperatures of concern (64°F 7DADM) for smolt emigration.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the smolt emigration period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA.

Temperature Threshold Analysis

The exceedance of temperature thresholds in the Sacramento River presented in the BA in Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49 by modeled daily water temperatures were evaluated based on thresholds identified in the USEPA's temperature water quality guidance (U.S. Environmental Protection Agency 2003). Two thresholds, 61°F 7DADM and 64°F 7DADM, were evaluated. The 61°F value corresponds to the upper end of the optimal smolt emigration range and represents each site as a core habitat location, and the 64°F value corresponds to the upper end of the suboptimal range and represents each site as a non-core habitat location. The 7DADM values were converted by month to function with daily model outputs (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51). Both thresholds were evaluated from Keswick Dam to Red Bluff.

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Tables 5.D-128 through Table 5.D-137. At Keswick Dam, Clear Creek, Balls Ferry, Bend Bridge, and Red Bluff, there would be very few exceedances above either threshold. At all locations for both thresholds, there would be no months or water year types with both a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance. Based on the modeling, there are no exceedances for either the 61°F 7DADM or 64°F 7DADM thresholds in the Keswick reach for either the PA or NAA scenario. At the Clear Creek location, the modeling indicates that exceedances occur in November, which is outside of the peak emigration period (January through March; but within the period of observed smolt emigration, November through June) (Table 2-84). At the Balls Ferry location, exceedances occur in November, May, and June, which are outside of the peak emigration period (Table 2-85). All exceedances are less than 5% of the potential days within the month. At Bend Bridge and Red Bluff, exceedances are more frequent and occur in November, April, May, and June, with the percentage of days approaching 50% in critical years at Red Bluff in June. However, all of these months are outside the peak emigration period. Overall, the modeling data suggests that the emigration of steelhead smolts will be minimally affected by water temperatures exceeding the EPA thresholds of 61°F 7DADM or 64°F 7DADM for core and non-core areas, respectively.

Table 2-84. Water Temperature Threshold Analysis Results, Steelhead, Smolt Emigration, Sacramento River at Clear Creek, 61°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	5.8	4.2	-1.7	13	9	-4	NA	NA	NA
	All	0.9	0.6	-0.2	13	9	-4	0.62	0.60	-0.02
Dec	W	0.0	0.0	0.0	0	0	0	0.62	0.60	-0.02
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-85. Water Temperature Threshold Analysis Results, Steelhead, Smolt Emigration, Sacramento River at Balls Ferry, 61°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	4.4	4.2	-0.3	8	7	-1	0.50	0.47	-0.03
	All	0.7	0.6	0.0	8	7	-1	0.50	0.47	-0.03
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.7	0.7	0.0	3	3	0	0.50	0.50	0
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.2	0.2	0	0	0	NA	0	NA
	C	1.1	1.1	0.0	2	1	-1	0.50	0.25	-0.25
	All	0.4	0.4	0.0	5	4	-1	0.50	0.36	-0.14
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.6	0.3	-0.3	0	0	0	0	0	0
	All	0.1	0.0	0.0	0	0	0	0	0	0

[1]7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

NMFS concludes that the temperature exceedances as represented by the modeling will not adversely affect smolt emigration during the peak period of steelhead migration downstream (January through March). For purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects that are likely to occur outside of the peak emigration period, particularly in downstream locations in April, May, and June. It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process.

NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Adult Immigration

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Bend Bridge, and Red Bluff during the August through March adult immigration period for steelhead are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8. Overall, mean water temperatures would change very little (predominantly less than 1°F) due to the PA at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, and would occur at Red Bluff in above normal years during August (Table 5.C.7-8 in Appendix C) and above- and below normal years during September, and at Bend Bridge in below normal years during September (Table 5.C.7-7 in Appendix C). These increases during September would overlap with the period of peak adult immigration (September through November).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA.

Temperature Threshold Analysis

To evaluate water temperature threshold exceedance during the adult immigration life stage at Keswick Dam, Bend Bridge, and Red Bluff, the USEPA's 7DADM threshold value of 68°F (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49) was used. The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51). In addition, the mean monthly threshold of 70°F, the average of studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range was used.

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-138 through Table 5.D-143. At Keswick Dam and Red Bluff, for both thresholds there would be no months or water year types with either a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA or a more-than-0.5°F difference in the magnitude of average daily exceedance.

At Bend Bridge, the percent of days exceeding the 68°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during August (5.1%) and September (5.3%) of critical water years (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 2-86 and Table 2-87 (BA Table 5.D-140 and BA Table 5.D-141). However, in no month or water year type would there be a more-than-0.5°F difference between NAA and PA in the magnitude of average daily exceedance above the threshold. Furthermore, there would be no months or water year types with either a more-than-5% increase in the percent of total days exceeding the 70°F threshold under the PA relative to the NAA or a more-than-0.5°F difference in the magnitude of average daily exceedance. The percentage of days in which the water temperature exceeded the 68°F 7DADM threshold is 11.6% for the NAA and 16.7%

for the PA in August, and 28.1% for the NAA and 33.3% for the PA in September. At the same location, the percentage of days in which the water temperature exceeded the 70°F threshold is 3.3% for the NAA and 4.7% for the PA in September.

Table 2-86. Water Temperature Threshold Analysis Results, Steelhead, Adult Immigration. Sacramento River at Bend Bridge, 68°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	11.6	16.7	5.1	56	81	25	1.30	1.31	0
	All	1.7	2.4	0.7	56	81	25	1.30	1.31	0
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	28.1	33.3	5.3	163	203	40	1.61	1.69	0.08
	All	4.1	4.9	0.8	163	203	40	1.61	1.69	0.08
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	3.2	1.9	-1.3	10	5	-5	0.83	0.71	-0.12
	All	0.5	0.3	-0.2	10	5	-5	0.83	0.71	-0.12
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1]7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-87. Water Temperature Threshold Analysis Results, Steelhead, Adult Immigration. Sacramento River at Bend Bridge, 70°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	3.3	4.7	1.4	8	13	5	0.67	0.76	0.10
	All	0.5	0.7	0.2	8	13	5	0.67	0.76	0.10
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

At Red Bluff, the percentage of days in which the water temperature exceeds the 68°F 7DADM threshold exceeds 20% in August and 50% in September in both the PA and NAA scenarios, with the PA having up to 4% more days in September (Table 2-88). These exceedances occur in critical water year types. When the higher 70°F mean monthly threshold is used, exceedances still occur in August and September in critical years, but the percentage of days in which exceedances occur falls to approximately 5% in August and 10% in September (Table 2-89).

Table 2-88. Water Temperature Threshold Analysis Results, Steelhead, Adult Immigration, Sacramento River at Red Bluff, 68°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold2			Degrees per day above threshold2		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	21.0	21.2	0.3	101	129	28	1.29	1.63	0.34
	All	3.1	3.1	0.0	101	129	28	1.29	1.63	0.34
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.6	0.6	0	1	1	NA	0.50	NA
	D	0.8	0.5	-0.3	1	1	0	0.20	0.33	0.13
	C	51.1	55.0	3.9	408	476	68	2.22	2.40	0.19
	All	7.7	8.3	0.6	409	478	69	2.16	2.35	0.19
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	10.5	9.7	-0.8	49	31	-18	1.26	0.86	-0.40
	All	1.6	1.4	-0.1	49	31	-18	1.26	0.86	-0.40
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-89. Water Temperature Threshold Analysis Results, Steelhead, Adult Immigration, Sacramento River at Red Bluff, 70°.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	4.3	5.6	1.3	5	13	8	0.31	0.62	0.31
	All	0.6	0.8	0.2	5	13	8	0.31	0.62	0.31
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	9.7	10.8	1.1	37	45	8	1.06	1.15	0.10
	All	1.4	1.6	0.2	37	45	8	1.06	1.15	0.10
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on immigrating adults. These exceedances would occur early in the immigration season (August and September) in the upper river. This time period overlaps with the beginning of the peak season of adult CCV steelhead immigration during September and October and has the potential to adversely affect adult steelhead physiologically during this period. Potential effects include diminishment of egg viability prior to spawning, leading to embryo morbidity during incubation, and mortality post hatching due to malformations incompatible with viability, thus reducing the potential magnitude of the next generation's population.

NMFS concludes that the elevated water temperatures under the PA during September and August of critical years will adversely affect the fitness of a large proportion of immigrating adult steelhead moving through the upper Sacramento River between Red Bluff and Keswick. It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5 Real-Time Operations Upstream of the Delta, and Section 3.3.3 Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Adult Holding

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Balls Ferry, and Red Bluff during the September through November CCV steelhead adult holding period are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-5, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, and would occur at Red Bluff in above- and below normal years during September (Table 5.C.7-8 in Appendix C).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.5-7, Figure 5.C.7.8-7). The curves for PA generally match those of the NAA. Further examination of above normal (Figure 2-13) and below normal (Figure 2-14) years during September at Red Bluff, the month and water year types with the largest changes in water temperatures (0.6°F), reveals that there is a general trend towards marginally higher temperatures under the PA but that the difference of 0.6°F in mean monthly temperatures between NAA and PA would cause no demonstrable differences between curves for the NAA and PA in each exceedance plot.

Temperature Threshold Analysis

To evaluate water temperature threshold exceedance during the steelhead adult holding life stage at Keswick Dam, Balls Ferry, and Red Bluff, the USEPA's 7DADM threshold value of 61°F was used as presented in the BA (Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Tables 5.D-144 through 5.D-146. At Keswick Dam, there would be no months or water year types with both a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-144). For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the percentage of days above the 61°F 7DADM threshold at Keswick is approximately 32% during August of critical years, 62% in September of critical years, and 50% in October of critical years for both scenarios. The modeling indicates that there is substantial potential for exceedances of the threshold for optimal water temperatures required for the holding of adult steelhead below Keswick Dam.

At Balls Ferry, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding either threshold under the PA relative to the NAA (BA

Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-145). However, there would be two more-than-five-percent reductions under the PA relative to the NAA in the percent of total days exceeding the 61°F 7DADM threshold: September (10% lower) and October (14% lower) of critical water years. During October of critical years, the difference in average daily exceedance above the threshold between the PA and NAA would be less than 0.5°F. In September, the average daily exceedance above the threshold under the PA would be 0.7°F higher than that under the NAA, indicating that the frequency of days above the threshold would decrease under the PA, but exceedances would be higher on average. For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the percentage of days above the 61°F 7DADM threshold at Balls Ferry is approximately 45% during August of critical years, 11% in dry and 85% in critical years in September, 69% in October of critical years, and 4% in November of critical years for both scenarios, with the NAA scenario typically having greater probability of exceedances than the PA scenario. The modeling indicates that there is substantial potential for exceedances of the threshold for optimal water temperatures required for the holding of adult steelhead.

At Red Bluff for both thresholds, there would be no months or water year types with both a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-146). There would be some instances when there would be a more-than-5% increase in the percent of total days exceeding the 61°F 7DADM threshold under the PA relative to the NAA, including August of below normal water years (9.4% increase) and September of above normal (7.7% increase), below normal (10.3% increase), and dry (5.5% increase) water years, but under the PA, none of these would see a concurrent increase of at least 0.5°F in the magnitude of average daily exceedance above the threshold. For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the percentage of days above the 61°F 7DADM threshold at Red Bluff increases from August through September, with a gradual decrease in October. In critical years, the percentage of days in which the threshold is exceeded increases from approximately 80% in August to greater than 97% in September, and is still approximately 80% in October. From August through October, the potential for water temperatures to exceed the 61°F 7DADM threshold exists for all water year types and indicates that conditions for holding adult steelhead is degraded under both the PA and NAA scenarios at the Red Bluff location.

For purposes of the analysis in Section 2.7 Integration and Synthesis, NMFS concludes that the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in elevated water temperatures from August through October that will adversely affect the fitness of holding adults in the upper Sacramento River between Red Bluff and Keswick.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process.

NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

American River

Spawning, Eggs Incubation and Alevin

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures during the December through May spawning and egg incubation/alevins period for steelhead in the American River reach between Hazel Avenue and Watt Avenue are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-15.

Overall, the PA would change mean water temperatures very little (less than 1°F) throughout the reach in all months and water year types of the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, and would occur at Watt

Avenue during critical years in March. This greatest increase would occur during the peak spawning and egg incubation/alevins period (January through March) on the American River.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of critical water years during March at Watt Avenue, where the largest increase in mean monthly water temperature was seen, reveals that the curves were similar overall and that that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in the exceedance plot (Figure 2-34).

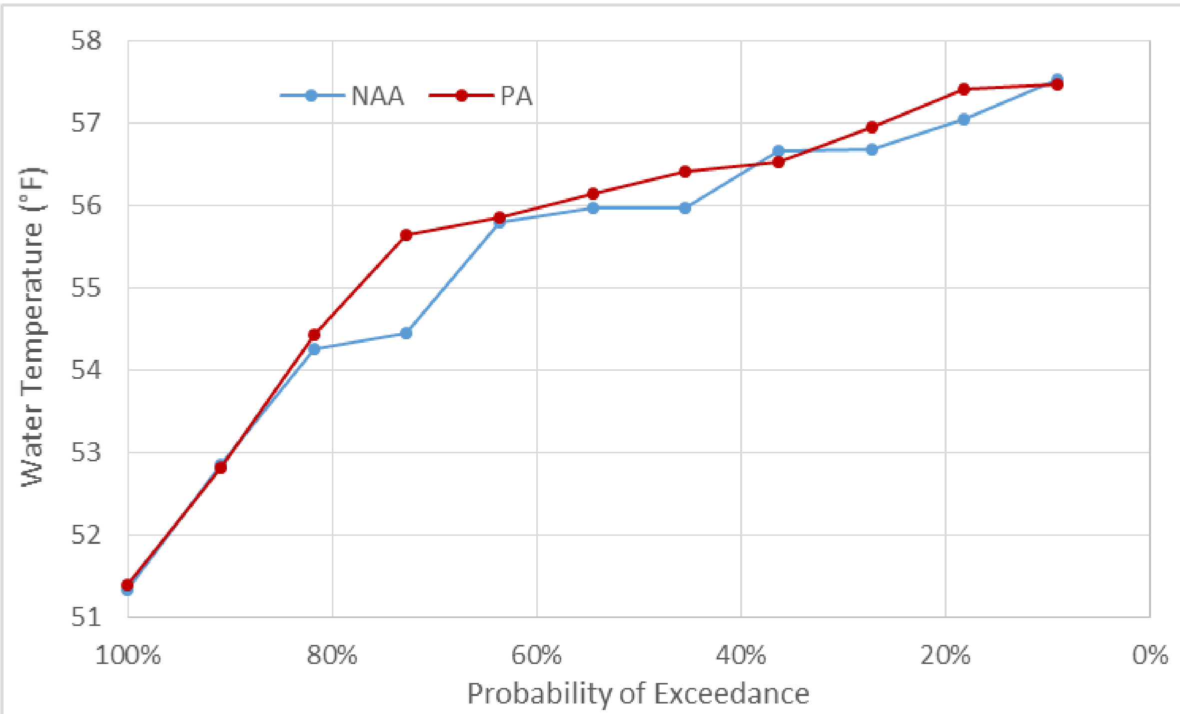

Figure 2-34. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in March of Critical Water Years.

Temperature Threshold Analysis

The exceedance of temperature thresholds in the American River presented in the BA in Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-50 by modeled daily water temperatures were evaluated based on thresholds identified from the literature. For steelhead spawning and egg/alevin incubation, the threshold used was 53°F (McCullough et al. 2001).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-161 through Table 5.D-162. At both Hazel Avenue and Watt Avenue, there would be no months or water year types in which there would be either 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance. However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, examination of the modeled temperature exceedances indicate that under both the PA and NAA scenarios the water temperature threshold for optimal egg/alevin development and survival is exceeded in December, March, April, and May. In April and May, the 53°F threshold is exceeded over 70% of the time in April, and 100% of the time in May at the Hazel Avenue location. This strongly indicates that eggs that are still in the gravel or laid in April and May will have the potential for substantially reduced viability and a high proportion of mortality or embryo abnormalities which will affect their future survival and fitness. The percentage of daily exceedances increases at the Watt Avenue location, which is farther downstream than the Hazel Avenue location, during the spring months, and is relatively similar during December. Exceedances of the 53°F threshold at the Watt Avenue location start in February during dry and critical water year types (20% in critical years). By March, the percentage of daily exceedances is approximately 6% in wet and above normal years, 40 to 50% in below normal and dry years, and 83% in critical years. The daily percentage of exceedances above the threshold reaches 90% or greater in most water year types in April and May at the Watt Avenue location. This data indicates that the water temperatures will be above the optimal threshold levels for most spawning from March through May, and that eggs and alevins that are still in the gravel during this time period will have a greater potential for mortality or reduced fitness and viability.

Overall, the water temperature modeling results and the threshold analysis indicate that thermal impacts on steelhead egg incubation and alevin development will largely be the same with implementation of either the PA or NAA. The PA is not expected to result in adverse effects, relative to the NAA. For purposes of the analysis in Section 2.7 Integration and Synthesis, NMFS concludes that the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in elevated water temperatures that will adversely affect egg incubation and alevin development at the Watt Avenue location in December and from February through June, particularly in drier water year types. Water temperatures at the Hazel Avenue location, which is the farthest upstream location accessible to steelhead in the American River and is just below Nimbus Dam, will adversely affect egg incubation and alevin development in December, and in April and May.

Kelt Emigration

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures during the February through May kelt emigration period for steelhead in the American River from Hazel Avenue to Watt Avenue are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-14, Table 5.C.7-15. See Appendix C of this Opinion, BA Table 5.C.7-14, American River at Hazel Ave, Monthly Temperature, and BA Table 5.C.7-15, American River at Watt Ave, Monthly Temperature.

Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or less than 1%) throughout the reach in all months and water year types of the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4%, and would occur at Watt Avenue during critical years in March.

Exceedance plots of mean monthly water temperatures were examined during each month and water year type throughout the kelt migration period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of critical water years during March at Watt Avenue, where the largest increase in mean monthly water temperature was seen, reveals that the curves were similar overall and that that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in the exceedance plot (Figure 2-35).

Temperature Threshold Analysis

There have been no known studies evaluating specific temperature effects on emigrating kelts. Therefore, adult immigration thresholds of 68°F 7DADM and 70°F were used for kelt migration, with an assumption that kelts migrating downstream would be affected by water temperatures similarly to adults migrating upstream (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-50). The 68°F 7DADM threshold was taken from (U.S. Environmental Protection Agency 2003) and the 70°F threshold represents the average of the studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range. The 7DADM threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-52).

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-163 through Table 5.D-166. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with either a more-than-5% increase in the percent of total days exceeding the 68°F 7DADM or 70°F threshold under the PA relative to the NAA, or a more-than-0.5°F difference in the magnitude of average daily exceedance.

When examining the percentage of days in which water temperatures exceeded the thresholds of 68°F 7DADM or 70°F during the February through May for kelt emigration, the modeling found that water temperatures rarely exceeded the thresholds at Hazel Avenue for the 68°F 7DADM and when this event occurred, it was by a minimal percentage of days (less than 3.5% in critical years for the PA). The 70°F threshold was never exceeded at Hazel Avenue for the same February through May time period. At the Watt Avenue location, exceedances of the 68°F 7DADM were more frequent and a higher percentage of days above the threshold were seen in the month of May. The modeled results for the PA indicated equivalent percentages of exceedance in the wetter year types, lower percentages of exceedances in below normal and dry water year types, but more frequent exceedances in the critical year type. In below normal and dry water year types, the modeling indicated that approximately 18% to 24% of the days in May would be above the threshold for both scenarios. This increased to 43% to 45% in critical year types. There were less frequent exceedances of the 70°F threshold as compared to the 68°F 7DADM. For all water year types except dry years, the percentage of exceedances were equivalent. In dry years, the PA scenario had a slightly lower rate of exceedance than the NAA scenario (5.2% to 6.1%). In critical years, there was still an approximately 22% chance of exceeding the 70°F threshold in May in critical years. Therefore, water temperatures should not affect kelt emigration downstream during the February through April time period, but may start to affect kelts in May as water temperatures warm in the lower portions of the American River.

Overall, the water temperature modeling results and the threshold analysis indicate that thermal impacts on steelhead kelt emigration will largely be the same with implementation of either the PA or NAA. The PA is not expected to result in adverse effects, relative to the NAA. For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, NMFS concludes that the water temperatures, as modeled under both the PA and NAA operational scenarios, will not adversely affect kelt emigration during the February through April period, but may begin to adversely affect kelt migration during May of critical years.

Juvenile Rearing

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures during the year-round juvenile rearing period for steelhead in the American River between Hazel Avenue and Watt Avenue are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-14, Table 5.C.7-15. See Appendix C of this Opinion, BA Table 5.C.7-14, American River at Hazel Ave, Monthly Temperature, and BA Table 5.C.7-15, American River at Watt Ave, Monthly Temperature.

Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the juvenile rearing reach in all months and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F, or up to 1.4%, and would occur at Watt Avenue in critical water years during August.

Exceedance plots of mean monthly water temperatures were examined during each month and water year type throughout the juvenile rearing period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of critical water years during August at Watt Avenue, where the largest increase in mean monthly water temperature was seen, reveals that the colder end of the curves overlap substantially, but the higher end of the PA curves indicate that water temperatures are up to approximately 4°F higher for individual months depending on the exceedance percentile (Figure 2-35).

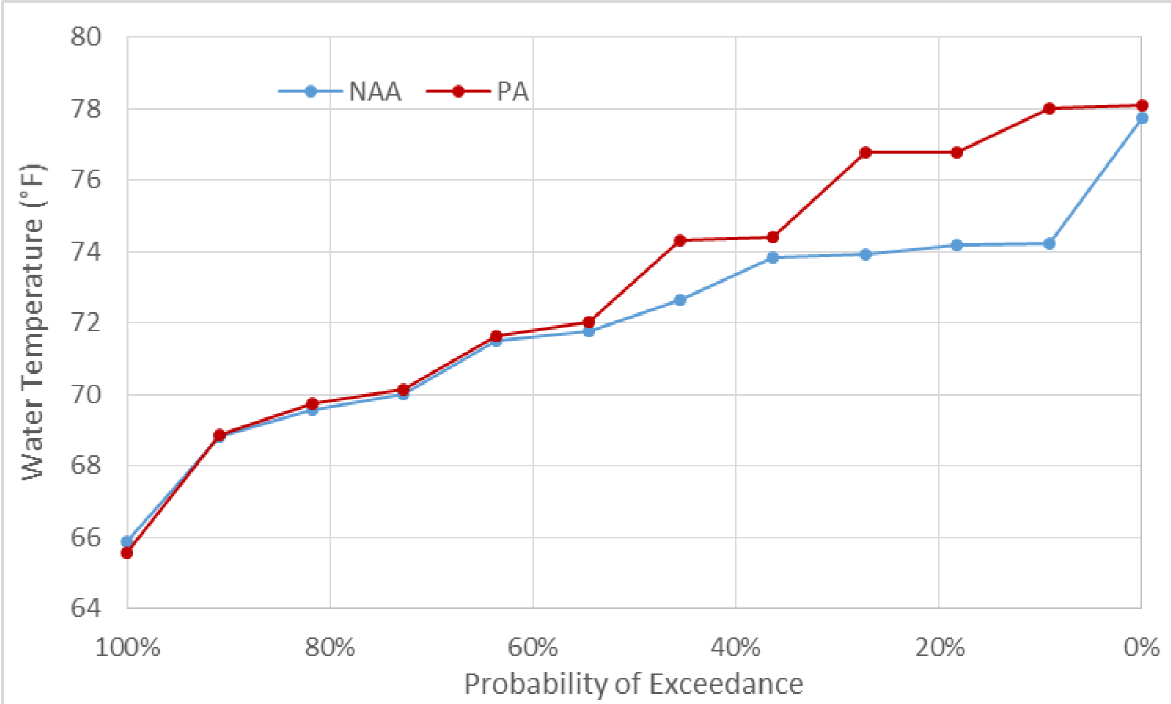

Figure 2-35. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in August of Critical Water Years.

Temperature Threshold Analysis

Threshold water temperatures of 63°F and 69°F (7DADM) were used to evaluate water temperature threshold exceedances during the steelhead juvenile rearing life stage in the American River between Hazel Avenue and Watt Avenue (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-50). Temperature thresholds were derived according to the methods previously discussed in the Sacramento River section for juvenile rearing.

Results of the water temperature thresholds analysis are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Tables 5.D-167 through 5.D-170. At Hazel Avenue, there would be two instances in which there would be more than 5% more days under the PA compared to the NAA on which temperatures would exceed the 63°F threshold: June (7.7% higher) and October (8.6% higher) of above normal water years. In neither instance would the magnitude of average daily exceedance under the PA be more than 0.5°F greater than that under the NAA. For the 69°F 7DADM threshold, there would be three instances in which there would be more than 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold: July of below normal water years (5.6% higher), August of critical water years (21.0% higher), and September of dry years (5.3% higher). In July of below normal years, the average daily exceedance above the threshold under the PA would also be 1.0°F higher than that under the NAA. Furthermore, in August of critical water years, the average daily exceedance above the threshold under the PA would also be 0.7°F higher than that under the NAA. These two instances could represent biologically meaningful negative effects on rearing juvenile steelhead. In September of dry years, there would be no concurrent increase of more than 0.5°F in the magnitude of average daily exceedance under the PA relative to the NAA.

For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, when examining the percentage of days in which the 63°F threshold is exceeded at the Hazel Avenue location, the modeling indicates that the threshold temperature will not be exceeded from December through April (Table 2-90). By May, modeled water temperatures increase at Hazel Avenue, increasing the percentage of days that exceed the threshold, particularly in drier water year types. The percentage of days exceeding the threshold reaches almost 40% for both the PA and NAA in critical years. In June, exceedances are approximately 11% for wet years, greater than 30% in above normal years, and over 50% in below normal and dry water year types. Critical water year types are predicted to have 80% of the days in May exceed the threshold criteria. For the remainder of the summer through September, approximately 90% of the days will be above the 63°F threshold water temperature for juvenile rearing. In October, water temperatures are still elevated and the modeling predicts that at least 50% of the days will exceed the threshold criteria in all but wet water year types. The modeling data indicates that there is a high potential for adverse water temperature conditions at the Hazel Avenue location that will negatively affect the viability of juvenile steelhead rearing in this reach of the river based on the 63°F threshold.

When using the higher water temperature threshold of 69°F 7DADM, there are no exceedances in water temperature from January through April, and very minimal exceedances in May for both the PA and NAA modeled scenarios (Table 2-91). Water temperatures begin to exceed the 69°F 7DADM threshold in June particularly for drier water year types. The exceedance percentage for below normal water year types is 13.6% for the NAA, and only 1.8% for the PA. In dry and critical water year types, the PA has a greater percentage of exceedances, 10.0% versus 9.7% in dry years and 17.8% versus 15.8% in critical years. Water temperatures continue to exceed the threshold temperature throughout the summer, but particularly in critical years. In July, the exceedance in a critical year is approximately 58% for both the PA and NAA, with the PA scenario being slightly greater. In August of critical years, the difference between the PA and NAA scenarios is much greater, 43.8% (PA) versus 22.8% (NAA). Conversely in September, the NAA scenario has a higher percentage of days exceeding the threshold in critical years 48.9% versus 46.1%, but in dry years the PA has a greater percentage of threshold exceedance days than the NAA scenario (13.8% versus 8.5%). By October, the water has cooled sufficiently that few days exceed the thermal threshold of 69°F 7DADM in any water year type, and there are no exceedances in the months of November and December for either the PA or NAA modeling scenarios. The Hazel Avenue location is the farthest upstream river reach that is currently accessible to steelhead on the American River. Any thermal threshold exceedances seen here in the modeling results would indicate that the entire American River corridor downstream of this location would also likely be over the threshold, as there are no significant tributaries downstream of this location to modify the water temperature.

Table 2-90. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, American River at Hazel Avenue, 63°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	3.7	3.7	0.0	42	40	-2	1.40	1.33	-0.07
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	22.9	24.0	1.2	128	137	9	1.64	1.67	0.03
	D	20.8	17.9	-2.9	253	189	-64	1.96	1.70	-0.26
	C	37.6	38.2	0.5	317	344	27	2.26	2.42	0.16
	All	14.8	14.4	-0.5	740	710	-30	1.96	1.95	-0.02
Jun	W	10.4	11.8	1.4	265	202	-63	3.27	2.20	-1.08
	AN	30.0	37.7	7.7	236	308	72	2.02	2.10	0.08
	BN	55.2	50.6	-4.5	694	498	-196	3.81	2.98	-0.83
	D	59.5	62.0	2.5	1,144	1,145	1	3.20	3.08	-0.13
	C	80.0	80.0	0.0	1,082	1,080	-2	3.76	3.75	-0.01
	All	41.7	43.3	1.7	3,421	3,233	-188	3.34	3.03	-0.30
Jul	W	69.2	70.5	1.2	1,001	953	-48	1.79	1.68	-0.12
	AN	88.8	83.9	-5.0	707	656	-51	1.97	1.94	-0.03
	BN	85.3	78.9	-6.5	826	799	-27	2.84	2.97	0.13
	D	82.4	80.5	-1.9	2,004	1,969	-35	3.92	3.95	0.02
	C	95.4	96.2	0.8	2,219	2,256	37	6.25	6.30	0.05
	All	81.5	79.9	-1.6	6,757	6,633	-124	3.26	3.26	0
Aug	W	49.6	48.3	-1.4	443	459	16	1.11	1.18	0.07

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	85.6	80.9	-4.7	479	477	-2	1.39	1.46	0.07
	BN	84.8	76.0	-8.8	798	731	-67	2.76	2.82	0.06
	D	96.8	95.5	-1.3	1,595	1,630	35	2.66	2.75	0.10
	C	89.2	93.0	3.8	1,459	1,795	336	4.39	5.19	0.79
	All	77.3	75.2	-2.1	4,774	5,092	318	2.43	2.66	0.23
Sep	W	69.2	66.4	-2.8	869	812	-57	1.61	1.57	-0.04
	AN	99.0	98.5	-0.5	754	789	35	1.95	2.05	0.10
	BN	98.8	98.8	0.0	850	941	91	2.61	2.89	0.28
	D	100.0	100.0	0.0	2,060	2,124	64	3.43	3.54	0.11
	C	99.4	99.4	0.0	1,846	1,774	-72	5.16	4.96	-0.20
	All	89.8	88.9	-1.0	6,379	6,440	61	2.89	2.95	0.06
Oct	W	37.3	36.8	-0.5	222	235	13	0.74	0.79	0.05
	AN	52.2	60.8	8.6	184	227	43	0.95	1.00	0.06
	BN	65.7	60.4	-5.3	432	417	-15	1.93	2.02	0.10
	D	75.2	69.7	-5.5	1,031	929	-102	2.21	2.15	-0.06
	C	82.8	77.7	-5.1	1,053	907	-146	3.42	3.14	-0.28
	All	59.5	57.7	-1.7	2,922	2,715	-207	1.96	1.87	-0.08
Nov	W	0.9	0.5	-0.4	9	5	-4	1.29	1.25	-0.04
	AN	0.6	0.3	-0.3	1	1	0	0.50	1.00	0.50
	BN	2.4	1.8	-0.6	11	6	-5	1.38	1.00	-0.38
	D	2.5	1.8	-0.7	18	11	-7	1.20	1.00	-0.20
	C	3.6	3.3	-0.3	17	13	-4	1.31	1.08	-0.22
	All	1.9	1.4	-0.5	56	36	-20	1.24	1.06	-0.19
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Table 2-91. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, American River at Hazel Avenue, 69°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.3	0.3	0.0	0	0	0	0	0	0
	D	0.0	0.3	0.3	0	0	0	NA	0	NA
	C	0.3	0.8	0.5	0	3	3	0	1.00	1.00
	All	0.1	0.2	0.2	0	3	3	0	0.50	0.50
Jun	W	0.8	0.0	-0.8	2	0	-2	0.33	NA	NA
	AN	0.5	0.8	0.3	1	2	1	0.50	0.67	0.17
	BN	13.6	1.8	-11.8	49	2	-47	1.09	0.33	-0.76
	D	9.7	10.0	0.3	106	87	-19	1.83	1.45	-0.38
	C	15.8	17.8	1.9	70	81	11	1.23	1.27	0.04
	All	6.8	5.4	-1.4	228	172	-56	1.36	1.29	-0.06
Jul	W	0.2	0.5	0.2	0	2	2	0	0.50	0.50

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	2.3	7.9	5.6	7	50	43	0.88	1.85	0.98
	D	17.9	18.7	0.8	146	162	16	1.32	1.40	0.08
	C	57.5	57.8	0.3	541	577	36	2.53	2.68	0.16
	All	13.2	14.2	1.1	694	791	97	2.07	2.19	0.11
Aug	W	0.2	0.0	-0.2	1	0	-1	0.50	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	9.7	4.1	-5.6	24	8	-16	0.73	0.57	-0.16
	D	2.9	3.5	0.6	9	13	4	0.50	0.59	0.09
	C	22.8	43.8	21.0	102	314	212	1.20	1.93	0.73
	All	5.4	7.8	2.4	136	335	199	0.99	1.68	0.70
Sep	W	0.8	0.4	-0.4	1	0	-1	0.17	0	-0.17
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	2.1	4.5	2.4	6	8	2	0.86	0.53	-0.32
	D	8.5	13.8	5.3	36	62	26	0.71	0.75	0.04
	C	48.9	46.1	-2.8	161	175	14	0.91	1.05	0.14
	All	9.8	10.9	1.1	204	245	41	0.85	0.92	0.07
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	1.9	1.9	0.0	6	7	1	0.50	0.58	0.08
	C	2.7	0.0	-2.7	5	0	-5	0.50	NA	NA
	All	0.9	0.5	-0.4	11	7	-4	0.50	0.58	0.08
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

At Watt Avenue, there would be no instances in which there would be more than 5% more days under the PA compared to the NAA on which temperatures would exceed the 63°F threshold (BA Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-169). There would be one water year type within 1 month in which the magnitude of average daily exceedance under the PA would be more than 0.5°F greater than that under the NAA: August of critical water years (1.0°F increase). There would be no instances in which there would be more than 5% more days under the PA compared to the NAA on which temperatures would exceed the 69°F threshold (Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 5.D-170), and the magnitude of average daily exceedance would be less than 0.5°F for this instance.

Table 2-92. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, American River at Watt Avenue, 63°F. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.4	0.4	0.0	1	1	0	0.33	0.33	0
	AN	0.3	0.3	0.0	0	0	0	0	0	0
	BN	20.0	20.3	0.3	131	134	3	1.98	2.00	0.02
	D	11.3	9.2	-2.2	125	92	-33	1.84	1.67	-0.17
	C	30.6	31.7	1.1	278	290	12	2.53	2.54	0.02
	All	10.1	9.8	-0.3	535	517	-18	2.16	2.15	0
May	W	13.6	13.8	0.1	330	329	-1	3.00	2.96	-0.04
	AN	32.0	32.0	0.0	232	233	1	1.80	1.81	0.01
	BN	56.3	54.5	-1.8	786	749	-37	4.09	4.03	-0.07
	D	59.2	58.9	-0.3	1,440	1,345	-95	3.92	3.68	-0.24
	C	78.8	77.7	-1.1	1,511	1,533	22	5.16	5.30	0.15
	All	42.9	42.5	-0.4	4,299	4,189	-110	3.94	3.88	-0.06
Jun	W	50.4	47.6	-2.8	1,091	939	-152	2.78	2.53	-0.25
	AN	84.1	81.8	-2.3	1,201	1,151	-50	3.66	3.61	-0.05
	BN	83.3	83.0	-0.3	1,722	1,297	-425	6.26	4.73	-1.53
	D	87.2	84.0	-3.2	2,941	2,772	-169	5.62	5.50	-0.12
	C	95.0	95.6	0.6	2,628	2,759	131	7.68	8.02	0.34
	All	75.7	73.7	-2.0	9,583	8,918	-665	5.15	4.92	-0.23
Jul	W	99.8	99.6	-0.1	3,534	3,377	-157	4.40	4.21	-0.19
	AN	95.5	96.3	0.7	1,706	1,709	3	4.43	4.40	-0.03
	BN	98.5	98.8	0.3	1,673	1,727	54	4.98	5.12	0.15
	D	98.5	98.7	0.2	4,044	4,022	-22	6.62	6.57	-0.05
	C	98.7	98.7	0.0	4,176	4,178	2	11.38	11.38	0.01
	All	98.5	98.6	0.2	15,133	15,013	-120	6.05	5.99	-0.06
Aug	W	98.9	98.6	-0.2	3,132	3,176	44	3.93	3.99	0.07

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	100.0	100.0	0.0	2,092	2,040	-52	5.19	5.06	-0.13
	BN	100.0	100.0	0.0	2,408	2,230	-178	7.06	6.54	-0.52
	D	100.0	100.0	0.0	4,506	4,710	204	7.27	7.60	0.33
	C	100.0	100.0	0.0	3,353	3,736	383	9.01	10.04	1.03
	All	99.6	99.6	-0.1	15,491	15,892	401	6.12	6.28	0.16
Sep	W	95.8	95.3	-0.5	2,130	2,135	5	2.85	2.87	0.02
	AN	100.0	100.0	0.0	1,589	1,669	80	4.07	4.28	0.21
	BN	100.0	100.0	0.0	1,892	1,947	55	5.73	5.90	0.17
	D	100.0	100.0	0.0	3,766	3,851	85	6.28	6.42	0.14
	C	100.0	100.0	0.0	3,042	3,051	9	8.45	8.48	0.03
	All	98.7	98.5	-0.2	12,419	12,653	234	5.12	5.22	0.11
Oct	W	49.0	48.9	-0.1	582	626	44	1.47	1.59	0.12
	AN	68.5	73.1	4.6	433	467	34	1.70	1.72	0.02
	BN	74.2	70.4	-3.8	590	578	-12	2.33	2.41	0.08
	D	79.8	75.6	-4.2	1,359	1,285	-74	2.75	2.74	-0.01
	C	84.7	82.5	-2.2	1,341	1,199	-142	4.26	3.91	-0.35
	All	68.2	67.0	-1.2	4,305	4,155	-150	2.51	2.47	-0.04
Nov	W	1.2	1.2	0.0	10	7	-3	1.11	0.78	-0.33
	AN	1.1	0.6	-0.6	3	2	-1	0.75	1.00	0.25
	BN	3.0	1.8	-1.2	14	7	-7	1.40	1.17	-0.23
	D	3.5	1.8	-1.7	22	13	-9	1.05	1.18	0.13
	C	3.9	5.0	1.1	15	14	-1	1.07	0.78	-0.29
	All	2.4	1.9	-0.5	64	43	-21	1.10	0.93	-0.17
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Table 2-93. Water Temperature Threshold Analysis Results, Steelhead, Juvenile Rearing, American River at Watt Avenue, 69°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	1.2	1.2	0.0	4	4	0	1.00	1.00	0.00
	D	0.7	0.2	-0.5	1	0	-1	0.25	0.00	-0.25
	C	6.1	6.9	0.8	27	25	-2	1.23	1.00	-0.23
	All	1.2	1.2	0.0	32	29	-3	1.07	0.97	-0.10
May	W	5.0	5.0	0.0	60	59	-1	1.50	1.48	-0.02
	AN	3.2	3.2	0.0	6	6	0	0.46	0.46	0.00
	BN	28.4	27.6	-0.9	211	203	-8	2.18	2.16	-0.02
	D	27.9	26.5	-1.5	360	301	-59	2.08	1.84	-0.25
	C	48.7	50.3	1.6	571	588	17	3.15	3.14	-0.01
	All	19.8	19.6	-0.2	1,208	1,157	-51	2.40	2.32	-0.07
Jun	W	13.5	12.9	-0.5	322	204	-118	3.07	2.02	-1.05
	AN	39.2	40.0	0.8	353	333	-20	2.31	2.13	-0.17
	BN	57.6	53.0	-4.5	939	562	-377	4.94	3.21	-1.73
	D	61.7	57.5	-4.2	1,396	1,276	-120	3.77	3.70	-0.07
	C	83.3	84.4	1.1	1,508	1,627	119	5.03	5.35	0.33
	All	45.4	43.9	-1.5	4,518	4,002	-516	4.04	3.70	-0.34
Jul	W	81.9	80.6	-1.2	1,367	1,248	-119	2.07	1.92	-0.15

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	AN	86.4	82.6	-3.7	659	682	23	1.89	2.05	0.15
	BN	84.8	81.5	-3.2	772	853	81	2.67	3.07	0.40
	D	89.7	88.5	-1.1	2,369	2,370	1	4.26	4.32	0.06
	C	96.8	94.6	-2.2	3,147	3,148	1	8.74	8.94	0.20
	All	87.1	85.1	-2.0	8,314	8,301	-13	3.76	3.84	0.08
Aug	W	67.6	70.2	2.6	1,146	1,167	21	2.10	2.06	-0.04
	AN	95.5	90.3	-5.2	935	903	-32	2.43	2.48	0.05
	BN	90.9	80.4	-10.6	1,450	1,298	-152	4.68	4.74	0.06
	D	97.9	99.7	1.8	2,719	2,919	200	4.48	4.72	0.24
	C	94.6	94.9	0.3	2,286	2,675	389	6.49	7.58	1.08
	All	86.5	85.6	-0.9	8,536	8,962	426	3.88	4.12	0.24
Sep	W	31.9	28.2	-3.7	276	318	42	1.11	1.45	0.34
	AN	65.4	71.5	6.2	329	378	49	1.29	1.35	0.06
	BN	87.6	87.9	0.3	771	830	59	2.67	2.86	0.19
	D	91.8	91.2	-0.7	1,706	1,790	84	3.10	3.27	0.18
	C	94.2	97.2	3.1	1,813	1,803	-10	5.35	5.15	-0.20
	All	68.4	68.5	0.1	4,895	5,119	224	2.91	3.04	0.13
Oct	W	1.5	1.7	0.2	11	17	6	0.92	1.21	0.30
	AN	2.7	2.7	0.0	5	4	-1	0.50	0.40	-0.10
	BN	12.0	11.7	-0.3	38	35	-3	0.93	0.88	-0.05
	D	19.2	17.1	-2.1	153	160	7	1.29	1.51	0.22
	C	47.0	38.4	-8.6	317	258	-59	1.81	1.80	-0.01
	All	14.2	12.5	-1.8	524	474	-50	1.47	1.51	0.05
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1]7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

For purposes of the analysis in the Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the water temperature modeling for the PA and NAA shows that there are no exceedances above the 63°F threshold from January through March. By April, warming river temperatures begin to exceed the threshold. These exceedances occur in below normal, dry, and critical water year types, and the greatest percentage of exceedances occur in critical water years (approximately 31% of the days). In May, the percentage of days above the thermal threshold continues to increase, ranging from approximately 13.7% in wet years to almost 80% in critical years. In June, all but the wet water years (approximately 50%) are above 80% exceedance with critical years over 95%. From July through September nearly 100% of the days exceed the 63°F threshold. By October, the water temperatures are beginning to cool, and the percentage of days that exceed the thermal threshold begins to decline, but is still in the 70 to 85% range for most water year types. In November, the percentage of days above the thermal threshold has dropped to less than 5% (critical years) and by December there are no modeled exceedances of the thermal threshold of 63°F in any water year type. The modeled water temperatures indicate that there will be very high percentages of times when the thermal thresholds will be exceeded over the summer months at the Watt Avenue location, implying that steelhead juveniles rearing in this reach will have a high likelihood of low fitness or possibly death from high water temperature exposure if they remain in this reach.

Like the 63°F threshold discussed above, the modeling of water temperatures during the winter months (January through March) indicate that there are no days with exceedances above the 69°F 7DADM threshold and, therefore, juvenile steelhead would rear under optimal thermal conditions in the river reach containing the Watt Avenue location during this period. By April, the water temperatures in the Watt Avenue reach are modeled to begin increasing and exceed the 69°F 7DADM threshold, primarily in below normal and critical water year types. By May, the modeling implies that approximately 26 to 28% of days in below normal and dry years exceed the thermal threshold, and up to 50% of days in critical years. During the summer period (June through September) the percentage of exceedances increases, reaching approximately 80% to 85% in July, and 90% to 95% in August for drier water year types. In September, the number of days with threshold exceedances are still high, particularly for drier water year types and reach approximately 95% in critical water year types. In October, modeled water temperatures begin to decrease and the percentage of days above the 69°F 7DADM threshold decreases substantially. However, in critical water year types, the percentage of days exceeding the threshold still ranges between 38.4% (PA) to 47.0% (NAA). By November and December, the modeled water temperatures have cooled sufficiently to avoid any exceedances of the thermal threshold. As discussed above, the water temperature modeling for the Watt Avenue reach during the summer period (June through September) indicates that thermal conditions will be detrimental to the rearing of steelhead juveniles based on the 69°F 7DADM threshold, leading to an increased risk of reduced fitness or mortality.

NMFS concludes that changes in water temperature conditions between the PA and NAA will not result in adverse effects to juvenile steelhead in the American River. However, for purposes of the analysis in the Section 2.7 Integration and Synthesis, the water temperature conditions under the PA when combined with the environmental baseline and modeled climate change impacts will adversely affect the rearing of juvenile steelhead in the American River from Hazel Avenue downstream to the confluence, including Watt Avenue from June through October, with particularly deleterious conditions over the summer from July through September.

An additional threshold analysis was conducted to determine how the PA would affect smoltification. A 54°F threshold was used, based on an average of temperatures from Zaugg and Wagner (1973), Adams et al. (1975), Zaugg (1981), and Hoar (1988), and above which smoltification can be impaired. This analysis was conducted for January through March in the reach from Hazel Avenue to Watt Avenue.

Results of the water temperature thresholds analysis for steelhead smoltification are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 2-94 and Table 2-95.

Table 2-94. Water Temperature Threshold Analysis Results, Steelhead, Smoltification, American River at Hazel Avenue, 54°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.9	0.6	-0.3	1	0	-1	0.33	0	-0.33
	D	6.6	6.8	0.2	47	43	-4	1.15	1.02	-0.12
	C	16.7	13.4	-3.2	67	56	-11	1.08	1.12	0.04
	All	4.2	3.7	-0.5	115	99	-16	1.08	1.05	-0.03

[1] Only includes days on which temperature exceeded threshold

Table 2-95. Water Temperature Threshold Analysis Results, Steelhead, Smoltification, American River at Watt Avenue, 54°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	13.2	13.8	0.6	74	75	1	1.64	1.60	-0.05
	All	1.9	2.0	0.1	74	75	1	1.64	1.60	-0.05
Mar	W	2.1	2.1	0.0	32	32	0	1.88	1.88	0
	AN	4.7	4.7	0.0	24	24	0	1.26	1.26	0
	BN	24.0	23.2	-0.9	170	168	-2	2.07	2.13	0.05
	D	36.1	34.8	-1.3	573	546	-27	2.56	2.53	-0.03
	C	69.9	72.3	2.4	738	803	65	2.84	2.99	0.15
	All	23.7	23.6	-0.1	1,537	1,573	36	2.55	2.62	0.07

[1] Only includes days on which temperature exceeded threshold

At Hazel Avenue and Watt Avenue, there would be no months or water year types with either a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or a more-than-0.5°F difference in the magnitude of average daily exceedance. However, the water temperature modeling also indicates that water temperature values will increase in February and March at both locations and increase the percentage of days in which the ambient water temperature exceeds the 54°F thermal threshold for optimal smoltification. At Hazel Avenue, water temperatures begin to exceed the thermal threshold in March in below normal, dry, and critical years. There is a minimal risk in below normal years, as measured by the percentage of days that will exceed the threshold (0.9% NAA, 0.6% PA), but the risk increases to 6.6% (NAA) and 6.8% (PA) in dry years, and 16.7% (NAA) and 13.4% (PA) in critical years. At the Watt Avenue location farther downstream, the number of days exceeding the thermal threshold is 13.2% (NAA) and 13.8% (PA) in critical years in February, and ranges from approximately 2% in wet years to approximately 70% in critical years in March. For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the modeling implies that successful smoltification may be hindered in March in drier years, but in particular during critical water year types under both the PA and NAA modeling scenarios.

Overall, the water temperature modeling results and the threshold analysis indicate that thermal impacts on steelhead juveniles and smoltification will largely be the same with implementation of either the PA or NAA operations. The PA is not expected to result in adverse effects, relative to the NAA. For purposes of the analysis in Section 2.7 Integration and Synthesis, NMFS concludes that the water temperature conditions under the PA when combined with the environmental baseline and modeled climate change from February through March will adversely affect smoltification of steelhead juveniles in the American River based on the modeling conducted. These adverse effects are more frequent and prevalent in drier water year types.

Smolt Emigration

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures in the American River in the reach from Hazel Avenue to Watt Avenue during the December through June smolt emigration period, which peaks during January through March, are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-14, Table 5.C.7-15. See Appendix C of this Opinion, BA Table 5.C.7-14, American River at Hazel Ave, Monthly Temperature, and BA Table 5.C.7-15, American River at Watt Ave, Monthly Temperature.

Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) throughout the American River in the reach from Hazel Avenue to Watt Avenue in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.4°F (0.5 to 0.6%), and would occur at Hazel Avenue during June of above normal water years and at Watt Avenue in June of critical years. These largest increases would be outside the peak period of smolt emigration.

Exceedance plots of mean monthly water temperatures were examined during each month and water year type throughout the smolt emigration period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The curves for PA generally match those of the NAA. Further examination of June of above normal water years at Hazel Avenue (Figure 2-36) and in June of critical years at Watt Avenue (Figure 2-37), where the largest increases in mean monthly water temperatures were seen, reveals that the curves were mostly similar overall with the exception of a few differences of more than 1°F in the middle of the range.

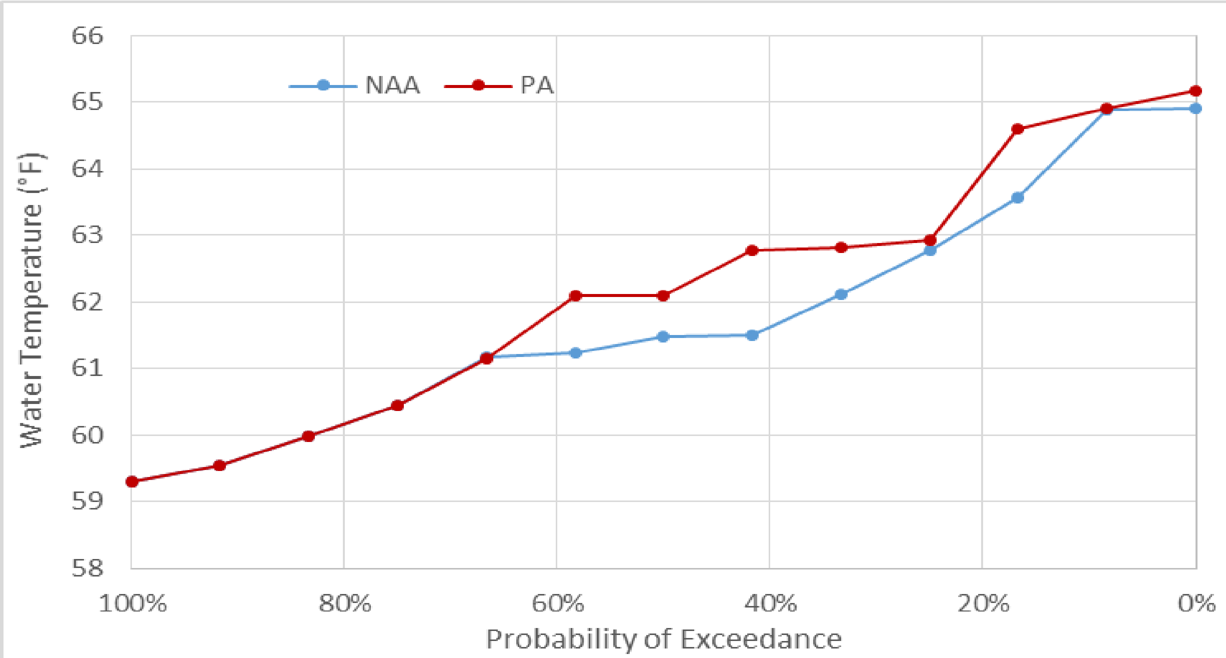

Figure 2-36. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Hazel Avenue in June of Above Normal Water Years.

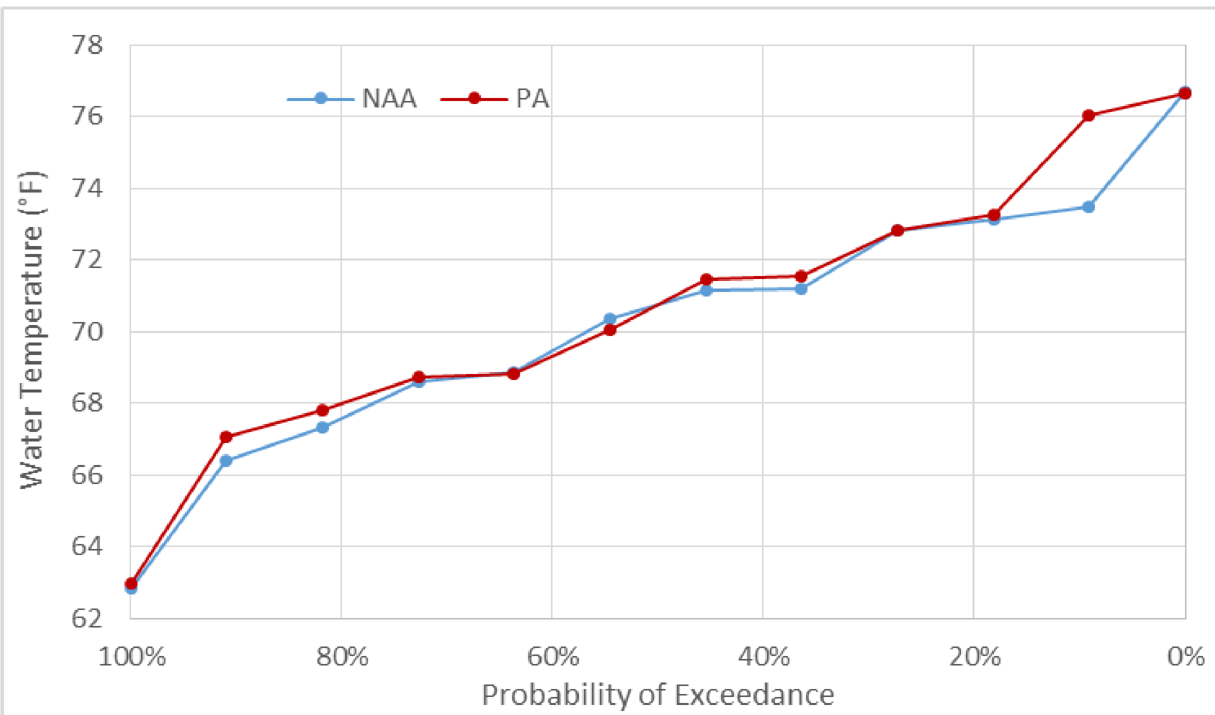

Figure 2-37. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in June of Critical Water Years.

Temperature Threshold Analysis

The exceedance of temperature thresholds in the American River between Hazel Avenue and Watt Avenue presented in the BA in Appendix 5.D, Section 5.D.2.1, Water Temperature

Analysis Methods, Table 5.D-50 by modeled daily water temperatures were evaluated based on thresholds identified in USEPA's temperature water quality guidance (U.S. Environmental Protection Agency 2003). Two thresholds, 61°F 7DADM and 64°F 7DADM, were evaluated. The 61°F value represents the core, defined by U.S. Environmental Protection Agency (2003) as "moderate to high [fish] density", location of Hazel Avenue; and the 64°F value represents non-core, defined by U.S. Environmental Protection Agency (2003) as "low to moderate density", location of Watt Avenue. The 7DADM values were converted by month to function with daily model outputs (Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-52).

Results of the water temperature thresholds analysis for steelhead smolt emigration are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 2-96 and Table 2-97 below (BA Table 5-D-171 and BA Table 5.D-172). At both Hazel Avenue and Watt Avenue, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or with a more-than-0.5°F difference in the magnitude of average daily exceedance. Based on the modeling, no exceedances of the 61°F 7DADM will occur during the peak of the smolt emigration period (January through March) at the Hazel Avenue location.

Table 2-96. Water Temperature Threshold Analysis Results, Steelhead, Smolt Emigration, American River at Hazel Avenue, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	10.6	10.9	0.3	28	28	0	0.80	0.78	-0.02
	D	2.2	1.7	-0.5	11	5	-6	0.85	0.50	-0.35
	C	7.8	7.5	-0.3	18	29	11	0.64	1.07	0.43
	All	3.1	3.0	-0.1	57	62	5	0.75	0.85	0.10
May	W	7.6	7.6	0.0	145	143	-2	2.38	2.34	-0.03
	AN	9.7	9.7	0.0	46	46	0	1.18	1.18	0
	BN	43.4	42.5	-0.9	441	442	1	2.98	3.05	0.07
	D	43.5	42.6	-1.0	776	659	-117	2.87	2.50	-0.38
	C	64.2	64.8	0.5	808	834	26	3.38	3.46	0.08
	All	29.8	29.5	-0.3	2,216	2,124	-92	2.93	2.83	-0.10
Jun	W	26.5	28.5	1.9	549	522	-27	2.65	2.35	-0.30
	AN	59.0	63.1	4.1	642	771	129	2.79	3.13	0.34
	BN	67.3	64.5	-2.7	1,184	965	-219	5.33	4.53	-0.80
	D	76.5	79.8	3.3	2,124	2,202	78	4.63	4.60	-0.03
	C	91.4	91.4	0.0	1,850	1,843	-7	5.62	5.60	-0.02
	All	58.8	60.5	1.7	6,349	6,303	-46	4.39	4.23	-0.15

[1]7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Table 2-97. Water Temperature Threshold Analysis Results, Steelhead, Smolt Emigration, American River at Watt Avenue, 64°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.6	0.6	0.0	5	5	0	1.00	1.00	0
	AN	0.3	0.3	0.0	1	1	0	1.00	1.00	0
	BN	22.1	23.3	1.2	180	185	5	2.47	2.40	-0.06
	D	14.0	13.2	-0.8	179	141	-38	2.13	1.78	-0.35
	C	36.9	36.7	-0.3	367	378	11	2.76	2.86	0.10
	All	12.0	12.0	-0.1	732	710	-22	2.47	2.41	-0.06
May	W	17.7	18.0	0.2	461	461	0	3.22	3.18	-0.04
	AN	48.6	48.9	0.2	402	404	2	2.05	2.05	0
	BN	62.8	61.9	-0.9	996	957	-39	4.65	4.54	-0.12
	D	68.9	68.7	-0.2	1,856	1,761	-95	4.35	4.13	-0.21
	C	84.9	84.7	-0.3	1,832	1,851	19	5.80	5.88	0.08
	All	51.0	50.9	-0.1	5,547	5,434	-113	4.28	4.20	-0.08
Jun	W	71.4	69.0	-2.4	1,831	1,648	-183	3.29	3.06	-0.22
	AN	97.9	97.9	0.0	1,758	1,700	-58	4.60	4.45	-0.15
	BN	93.0	92.1	-0.9	2,172	1,745	-427	7.07	5.74	-1.33
	D	97.5	96.0	-1.5	3,812	3,610	-202	6.52	6.27	-0.25
	C	98.3	98.9	0.6	3,169	3,302	133	8.95	9.28	0.32
	All	88.8	87.6	-1.2	12,742	12,005	-737	5.83	5.57	-0.26

[1]7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, daily thermal threshold exceedances at Hazel Avenue will begin in April in below normal, dry, and critical water year types with typically less than 10% of the days exceeding the threshold. By May, exceedances occur in all water year types, but will be highest in drier water years, reaching approximately 43% in below and dry years, and 65% in critical years. By June, all water years types are expected to see at least 25% of the days exceeding the thermal threshold, with critical years surpassing 90% of the days. The Watt Avenue location data indicates that there will be no daily exceedances during the peak smolt emigration months of January through March. Daily water temperature threshold exceedances begin in April, as seen in the Hazel Avenue data, but are greater in magnitude. Daily exceedances in April are at least 14% in dry years and reach approximately 37% in critical years. By May more than half of the days are expected to exceed the thermal threshold with the exception of wet years (18% exceedance). This data implies that steelhead smolts that emigrate prior to April should have thermal conditions that are protective and conducive to successful outmigration. Those fish which emigrate later in the spring will do so under degraded thermal conditions that are likely to reduce their fitness and viability. Overall, the modeling data suggests that the emigration of steelhead smolts will be minimally affected by water temperatures exceeding the EPA thresholds of 61°F 7DADM or 64°F 7DADM for core and non-core areas, respectively.

Overall, the water temperature modeling results and the threshold analysis indicate that thermal impacts on the steelhead smolt emigration life stage will largely be the same with implementation of either the PA or NAA operations. The PA is not expected to result in adverse effects, relative to the NAA. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the PA when combined with the environmental baseline and modeled climate change impacts is expected to result in adverse effects in April, May, and June, for emigrating steelhead smolts leaving the American River after the peak emigration period likely impacting a medium proportion of the life stage.

Adult Immigration

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures in the American River at Hazel Avenue and Watt Avenue during the October through April adult immigration period for steelhead are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-14, Table 5.C.7-15. See Appendix C of this Opinion, BA Table 5.C.7-14, American River at Hazel Ave, Monthly Temperature, and BA Table 5.C.7-15, American River at Watt Ave, Monthly Temperature.

Overall, the PA would change mean water temperatures very little (less than 1°F) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, and would occur at Hazel Avenue during October of above normal water years, and at Watt Avenue during March of critical water years and October of above normal water years.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA period. Further examination of October of above normal water years at

Hazel Avenue (Figure 2-38), March of critical water years at Watt Avenue (Figure 2-34), and October of above normal water years at Watt Avenue (Figure 2-39), where the largest increases in mean monthly water temperatures were seen, reveals that the curves were largely similar overall and that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in each exceedance plot. A difference of 0.2°F is likely within the uncertainty of the CALSIM and HEC5Q models, as described in the BA in Appendix 5.A, CALSIM Methods and Results, Section 5.A.4.5, Limitations and Appropriate Use of Model Results, and Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.2.5, Model Limitations. One exception would be at Hazel Avenue in October of above normal water years, in which there would be 2 years during which water temperatures under the PA would be approximately 1°F higher than those under the NAA (Figure 2-38). Further examination of these years reveals that this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there are no operational requirements, such as cold-water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures. Mean Folsom September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 8% lower mean storage during dry water years under the PA (BA Appendix 5.A, CALSIM Methods and Results). Therefore, there is no practical reason why actual operations under the PA would be different from those under the NAA in these months and years.

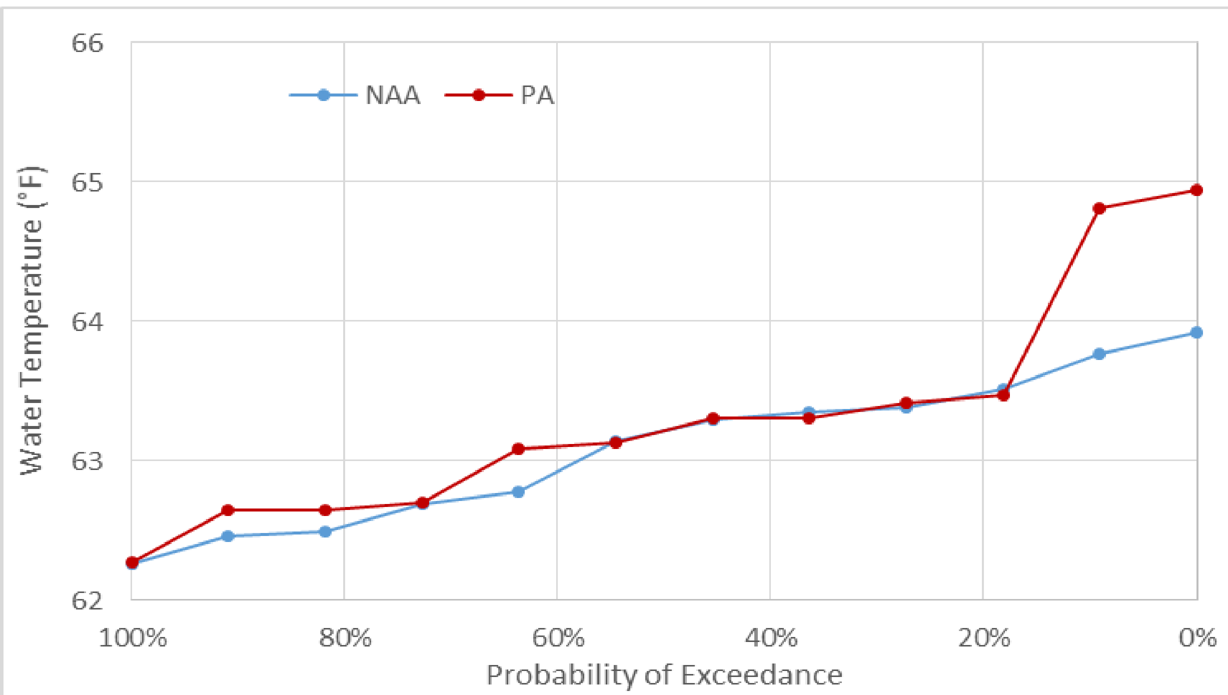

Figure 2-38. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Hazel Avenue in October of Above Normal Water Years.

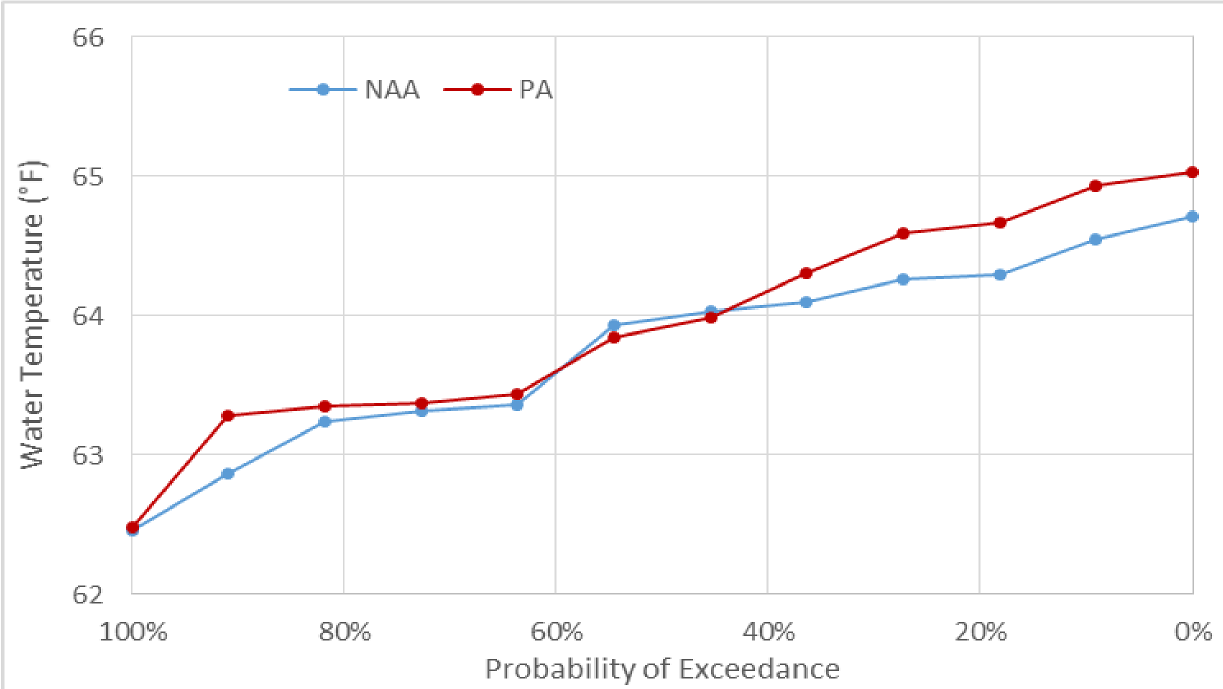

Figure 2-39. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in October of Above Normal Water Years.

Temperature Threshold Analysis

To evaluate water temperature threshold exceedance during the steelhead adult immigration life stage at Hazel Avenue and Watt Avenue, thresholds of 68°F 7DADM and 70°F were used (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-50). The 68°F 7DADM threshold was taken from U.S. Environmental Protection Agency (2003) and the 70°F threshold represents the average of the studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range. The 7DADM threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-52).

Results of the water temperature thresholds analysis for adult steelhead immigration are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Table 2-98 through Table 2-101 (BA Table 5.D-175 through BA Table 5.D-178).

Table 2-98. Water Temperature Threshold Analysis Results, Steelhead, Adult Immigration, American River at Hazel Avenue, 68°F 7DADM.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Oct	W	0.0	0.2	0.2	0	0	0	NA	0	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	2.6	0.9	-1.8	4	1	-3	0.44	0.33	-0.11
	D	4.7	5.2	0.5	25	25	0	0.86	0.78	-0.08
	C	22.6	20.7	-1.9	42	30	-12	0.50	0.39	-0.11
	All	4.9	4.5	-0.3	71	56	-15	0.58	0.49	-0.09
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1]7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-99. Water Temperature Threshold Analysis Results, Steelhead, Adult Immigration, American River at Hazel Avenue, 70°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] Only includes days on which temperature exceeded threshold

Table 2-100. Water Temperature Threshold Analysis Results, Steelhead, Adult Immigration, American River at Watt Avenue, 68°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[2]			Degrees per day above threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Oct	W	3.7	4.5	0.7	30	37	7	1.00	1.03	0.03
	AN	9.7	13.7	4.0	25	33	8	0.69	0.65	-0.05
	BN	22.6	22.9	0.3	98	97	-1	1.27	1.24	-0.03
	D	31.9	31.3	-0.6	308	307	-1	1.56	1.58	0.03
	C	62.1	55.4	-6.7	521	436	-85	2.26	2.12	-0.14
	All	22.8	22.5	-0.3	982	910	-72	1.72	1.61	-0.11
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	2.7	2.7	0.0	10	9	-1	1.11	1.00	-0.11
	D	1.5	1.5	0.0	7	6	-1	0.78	0.67	-0.11
	C	9.4	9.7	0.3	53	54	1	1.56	1.54	-0.02
	All	2.1	2.2	0.0	70	69	-1	1.35	1.30	-0.04

[1]7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

Table 2-101. Water Temperature Threshold Analysis Results, Steelhead, Adult Immigration, American River at Watt Avenue, 70°F.

Month	WYT	Percent of days above threshold			Sum of degree-days above threshold[1]			Degrees per day above threshold[1]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	2.1	1.9	-0.2	16	20	4	1.23	1.67	0.44
	C	10.8	8.6	-2.2	31	16	-15	0.78	0.50	-0.28
	All	2.1	1.8	-0.4	47	36	-11	0.89	0.82	-0.07
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.6	0.6	0.0	2	2	0	1.00	1.00	0
	All	0.1	0.1	0.0	2	2	0	1.00	1.00	0

[1] Only includes days on which temperature exceeded threshold

At both Hazel Avenue and Watt Avenue, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or with a more-than-0.5°F difference in the magnitude of average daily exceedance. For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the modeling data shows that there are no days that are expected to exceed the 68°F 7DADM thermal threshold from November through April at the Hazel Avenue location under any water year type. Exceedances are only observed in the modeled scenarios in October, and then primarily in critical water years when approximately 20 to 22% of the days will exceed the thermal threshold. Exceedances in October occur in below normal and dry years and no more than approximately 5% of the days in the month are expected to exceed the threshold. The modeling for the 70°F threshold at Hazel Avenue shows that the water temperatures are not expected to exceed this threshold in any month between October and April under in any water year type. Therefore, water temperatures are not expected to negatively impact adult immigration of steelhead in the American River reach occupied by the Hazel Avenue location except during October of critical water years using the lower 68°F thermal threshold standard.

For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the modeling of water temperatures at Watt Avenue indicates that the 68°F 7DADM thermal threshold will be exceeded in both October and April. All water year types will have exceedances in October, with the percentage of days exceeding the threshold increasing with drier water year types. Wet and above normal years will have less than 14% exceedances of the threshold. The percent exceedances will increase to approximately 23% in below normal years, 32% in dry years and between 55% (PA) and 62% (NAA) in critical years. The month of April will have low numbers of days that will exceed the thermal threshold, increasing with drier water year types up to approximately 10% in critical years. The modeling results using the higher 70°F threshold substantially reduce the number of days that will exceed the threshold. Exceedances occur primarily in the critical years in October, and then are less than 11% of the days in October. The other water years are less than 2% in October. There is a negligible level of exceedances above thermal threshold in April in critical years (0.6%). The modeling implies that most of the immigration period for adult steelhead in the American River will not be affected by thermal conditions except for October at the Watt Avenue location. Fish that move upriver after October should see conditions that are favorable to upstream movements.

Overall, the water temperature modeling results and the threshold analysis indicate that thermal impacts on steelhead adult immigration will largely be the same with implementation of either the PA or NAA operations. The PA is not expected to result in adverse effects, relative to the NAA. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects at Watt Avenue and Hazel Avenue in October, particularly in drier years and especially critically dry years, and to a lesser degree in April, based on the lower thermal threshold of 68°F 7DADM. The higher threshold of 70°F will have a lower level of adverse effects on adult migration in these two months. NMFS concludes that there will be no adverse effects if the 70°F threshold is used at the Hazel Avenue location, and a limited adverse effect at the Watt Avenue location for this more lenient threshold.

Adult Holding

Monthly Temperatures and Exceedance Plots

Modeled mean monthly water temperatures in the American River at Hazel Avenue and Watt Avenue during the October and November steelhead adult holding period are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-14, Table 5.C.7-15. See Appendix C of this Opinion, BA Table 5.C.7-14, American River at Hazel Ave, Monthly Temperature, and BA Table 5.C.7-15, American River at Watt Ave, Monthly Temperature.

Overall, the PA would change mean water temperatures very little (less than 1°F) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F (0.4%), and would occur at both locations during October of above normal water years.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of October in above normal years at Watt Avenue (Figure 2-39), where the largest increase in mean monthly water temperatures were seen, reveals that the curves were largely similar overall and that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in the exceedance plot. A difference of 0.2°F is likely within the uncertainty of the CALSIM and HEC5Q models, as described in the BA in Appendix 5.A, CALSIM Methods and Results, Section 5.A.4.5, Limitations and Appropriate Use of Model Results, and Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.2.5, Model Limitations. Further examination of October of above normal water years at Hazel Avenue (Figure 2-38), also where the largest increase in mean monthly water temperatures were seen, reveals that there would be two years during which water temperatures under the PA would be approximately 1°F higher than those under the NAA. However, upon closer examination, this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there are no operational requirements, such as cold-water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures.

Temperature Threshold Analysis

To evaluate water temperature threshold exceedance during the steelhead adult holding life stage at Hazel Avenue and Watt Avenue, the USEPA’s 7DADM threshold value of 61°F was used in the BA in Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-50) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-52).

Results of the water temperature thresholds analysis for adult steelhead holding are presented in the BA in Appendix 5.D, Section 5.D.2.5, Detailed Water Temperature Threshold Analysis Results, Tables 5.D-179 and 5.D-180. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or with a more-than-0.5°F difference in the magnitude of average daily exceedance. As such, adverse thermal effects on steelhead holding in the American River resulting from changes to upstream operations as a result of the PA are not expected. For purposes of the analysis in Section 2.7 Integration and Synthesis, the modeling results, which represent the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, indicate that at the Hazel Avenue location, the percentage of daily exceedances above the 61°F 7DADM would occur in all water year types in the months of October and November. In October, exceedances range from approximately 68% of the days in wet year types to approximately 100% of the days in critical year types. November has substantially less days in which the thermal threshold is exceeded, ranging from approximately 5% of the days in a wet year to approximately 15% in critical years. The downstream location at Watt Avenue shows a greater percentage of days in which the thermal threshold is exceeded during the adult holding period in October and November. In October, the number of days in which the thermal threshold is exceeded range from approximately 93% in wet years to 100% in the dry and critical year types. Like Hazel Avenue, November has less days in which the thermal threshold is exceeded, but the more downstream location of Watt Avenue has a greater proportion of days exceeding the threshold. The number of days in which the threshold is exceeded range from approximately 10% in wet years to 30% in critical years. This modeling for the river temperatures at Watt and Hazel Avenues implies that adult steelhead holding at either location in October will experience substantial risk for damage to their gametes and overall fitness prior to spawning. The thermal conditions in November show improvements based on the modeling, but a still substantial proportion of the population is at risk in drier years.

Overall, the water temperature modeling results and the threshold analysis indicate that thermal impacts on steelhead adult holding will largely be the same with implementation of either the PA or NAA operations. The PA is not expected to result in adverse effects, relative to the NAA. For purposes of the analysis in Section 2.7 Integration and Synthesis, NMFS concludes that the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in substantial adverse effects to holding adult steelhead at the Watt Avenue location in October and to a lesser extent in November based on the thermal threshold of 61°F 7DADM. Adult steelhead holding at the Hazel Avenue location will have substantial adverse effects related to the thermal conditions resulting from the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts in the months of October and to a lesser extent in November.

2.5.1.2.1.4 Green Sturgeon Exposure and Risk

Water temperature is likely a key factor in sturgeon recruitment and development. Lab-based data from the nDPS indicate that eggs hatch after 144-192 hours when incubated at a temperature of 15.7 ± 0.02°C (Deng et al. 2002). Van Eenennaam et al. (2005) found that the hatching rate for green sturgeon eggs was slightly reduced when incubation temperatures were less than 11°C. They also found that the upper lethal temperature for developing embryos to be approximately 22 to 23°C, with sub-lethal effects from 17.5 to 22.2°C (Van Eenennaam et al. 2005). In the laboratory, metamorphosis from larvae to juvenile of Northern DPS green sturgeon occurred at approximately 45 days post-hatch, at lengths of 62-94 mm (Deng et al. 2002). Based on these temperature thresholds and requirements for the early life stages of this species, the predicted range of water temperatures in the upper Sacramento River following implementation of the PA is not expected to adversely affect the reproductive success, growth, or survival of sDPS green sturgeon.

2.5.1.2.1.5 Fall/Late fall-run Exposure and Risk

2.5.1.2.1.5.1 Sacramento River

2.5.1.2.1.5.1.1 Fall-run Chinook Salmon

Fall-run Chinook salmon exposure and risk to warm water temperatures occurring in the Sacramento River under the PA are discussed below by life stage in the following order: (1) spawning, egg incubation, and alevin development; (2) fry and juvenile rearing and outmigration; and (3) adult immigration and holding.

Spawning, Egg Incubation, and Alevin Development

Sacramento River fall-run Chinook salmon spawn from Keswick Dam to Princeton Ferry, with the vast majority (i.e., 94%) occurring upstream from Tehama Bridge (Table 2-102). Fall-run Chinook salmon eggs and alevins occur in the Sacramento River from the time when spawning begins in September through fry emergence in January (Vogel and Marine 1991).

Table 2-102. Spatial Distribution of Spawning Redds in the Sacramento River Based on Aerial Redd Surveys, Fall-run Chinook Salmon, 2003–2014. (Source: BA; initial source is CDFW).

Reach	Mean Annual Percent of Total Redds Sighted
Keswick to ACID Dam	16.3
ACID Dam to Highway 44 Bridge	5.5
Highway 44 Bridge to Airport Road Bridge	12.3
Airport Rd. Bridge to Balls Ferry Bridge	16.2
Balls Ferry Bridge to Battle Creek	10.3
Battle Creek to Jelly's Ferry Bridge	12.7
Jelly's Ferry Bridge to Bend Bridge	6.6
Bend Bridge to Red Bluff Diversion Dam	3.5
Red Bluff Diversion Dam to Tehama Br.	10.8
Tehama Br. To Woodson Bridge	3.1
Woodson Bridge to Hamilton City Br.	1.8
Hamilton City Bridge to Ord Ferry Br.	0.8
Ord Ferry Br. To Princeton Ferry.	0.1

ACID = Anderson-Cottonwood Irrigation District

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures during the September through January spawning, egg incubation, and alevins period for fall-run Chinook salmon, which peaks in October through December, are presented in the BA in Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. As stated in the BA, overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately a 1% change) from Keswick to Red Bluff in all months of the period and water year types. The largest increase in mean monthly water temperatures under the PA relative to the NAA would be 0.7°F, or up to 1%, and would occur at Red Bluff in wet and above normal years during September. This largest increase in water temperature would not overlap spatially or temporally with peak fall-run Chinook salmon spawning, which occurs upstream from Red Bluff in October and November.

Exceedance plots of monthly mean water temperatures were examined during each month and water year type throughout the spawning and incubation period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The curves for the PA generally overlap those of the NAA. Further examination of above normal (Figure 2-40) and below normal years during September at Red Bluff (Figure 2-41) and in below normal years during September at Bend Bridge (Figure 2-42), where the largest modeled increases in mean monthly water temperatures due to the PA were found, reveals that water temperatures under the PA are almost always slightly warmer than under the NAA, with typically less than a degree (F) difference between the two alternatives.

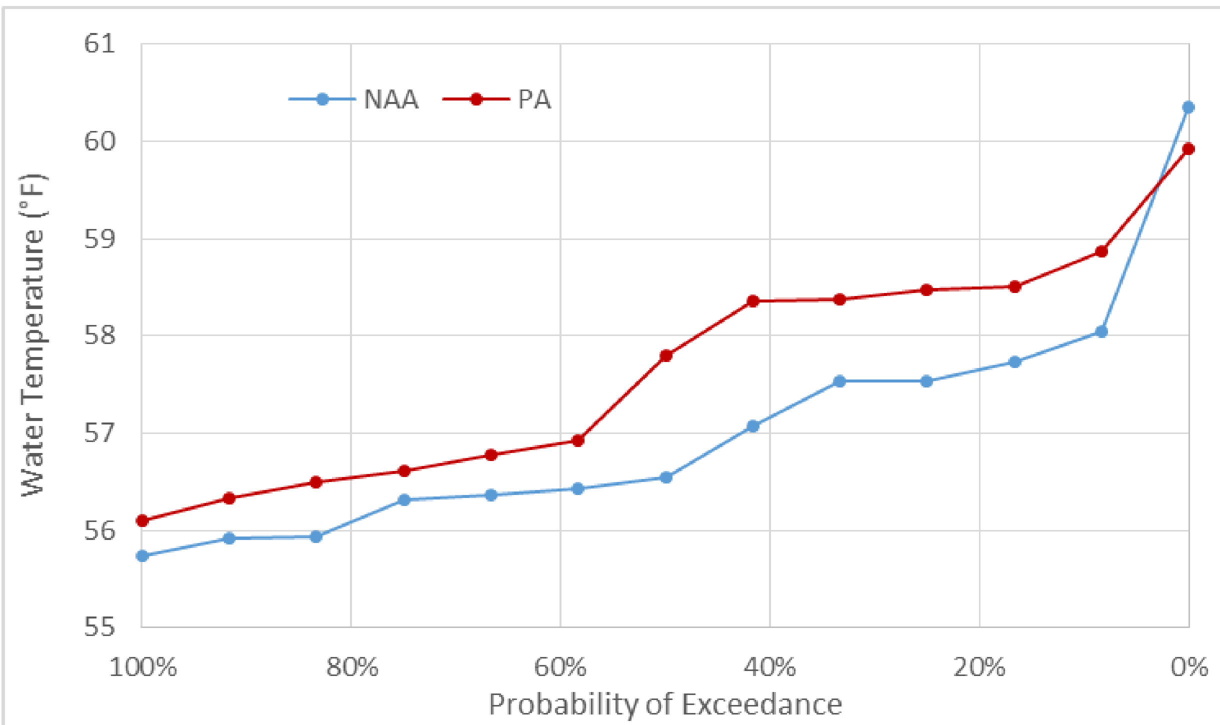

Figure 2-40. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years.

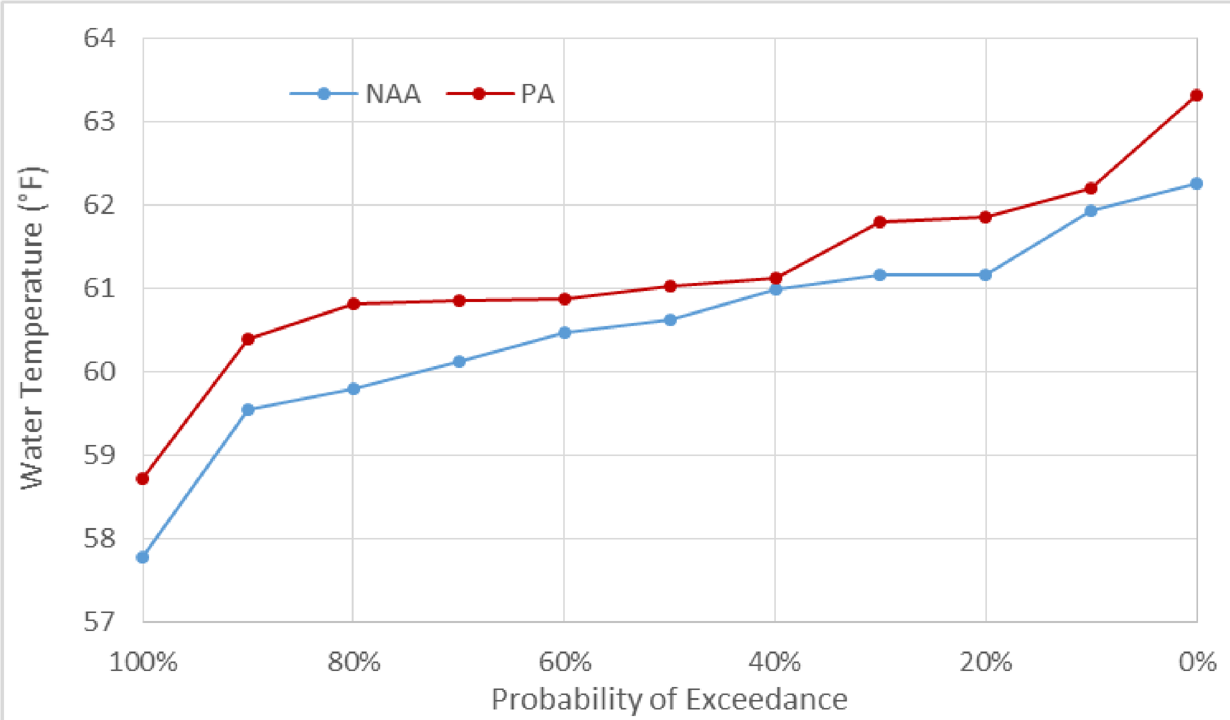

Figure 2-41. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years.

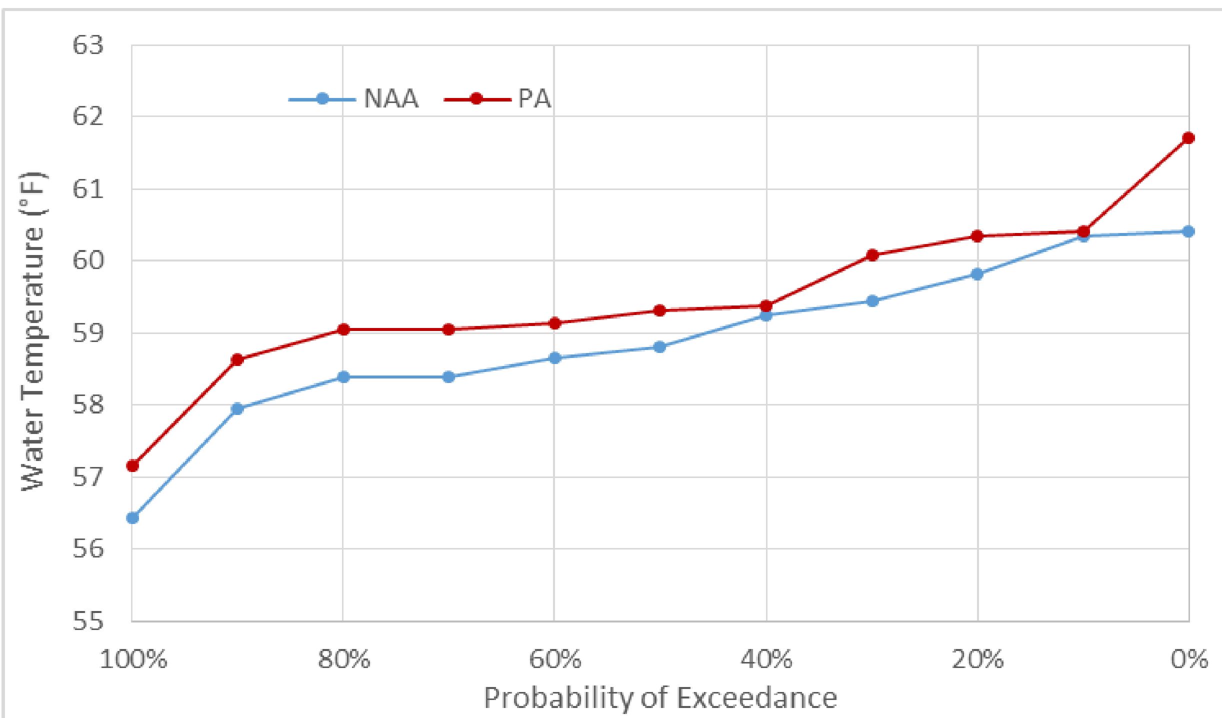

Figure 2-42. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in September of Below Normal Water Years.

The water temperature exceedance plots are useful for assessing whether the PA is expected to make conditions warmer, colder, or have little impact relative to the NAA. The plots clearly show that the latter (little impact) is the case. What the plots do not show is how fish life stages, in this case fall-run Chinook salmon eggs and alevins, will be affected by the PA thermal regime.

Biological Tools

To take the analysis a step further and evaluate how PA water temperatures are expected to affect fall-run Chinook salmon egg incubation and alevin development, we looked at results of the NMFS Southwest Fisheries Science Center's newly developed egg mortality model[6] (Martin et al. 2016), as well as results from two biological analyses presented in the BA—a water temperature thresholds analysis and SALMOD. Overall, because the three biological tools utilize daily (thresholds analysis and the egg/alevin mortality model) or weekly (SALMOD) water temperatures downscaled from modeled monthly values, the certainty of their respective abilities to accurately estimate thermal impacts to eggs and alevins in the Sacramento River with implementation of the PA is low.[7] Eggs and alevins developing in the Sacramento River spawning gravels experience a thermal regime that varies between day and night and from one day to the next. The water temperature modeling utilized in the biological models does not capture that level of thermal variation. Nevertheless, the biological models are useful quantitative indicators of potential thermal impacts under the PA. The SWFSC's egg mortality model, the thresholds analysis, and SALMOD are discussed below in that order.

Temperature Threshold Analysis

The water temperature thresholds analysis presented in the BA provides another indication that water temperatures under the PA are not expected to increase in relation to the NAA. As pointed out in the BA (pages 5.E-153 and 5.E-154), the differences in the percent of days above the spawning, egg, and alevin water temperature threshold (i.e., 55.4 7DADM) between the NAA and the PA would be minimal across months, locations, and water year types (BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E.1-1 through 5.E.1-5). However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of fall-run Chinook salmon eggs and alevins in every single year regardless of water year type. That is because water temperatures are frequently expected to exceed 55.4°F 7DADM for a long duration during peak spawning and egg incubation months over a range of hydrologic conditions. For example, the water temperature threshold analysis shows that even in wet years at the Keswick Dam gauge, water temperatures under the PA will exceed the temperature threshold for 61% of the days in November (Table 2-103).

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[6] The egg mortality model developed by Reclamation that is used in the BA has not been incorporated into this biological opinion because it is based on thermal tolerance studies conducted in the laboratory which substantially underestimate egg mortality in natural conditions (e.g., a salmon redd in the Sacramento River) (Martin et al. 2016). The SWFSC's egg mortality model is based on a relationship between temperature and egg survival derived from field data, providing a more reliable tool for estimating thermal effects on salmon eggs than Reclamation's egg mortality model.

[7] Additional key assumptions and data limitations that influence the reliability of results from SALMOD are highlighted in NRC (2010).

Table 2-103. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Spawning and Embryo Incubation, Sacramento River at Keswick, 55.4°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	9.7	13.6	3.9	17	21	4	0.53	0.47	-0.06
	D	19.7	15.8	-3.8	58	33	-25	0.49	0.35	-0.14
	C	86.7	83.3	-3.3	2,350	2,273	-77	7.53	7.58	0.04
	All	18.8	17.9	-0.9	2,425	2,327	-98	5.25	5.29	0.04
Oct	W	10.7	10.2	-0.5	45	29	-16	0.52	0.35	-0.17
	AN	5.4	3.8	-1.6	5	2	-3	0.25	0.14	-0.11
	BN	27.9	24.0	-3.8	42	20	-22	0.44	0.24	-0.20
	D	40.8	41.5	0.6	139	112	-27	0.55	0.44	-0.11
	C	99.5	100.0	0.5	2,175	2,019	-156	5.88	5.43	-0.45
	All	32.8	32.1	-0.7	2,406	2,182	-224	2.92	2.70	-0.22
Nov	W	67.2	61.3	-5.9	404	360	-44	0.77	0.75	-0.02
	AN	50.8	37.5	-13.3	128	92	-36	0.70	0.68	-0.02
	BN	40.6	37.0	-3.6	138	101	-37	1.03	0.83	-0.20
	D	45.7	48.3	2.7	199	212	13	0.73	0.73	0
	C	86.1	86.1	0.0	625	617	-8	2.02	1.99	-0.03
	All	58.6	54.9	-3.7	1,494	1,382	-112	1.05	1.04	-0.01
Dec	W	8.3	7.8	-0.5	50	39	-11	0.75	0.62	-0.13
	AN	6.2	3.0	-3.2	15	4	-11	0.65	0.36	-0.29
	BN	11.4	7.6	-3.8	23	17	-6	0.59	0.65	0.06
	D	2.6	2.9	0.3	7	9	2	0.44	0.50	0.06
	C	14.0	14.5	0.5	31	32	1	0.60	0.59	0
	All	7.8	6.8	-1.0	126	101	-25	0.64	0.59	-0.05
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	5.0	5.0	0.0	16	16	0	0.80	0.80	0
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.8	0.8	0.0	16	16	0	0.80	0.80	0

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

The longer the duration of exposure to water temperatures that are warmer than the threshold, the greater the severity of adverse effects. Conditions worsen further downstream at the Clear Creek, Balls Ferry, Bend Bridge, and Red Bluff locations, particularly in October, with PA water temperatures exceeding the egg and alevin threshold (i.e., 55.4°F 7DADM) for 82% to 100% of the days across all water year types. From a qualitative context, egg and alevin mortality above natural levels (i.e., little to no thermal stress) is expected under such a thermal regime, and that is what the quantitative biological models (SWFSC's egg mortality model and SALMOD) predict as well.

Southwest Fisheries Science Center's Egg Mortality Model

The SWFSC egg mortality model, described above in the winter-run Chinook salmon section, was linked with a 1-dimensional temperature model of the Sacramento River with one km spatial resolution (Pike et al. 2013) to estimate daily survival probabilities for eggs when exposed to water temperatures under the PA and NAA. Figure 2-43 shows the fall-run Chinook salmon egg survival probability under the PA and NAA for all water years combined and by water year type. These results show the survival after accounting for only the effects of water temperature. Other factors affecting egg and alevin survival such as physical disturbance from redd superimposition would lower the water temperature dependent survival shown in Figure 2-43.

Fall-run Chinook salmon egg survival is expected to be less than 50% throughout much of the spawning habitat in September and early October in all water years under either alternative. In critical water years, egg survival would be less than 10% throughout the spawning habitat for all of September and the beginning of October. Even in the wetter water years, egg survival in that time frame is less than 50% except for the first few kilometers. These results suggest that Sacramento River water temperature-related egg survival will largely be the same under the PA and NAA. As such, adverse thermal effects on fall-run Chinook salmon eggs resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of fall-run Chinook salmon eggs.

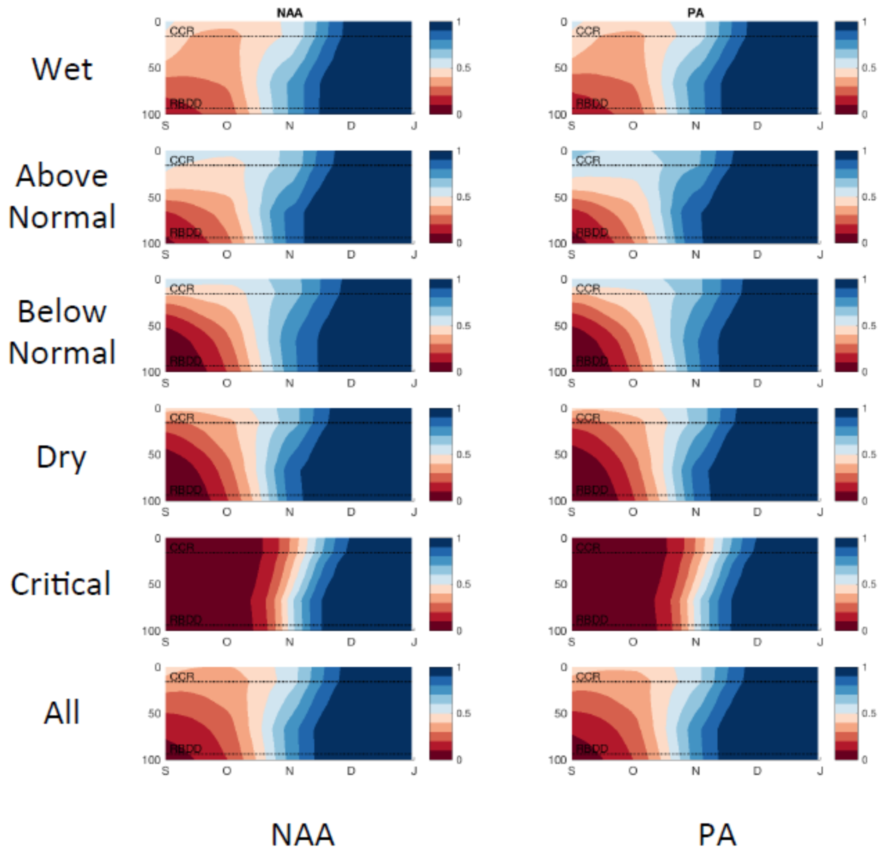


Figure 2-43. Fall-run Chinook Salmon Egg Survival Landscape from the SWFSC's Temperature Dependent Egg Survival Model. Primary Y-axis is distance in km downstream from Keswick Dam. The color key is the probability of survival.

SALMOD Model

The SALMOD model predicts water temperature-related mortality of fall-run Chinook salmon eggs and alevins the Sacramento River. This water temperature-related mortality is split up as pre-spawn (in vivo, or in the mother before spawning) and egg (in the gravel) mortality (see BA Attachment 5.D.2, SALMOD Model, for a full description).

Table 2-60 presents results for water temperature-related mortality of spawning, eggs, and alevins, in addition to all sources of mortality for fall-run Chinook salmon predicted by SALMOD discussed in other sections of this document. Blue numbers indicate a reduction in mortality and red numbers indicate an increase in mortality. For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, mean annual egg and alevin mortality under the PA predicted by SALMOD ranges from 182,221 in below normal water years to 18,248,020 in critical water years. For all water year types combined, mean annual egg and alevin mortality under the PA is estimated at 5,683,877. When mortality from redd dewatering, redd scour, and redd superimposition are added to the temperature-related mortality, the mean annual egg and alevin mortality under the PA ranges from 485,979 in below normal water years to 18,625,799 in critical water years (BA Table 5.3-37 in Appendix C).

Overall, results of the SWFSC egg mortality model, the water temperature thresholds analysis, and SALMOD collectively indicate that thermal impacts on fall-run Chinook salmon spawning, egg incubation, and alevin development will largely be the same with implementation of either the NAA or PA.

Adverse thermal effects on these life stages resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in substantial water temperature-related mortality (a large proportion of the year class) in all water years, with the greatest mortality in the drier years.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5 Real-Time Operations Upstream of the Delta, and Section 3.3.3 Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

It is important to note that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Fry and Juvenile Rearing and Outmigration

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures during the December through June fry and juvenile rearing period for fall-run Chinook salmon in the Sacramento River upstream of the Delta are nearly identical between the PA and NAA (see BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10). Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) throughout the juvenile rearing reach of Keswick to Knights Landing in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F (0.5% to 0.7%), and would occur at Keswick, above Clear Creek, Balls Ferry, and Bend Bridge in below normal years during May, which is outside the peak period of presence for fall- run Chinook salmon fry and juveniles.

Temperature Threshold Analysis

As presented in the BA, the water temperature thresholds analysis for fall-run Chinook salmon juvenile rearing and emigration have been combined and the period of December through June was evaluated. The threshold used was from the USEPA's 7DADM value of 61°F for the core juvenile rearing reach from Keswick to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing (BA Table 5.E-22). The 7DADM values were converted by month to function with daily model outputs (see BA Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-4).

Results of the water temperature thresholds analysis are presented in BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Tables 5.E.1-6 through 5.E.1-11. At all locations, there would be no months or water year types in which there would be both more than 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, the thresholds analysis indicates that, relative to the NAA, any adverse effects under the PA would be undetectable on fall-run Chinook salmon juvenile rearing and emigration.

For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, results of the water temperature thresholds analysis indicate that an adverse effect to fall-run Chinook salmon juveniles is expected (Table 2-104 through Table 2-106). The general pattern is that daily occurrences of threshold exceedances increase as fish move downstream from Balls Ferry and as the season progresses from April through June. As such, the frequency of adverse effects to fall-run Chinook salmon juveniles are expected to increase from Balls Ferry downstream to Knights Landing and from month to month during the April through June period. The mean percentage of days for all water years combined where April through June water temperatures under the PA are expected to exceed the 7DADM thresholds (61°F for core, 64°F for non-core) during ranges from 0.1% up to 6.9% at Bend Bridge; from 1.2% to 15.2% at Red Bluff; and from 5.1% to 100% at Knights Landing. Additionally, the severity of adverse effects to fall-run Chinook salmon juveniles' increases from upstream to downstream. This is evident by the increase in the degrees per day above the threshold for all water years combined from low levels (e.g., a degree or less) at Bend Bridge and Red Bluff to up to 7.4°F in June at Knights Landing.

Table 2-104. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Juvenile Rearing and Emigration, Sacramento River at Bend Bridge, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.2	0.2	0.0	1	1	0	1.00	1.00	0
	C	0.3	0.3	0.0	1	0	-1	1.00	0	-1.00
	All	0.1	0.1	0.0	2	1	-1	1.00	0.50	-0.50
May	W	6.2	6.2	0.0	50	50	0	1.00	1.00	0
	AN	5.5	5.5	0.0	26	26	0	1.18	1.18	0
	BN	0.3	2.9	2.6	0	7	7	0	0.70	0.70
	D	9.4	7.7	-1.6	66	55	-11	1.14	1.15	0.01
	C	9.4	9.4	0.0	36	32	-4	1.03	0.91	-0.11
	All	6.5	6.5	0.0	178	170	-8	1.07	1.03	-0.04
Jun	W	5.3	5.5	0.3	36	37	1	0.88	0.86	-0.02
	AN	4.4	4.4	0.0	16	16	0	0.94	0.94	0
	BN	3.6	3.3	-0.3	10	10	0	0.83	0.91	0.08
	D	0.3	0.2	-0.2	1	0	-1	0.50	0	-0.50
	C	29.7	26.9	-2.8	113	79	-34	1.06	0.81	-0.24
	All	7.3	6.9	-0.4	176	142	-34	0.98	0.84	-0.14

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-105. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Juvenile Rearing and Emigration, Sacramento River at Red Bluff, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.5	0.5	0.0	2	2	0	0.50	0.50	0.00
	AN	0.5	0.5	0.0	1	1	0	0.50	0.50	0.00
	BN	0.0	0.3	0.3	0	0	0	NA	0	NA
	D	2.7	2.8	0.2	11	11	0	0.69	0.65	-0.04
	C	1.7	1.7	0.0	6	6	0	1.00	1.00	0.00
	All	1.1	1.2	0.1	20	20	0	0.71	0.67	-0.05
May	W	15.8	15.9	0.1	162	162	0	1.28	1.27	-0.01
	AN	14.6	12.2	-2.5	81	76	-5	1.37	1.55	0.18
	BN	5.3	8.8	3.5	10	24	14	0.56	0.80	0.24
	D	19.0	14.8	-4.2	181	150	-31	1.53	1.63	0.10
	C	25.3	23.7	-1.6	127	118	-9	1.35	1.34	-0.01
	All	16.4	15.2	-1.1	561	530	-31	1.35	1.37	0.02
Jun	W	12.7	12.4	-0.3	103	103	0	1.04	1.06	0.02
	AN	10.8	9.0	-1.8	39	37	-2	0.93	1.06	0.13
	BN	7.0	6.1	-0.9	23	21	-2	1.00	1.05	0.05
	D	4.3	2.8	-1.5	20	11	-9	0.77	0.65	-0.12
	C	46.7	40.8	-5.8	238	186	-52	1.42	1.27	-0.15
	All	14.6	12.8	-1.7	423	358	-65	1.18	1.13	-0.05

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-106. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Juvenile Rearing and Emigration, Sacramento River at Knights Landing, 64°F 7DADM.

		Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
Month	WYT	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.5	0.5	0.0	1	1	0	0.33	0.33	0
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.1	0.1	0.0	1	1	0	0.33	0.33	0
Apr	W	5.1	5.1	0.0	35	35	0	0.88	0.88	0
	AN	9.2	9.0	-0.3	34	34	0	0.94	0.97	0.03
	BN	36.7	38.5	1.8	171	181	10	1.41	1.43	0.01
	D	22.2	21.2	-1.0	232	224	-8	1.74	1.76	0.02
	C	35.8	34.4	-1.4	209	203	-6	1.62	1.64	0.02
	All	18.7	18.4	-0.2	681	677	-4	1.48	1.49	0.01
May	W	72.2	72.3	0.1	2,517	2,536	19	4.32	4.35	0.03
	AN	87.8	87.8	0.0	1,768	1,759	-9	4.99	4.97	-0.03
	BN	96.5	97.1	0.6	1,538	1,561	23	4.67	4.72	0.04
	D	95.8	95.3	-0.5	3,299	3,065	-234	5.55	5.19	-0.37
	C	98.7	97.8	-0.8	2,152	2,114	-38	5.86	5.81	-0.06
	All	87.6	87.5	-0.1	11,274	11,035	-239	5.06	4.96	-0.10
Jun	W	98.7	98.7	0.0	5,886	5,747	-139	7.64	7.46	-0.18
	AN	100.0	100.0	0.0	3,022	2,769	-253	7.75	7.10	-0.65
	BN	100.0	100.0	0.0	2,354	2,143	-211	7.13	6.49	-0.64
	D	100.0	100.0	0.0	4,867	4,403	-464	8.11	7.34	-0.77
	C	100.0	100.0	0.0	3,262	3,080	-182	9.06	8.56	-0.51
	All	99.6	99.6	0.0	19,391	18,142	-1,249	7.91	7.40	-0.51

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Overall, the monthly temperature results, exceedance plots, and threshold analysis collectively indicate that thermal impacts on fall-run Chinook salmon fry and juvenile rearing and outmigration will largely be the same with implementation of either the NAA or PA.

Adverse thermal effects on these life stages resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5 Real-Time Operations Upstream of the Delta, and Section 3.3.3 Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

It is important to note that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Adult Immigration and Holding

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures presented in the BA were evaluated in the Sacramento River at Keswick, Bend Bridge, and Red Bluff during the July through December adult immigration period for fall-run Chinook salmon. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) at these locations in all months and water year types in the period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.3.7-7, Table 5.C.7-8). The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F (0.9% to 1.1%), and would occur at Bend Bridge in below normal years during September and at Red Bluff in below normal years during August and above normal and below normal water years during September (Reclamation 2016).

Exceedance plots of monthly mean water temperatures were examined during each month and water year type throughout the adult immigration period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The curves for the PA generally match those of the NAA. For the cases with the highest increase in mean monthly water temperatures under the PA, temperatures under the PA would be consistently higher than those under the NAA by 0.5°F to 1°F across the range of temperatures (Figure 2-44 through Figure 2-47; BA Figures 5.E-145 through 5.E-148).

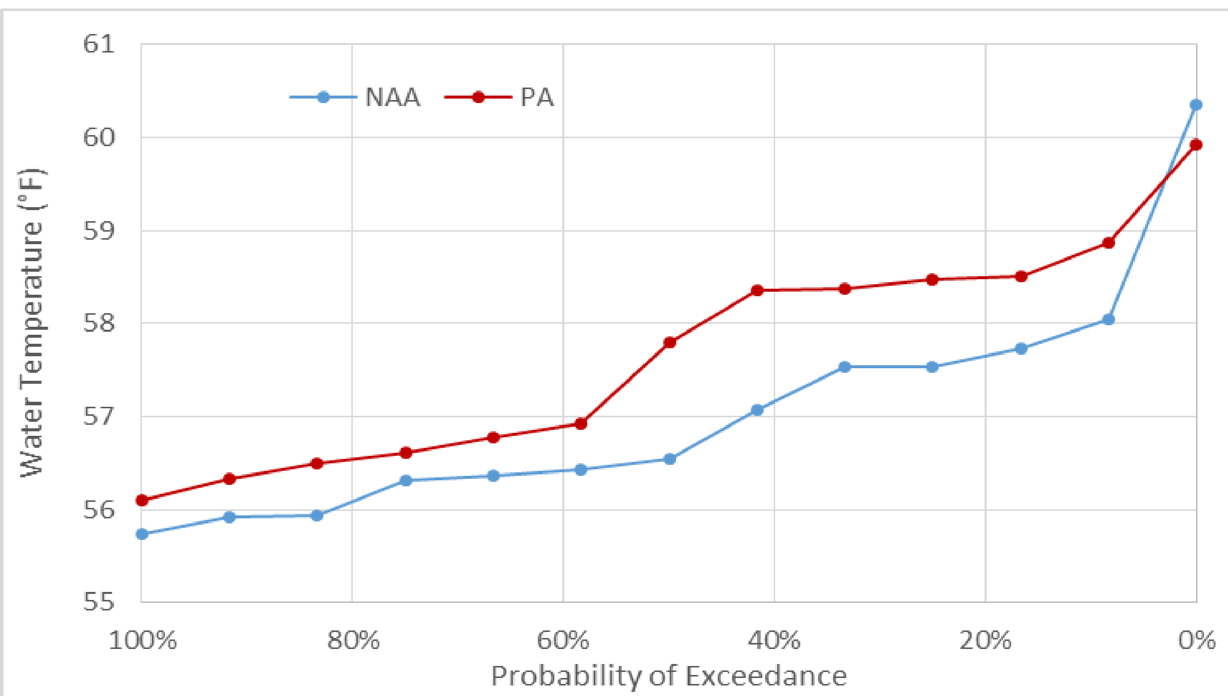


Figure 2-44. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years.

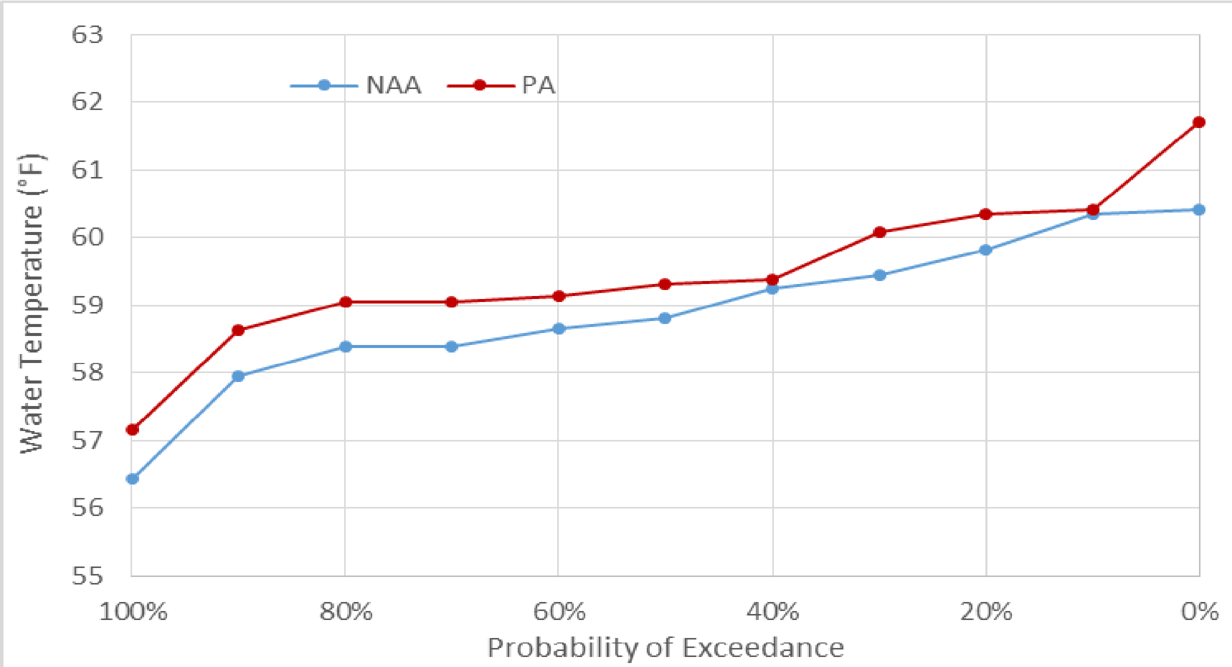


Figure 2-45. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in September of Below Normal Water Years.

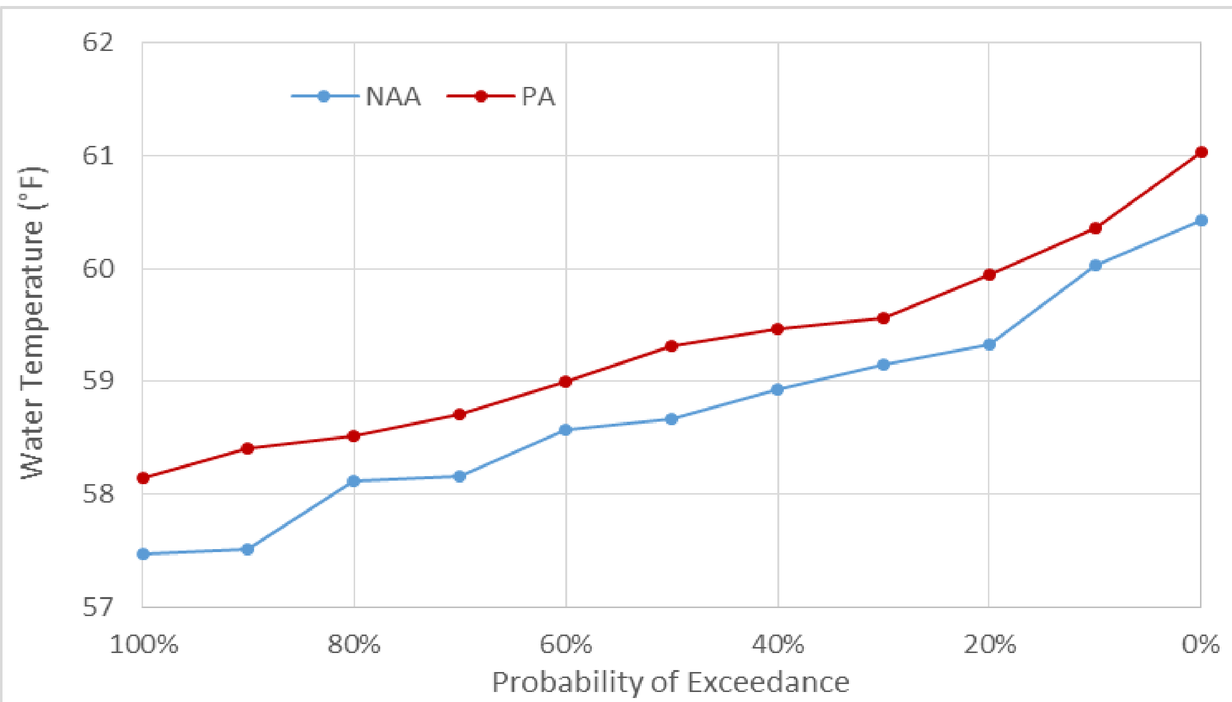


Figure 2-46. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Below Normal Water Years.

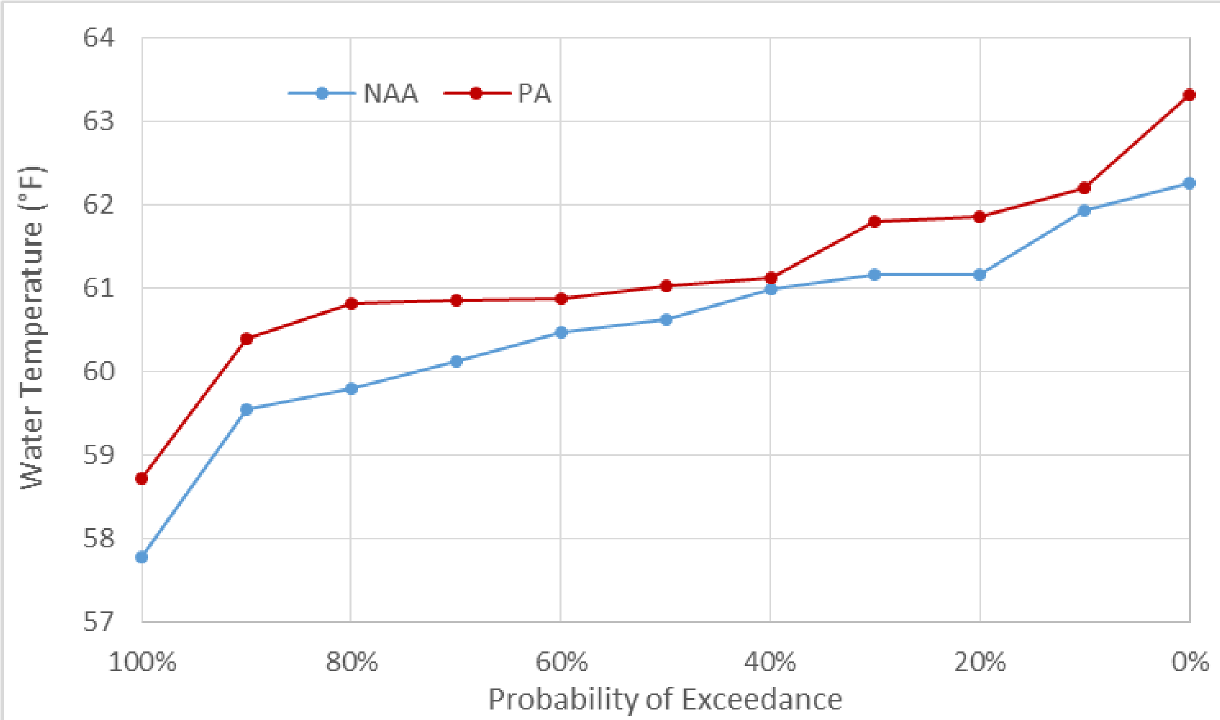


Figure 2-47. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years.

Temperature Threshold Analysis

The USEPA's 7DADM threshold value of 68°F was used to evaluate water temperature threshold exceedance during the fall-run Chinook salmon adult immigration life stage at Keswick, Bend Bridge, and Red Bluff. The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D- 4).

Results of the water temperature thresholds analysis are presented in BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E-12 through 5.E-14. At Keswick and Red Bluff, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and no more-than-0.5°F difference in the magnitude of average daily exceedance (BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E.1-12 and Table 5.E.1-14).

At Bend Bridge, there would be two instances during which the percent of days exceeding the 68°F DADM under the PA would be more than 5% higher than under the NAA: August in critical years (5.1% higher under the PA) and September of critical years (5.3% higher under the PA) (Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E.1-13). However, there would be a negligible (less than 0.1°F) difference in average daily exceedance in both instances. Therefore, it was concluded that any adverse effects on fall-run adult immigration relative to the NAA would be undetectable.

Overall, these temperature threshold analysis results indicate that any adverse water temperature-related effects of the PA relative to the NAA on fall-run Chinook salmon adult immigration conditions in the Sacramento River would be undetectable relative to the NAA.

For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, results of the water temperature thresholds analysis show that adverse effects to Sacramento River fall-run Chinook salmon adults during upstream migration are unlikely to occur, except for during critical water years (Table 2-107 through Table 2-109). The 68°F threshold for the protection of adult immigration is expected to be exceeded in critical water years at Keswick, Bend Bridge, and Red Bluff. The percentage of days that exceed the threshold in critical years ranges up to 2% at Keswick, 33% at Bend Bridge, and 55% at Red Bluff. The only other occurrences of the 68°F threshold being exceeded were at Red Bluff during below normal and dry years, but each of those were for less than 1% of the days during September. Overall, these temperature threshold analysis results indicate that adverse water temperature-related effects on fall-run Chinook salmon adult immigration in the Sacramento River would be limited to critical water years.

Table 2-107. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Immigration, Sacramento River at Keswick, 68°F 7DADM.

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	2.2	2.2	0	3	3	NA	0.38	NA
	All	0.0	0.3	0.3	0	3	3	NA	0.38	NA
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-108. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Immigration, Sacramento River at Bend Bridge, 68°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	11.6	16.7	5.1	56	81	25	1.30	1.31	0
	All	1.7	2.4	0.7	56	81	25	1.30	1.31	0
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	28.1	33.3	5.3	163	203	40	1.61	1.69	0.08
	All	4.1	4.9	0.8	163	203	40	1.61	1.69	0.08
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	3.2	1.9	-1.3	10	5	-5	0.83	0.71	-0.12
	All	0.5	0.3	-0.2	10	5	-5	0.83	0.71	-0.12
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-109. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Immigration, Sacramento River at Red Bluff, 68°F 7DADM.

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	21.0	21.2	0.3	101	129	28	1.29	1.63	0.34
	All	3.1	3.1	0.0	101	129	28	1.29	1.63	0.34
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.6	0.6	0	1	1	NA	0.5	NA
	D	0.8	0.5	-0.3	1	1	0	0.20	0.33	0.13
	C	51.1	55.0	3.9	408	476	68	2.22	2.40	0.19
	All	7.7	8.3	0.6	409	478	69	2.16	2.35	0.19
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	10.5	9.7	-0.8	49	31	-18	1.26	0.86	-0.40
	All	1.6	1.4	-0.1	49	31	-18	1.26	0.86	-0.40
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Water temperature-related impacts to Sacramento River fall-run Chinook salmon adult holding were evaluated with a thresholds analysis using the USEPA's 7DADM threshold value of 61°F for the holding months of July and August at Keswick, Balls Ferry, and Red Bluff.

Results of the water temperature thresholds analysis are presented in BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E-12 through 5.E-14. At Keswick and Red Bluff, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and no more-than-0.5°F difference in the magnitude of average daily exceedance (BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E.1-12 and Table 5.E.1-14).

At Bend Bridge, there would be two instances during which the percent of days exceeding the 68°F DADM under the PA would be more than 5% higher than under the NAA: August in critical years (5.1% higher under the PA) and September of critical years (5.3% higher under the PA) (BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E.1-13). However, there would be a negligible (less than 0.1°F) difference in average daily exceedance in both instances. Therefore, it was concluded that any adverse effects on fall-run adult immigration, relative to the NAA, would be undetectable.

For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, at Keswick, adverse effects to holding fall-run Chinook salmon are expected only during September of critical water years, during which 32.5% of the days would exceed the 61° threshold. The occurrence of water temperature threshold exceedances increases slightly moving downstream to Balls Ferry where adverse effects to holding fall-run Chinook salmon are expected only during critical water years for 12.1% of the days in July and for 42.5% of the days in August. Thermal conditions for holding fall-run Chinook salmon become much worse at Red Bluff. There adverse effects would be expected in all water years in July and August with the 61°F threshold being exceeded up to 79% of the days in August of critical years. See Table 2-110 through Table 2-112.

Table 2-110. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Holding, Sacramento River at Keswick, 61°F 7DADM.

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.3	0.0	-0.3	0	0	0	0	NA	NA
	All	0.0	0.0	0.0	0	0	0	0	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	32.8	32.5	-0.3	245	269	24	2.01	2.22	0.21
	All	4.8	4.8	0.0	245	269	24	2.01	2.22	0.21

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-111. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Holding, Sacramento River at Balls Ferry, 61°F 7DADM.

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	9.7	12.1	2.4	54	65	11	1.50	1.44	-0.06
	All	1.4	1.8	0.4	54	65	11	1.50	1.44	-0.06
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	2.3	0.2	-2.1	4	0	-4	0.29	0.10	-0.19
	C	46.0	42.5	-3.5	799	802	3	4.67	5.08	0.40
	All	7.3	6.3	-1.0	803	802	-1	4.34	5.04	0.70

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-112. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Holding, Sacramento River at Red Bluff, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jul	W	8.4	8.4	0.0	46	46	0	0.68	0.68	0.00
	AN	0.5	0.2	-0.2	1	1	0	0.50	1.00	0.50
	BN	5.0	2.9	-2.1	7	4	-3	0.41	0.40	-0.01
	D	10.5	9.5	-1.0	28	19	-9	0.43	0.32	-0.11
	C	66.1	72.6	6.5	470	548	78	1.91	2.03	0.12
	All	3.6	3.7	0.1	552	618	66	1.39	1.51	0.13
Aug	W	18.0	15.9	-2.1	134	117	-17	0.92	0.91	-0.01
	AN	12.7	9.7	-3.0	47	20	-27	0.92	0.51	-0.41
	BN	15.2	24.6	9.4	22	53	31	0.42	0.63	0.21
	D	57.7	51.6	-6.1	519	391	-128	1.45	1.22	-0.23
	C	85.5	79.0	-6.5	1,363	1,311	-52	4.29	4.46	0.17
	All	7.4	7.1	-0.3	2,085	1,892	-193	2.26	2.19	-0.07

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold

Overall, the monthly temperature results, exceedance plots, and threshold analysis collectively indicate that thermal impacts on fall-run Chinook salmon adult immigration and holding will largely be the same with implementation of either the NAA or PA.

Adverse thermal effects on these life stages resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects.

It is important to note that adverse effects indicated by the modeling could to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process could minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

It is important to note that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

2.5.1.2.1.5.1.2 Late Fall-run Chinook Salmon

Late fall-run Chinook salmon exposure and risk to warm water temperatures occurring in the Sacramento River under the PA are discussed below by life stage in the following order: (1) spawning, egg incubation, and alevin development; (2) fry and juvenile rearing and outmigration; and (3) adult immigration. Much of the following analysis is taken directly from the BA.

Spawning, Egg Incubation, and Alevin Development

Sacramento River late fall-run Chinook salmon spawn from Keswick Dam to Princeton Ferry, with the vast majority occurring upstream from Battle Creek (Table 2-113). Fall-run Chinook salmon eggs and alevins occur in the Sacramento River from the time when spawning begins in December through fry emergence in June (BA).

Table 2-113. Spatial Distribution of Spawning Redds in the Sacramento River Based on Aerial Redd Surveys, Late Fall-run Chinook Salmon, 2003–2014. (Source: BA, initial source is CDFW)

Reach	Mean Annual Percent of Total Redds Sighted
Keswick to ACID Dam	67.6
ACID Dam to Highway 44 Bridge	5.0
Highway 44 Bridge to Airport Road Bridge	3.7
Airport Rd. Bridge to Balls Ferry Bridge	7.9
Balls Ferry Bridge to Battle Creek	5.2
Battle Creek to Jelly's Ferry Bridge	2.8
Jelly's Ferry Bridge to Bend Bridge	1.0
Bend Bridge to Red Bluff Diversion Dam	0.5
Below Red Bluff Diversion Dam	6.2

ACID = Anderson-Cottonwood Irrigation District

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures were evaluated during the December through June spawning, egg incubation, and alevin period for late fall-run Chinook salmon. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F) throughout the spawning reach of Keswick to Red Bluff in all months of the period and water year types (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Result, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8). The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F, or up to 0.7%, and would occur during May of below normal water years at Keswick, above Clear Creek, Balls Ferry, and Bend Bridge. These largest increases during May would not occur during the period of peak presence of spawners, eggs, and alevins.

Temperature Threshold Analysis

To evaluate water temperature threshold exceedance during the spawning, egg incubation, and alevin life stages between Keswick and Red Bluff, the USEPA's 7DADM threshold value of 55.4°F was used (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately.

Detailed results of the water temperature thresholds analysis are presented in BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E.1-18 through Table 5.E.1-22. At Keswick, Bend Bridge, and Red Bluff, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold (BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Tables 5.E.1-18, 5.E.1-21, 5.E.1-22). Therefore, it was concluded that thermal impacts to late fall-run Chinook salmon spawning, egg incubation, and alevin development at Keswick under the PA are not expected to be different than those under the NAA.

At Clear Creek, the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during May of below normal years (6.2%) (BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E.1-19). There would also be a 1.3°F increase in the magnitude of average daily exceedance under the PA relative to the NAA during May of below normal years. Further examination of model outputs reveals that it is largely the result of a single year (1923), but there is no reason why the reservoir could not be operated similar to the NAA during real-time operations, particularly because water temperatures during June under the PA would be lower than those under the NAA. As a result, it was concluded that CALSIM provided spurious results for May of 1923 and, in reality, thermal impacts to late fall-run Chinook salmon spawning, egg incubation, and alevin development at Clear Creek under the PA are not expected to be different than those under the NAA.

At Balls Ferry, the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during May of below normal years (6.2%) (Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Table 5.E.1-20). There would also be a 0.6°F increase in the magnitude of average daily exceedance under the PA relative to the NAA during May of below normal years. Further examination of model outputs reveals that it is largely the result of a single year (1923), but there is no reason why the reservoir could not be operated similar to the NAA during real-time operations, particularly because water temperatures during June under the PA would be lower than those under the NAA. As a result, it was concluded that CALSIM provided spurious results for May of 1923 and, in reality, thermal impacts to late fall-run Chinook salmon spawning, egg incubation, and alevin development at Balls Ferry under the PA are not expected to be different than those under the NAA.

Overall, the thresholds analysis indicates that water temperature-related effects on late fall- run Chinook salmon spawning egg incubation, and alevin development under the PA are not expected to be different than those under the NAA. However, for purposes of the analysis in the Section 2.7 Integration and Synthesis section, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on at least a small proportion of late fall-run Chinook salmon eggs, given that the 55.4°F 7DADM threshold is exceeded at the beginning (December) and end of the life stage (May and June) in most water years even at the most upstream spawning reaches (BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Tables 5.E.1-18, 5.E.1-21, 5.E.1-22). The spatial and temporal distributions of both the water temperature threshold exceedances and late fall-run Chinook salmon spawning and egg incubation match up such that even in wet water year types it is likely that at least some eggs would be exposed to stressful water temperatures.

It is important to note that adverse effects indicated by the modeling could to some extent be minimized by real-time operational management described in the BA in Section 3.1.5 Real-Time Operations Upstream of the Delta, and Section 3.3.3 Real-Time Operational Decision-Making Process. Real-time operations does not typically consider water temperature impacts on late fall-run Chinook salmon, but the process is set up to do so and the precedent of considering non-listed species in real-time water temperature operations decisions has been set for the CVP. On the American River, real-time operational decisions related to water temperature management consider the thermal requirements of fall-run Chinook salmon spawning adults and eggs every summer and fall.

NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling could be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process could minimize adverse effects on late fall-run Chinook salmon indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Reclamation’s Egg Mortality Model

The Reclamation Egg Mortality Model provides temperature-related estimates of late fall-run egg mortality in the Sacramento River (see BA Attachment 5.D.1, Reclamation Egg Mortality Model, for full model description). As noted above in the water temperature analyses for the other Chinook salmon runs, this egg mortality model is based on a relationship between temperature and Chinook salmon egg mortality that likely substantially underestimates actual mortality in the field. Nevertheless, it is used to compare late fall-run Chinook salmon egg mortality between the PA and NAA because results from the SWFSC’s temperature-dependent egg mortality model were not available for late fall-run Chinook salmon.

Results of the model are presented in Table 2-114 and Figure 2-48 through 2-53. Because the egg life stage has the highest potential effect on the propagation of population size in a life cycle context, a conservative value of a more-than-2% change in percent of total individuals (on a raw scale) was considered a detectable effect. The results indicate that there would be negligible differences in mortality (<0.3%) between the NAA and PA for all water year types combined and for each water year type separately.

However, for purposes of the analysis in the Section 2.7 Integration and Synthesis section, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on late fall-run Chinook salmon eggs. Egg mortality ranges from 2.1% in above normal water years to 4.7% in critical water years (Table 2-114). As previously discussed, based on Martin et al. (2016), Reclamation's egg mortality model likely underestimates egg mortality.

It is important to note that adverse effects indicated by the modeling could to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process (see further discussion in the Temperature Thresholds Analysis section immediately above).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

Table 2-114. Late Fall-run Chinook Salmon Egg Mortality (Percent of Total Individuals) and Differences (Percent Differences) between Model Scenarios, Reclamation Egg Mortality Model.

WYT	NAA	PA	PA vs. NAA
Wet	3.1	2.9	-0.1 (-5%)
Above Normal	2.4	2.1	-0.3 (-13%)
Below Normal	2.5	2.4	-0.1 (-5%)
Dry	2.7	2.6	-0.03 (-1%)
Critical	4.8	4.7	-0.1 (-2%)
All	3.0	2.9	-0.1 (-4%)

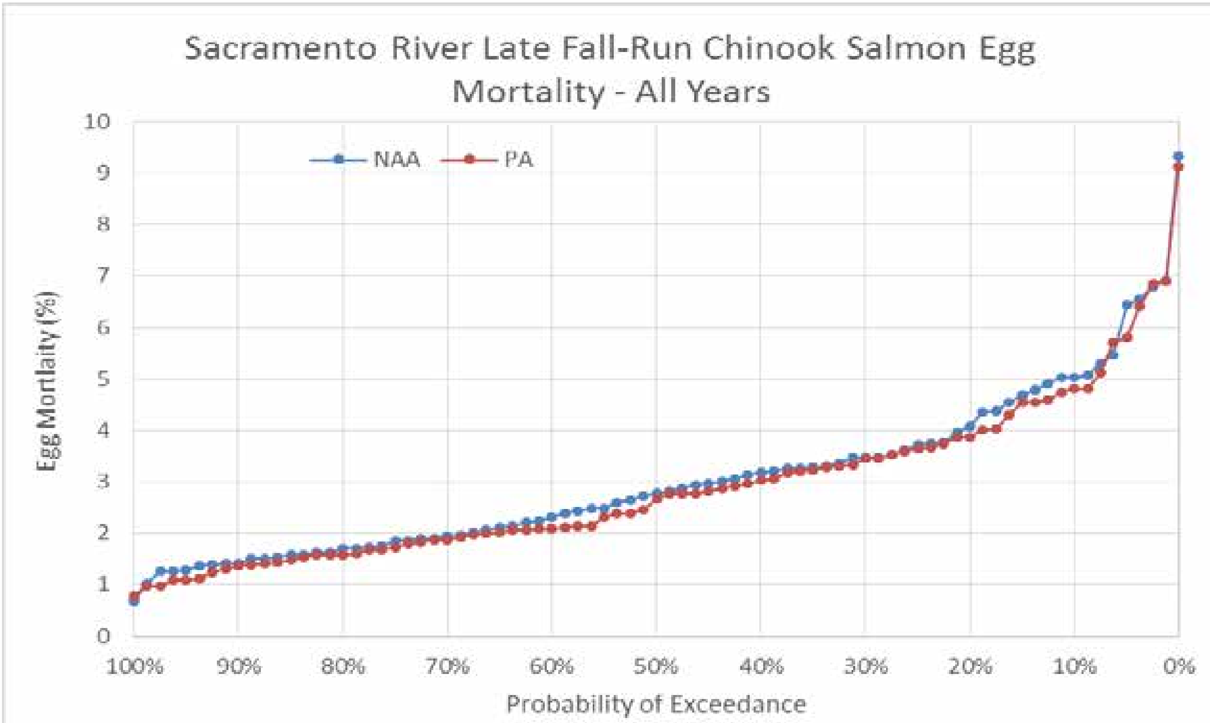


Figure 2-48. Exceedance Plot of Late Fall-run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, All Water Years.

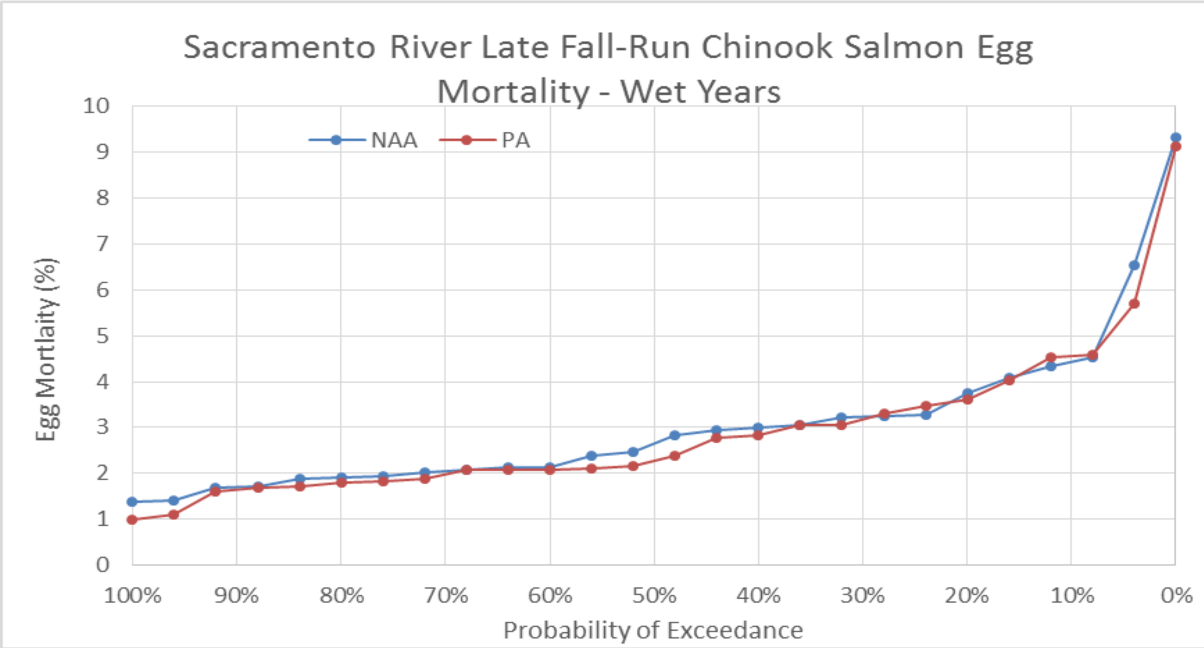


Figure 2-49. Exceedance Plot of Late Fall-run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Wet Water Years.

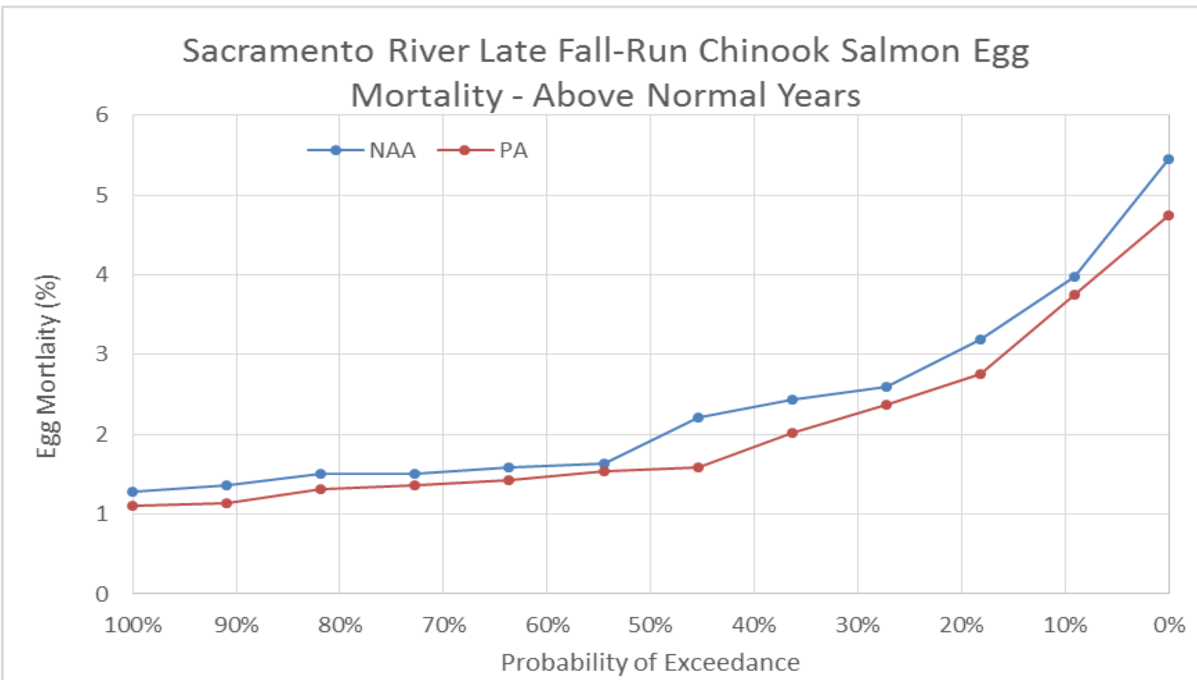


Figure 2-50. Exceedance Plot of Late Fall-run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Above Normal Water Years.

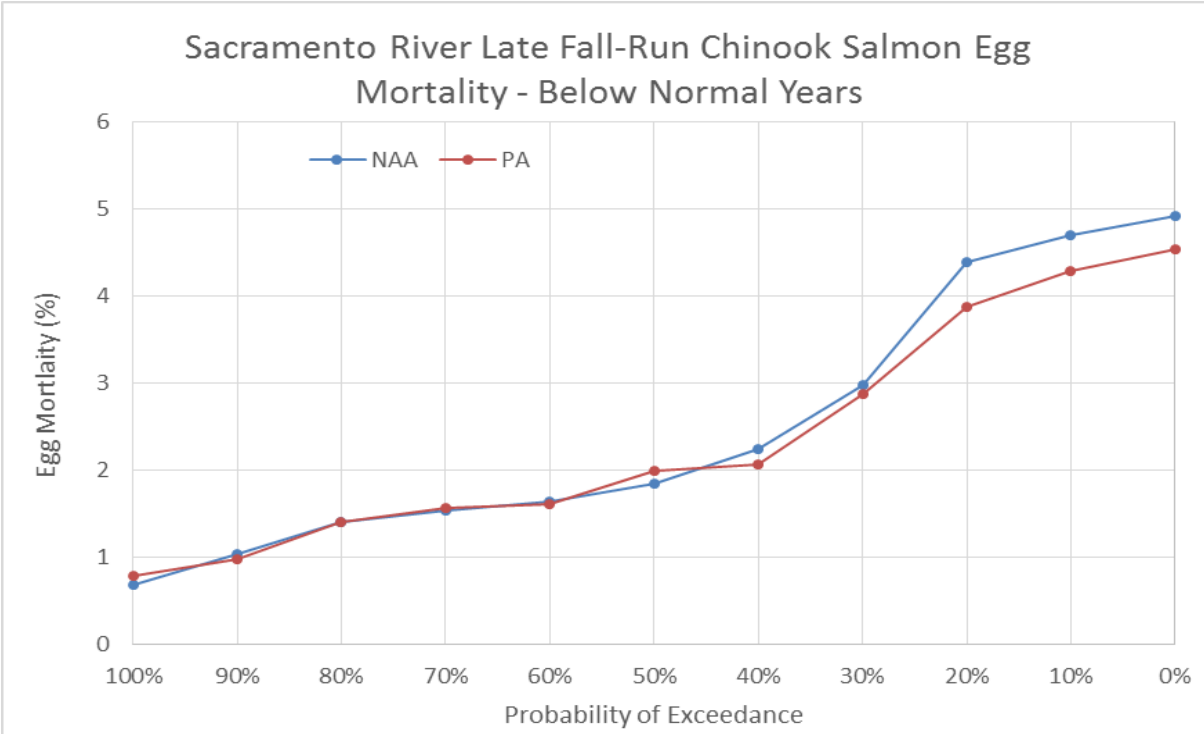


Figure 2-51. Exceedance Plot of Late Fall-run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Below Normal Water Years.

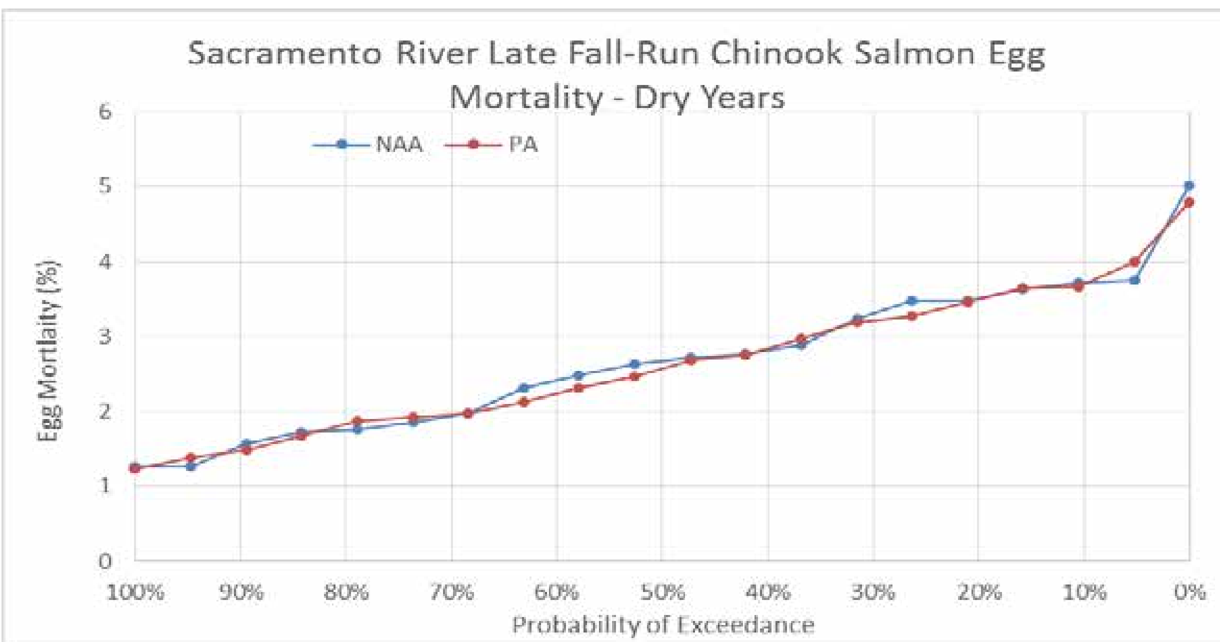


Figure 2-52. Exceedance Plot of Late Fall-run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Dry Water Years.

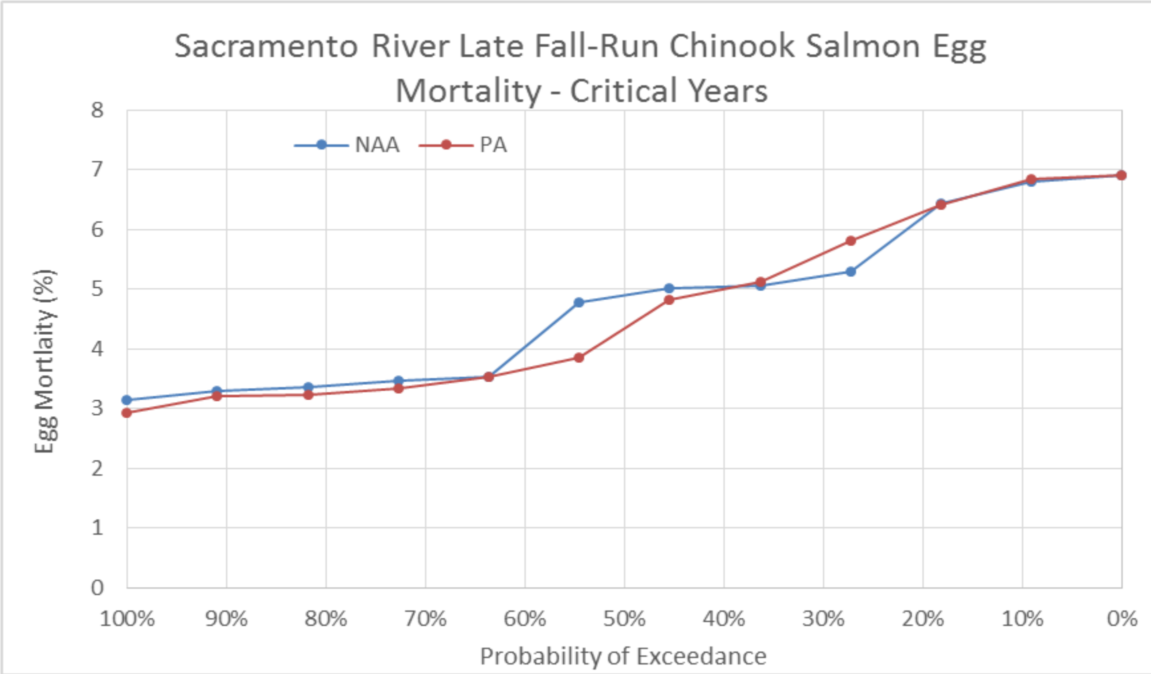


Figure 2-53. Exceedance Plot of Late Fall-run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Critical Water Years.

SALMOD

The SALMOD model provides predicted water temperature-related mortality of late fall-run Chinook salmon eggs and alevins the Sacramento River. This water temperature-related mortality of late fall-run Chinook salmon eggs and alevins is split up as pre-spawn (in vivo, or in the mother before spawning) and egg (in the gravel) mortality (see BA Attachment 5.D.2, SALMOD Model, for full details). The annual exceedance plot of temperature-related mortality of late fall-run Chinook salmon eggs and alevins is presented in Figure 2-54. The model indicates that, combining all water year types, water temperature-related mortality of the egg and alevin life stages would decrease by 14 fish (~0%) under the PA relative to the NAA. Within this life stage, there would be no difference in pre-spawn mortality (0 fish in both scenarios, and a decrease in egg mortality of 14 fish (~0%). Within individual water year types, only below normal water years would have an increase in mortality (2,649 eggs, or 223%), which is a negligible quantity of eggs considering the starting value of eggs is 13,325,000. As a result, it is concluded that the SALMOD Model shows that mortality of late fall- run Chinook salmon eggs and alevins under the PA is not expected to be different than under the NAA.

However, for purposes of the analysis in the Section 2.7 Integration and Synthesis section, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on late fall-run Chinook salmon eggs and alevins. As indicated by Figure 2-54, water temperature related mortality increases from near zero starting with roughly the warmest 30 percent of years and increases up to almost 200,000 in the warmest years.

It is important to note that adverse effects indicated by the modeling could to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-

Making Process (see further discussion in the late fall-run Chinook Salmon Temperature Thresholds Analysis section above).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

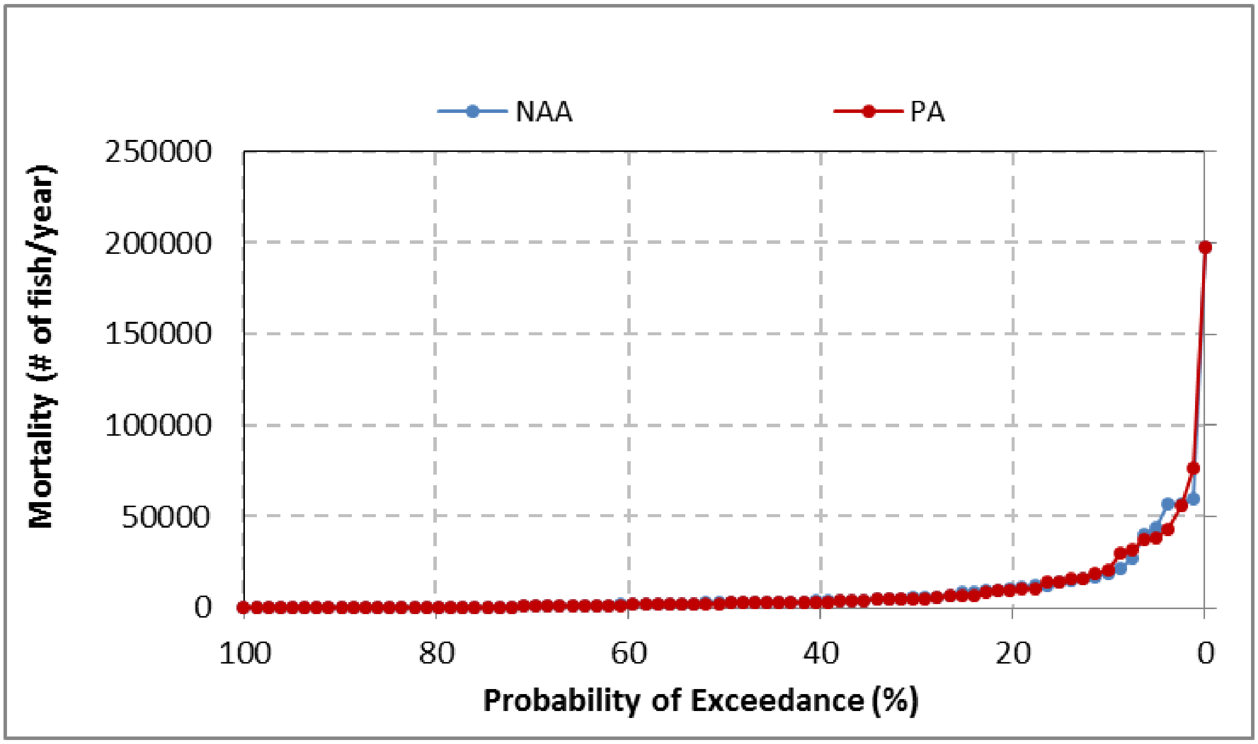


Figure 2-54. Exceedance Plot of Annual Water Temperature-Based Mortality (#of Fish/Year) of Late Fall-run Chinook Salmon Spawning, Egg Incubation, and Alevins Estimated with SALMOD.

Fry and Juvenile Rearing and Outmigration

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures were evaluated during the March through July fry and juvenile primary rearing period for late fall-run Chinook salmon in the Sacramento River upstream of the Delta. Overall, the PA would change mean water temperatures very little (predominantly less than 0.4°F) throughout the fry and juvenile rearing reach of Keswick to Knights Landing in all months and water year types in the period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7- 7, Table 5.C.7-8, Table 5.C.7-10). The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.4°F (0.6%), and would occur at Knights Landing in critical water years during July.

Exceedance plots of monthly mean water temperatures were examined during each month and water year type throughout the juvenile rearing period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7). The curves for the PA generally match those of the NAA. Further examination of critical water years in July at Knights Landing, where the largest increase in mean monthly water temperature was seen, indicates that water temperatures under the PA would be higher than those under NAA for the middle portion of the exceedance range (approximately 40% to 80%) by up to approximately 1°F and similar between scenarios throughout the remainder of the exceedance range (Figure 2-55).

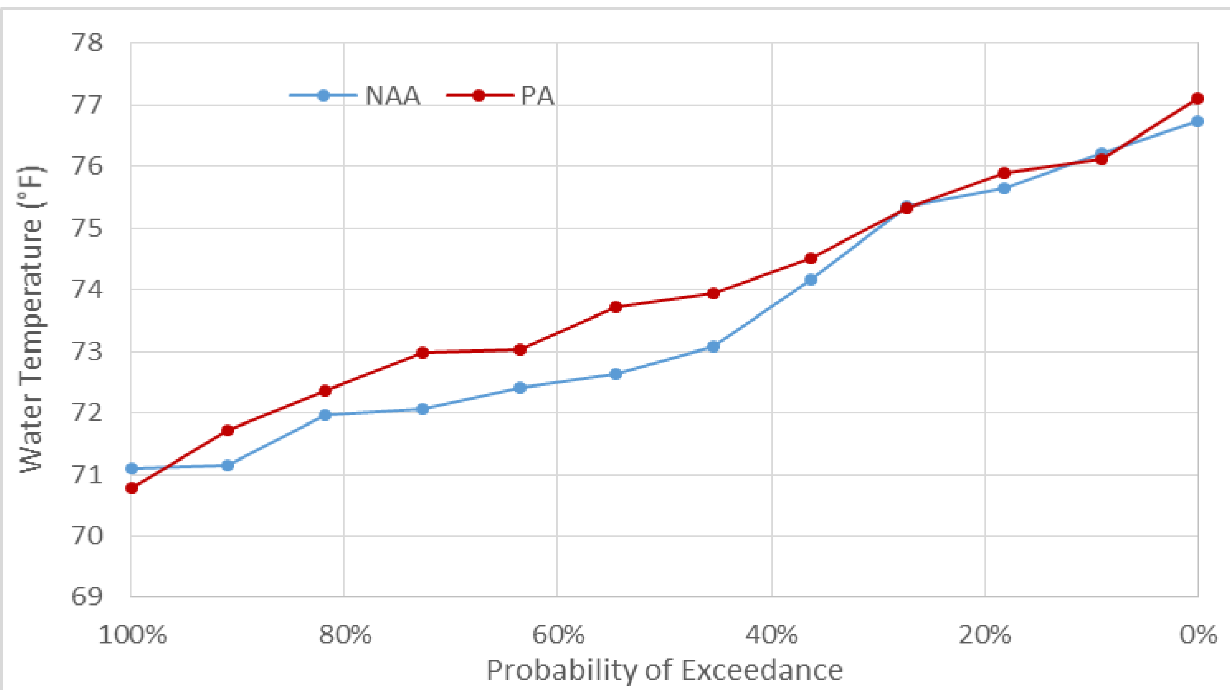


Figure 2-55. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Knights Landing in July of Critical Water Years.

Temperature Threshold Analysis

For purposes of this analysis, the water temperature thresholds analysis for late fall-run Chinook salmon fry and juvenile rearing and emigration were combined and the period of March through January was evaluated. For this analysis, the thresholds used were from the USEPA's 7DADM value of 61°F for core juvenile rearing reach from Keswick to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing. The 7DADM values were converted to function with daily model outputs for each month separately (BA Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-4).

Results of the water temperature thresholds analysis are presented below for Keswick, Clear Creek, Balls Ferry, Bend, Red Bluff, and Knights Landing. At Keswick, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold (Table 2-115). There would be two instances in which average daily exceedance would be 0.5°F: September of critical years and September for all water year types combined (reflecting that the only differences in threshold exceedance among water year types during September would occur during critical years). However, there would be no concomitant increase in the percent of days exceeding the threshold in these instances. Therefore, it was concluded that there would be no effect under the PA at Keswick, relative to the NAA.

Table 2-115. Water Temperature Threshold Analysis Results, Late Fall-run Chinook Salmon, Juvenile Rearing and Emigration, Sacramento River at Keswick, 61°F 7DADM.[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.3	0.0	-0.3	0	0	0	0.00	NA	NA
	All	0.0	0.0	0.0	0	0	0	0.00	NA	NA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	32.8	32.5	-0.3	245	269	24	2.01	2.22	0.21
	All	4.8	4.8	0.0	245	269	24	2.01	2.22	0.21
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	64.4	60.0	-4.4	857	909	52	3.69	4.21	0.51
	All	9.4	8.8	-0.7	857	909	52	3.69	4.21	0.51
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	52.7	49.5	-3.2	450	407	-43	2.30	2.21	-0.08
	All	7.8	7.3	-0.5	450	407	-43	2.30	2.21	-0.08

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.6	0.0	-0.6	1	0	-1	NA	NA	NA
	All	0.1	0.0	-0.1	1	0	-1	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Notes:
1 7DADM = Seven-day average daily maximum
2 Only includes days on which temperature exceeded threshold
3 NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

At Clear Creek, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Table 2-116). However, the percent of days exceeding the threshold under the PA would be more than 5% lower than under the NAA during September and October of critical water years (6.7% and 11.8%, respectively). Despite this reduction during September of critical water years, the difference in mean daily exceedance would increase by 0.67°F. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances per day would be higher on average.

Table 2-116. Water Temperature Threshold Analysis Results, Late Fall-run Chinook Salmon, Juvenile Rearing and Emigration, Sacramento River at Clear Creek, 61°F 7DADM.[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	3.0	3.2	0.3	10	9	-1	0.91	0.75	-0.16
	All	0.4	0.5	0.0	10	9	-1	0.91	0.75	-0.16

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	41.1	39.2	-1.9	543	565	22	3.55	3.87	0.32
	All	6.0	5.7	-0.3	543	565	22	3.55	3.87	0.32
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	73.1	66.4	-6.7	1,458	1,484	26	5.54	6.21	0.67
	All	10.7	9.7	-1.0	1,458	1,484	26	5.54	6.21	0.67
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	79.8	68.0	-11.8	903	801	-102	3.04	3.17	0.13
	All	11.8	10.1	-1.8	903	801	-102	3.04	3.17	0.13
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	5.8	4.2	-1.7	13	9	-4	0.62	0.60	-0.02
	All	0.9	0.6	-0.2	13	9	-4	0.62	0.60	-0.02
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Notes:
1 7DADM = Seven-day average daily maximum
2 Only includes days on which temperature exceeded threshold
3 NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

At Balls Ferry, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the 61°F 7DADM threshold, and no more-than-0.5°F difference in the magnitude of average daily exceedance (Table 2-117). Therefore, it was concluded that there would be no effect under the PA, relative to the NAA. There are also two situations at Balls Ferry during which the percent of days exceeding the threshold under the PA would be more than 5% lower than under the NAA during September and October of critical water years (10% and 14%, respectively). Despite this reduction during September of critical water years, the difference in mean daily exceedance would increase by 0.71°F. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances per day would be higher on average.

Table 2-117. Water Temperature Threshold Analysis Results, Late Fall-run Chinook Salmon, Juvenile Rearing and Emigration, Sacramento River at Balls Ferry, 61°F 7DADM[1].

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	0.7	0.7	0.0	3	3	0	0.50	0.50	0
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.2	0.2	0	0	0	NA	0	NA
	C	1.1	1.1	0.0	2	1	-1	0.50	0.25	-0.25
	All	0.4	0.4	0.0	5	4	-1	0.50	0.36	-0.14
Jun	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.6	0.3	-0.3	0	0	0	0	0	0
	All	0.1	0.0	0.0	0	0	0	0	0	0
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	9.7	12.1	2.4	54	65	11	1.50	1.44	-0.06
	All	1.4	1.8	0.4	54	65	11	1.50	1.44	-0.06
Aug	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	2.3	0.2	-2.1	4	0	-4	0.29	0	-0.29

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	C	46.0	42.5	-3.5	799	802	3	4.67	5.08	0.40
	All	7.3	6.3	-1.0	803	802	-1	4.34	5.04	0.70
Sep	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	3.9	6.1	2.1	6	13	7	0.46	0.65	0.19
	D	12.2	11.0	-1.2	52	37	-15	0.71	0.56	-0.15
	C	83.9	73.9	-10.0	1,667	1,658	-9	5.52	6.23	0.71
	All	15.8	14.3	-1.5	1,725	1,708	-17	4.45	4.85	0.41
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.2	0.2	0	0	0	NA	0	NA
	C	76.6	62.6	-14.0	827	742	-85	2.90	3.18	0.28
	All	11.4	9.3	-2.0	827	742	-85	2.90	3.17	0.27
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	4.4	4.2	-0.3	8	7	-1	0.50	0.47	-0.03
	All	0.7	0.6	0.0	8	7	-1	0.50	0.47	-0.03
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Notes:
1 7DADM = Seven-day average daily maximum
2 Only includes days on which temperature exceeded threshold
3 NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

At Bend Bridge, the percent of days exceeding the 61°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during July of critical water years (7.8%), August (5.9%) and September of below normal (15.8%) and dry (8.0%) water years (Table 2-118). There would also be a reduction in the percent of days exceeding the threshold of 8.4% and 11.6% in August of dry and critical water years, respectively, and of 11% in October of critical water years. There would not be an increase in average daily exceedance except in August of critical water years. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances per day would be higher on average.

Table 2-118. Water Temperature Threshold Analysis Results, Late Fall-run Chinook Salmon, Juvenile Rearing and Emigration, Sacramento River at Bend Bridge, 61°F 7DADM.[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.2	0.2	0.0	1	1	0	1.00	1.00	0.00
	C	0.3	0.3	0.0	1	0	-1	1.00	0	-1.00
	All	0.1	0.1	0.0	2	1	-1	1.00	0.50	-0.50
May	W	6.2	6.2	0.0	50	50	0	1.00	1.00	0.00
	AN	5.5	5.5	0.0	26	26	0	1.18	1.18	0.00
	BN	0.3	2.9	2.6	0	7	7	0	0.70	0.70
	D	9.4	7.7	-1.6	66	55	-11	1.14	1.15	0.01
	C	9.4	9.4	0.0	36	32	-4	1.03	0.91	-0.11
	All	6.5	6.5	0.0	178	170	-8	1.07	1.03	-0.04
Jun	W	5.3	5.5	0.3	36	37	1	0.88	0.86	-0.02
	AN	4.4	4.4	0.0	16	16	0	0.94	0.94	0.00
	BN	3.6	3.3	-0.3	10	10	0	0.83	0.91	0.08
	D	0.3	0.2	-0.2	1	0	-1	0.50	0	-0.50
	C	29.7	26.9	-2.8	113	79	-34	1.06	0.81	-0.24
	All	7.3	6.9	-0.4	176	142	-34	0.98	0.84	-0.14
Jul	W	3.3	3.7	0.4	7	7	0	0.26	0.23	-0.03
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	1.2	0.6	-0.6	1	0	-1	0.25	0	-0.25
	D	1.3	1.1	-0.2	1	1	0	0.13	0.14	0.02
	C	56.2	64.0	7.8	332	384	52	1.59	1.61	0.02
	All	9.8	10.9	1.1	341	392	51	1.38	1.42	0.04

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	4.1	3.8	-0.2	21	22	1	0.64	0.71	0.07
	AN	2.7	0.5	-2.2	6	0	-6	0.55	0	-0.55
	BN	0.6	6.5	5.9	1	8	7	0.50	0.36	-0.14
	D	33.1	24.7	-8.4	206	118	-88	1.00	0.77	-0.23
	C	77.2	65.6	-11.6	1,107	1,090	-17	3.86	4.47	0.61
	All	21.2	17.8	-3.4	1,341	1,238	-103	2.49	2.74	0.25
Sep	W	0.8	0.5	-0.3	4	1	-3	0.67	0.25	-0.42
	AN	0.8	0.0	-0.8	1	0	-1	0.33	NA	NA
	BN	26.1	41.8	15.8	85	159	74	0.99	1.15	0.16
	D	46.8	54.8	8.0	469	517	48	1.67	1.57	-0.10
	C	93.9	92.2	-1.7	1,897	1,882	-15	5.61	5.67	0.06
	All	29.0	32.6	3.6	2,456	2,559	103	3.44	3.19	-0.25
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	1.8	1.3	-0.5	5	4	-1	0.45	0.50	0.05
	C	69.6	58.6	-11.0	757	685	-72	2.92	3.14	0.22
	All	10.8	9.0	-1.8	762	689	-73	2.82	3.05	0.23
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	1.7	1.9	0.3	2	2	0	0.33	0.29	-0.05
	All	0.2	0.3	0.0	2	2	0	0.33	0.29	-0.05
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Notes:
1 7DADM = Seven-day average daily maximum
2 Only includes days on which temperature exceeded threshold
3 NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

At Red Bluff, the percent of days exceeding the 61°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during July of critical water years (6.5%), August of below normal years (9.4%), and September of above normal (7.7%), below normal (10.3%), and dry (5.5%) water years (Table 2-119). However, in no month or water year type would there be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no effect at Red Bluff under the PA, relative to the NAA.

Table 2-119. Water Temperature Threshold Analysis Results, Late Fall-run Chinook Salmon, Juvenile Rearing and Emigration, Sacramento River at Red Bluff, 64°F 7DADM.[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
May	W	1.2	1.2	0.0	11	11	0	1.10	1.10	0
	AN	2.0	2.0	0.0	8	8	0	1.00	1.00	0
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	2.7	2.1	-0.6	12	10	-2	0.71	0.77	0.06
	C	3.2	2.7	-0.5	6	5	-1	0.50	0.50	0
	All	1.8	1.6	-0.2	37	34	-3	0.79	0.83	0.04
Jun	W	0.9	0.9	0.0	6	6	0	0.86	0.86	0
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	3.9	1.9	-1.9	7	4	-3	0.50	0.57	0.07
	All	0.9	0.6	-0.3	13	10	-3	0.62	0.71	0.10
Jul	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	12.6	17.7	5.1	46	62	16	0.98	0.94	-0.04
	All	1.8	2.6	0.7	46	62	16	0.98	0.94	-0.04

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	0.2	0.2	0.0	0	0	0	0	0	0
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	6.1	1.8	-4.4	22	4	-18	0.58	0.36	-0.22
	C	43.0	44.9	1.9	624	632	8	3.90	3.78	-0.12
	All	7.9	7.1	-0.8	646	636	-10	3.23	3.53	0.30
Sep	W	0.4	0.0	-0.4	1	0	-1	0.33	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	14.5	26.1	11.5	50	93	43	1.04	1.08	0.04
	D	33.5	39.3	5.8	333	363	30	1.66	1.54	-0.12
	C	90.0	87.2	-2.8	1,481	1,497	16	4.57	4.77	0.20
	All	23.4	25.9	2.4	1,865	1,953	88	3.24	3.07	-0.17
Oct	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	42.7	41.7	-1.1	420	393	-27	2.64	2.54	-0.11
	All	6.3	6.2	-0.2	420	393	-27	2.64	2.54	-0.11
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Notes:
1 7DADM = Seven-day average daily maximum
2 Only includes days on which temperature exceeded threshold
3 NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

At Knights Landing, the percent of days exceeding the 64°F 7DADM threshold for non-core rearing and emigration habitat under the PA would be more than 5% higher than under the NAA during October of wet water years (6.9%) (Table 2-120). There would also be a 7.9% reduction in the percent of days exceeding the threshold during October of below normal water years. However, in neither of these situations would there also be a more than 0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no effect under the PA, relative to the NAA.

Table 2-120. Water Temperature Threshold Analysis Results, Late Fall-run Chinook Salmon, Juvenile Rearing and Emigration, Sacramento River at Knights Landing, 64°F 7DADM.[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.5	0.5	0.0	1	1	0	0.33	0.33	0.00
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.1	0.1	0.0	1	1	0	0.33	0.33	0.00
Apr	W	5.1	5.1	0.0	35	35	0	0.88	0.88	0.00
	AN	9.2	9.0	-0.3	34	34	0	0.94	0.97	0.03
	BN	36.7	38.5	1.8	171	181	10	1.41	1.43	0.01
	D	22.2	21.2	-1.0	232	224	-8	1.74	1.76	0.02
	C	35.8	34.4	-1.4	209	203	-6	1.62	1.64	0.02
	All	18.7	18.4	-0.2	681	677	-4	1.48	1.49	0.01
May	W	72.2	72.3	0.1	2,517	2,536	19	4.32	4.35	0.03
	AN	87.8	87.8	0.0	1,768	1,759	-9	4.99	4.97	-0.03
	BN	96.5	97.1	0.6	1,538	1,561	23	4.67	4.72	0.04
	D	95.8	95.3	-0.5	3,299	3,065	-234	5.55	5.19	-0.37
	C	98.7	97.8	-0.8	2,152	2,114	-38	5.86	5.81	-0.06
	All	87.6	87.5	-0.1	11,274	11,035	-239	5.06	4.96	-0.10
Jun	W	98.7	98.7	0.0	5,886	5,747	-139	7.64	7.46	-0.18
	AN	100.0	100.0	0.0	3,022	2,769	-253	7.75	7.1	-0.65
	BN	100.0	100.0	0.0	2,354	2,143	-211	7.13	6.49	-0.64
	D	100.0	100.0	0.0	4,867	4,403	-464	8.11	7.34	-0.77
	C	100.0	100.0	0.0	3,262	3,080	-182	9.06	8.56	-0.51
	All	99.6	99.6	0.0	19,391	18,142	-1,249	7.91	7.40	-0.51
Jul	W	100.0	100.0	0.0	7,366	7,265	-101	9.14	9.01	-0.13
	AN	100.0	100.0	0.0	3,022	3,025	3	7.50	7.51	0.01
	BN	100.0	100.0	0.0	2,684	2,631	-53	7.87	7.72	-0.16
	D	100.0	100.0	0.0	5,472	5,535	63	8.83	8.93	0.10
	C	100.0	100.0	0.0	4,034	4,189	155	10.84	11.26	0.42
	All	100.0	100.0	0.0	22,578	22,645	67	8.88	8.91	0.03

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Aug	W	100.0	100.0	0.0	7,777	7,697	-80	9.65	9.55	-0.10
	AN	100.0	100.0	0.0	3,588	3,642	54	8.90	9.04	0.13
	BN	100.0	100.0	0.0	2,856	3,201	345	8.38	9.39	1.01
	D	100.0	100.0	0.0	6,423	6,282	-141	10.36	10.13	-0.23
	C	100.0	100.0	0.0	4,372	4,303	-69	11.75	11.57	-0.19
	All	100.0	100.0	0.0	25,016	25,125	109	9.84	9.88	0.04
Sep	W	82.6	84.1	1.5	2,229	2,272	43	3.46	3.46	0.00
	AN	99.7	100.0	0.3	1,815	2,149	334	4.67	5.51	0.84
	BN	100.0	100.0	0.0	2,886	3,144	258	8.75	9.53	0.78
	D	100.0	100.0	0.0	6,001	6,128	127	10.00	10.21	0.21
	C	100.0	100.0	0.0	4,223	4,261	38	11.73	11.84	0.11
	All	94.4	95.0	0.5	17,154	17,954	800	7.38	7.69	0.30
Oct	W	27.3	34.2	6.9	217	337	120	0.99	1.22	0.23
	AN	31.5	33.1	1.6	250	292	42	2.14	2.37	0.24
	BN	49.3	41.3	-7.9	444	406	-38	2.64	2.88	0.24
	D	57.1	52.7	-4.4	1,004	961	-43	2.84	2.94	0.10
	C	89.8	88.2	-1.6	1,545	1,558	13	4.63	4.75	0.12
	All	47.5	47.6	0.1	3,460	3,554	94	2.90	2.97	0.07
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	2.2	1.7	-0.6	6	5	-1	0.75	0.83	0.08
	All	0.3	0.2	-0.1	6	5	-1	0.75	0.83	0.08
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Notes:
1 7DADM = Seven-day average daily maximum
2 Only includes days on which temperature exceeded threshold
3 NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Overall, the thresholds analysis indicates that any adverse water temperature-related effects of the PA relative to the NAA on late fall-run Chinook salmon juvenile rearing and emigration would be undetectable. However, for purposes of the analysis in the Section 2.7 Integration and Synthesis section, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of late fall-run Chinook salmon juveniles. The 61°F 7DADM threshold for the core rearing reaches upstream of Red Bluff is exceeded primarily in only critical water years, and the 64°F 7DADM is exceeded at Red Bluff during the summer of drier years and is exceeded for the entire summer at Knights Landing by as much as 100% of the days in all water years (Tables 2-115 through 2-120).

It is important to note that adverse effects indicated by the modeling could to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process (see further discussion in the late fall-run Chinook salmon spawning and egg incubation Temperature Thresholds Analysis section above).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

SALMOD

The SALMOD model provides predicted water temperature-related fry and juvenile late fall-run Chinook salmon mortality, which is a combination of mortality of the fry, pre-smolt, and immature smolt life stages (see BA Attachment 5.D.2, SALMOD Model, for full model description). The annual exceedance plot is presented in Figure 2-56. These results indicate that there would be a 5,856 fish (5%) increase in water temperature-related mortality of late fall-run Chinook salmon fry and juveniles under the PA compared to the NAA. This increase would be seen mostly in below normal water years (3,824 fish, or 108%, increase). However, considering that the number of fish produced in the model each year is 13,325,000, these values of mortality would be very small and any adverse effects of the PA relative to the NAA on late fall-run Chinook salmon would be undetectable.

However, for purposes of the analysis in the Section 2.7 Integration and Synthesis section, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on late fall-run Chinook salmon during drier water year types. As indicated by Figure 2-56, water temperature related mortality increases from near zero starting with roughly the warmest 18% of years and increases up to almost 1,800,000 in the warmest years.

It is important to note that adverse effects indicated by the modeling could to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process (see further discussion in the late fall-run Chinook salmon spawning and egg incubation Temperature Thresholds Analysis section above).

Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater thermal stress beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emissions scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the proposed action combined with the environmental baseline and modeled climate change past 2030.

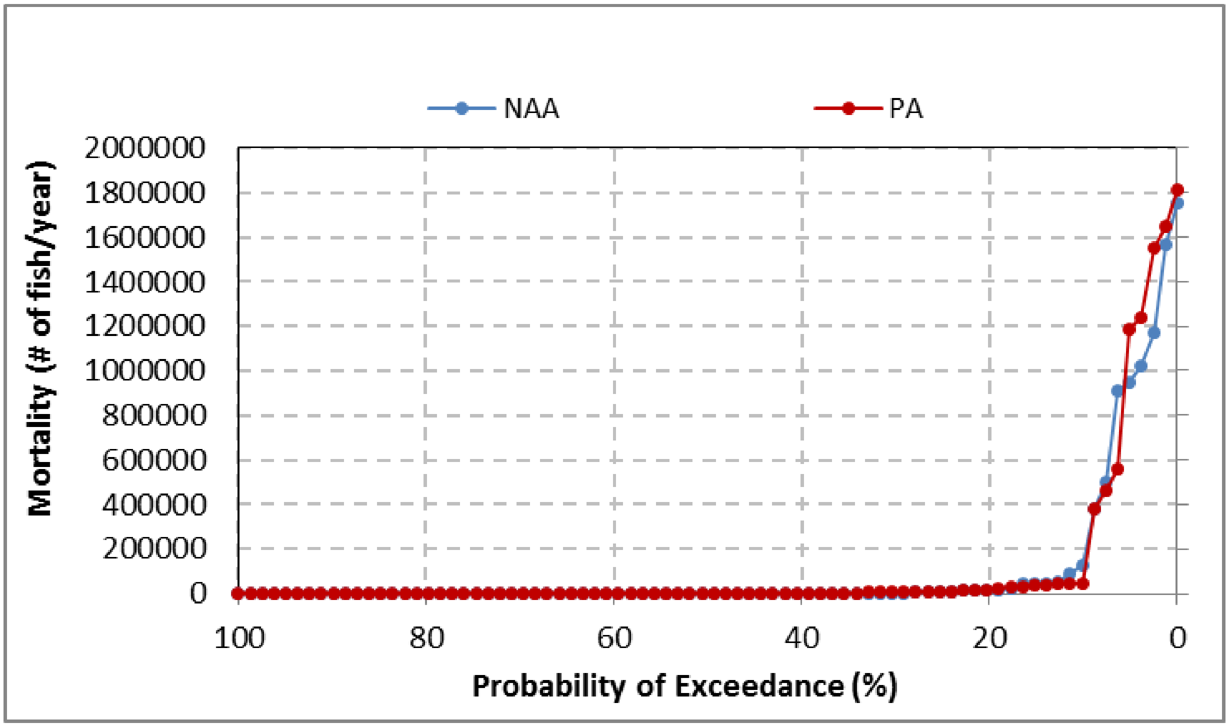


Figure 2-56. Exceedance Plot of Annual Water Temperature-Based Mortality (# of Fish/Year) of Late Fall-run Chinook Salmon Fry and Juveniles.

Adult Immigration

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures were evaluated in the Sacramento River at Keswick, Bend Bridge, and Red Bluff during the November through April adult immigration period for late fall-run Chinook salmon. Overall, the PA would change mean water temperatures very little (less than 1°F) at these locations in all months and water year types in the period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8).

The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4%, and would occur at Bend Bridge and Red Bluff in critical water years during February. Despite the increase, water temperatures would remain less than 52°F in both locations under both scenarios during this time, which is well below a temperature range of concern.

Exceedance plots of monthly mean water temperatures were examined during each month and water year type throughout the spawning and incubation period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The curves for the PA generally match those of the NAA. For critical years during February at Bend Bridge and Red Bluff, where the largest increase in mean monthly water temperature was seen, curves would be nearly identical between the NAA and PAA, except for 2 years in which the PA would be approximately 1°F higher (Figure 2-57, Figure 2-58). However, water temperatures would not differ in the large majority of years at both locations. Therefore, it is concluded that there would be no substantial water temperature differences between NAA and PA in February of critical water years at either location.

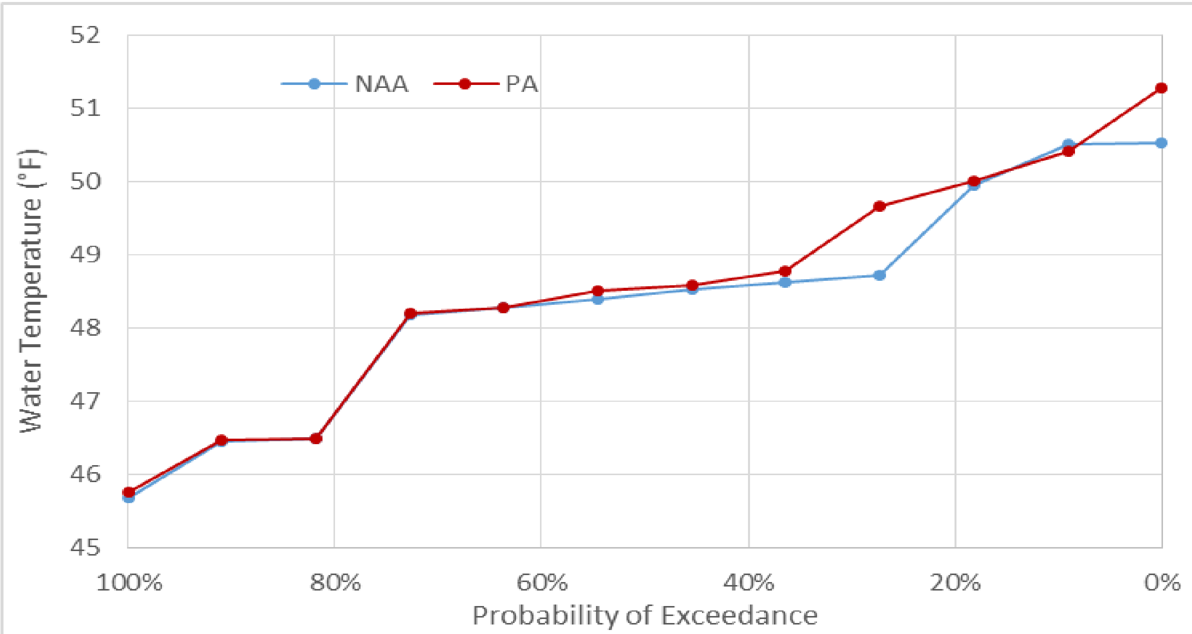


Figure 2-57. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in February of Critical Water Years.

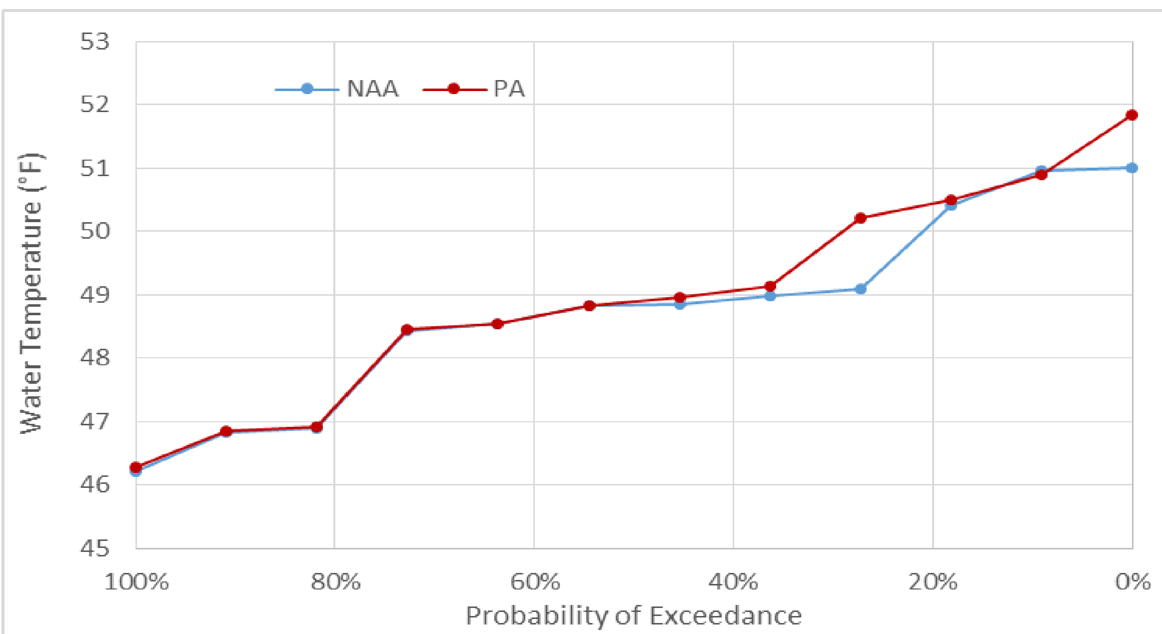


Figure 2-58. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in February of Critical Water Years.

Temperature Threshold Analysis

To evaluate water temperature threshold exceedance during the adult immigration life stage at Keswick, Bend Bridge, and Red Bluff, the USEPA's 7DADM threshold value of 68°F was used. The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-4).

Results of the water temperature thresholds analysis are presented in Tables 2-121 through 2-123. At all three locations, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance.

Table 2-121. Water Temperature Threshold Analysis Results, Late Fall-run Chinook Salmon, Adult Immigration, Sacramento River at Keswick, 68°F 7DADM.[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Notes:
1 7DADM = Seven-day average daily maximum
2 Only includes days on which temperature exceeded threshold
3 NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-122. Water Temperature Threshold Analysis Results, Late Fall-run Chinook Salmon, Adult Immigration, Sacramento River at Bend Bridge, 68°F 7DADM.[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Notes:
1 7DADM = Seven-day average daily maximum
2 Only includes days on which temperature exceeded threshold
3 NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-123. Water Temperature Threshold Analysis Results, Late Fall-run Chinook Salmon, Adult Immigration, Sacramento River at Red Bluff, 68°F 7DADM.[1]

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

Notes:
1 7DADM = Seven-day average daily maximum
2 Only includes days on which temperature exceeded threshold
3 NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Overall, these temperature threshold analysis results indicate that any water temperature-related adverse effects of the PA relative to the NAA on late fall-run Chinook salmon adult immigration conditions in the Sacramento River would be undetectable. Additionally, for purposes of the analysis in the Section 2.7 Integration and Synthesis section, the temperature thresholds analysis indicates that the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is not expected to result in adverse effects on late fall-run Chinook salmon immigration. The water temperature threshold value of 68°F 7DADM was not exceeded at any location in any month or any water year type.

SALMOD

The SALMOD model integrates all early life stages of late fall-run Chinook salmon race on an annual basis and provides an Annual Potential Production value (Attachment 5.D.2, SALMOD Model). This value represents all individuals that survive from the pre-spawn egg stage through the immature smolt stage in each year of the 80-year simulation period. Individual years are independent of one another and, therefore, effects through time cannot be evaluated as a time series.

Mean late fall-run Chinook salmon production values and differences between scenarios are presented in Table 2-124 and an exceedance plot is provided in Figure 2-59. Overall (all water year types), these results indicate that changes in late fall -run Chinook salmon production under the PA relative to the NAA would be negligible (1% difference). This result is consistent for the separate water year types (3% difference or less) as well.

Table 2-124. Mean Annual Potential Production of Late Fall-run Chinook Salmon and Differences Between Model Scenarios, SALMOD.

Analysis Period	Annual Potential Production (# of Fish/year)
All Water Year Types Combined	
Full Simulation Period[1]	
NAA	1,810,410
PA	1,797,449
Difference	-12,961
Percent Difference[2]	-1
Water Year Types[3]	
Wet (32.5%)	
NAA	1,983,169
PA	1,963,584
Difference	-19,584
Percent Difference	-1
Above Normal (12.5%)	
NAA	1,639,594
PA	1,633,821
Difference	-5,773
Percent Difference	0
Below Normal (17.5%)	
NAA	2,069,244
PA	2,019,856
Difference	-49,389
Percent Difference	-2
Dry (22.5%)	
NAA	1,801,338
PA	1,775,288
Difference	-26,050
Percent Difference	-1
Critical (15%)	
NAA	1,399,166
PA	1,448,020
Difference	48,854
Percent Difference	3

1 Based on the 80-year simulation period

2 Relative difference of the annual average

3 As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995). Water years may not correspond to the biological years in SALMOD.

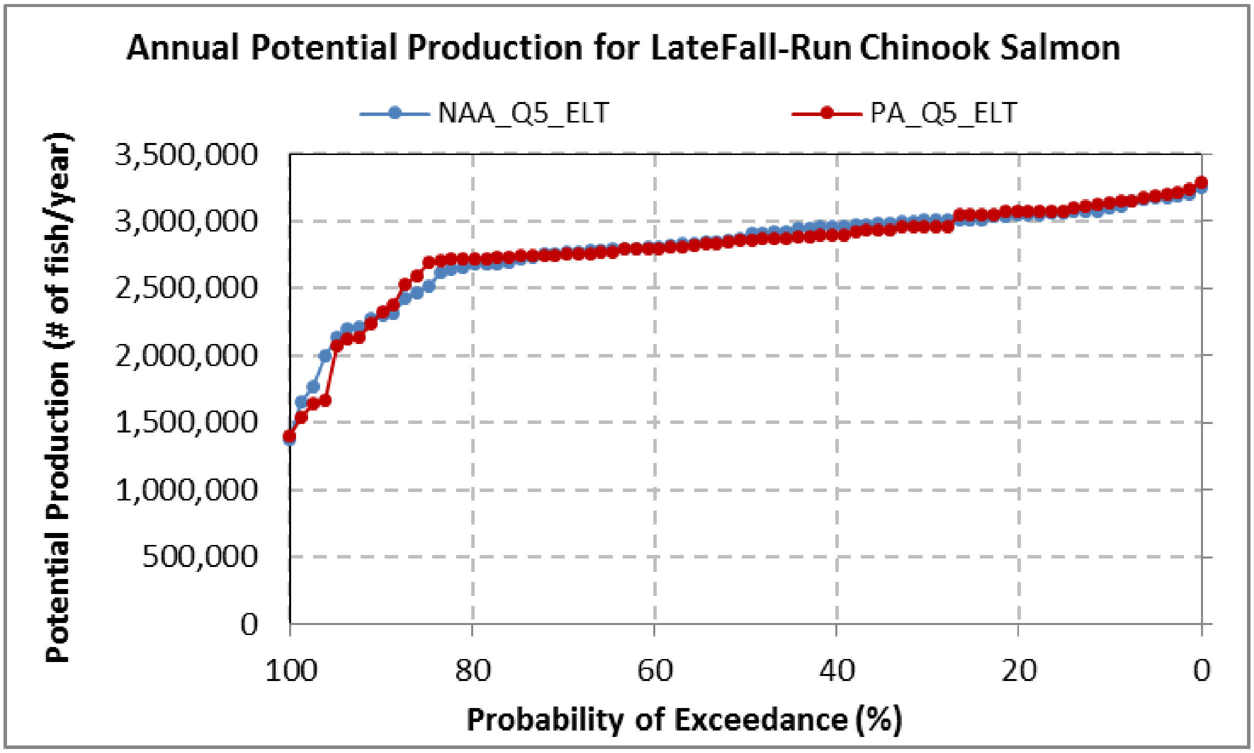


Figure 2-59. Exceedance Plot for Annual Potential Production (# of Fish/Year) of Late Fall-run Chinook Salmon, SALMOD.

The frequency at which annual production was below minimum production thresholds was evaluated as a measure of a worst-case scenario for late fall-run Chinook salmon. Thresholds were determined as 5% and 10% of the number of eggs used as inputs into the model. The initial egg value was 13,325,000 for both NAA and PA and, therefore, the 5% and 10% values were 666,250 fish per year and 1,332,500 fish per year, respectively. Results are presented in Table 2-125. There would be one less year (11% lower) under the PA compared to the NAA during which production would be below the 5% (666,250 fish) threshold. There would be two fewer years (20% lower) under the PA compared to the NAA during which production would be below the 10% (1,332,500 fish) threshold. Therefore, the PA would have no negative effects on the frequency of worst-case scenario years for late fall-run Chinook salmon, relative to the NAA.

Table 2-125. Number of Years During Which Late Fall-run Chinook Salmon Production Would be Lower than Production Thresholds and Differences (Percent Differences) Between Model Scenarios, SALMOD.

Production Threshold (# of Fish)	NAA (# of Years)	PA (# of Years)	PA vs. NAA (# of Years [%])
666,250 (based on 5% of eggs)	0	0	0 (NA[1])
1,332,500 (based on 10% of eggs)	0	0	0 (NA[1])

[1]NA = Could not be calculated because dividing by 0

2.5.1.2.1.5.2 American River

The analysis presented in this section is focused solely on fall-run Chinook salmon because late-fall Chinook salmon do not occur in the American River.

Spawning, Egg Incubation, and Alevin

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures were evaluated during the October through January spawning, egg incubation, and alevin period for fall-run Chinook salmon in the American River reach between Hazel Avenue and Watt Avenue. Nearly all fall-run Chinook salmon spawning in the American River occurs from Watt Avenue upstream (Table 2-126; BA Table 5.D.1-4 in Appendix 5D Attachment 1).

Table 2-126. Lower American River Spawning Distributions.

No.	River Reach	Spawning Distribution (%)
1	Nimbus Dam – Sunrise Blvd	31
2	Sunrise Blvd – A. Hoffman/Cordova	59
3	A. Hoffman/Cordova – Arden	5
4	Arden – Watt Ave	3
5	Watt Ave – Filtration Plant	1
6	Filtration Plant – H St	0
7	H St – Paradise	1
8	Paradise – 16th St	0
9	16th St – Mouth	0

Overall, the PA would change mean water temperatures very little (less than 1°F, or less than 1%) throughout the reach in all months and water year types of the period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-15 (shown in Appendix C of this Opinion). The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4%, and would occur at both Hazel Avenue and Watt Avenue during above normal water years during October. This greatest increase would occur outside of the peak spawning, egg incubation, and alevin period (November and December). See Appendix C of this Opinion, BA Table 5.C.7-14, American River at Hazel Ave, Monthly Temperature and BA Table 5.C.7-15, American River at Watt Ave, Monthly Temperature.

Temperature Threshold Analysis

The exceedance of temperature thresholds in the American River presented in the BA in Appendix, Methods, Table 5.E-22 by modeled daily water temperatures were evaluated based on thresholds identified from the literature and the USEPA's temperature water quality guidance (U.S. Environmental Protection Agency 2003). For spawning, egg incubation, and alevin presence, the threshold used was from the USEPA's 7-day average daily maximum (7DADM) value of 55.4°F, converted by month to function with daily model outputs for each month separately (BA Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-4).

The water temperature thresholds analysis presented in the BA provides an indication that water temperatures in the American River under the PA are not expected to increase in relation to the NAA during fall-run Chinook salmon spawning, egg incubation, and alevin development. As pointed out in the BA (pages 5.E-283), the differences in the percent of days above the spawning, egg, and alevin water temperature threshold (i.e., 55.4 7DADM) between the NAA and the PA would be minimal across months, locations, and water year types (BA Attachment 5.E.1, Fall-/Late Fall-Run Chinook Salmon Water Temperature Threshold Analysis Results, Tables 5.E.1-32 through 5.E.1-33). At both Hazel Avenue and Watt Avenue, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance (Table 2-127 and Table 2-128).

However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on fall-run Chinook salmon eggs in every single year regardless of water year type. That is because water temperatures are expected to exceed 55.4F 7DADM for a long duration during the peak of spawning and egg incubation over the full range of hydrologic conditions. For example, the water temperature threshold analysis shows that water temperatures at Hazel Avenue under the PA during the peak spawning month of November will exceed the temperature threshold for at least 80% of the days in critical water years ranging up to 91% of the days in wet water years (Table 2-127; BA Table 5.E.1-32). The longer the duration of exposure to water temperatures that are warmer than the threshold, the greater the severity of adverse effects. Conditions worsen further downstream at near Watt Avenue, with PA water temperatures in November exceeding the egg and alevin threshold (i.e., 55.4F 7DADM) for 83% to 93% of the days across all water year types (Table 5.E.1-33). Egg and alevin mortality above natural levels (i.e., little to no thermal stress) is expected under such a thermal regime, clearly resulting in adverse effects on a large proportion of fall-run Chinook salmon eggs and alevins in the American River.

Overall, the water temperature modeling results and the threshold analysis indicate that thermal impacts on fall-run Chinook salmon spawning, egg incubation, and alevin development will largely be the same with implementation of either the PA or NAA operations. The PA is not expected to result in adverse effects, relative to the NAA.

Adverse thermal effects on these life stages resulting from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in substantial water temperature-related mortality (a large proportion of the life stage) in all water years.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-

Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Table 2-127. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Spawning and Embryo Incubation, American River at Hazel Avenue, 55.4°F 7DADM.

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Oct	W	100.0	100.0	0.0	5,499	5,518	19	6.82	6.85	0.02
	AN	100.0	100.0	0.0	3,083	3,167	84	8.29	8.51	0.23
	BN	100.0	100.0	0.0	3,078	3,054	-24	9.03	8.96	-0.07
	D	100.0	100.0	0.0	5,973	5,785	-188	9.63	9.33	-0.30
	C	100.0	100.0	0.0	4,031	3,871	-160	10.84	10.41	-0.43
	All	100.0	100.0	0.0	21,664	21,395	-269	8.63	8.52	-0.11
Nov	W	89.9	91.4	1.5	2,006	1,957	-49	2.86	2.74	-0.12
	AN	84.4	84.2	-0.3	862	852	-10	2.84	2.81	-0.02
	BN	86.7	83.0	-3.6	951	861	-90	3.33	3.14	-0.18
	D	83.0	80.5	-2.5	1,624	1,528	-96	3.26	3.16	-0.10
	C	80.6	80.3	-0.3	1,153	1,136	-17	3.98	3.93	-0.05
	All	85.6	84.9	-0.7	6,596	6,334	-262	3.17	3.07	-0.10
Dec	W	15.0	15.6	0.6	243	229	-14	2.01	1.82	-0.19
	AN	6.7	6.5	-0.3	33	31	-2	1.32	1.29	-0.03
	BN	9.1	5.0	-4.1	35	21	-14	1.13	1.24	0.11
	D	1.9	2.4	0.5	10	9	-1	0.83	0.60	-0.23
	C	5.1	6.2	1.1	26	27	1	1.37	1.17	-0.19
	All	8.3	8.2	-0.1	347	317	-30	1.67	1.55	-0.12
Jan	W	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	AN	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	BN	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	D	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	C	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	All	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold

[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-128. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Spawning and Embryo Incubation, American River at Watt Avenue, 55.4°F 7DADM.

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Oct	W	100.0	100.0	0.0	7,326	7,391	65	9.09	9.17	0.08
	AN	100.0	100.0	0.0	3,858	3,925	67	10.37	10.55	0.18
	BN	100.0	100.0	0.0	3,752	3,737	-15	11.00	10.96	-0.04
	D	100.0	100.0	0.0	7,196	7,060	-136	11.61	11.39	-0.22
	C	100.0	100.0	0.0	4,837	4,699	-138	13.00	12.63	-0.37
	All	100.0	100.0	0.0	26,969	26,812	-157	10.74	10.68	-0.06
Nov	W	92.1	93.2	1.2	2,648	2,602	-46	3.69	3.58	-0.11
	AN	87.2	88.9	1.7	1,102	1,092	-10	3.51	3.41	-0.10
	BN	88.8	87.6	-1.2	1,195	1,124	-71	4.08	3.89	-0.19
	D	86.3	83.2	-3.2	2,050	1,957	-93	3.96	3.92	-0.04
	C	84.7	84.4	-0.3	1,432	1,428	-4	4.70	4.70	0.00
	All	88.4	88.0	-0.4	8,427	8,203	-224	3.92	3.83	-0.09
Dec	W	15.0	15.6	0.6	224	213	-11	1.85	1.69	-0.16
	AN	6.5	6.5	0.0	32	30	-2	1.33	1.25	-0.08
	BN	8.8	5.0	-3.8	31	16	-15	1.03	0.94	-0.09
	D	2.4	2.4	0.0	15	13	-2	1.00	0.87	-0.13
	C	5.1	6.5	1.3	16	17	1	0.84	0.71	-0.13
	All	8.3	8.2	-0.1	318	289	-29	1.52	1.40	-0.12
Jan	W	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	AN	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	BN	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	D	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	C	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA
	All	0.0	0.0	0.0	0.0	0.0	0.0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Fry and Juvenile Rearing and Outmigration

Monthly Temperatures and Exceedance Plots

Mean monthly water temperatures were evaluated during the December through June juvenile rearing and emigration period for fall-run Chinook salmon in the American River between Hazel Avenue and Watt Avenue; the emigration peaks during January and February. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) throughout the fry and juvenile rearing reach in all months and water year types (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-14, Table 5.C.7-15). See Appendix C of this

Opinion, BA Table 5.C.7-14, American River at Hazel Ave, Monthly Temperature and BA Table 5.C.7-15, American River at Watt Ave, Monthly Temperature.

The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4%, and would occur at Watt Avenue in critical water years during March, outside the peak period of rearing.

As presented in the BA, the water temperature thresholds analysis for fall-run Chinook salmon juvenile rearing and emigration have been combined and the period of December through June was evaluated. The threshold used was from the USEPA's 7DADM value of 61°F for the core juvenile rearing reach represented by Hazel Avenue and 64°F for the non-core juvenile rearing reach represented by Watt Avenue.

Temperature Threshold Analysis

The water temperature thresholds analysis presented in the BA provides another indication that water temperatures under the PA are not expected to increase in relation to the NAA (Tables 2-131 and 2-132). Adverse effects on fall-run Chinook salmon juveniles in the American River under the PA are not expected, relative to the NAA.

For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, results of the water temperature thresholds analysis indicate that an adverse effect to fall-run Chinook salmon juveniles in the American River is expected (Table 2-129 and Table 2-130). The general pattern is that daily occurrences of threshold exceedances increase as fish move downstream from Hazel Avenue and as the season progresses from April to May, and although the tabular results for the threshold analysis erroneously do not include June, it is safely assumed that the trend of increasing threshold exceedances continues through June because the mean monthly water temperature results show a warming trend from April through June at both the Hazel and Watt Avenue locations. As such, the frequency of adverse effects to fall-run Chinook salmon juveniles are expected to increase from Hazel Avenue downstream and from month to month during the April through June period. The mean percentage of days for all water years combined where April and May water temperatures under the PA are expected to exceed the 7DADM thresholds (61°F for core at Hazel, 64°F for non-core at Watt) ranges from 3% up to 30% at Hazel Avenue and from 12% to 51% at Watt Avenue.

Table 2-129. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Juvenile Rearing and Emigration, American River at River at Hazel Avenue, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	10.6	10.9	0.3	28	28	0	0.80	0.78	-0.02
	D	2.2	1.7	-0.5	11	5	-6	0.85	0.50	-0.35
	C	7.8	7.5	-0.3	18	29	11	0.64	1.07	0.43
	All	3.1	3.0	-0.1	57	62	5	0.75	0.85	0.10
May	W	7.6	7.6	0.0	145	143	-2	2.38	2.34	-0.03
	AN	9.7	9.7	0.0	46	46	0	1.18	1.18	0
	BN	43.4	42.5	-0.9	441	442	1	2.98	3.05	0.07
	D	43.5	42.6	-1.0	776	659	-117	2.87	2.50	-0.38
	C	64.2	64.8	0.5	808	834	26	3.38	3.46	0.08
	All	29.8	29.5	-0.3	2,216	2,124	-92	2.93	2.83	-0.10

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-130. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Juvenile Rearing and Emigration, American River at Watt Avenue, 64°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

		Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
Month	WYT	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.6	0.6	0.0	5	5	0	1.00	1.00	0
	AN	0.3	0.3	0.0	1	1	0	1.00	1.00	0
	BN	22.1	23.3	1.2	180	185	5	2.47	2.40	-0.06
	D	14.0	13.2	-0.8	179	141	-38	2.13	1.78	-0.35
	C	36.9	36.7	-0.3	367	378	11	2.76	2.86	0.10
	All	12.0	12.0	-0.1	732	710	-22	2.47	2.41	-0.06
May	W	17.7	18.0	0.2	461	461	0	3.22	3.18	-0.04
	AN	48.6	48.9	0.2	402	404	2	2.05	2.05	0
	BN	62.8	61.9	-0.9	996	957	-39	4.65	4.54	-0.12
	D	68.9	68.7	-0.2	1,856	1,761	-95	4.35	4.13	-0.21
	C	84.9	84.7	-0.3	1,832	1,851	19	5.80	5.88	0.08
	All	51.0	50.9	-0.1	5,547	5,434	-113	4.28	4.20	-0.08

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Additionally, the severity of adverse effects to fall-run Chinook salmon juveniles under combined thermal effect of PA implementation when added to the environmental baseline and modeled climate change impacts increases from upstream to downstream. This is evident by the increase in the degrees per day above the thresholds for all water years combined from Hazel Avenue to Watt Avenue during both May and June. The water temperature thresholds analysis results indicate that adverse effects to juvenile fall-run Chinook salmon are expected in April, May, and June in all water years with implementation of the PA when added to the environmental baseline and modeled climate change impacts.

Overall, the water temperature modeling results and the threshold analysis indicate that thermal impacts on fall-run Chinook salmon fry and juveniles in the American River will largely be the same with implementation of either the PA or NAA operations. The PA is not expected to result in adverse effects, relative to the NAA. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on a large proportion of American River fall-run Chinook salmon fry and juveniles.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Table 2-131. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Juvenile Rearing and Emigration, American River at River at Hazel Avenue, 61°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	10.6	10.9	0.3	28	28	0	0.80	0.78	-0.02
	D	2.2	1.7	-0.5	11	5	-6	0.85	0.50	-0.35
	C	7.8	7.5	-0.3	18	29	11	0.64	1.07	0.43
	All	3.1	3.0	-0.1	57	62	5	0.75	0.85	0.10
May	W	7.6	7.6	0.0	145	143	-2	2.38	2.34	-0.03
	AN	9.7	9.7	0.0	46	46	0	1.18	1.18	0
	BN	43.4	42.5	-0.9	441	442	1	2.98	3.05	0.07
	D	43.5	42.6	-1.0	776	659	-117	2.87	2.50	-0.38
	C	64.2	64.8	0.5	808	834	26	3.38	3.46	0.08
	All	29.8	29.5	-0.3	2,216	2,124	-92	2.93	2.83	-0.10

[1]7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-132. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Juvenile Rearing and Emigration, American River at Watt Avenue, 64°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Jan	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Feb	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Mar	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Apr	W	0.6	0.6	0.0	5	5	0	1.00	1.00	0
	AN	0.3	0.3	0.0	1	1	0	1.00	1.00	0
	BN	22.1	23.3	1.2	180	185	5	2.47	2.40	-0.06
	D	14.0	13.2	-0.8	179	141	-38	2.13	1.78	-0.35
	C	36.9	36.7	-0.3	367	378	11	2.76	2.86	0.10
	All	12.0	12.0	-0.1	732	710	-22	2.47	2.41	-0.06
May	W	17.7	18.0	0.2	461	461	0	3.22	3.18	-0.04
	AN	48.6	48.9	0.2	402	404	2	2.05	2.05	0
	BN	62.8	61.9	-0.9	996	957	-39	4.65	4.54	-0.12
	D	68.9	68.7	-0.2	1,856	1,761	-95	4.35	4.13	-0.21
	C	84.9	84.7	-0.3	1,832	1,851	19	5.80	5.88	0.08
	All	51.0	50.9	-0.1	5,547	5,434	-113	4.28	4.20	-0.08

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Adult Immigration

Monthly Temperatures and Exceedance Plots

As with the other life stage periods, water temperatures expected to occur during the September through December period for fall-run Chinook salmon adult immigration under the PA will be similar to those under the NAA. Mean monthly water temperatures were evaluated in the American River at Hazel Avenue and Watt Avenue during the September through December adult immigration period for fall-run Chinook salmon, with a peak of September and October. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) at these locations in all months and water year types in the period (BA Appendix 5.C, Upstream Water Temperature Methods and Results, Section 5.C.7, Upstream Water Temperature Modeling Results, Table 5.C.7-14, Table 5.C.7-15). See Appendix C of this Opinion, BA Table 5.C.7-14, American River at Hazel Ave, Monthly Temperature and BA Table 5.C.7-15, American River at Watt Ave, Monthly Temperature. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F (0.4%), and would occur at Hazel Avenue during September of below normal water years, within the peak period of adult immigration.

Temperature Threshold Analysis

As presented in the BA, the USEPA's 7DADM threshold value of 68°F was used to evaluate water temperature threshold exceedance during the fall-run Chinook salmon adult immigration life stage at Hazel Avenue and Watt Avenue. The threshold was converted to function with daily model outputs for each month separately (BA Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.2.1, Water Temperature Analysis Methods, Table 5.D-4).

Results of the water temperature thresholds analysis for adult fall-run Chinook salmon immigration are presented in Table 2-134 and Table 2-135. At Hazel Avenue, there would be one month and water year type (below normal water years during September) in which there would be a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA (8.8%), but there would not be a more-than-0.5°F difference in the magnitude of average daily exceedance. At Watt Avenue, there would be no months or water types in which there would be a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA or a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that any adverse water temperature-related effects of the PA on adult fall-run Chinook salmon immigration would be similar to those of the NAA. See Table 2-133 below and BA Table 5.E-37 in Appendix C of this Opinion.

Table 2-133. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 4 between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	24.9	26.5	1.6 (6%)
	Above Normal	13.5	12.2	-1.39 (-10%)
	Below Normal	3.1	1.2	-1.9 (-63%)
	Dry	1.0	0.6	-0.4 (-37%)
	Critical	3.5	1.7	-1.8 (-51%)
September	All	11.2	10.9	-0.3 (-3%)
October	Wet	9.3	6.6	-2.7 (-29%)
	Above Normal	8.9	10.0	1.1 (12%)
	Below Normal	6.4	10.9	4.4 (69%)
	Dry	5.0	6.2	1.3 (25%)
	Critical	4.0	2.8	-1.3 (-31%)
	All	7.0	7.0	0 (0%)
November	Wet	29.8	15.3	-14.5 (-49%)
	Above Normal	28.2	12.6	-15.6 (-55%)
	Below Normal	5.1	3.5	-1.6 (-31%)
	Dry	3.4	2.5	-0.9 (-27%)
	Critical	0.8	2.6	1.7 (208%)
	All	15.4	8.2	-7.2 (-46%)

However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, adverse effects to fall-run Chinook salmon eggs under the PA are expected to occur in every single year regardless of water year type. That is because water temperatures are expected to exceed the 68°F 7DADM threshold for a long duration during the peak of adult immigration over the full range of hydrologic conditions. For example, the water temperature threshold analysis shows that water temperatures at Watt Avenue under the PA during the peak adult immigration month of October will exceed the temperature threshold for at least 5% of the days in critical water years ranging up to 55% of the days in wet water years (Table 2-134). The longer the duration of exposure to water temperatures that are warmer than the threshold, the greater the severity of adverse effects. Conditions worsen for any adult fall-run Chinook salmon immigrating into the American River in September, with PA water temperatures at Watt Avenue exceeding the water temperature threshold (i.e., 68°F 7DADM) for 54% of the days in wet water years up to 100% of the days in critical water years (Table 2-134). The extended duration of exposure to water temperatures above the threshold is expected to increase the probability of pre-spawn mortality of adults and reduce in vitro egg viability, resulting in adverse effects on a large proportion of fall-run Chinook salmon eggs in the American River.

Table 2-134. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Immigration, American River at Watt Avenue, 68°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Sep	W	55.9	54.1	-1.8	619	634	15	1.42	1.50	0.08
	AN	91.5	96.4	4.9	636	708	72	1.78	1.88	0.10
	BN	97.3	96.4	-0.9	1,079	1,134	55	3.36	3.57	0.20
	D	98.7	98.5	-0.2	2,282	2,367	85	3.85	4.01	0.15
	C	97.2	99.7	2.5	2,157	2,159	2	6.16	6.01	-0.15
	All	83.6	84.0	0.4	6,773	7,002	229	3.29	3.39	0.09
Oct	W	3.7	4.5	0.7	30	37	7	1.00	1.03	0.03
	AN	9.7	13.7	4.0	25	33	8	0.69	0.65	-0.05
	BN	22.6	22.9	0.3	98	97	-1	1.27	1.24	-0.03
	D	31.9	31.3	-0.6	308	307	-1	1.56	1.58	0.03
	C	62.1	55.4	-6.7	521	436	-85	2.26	2.12	-0.14
	All	22.8	22.5	-0.3	982	910	-72	1.72	1.61	-0.11
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1]7DADM = Seven day average daily maximum

[2] Only includes days on which temperature exceeded threshold[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Overall, the water temperature modeling results and the threshold analysis indicate that thermal impacts on fall-run Chinook salmon adult immigration in the American River will largely be the same with implementation of either the PA or NAA operations. The PA is not expected to result in adverse effects, relative to the NAA. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in adverse effects on at least a medium proportion of fall-run Chinook salmon adults in the American River.

It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, *Real-Time*

Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Currently, to facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and CDFW) determinations, Reclamation, DWR, and the fish and wildlife agencies utilize a set of processes to collect data, disseminate information, develop information, develop recommendations, make decisions, and provide transparency (U.S. Bureau of Reclamation 2008; NMFS 2009; USFWS 2009; USFWS 2008). This process consists of numerous teams that meet on a regular basis to review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species (see BA Section 3.1.5.1 Ongoing Processes to support Real-Time Decision Making).

Table 2-135. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Immigration, American River at Hazel Avenue, 68°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Sep	W	2.9	3.3	0.4	13	11	-2	0.57	0.42	-0.14
	AN	0.0	1.5	1.5	0	1	1	NA	0.17	NA
	BN	3.3	12.1	8.8	15	35	20	1.36	0.88	-0.49
	D	28.3	31.2	2.8	147	192	45	0.86	1.03	0.16
	C	76.7	72.5	-4.2	392	394	2	1.42	1.51	0.09
	All	19.5	21.1	1.6	567	633	66	1.18	1.22	0.04
Oct	W	0.0	0.2	0.2	0	0	0	NA	0	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	2.6	0.9	-1.8	4	1	-3	0.44	0.33	-0.11
	D	4.7	5.2	0.5	25	25	0	0.86	0.78	-0.08
	C	22.6	20.7	-1.9	42	30	-12	0.50	0.39	-0.11
	All	4.9	4.5	-0.3	71	56	-15	0.58	0.49	-0.09
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1]7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold
[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

Table 2-136. Water Temperature Threshold Analysis Results, Fall-run Chinook Salmon, Adult Immigration, American River at Watt Avenue, 68°F 7DADM. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	Percent of Days Above Threshold			Sum of Degree-Days Above Threshold[2]			Degrees per Day Above Threshold[2,3]		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Sep	W	55.9	54.1	-1.8	619	634	15	1.42	1.50	0.08
	AN	91.5	96.4	4.9	636	708	72	1.78	1.88	0.10
	BN	97.3	96.4	-0.9	1,079	1,134	55	3.36	3.57	0.20
	D	98.7	98.5	-0.2	2,282	2,367	85	3.85	4.01	0.15
	C	97.2	99.7	2.5	2,157	2,159	2	6.16	6.01	-0.15
	All	83.6	84.0	0.4	6,773	7,002	229	3.29	3.39	0.09
Oct	W	3.7	4.5	0.7	30	37	7	1.00	1.03	0.03
	AN	9.7	13.7	4.0	25	33	8	0.69	0.65	-0.05
	BN	22.6	22.9	0.3	98	97	-1	1.27	1.24	-0.03
	D	31.9	31.3	-0.6	308	307	-1	1.56	1.58	0.03
	C	62.1	55.4	-6.7	521	436	-85	2.26	2.12	-0.14
	All	22.8	22.5	-0.3	982	910	-72	1.72	1.61	-0.11
Nov	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA
Dec	W	0.0	0.0	0.0	0	0	0	NA	NA	NA
	AN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	BN	0.0	0.0	0.0	0	0	0	NA	NA	NA
	D	0.0	0.0	0.0	0	0	0	NA	NA	NA
	C	0.0	0.0	0.0	0	0	0	NA	NA	NA
	All	0.0	0.0	0.0	0	0	0	NA	NA	NA

[1] 7DADM = Seven day average daily maximum
[2] Only includes days on which temperature exceeded threshold[3] NA = Not applicable; this value could not be calculated in these columns because the threshold was not exceeded by the scenario

2.5.1.2.2 Redd Dewatering

Redd dewatering is a risk to incubating salmonid eggs and alevin. Water must move through a redd at a swift enough velocity to sweep out fine sediment and metabolic waste. Otherwise, incubating eggs do not receive sufficiently clean, oxygenated water to support proper development (Vaux 1968). Salmonid redd dewatering can occur when water levels decrease after redd construction and spawning, exposing buried and otherwise submerged eggs or alevins to air.

Dewatering can affect eggs and alevins in multiple ways. Dewatered gravel must maintain near 100% humidity for eggs and embryos to survive over successive days. While inadequate moisture and dissolved oxygen have been shown to affect the survival of all egg stages, the post-hatch eleuthroembryo and alevin stage are most sensitive to redd dewatering and usually die within 24 hours (Becker et al. 1983). Studies have shown that dewatering can impair egg and alevin development and cause direct mortality due to desiccation, insufficient oxygen levels, waste metabolite toxicity, and thermal stress (Reiser and White 1983, Becker and Neitzel 1985).

Redd dewatering can be a major source of salmonid population mortality in any water year type. Salmonid redds require cool, oxygenated, low turbidity water for approximately three to four months to complete the egg-alevin life stages (Williams 2006). Therefore, the water level conditions at spawning should be maintained for at least three months after eggs are deposited in the gravel. Any reduction in water level within that period introduces a dewatering risk, almost regardless of the spawning condition. Because instream flows on the Sacramento and American rivers are primarily dependent on reservoir releases, the risk of redd dewatering can in large part be controlled through water operations.

Dewatering of green sturgeon spawning areas is not a concern because of the different spawning habitat that these fish use in contrast to the type of habitat conditions necessary for salmonid spawning. Green sturgeon spawning primarily occurs in cool sections of the upper mainstem Sacramento River in deep pools containing small to medium sized gravel, cobble or boulder substrate (Klimley et al. 2015, Poytress et al. 2015). Sturgeon eggs primarily adhere to gravel or cobble substrates, or settle into crevices (Moyle et al. 1995, Van Eenennaam et al. 2001, Poytress et al. 2015) where they incubate for a period of seven to nine days and remain near the hatching area for 18 to 35 days prior to dispersing (Van Eenennaam et al. 2001, Deng et al. 2002, Poytress et al. 2015). Larval activity is primarily nocturnal, with peaks in migration between dusk and dawn (Poytress et al. 2015). Larvae utilize benthic structure (Van Eenennaam et al. 2001, Deng et al. 2002, Kynard et al. 2005) and seek refuge within crevices, but will forage over hard surfaces (Nguyen and Crocker 2006).

2.5.1.2.2.1 Winter-run Exposure and Risk

Sacramento River winter-run Chinook salmon eggs and alevins are most vulnerable to dewatering during periods of significant river flow fluctuation in the Sacramento River, which can occur in August, late in the incubation period (Vogel and Marine 1991).

Essentially all winter-run Chinook salmon redds are constructed in the Sacramento River upstream of Battle Creek with 45% of redds occurring in the two miles between A.C.I.D. Dam and Keswick Dam and a further 56.3% of redds occurring between A.C.I.D. Dam and Keswick Dam and a further 56.3% of redds occurring between A.C.I.D. Dam and the Airport road bridge (18 RM downstream of Keswick Dam, Table 2-102).

The redd dewatering analysis presented in the BA and below relies upon the relationships between flow fluctuations and redd dewatering for Chinook salmon in the Sacramento River between Keswick Dam and Battle Creek (USFWS 2006). As such, the analysis covers the Sacramento River upstream of the Battle Creek confluence and what is 99.7% of the habitat used for Sacramento River winter-run Chinook salmon spawning and egg incubation, based on the spatial distribution of redds from 2003-2014 (Table 2-102).

The percentage of winter-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated using CALSIM II estimates of monthly mean flows during the three months following each month of spawning combined with the functional relationships developed in field studies by U.S. Fish and Wildlife Service (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows (BA Appendix 5D.2.2, Spawning Flows Methods). The analysis estimated winter-run Chinook salmon redd dewatering under the PA and NAA for the three upstream river segments (Segments 4, 5 and 6).

River Segment 4 stretches 8 miles from Battle Creek to the confluence with Cow Creek; Segment 5 reaches 16 miles from Cow Creek to the A.C.I.D. Dam; and Segment 6 covers 2 miles from A.C.I.D. Dam to Keswick Dam. Detailed information on redd dewatering analysis methods is provided in the BA in Appendix 5D.2.2, Spawning Flows Methods.

Differences in winter-run Chinook salmon redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for the April through August months of spawning. Because river Segment 5 is the longest segment and includes the bulk of the analyzed winter-run Chinook salmon spawning area, those results are described in more detail here. The exceedance curves for the PA generally show consistently small, but higher redd dewatering percentages than those for the NAA for all water year types combined, and individually for all water year types except those that are critically dry (Figure 2-60 through Figure 2-65).

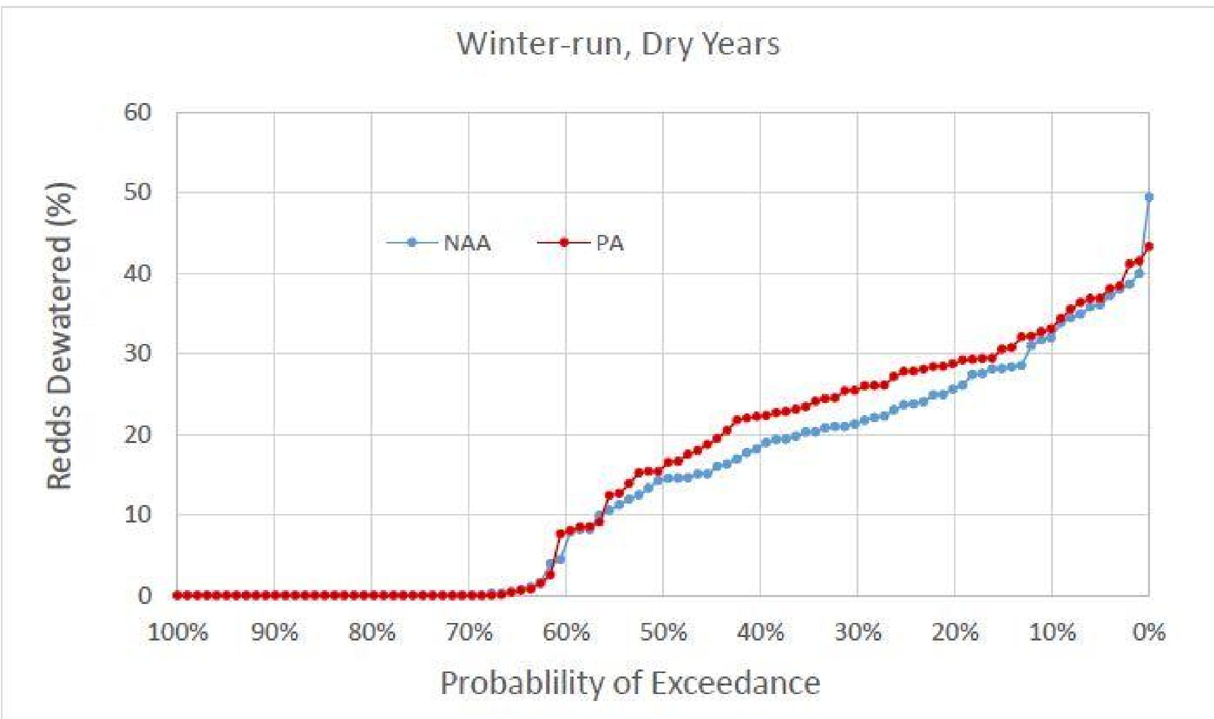


Figure 2-60. Exceedance Plot of Winter-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Dry Water Years.

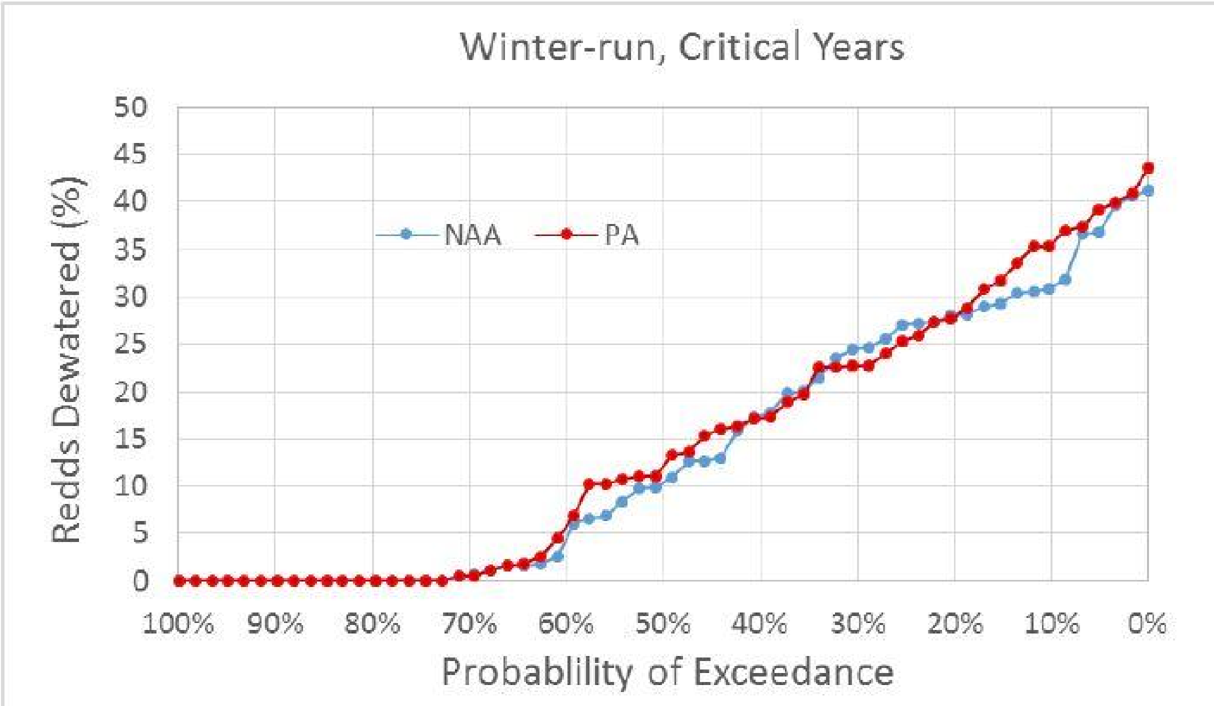


Figure 2-61. Exceedance Plot of Winter-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Critical Water Years.

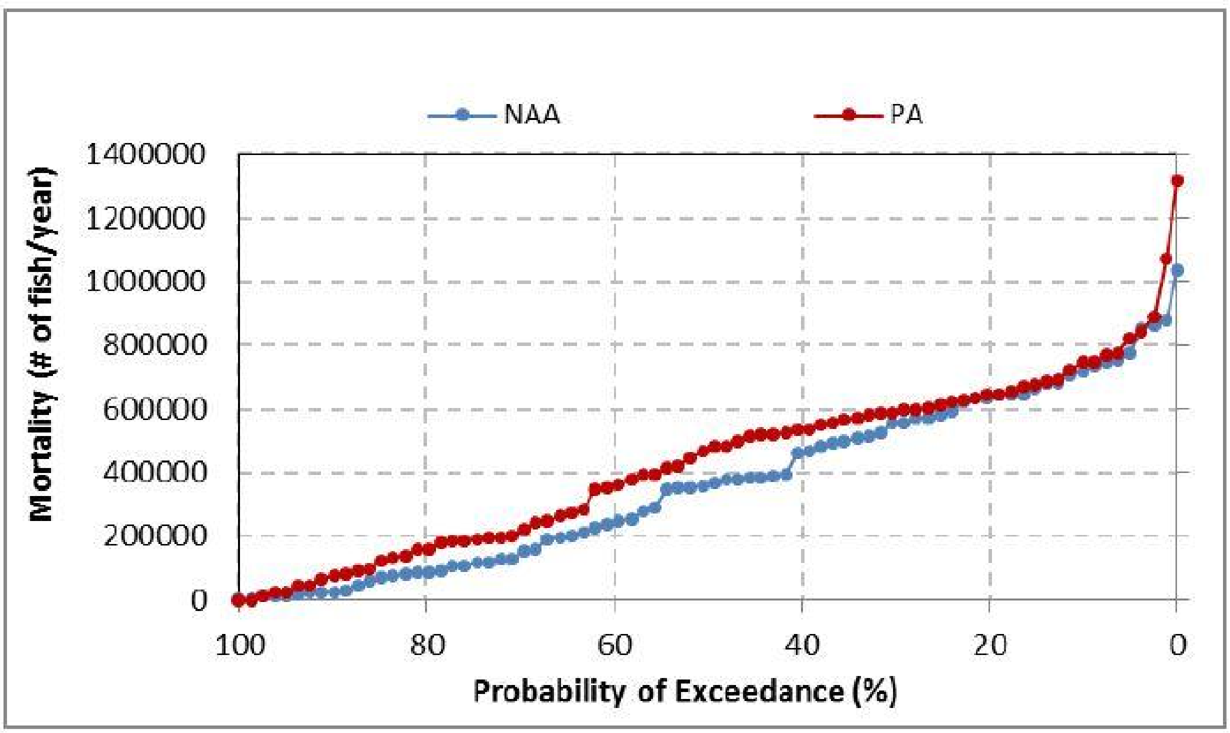


Figure 2-62. Exceedance Plot of Annual Flow-Based Mortality (#of Fish/Year) of Winter-run Chinook Salmon Spawning, Egg Incubation, and Alevins.

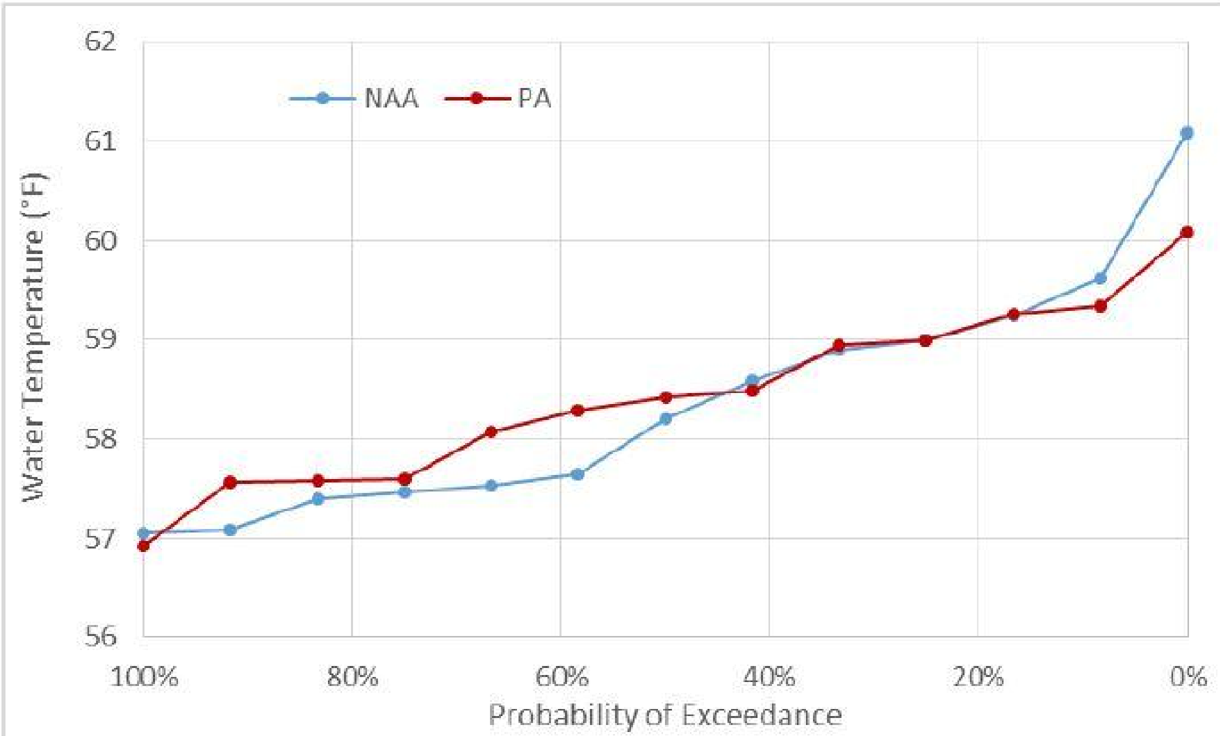


Figure 2-63. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Above Normal Water Years.

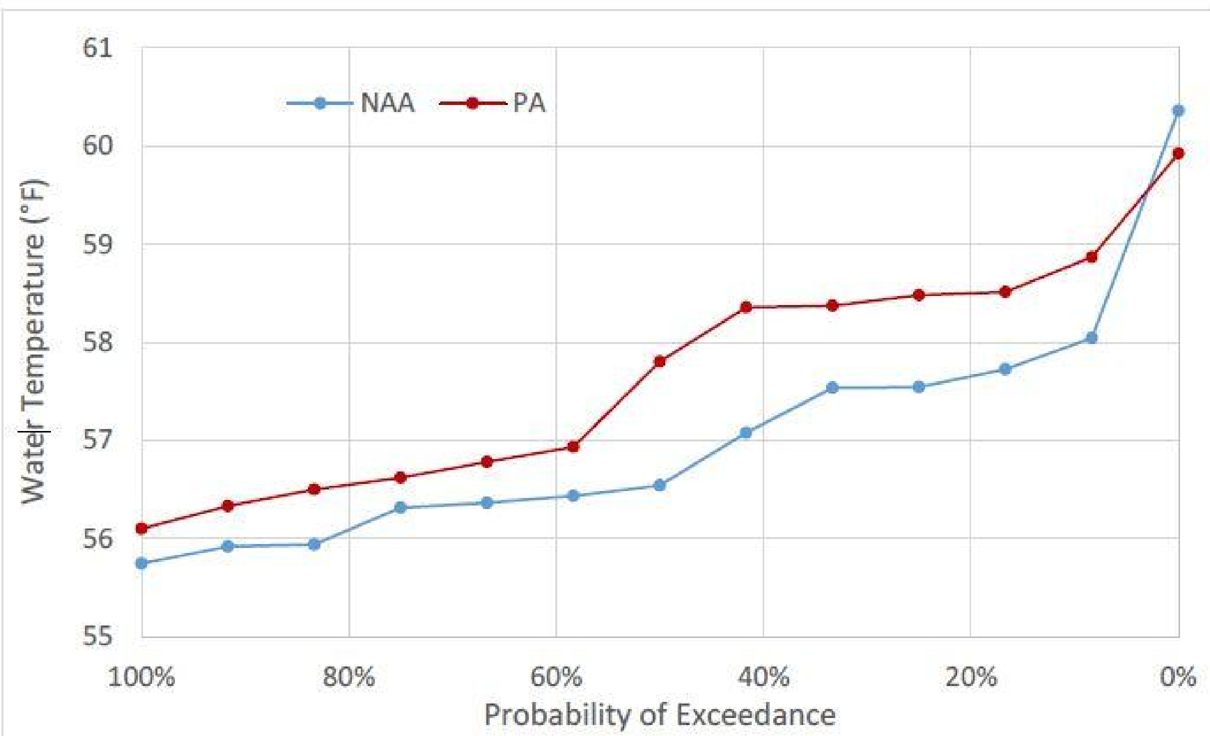


Figure 2-64. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years.

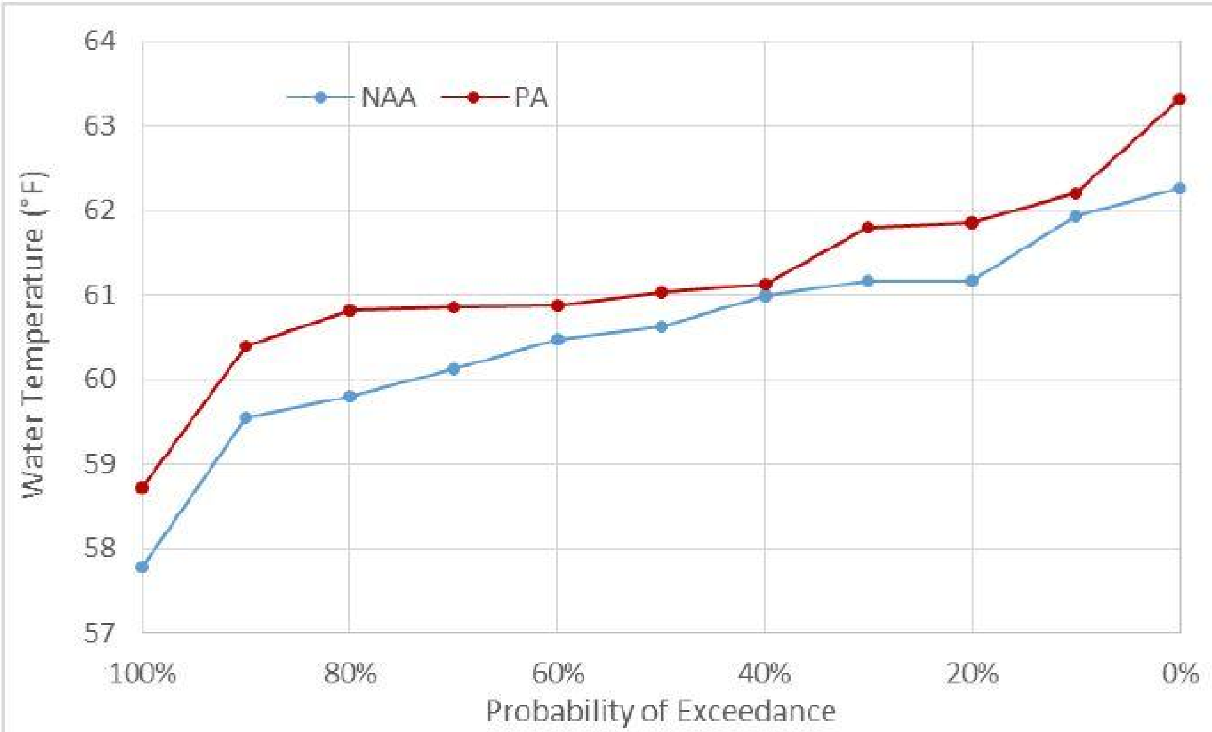


Figure 2-65. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years.

The biggest differences in the dewatering curves are predicted for above normal water years, with about 25% of all months having greater than 10% of redds dewatered under the NAA, but about 38% of all months having greater than 10% of redds dewatered under the PA (a 13% increase).

Tabular results from the BA show the differences between the PA and NAA in the mean percentage of redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined (Table 2-137). Similar to redd dewatering exceedance plots, the tabular results show a small, but consistent, difference in redd dewatering risk between the PA and NAA. Absolute differences between the PA and NAA percentages of greater than 5% were flagged as potentially having a biologically meaningful effect (BA). The mean percent redds dewatered under the PA is predicted to range between three and 7% greater (raw difference) than the means under the NAA during June of all water year types except wet years, and to be between three and 6% greater during August of wet and above normal years, respectively. The percent change (relative change rather than raw change) in the means for these months and water year types ranged from 26% to 89% greater under the PA than under the NAA. The large percentages for many of the months and water year types are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes. During April and May, redd dewatering would differ minimally between the PA and NAA.

Table 2-137. Winter-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
April	Wet	6.1	6.0	0 (0%)
	Above Normal	0.8	0.9	0.14 (19%)
	Below Normal	0.0	0.0	0 (-61%)
	Dry	0.4	0.2	-0.2 (-53%)
	Critical	1.4	1.3	-0.1 (-9%)
	All	2.4	2.3	-0.1 (-2%)
May	Wet	0.4	0.4	0 (1%)
	Above Normal	0.3	0.4	0.1 (31%)
	Below Normal	0.0	0.0	0 (0%)
	Dry	0.7	0.6	-0.2 (-22%)
	Critical	0.2	0.2	0 (10%)
	All	0.4	0.4	0 (-6%)
June	Wet	1.1	1.2	0.1 (9%)
	Above Normal	3.5	6.3	2.8 (79%)
	Below Normal	16.1	22.9	6.8 (43%)
	Dry	20.5	25.8	5.3 (26%)
	Critical	16.5	21.8	5.3 (32%)
	All	10.5	13.9	3.5 (33%)
July	Wet	10.8	14.3	3.5 (32.4%)
	Above Normal	17.5	18.2	0.6 (4%)
	Below Normal	28.5	31.8	3.3 (12%)
	Dry	29.8	30.9	1.1 (4%)
	Critical	27.7	28.0	0.3 (0.9%)
	All	21.4	23.3	2 (9%)
August	Wet	5.5	8.5	3 (55%)
	Above Normal	7.1	13.4	6.3 (89%)
	Below Normal	18.9	17.9	-1 (-5%)
	Dry	16.5	18.5	2 (12%)
	Critical	21.7	20.6	-1.1 (-5%)
	All	12.6	14.8	2.2 (17%)

Another source of information suggesting that winter-run redd dewatering in the Sacramento River will increase under the PA comes from the SALMOD results presented in the BA (see Appendix C of this Opinion, BA Table 5.C.7-14). The SALMOD model provides predicted flow-related mortality of SR winter-run Chinook salmon spawning, eggs and alevins, divided into “incubation” (which refers to redd dewatering and scour) and “superimposition” (which refers to redd overlap) mortality (see BA Attachment 5.D.2, SALMOD Model). Under the PA the number of winter-run Chinook salmon eggs and alevins predicted to die from redd dewatering and scour during incubation ranges from 244,211 in wet years to 714,331 in below normal years, with an average over all water year types of 430,651.

Collectively, the estimated percentage of redd dewatering presented in the exceedance plots (Figure 2-60 through Figure 2-65) and Table 2-138 indicate that there is a medium degree of certainty that Sacramento River redd dewatering under the PA is a medium-level magnitude stressor to SR winter-run Chinook salmon in all water years except critically dry years, when dewatering under the PA is a low-level magnitude stressor.

There is also a medium-degree of certainty that the SALMOD results show a combined effect of redd dewatering and scour under the PA places a medium-level magnitude stress on SR winter-run Chinook salmon. The certainty of these magnitude rankings is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale.

2.5.1.2.2.2 Spring-run Exposure and Risk

CV Spring-run Chinook salmon enter freshwater (Sacramento River) as immature fish, beginning in March (Yoshiyama et al. 1998). Although some CV spring-run Chinook salmon remain in the mainstem Sacramento River, many migrate far upriver and enter its tributaries, peaking around mid-April, completing by the end of July (Lindley et al. 2004). CV spring-run Chinook salmon then delay spawning for weeks or months holding in cool deep pools. Spawning occurs in September, and embryos hatch in 40 to 60 days and remain in the gravel as alevins for another 4 to 6 weeks, usually after the yolk sac is fully absorbed (NMFS 2014). Depending on water temperatures, emergence may begin as early as November, peaking in December and January, and may continue through spring (Moyle 2002).

Monitoring CV spring-run Chinook salmon spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from fall-run Chinook salmon. Therefore, even though physical habitat conditions can support spawning and incubation, genetic diversity through introgression may be at risk, as well as redd superimposition (CDFG 1998). Aerial redd surveys conducted by CDFW base CV spring-run Chinook salmon redd counts on observations in the month of September. Total redds by reach from 2001 to 2016 are shown in the table below. The eight most recent years of observations (2009 to 2016) were very low, with numbers of redd observations near zero (with the exception of 57 redds in 2013), and in three of the years no surveys were completed (Table 2-95).

Table 2-138. Spatial Distribution of Spring-run Chinook Salmon Redds in the Sacramento River Based on Aerial Redd Surveys in September, 2001–2016. (BA source CDFW, unpublished data)

Reach	Mean Annual Percent of Total Redds Sighted	Total Redds
Keswick to ACID Dam	12.4	56
ACID Dam to Highway 44 Bridge	32.8	108
Highway 44 Bridge to Airport Road Bridge	27.7	141
Airport Rd. Bridge to Balls Ferry Bridge	10.9	48
Balls Ferry Bridge to Battle Creek	7.3	29

Reach	Mean Annual Percent of Total Redds Sighted	Total Redds
Battle Creek to Jelly's Ferry Bridge	1.5	35
Jelly's Ferry Bridge to Bend Bridge	2.6	10
Bend Bridge to Red Bluff Diversion Dam	0.8	2
Below Red Bluff Diversion Dam	4.1	21

ACID = Anderson-Cottonwood Irrigation District

Spring-run Chinook salmon eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins, usually in September, through alevin emergence around late December. The redd dewatering analysis presented in the BA and below relies upon the relationships between flow fluctuations and redd dewatering for Chinook salmon in the Sacramento River between Keswick Dam and Battle Creek (USFWS 2006). As such, the analysis covers the Sacramento River upstream of the Battle Creek confluence. Based on the spatial distribution of spring-run Chinook salmon redds from 2003-2014 (Table 2-13), 91% of the habitat used for Sacramento River spring-run Chinook salmon spawning and egg incubation was analyzed for potential risks from dewatering, while the remaining 9% of spawning habitat downstream of the Battle Creek confluence was not.

Differences in spring-run redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for August through October spring-run spawning. The exceedance curves for the PA generally show slightly higher redd dewatering percentages than those for the NAA for all water year types combined and substantially higher dewatering percentages for above normal and below normal water year types in particular Figure 2-66 through Figure 2-71. The biggest differences in the dewatering curves are predicted for above normal water years, with about 24% of all months having greater than 20% of redds dewatered under the NAA, but about 43% of all months having greater than 20% of redds dewatered under the PA.

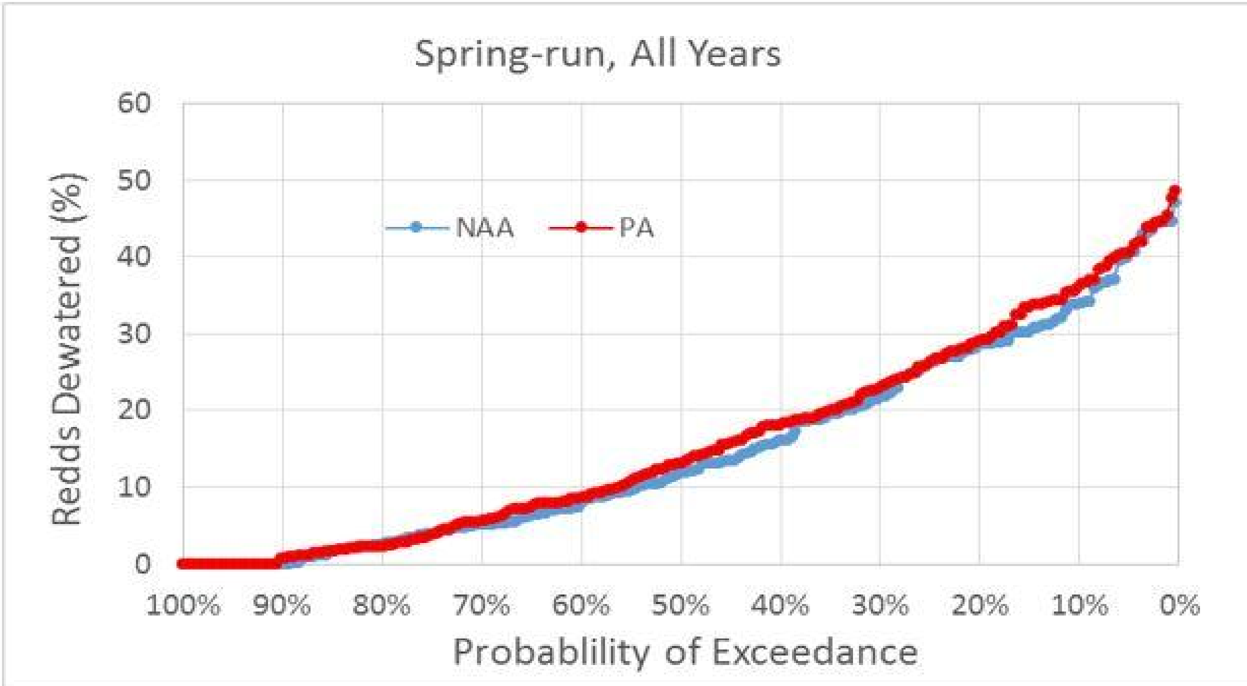


Figure 2-66. Exceedance Plot of Spring-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, All Water Years.

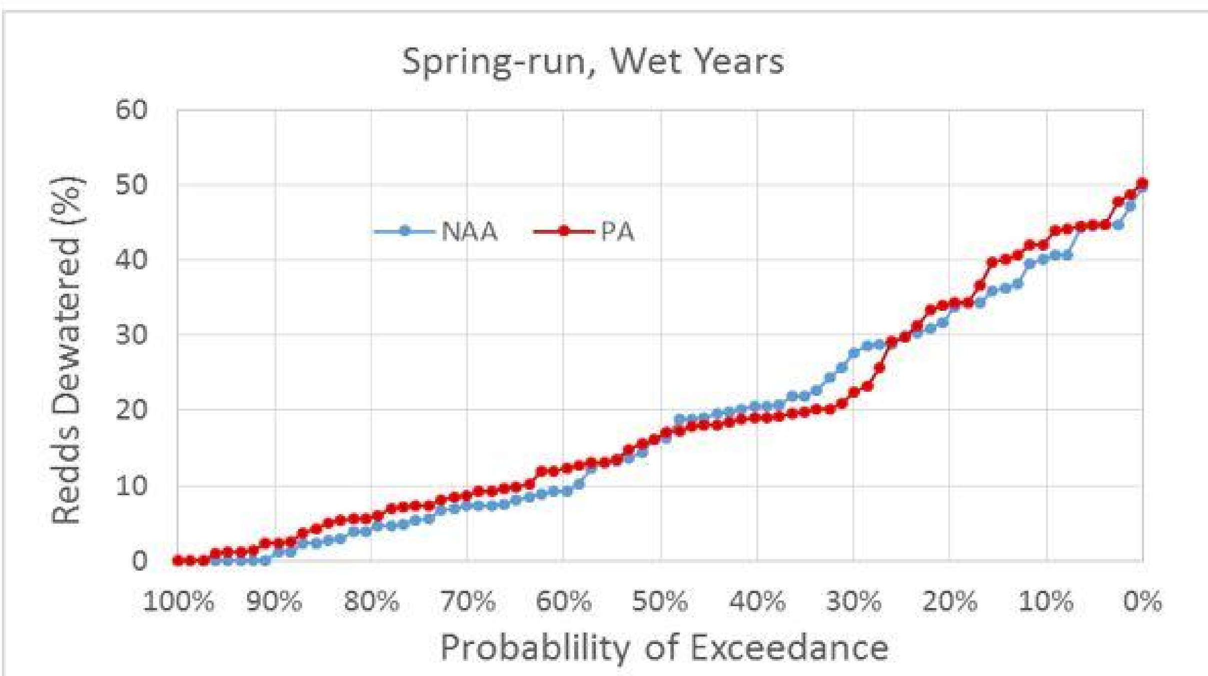


Figure 2-67. Exceedance Plot of Spring-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, All Water Years.

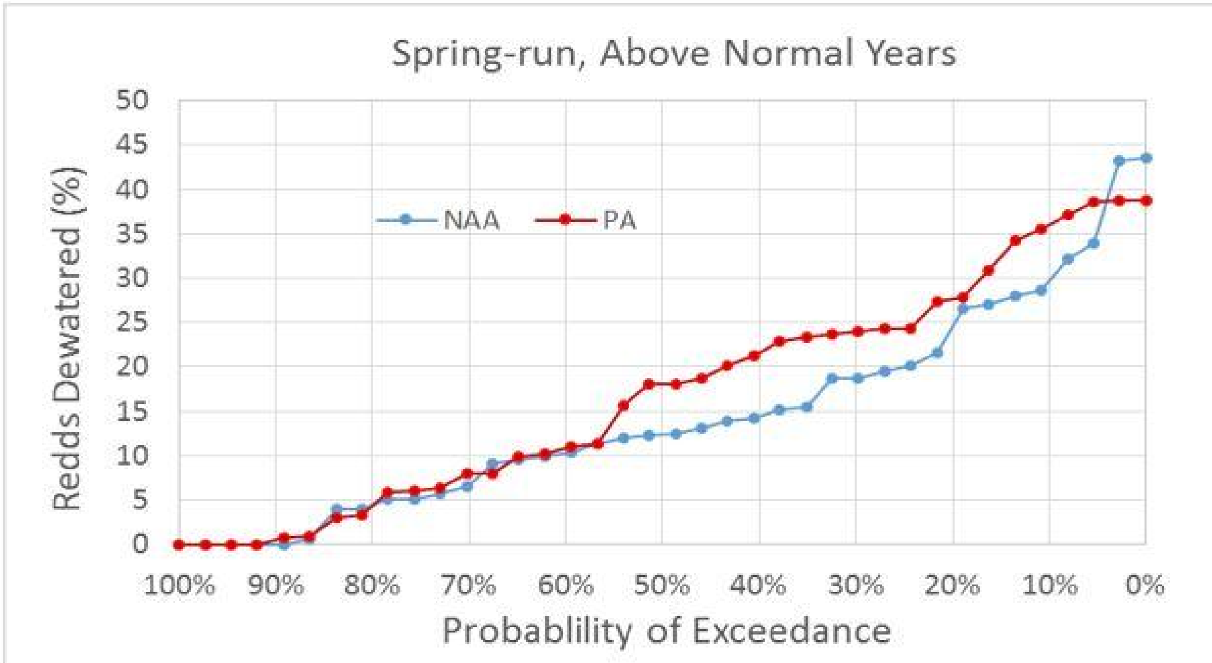


Figure 2-68. Exceedance Plot of Spring-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Above Normal Water Years.

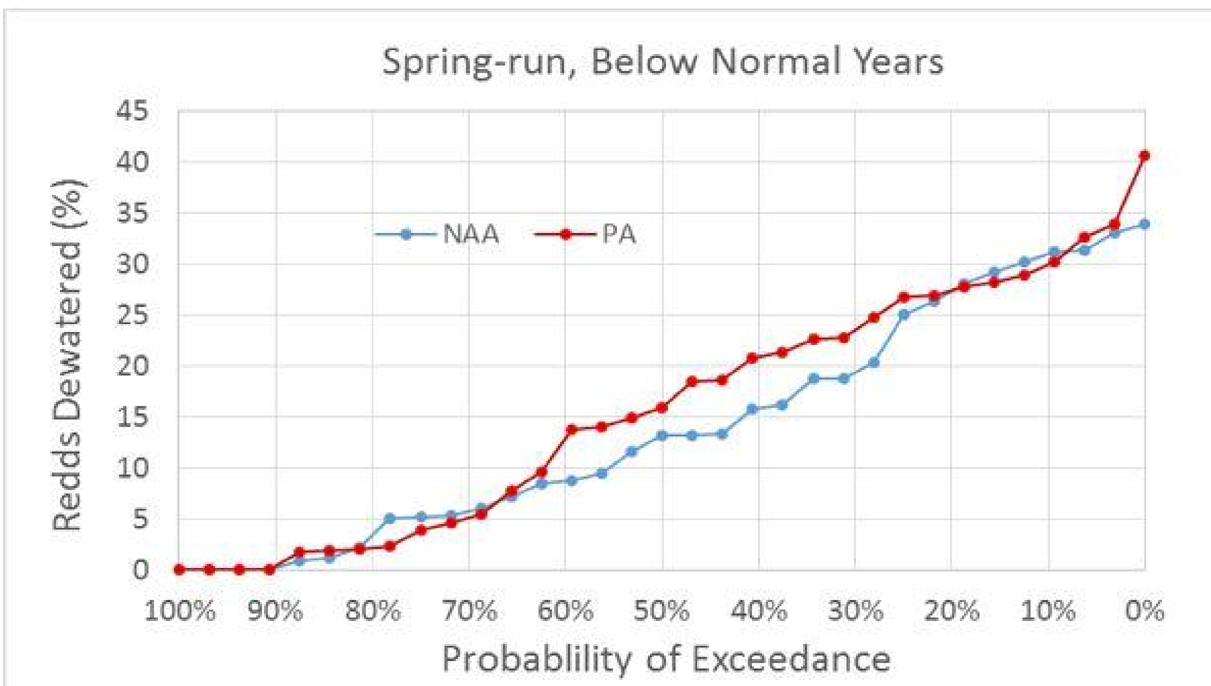


Figure 2-69. Exceedance Plot of Spring-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Below Normal Water Years.

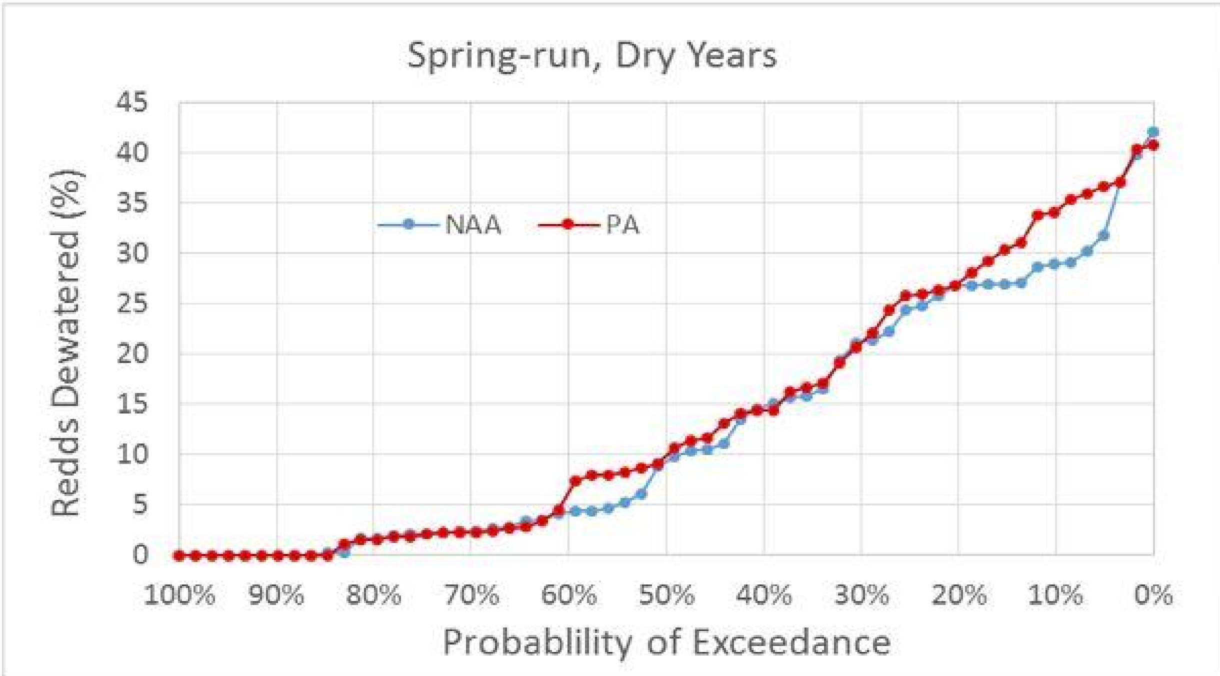


Figure 2-70. Exceedance Plot of Spring-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Dry Water Years.

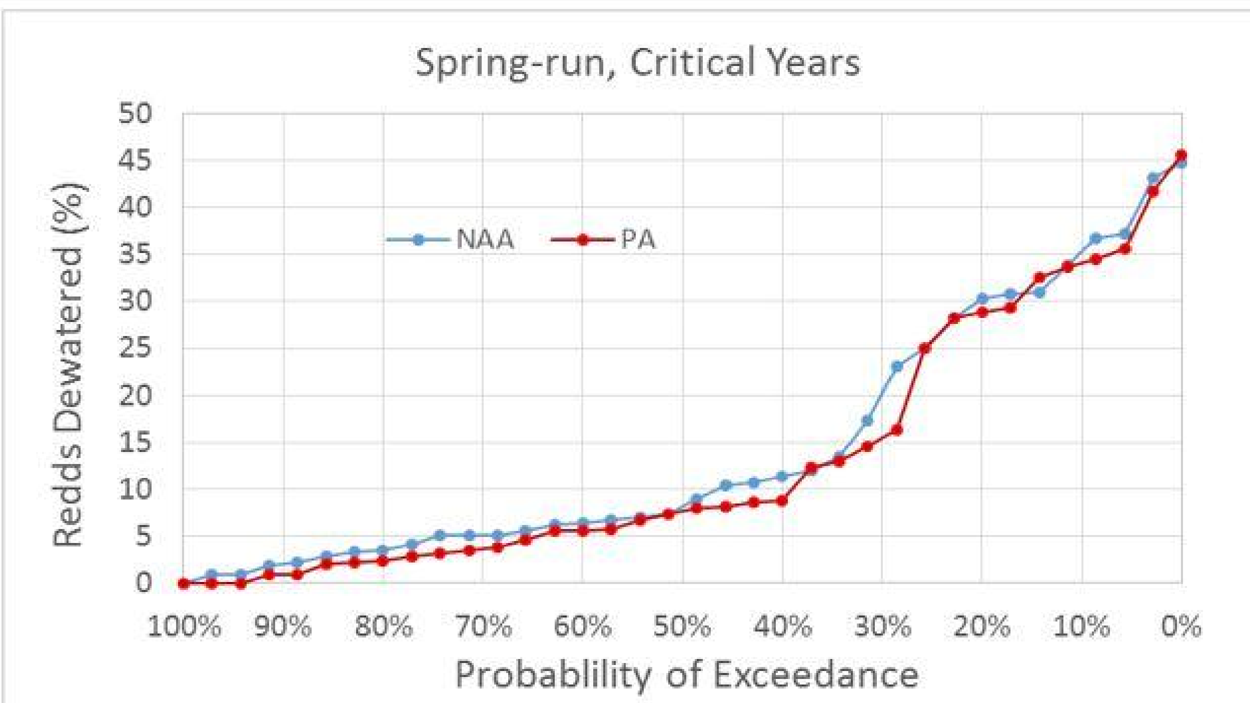


Figure 2-71. Exceedance Plot of Spring-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Critical Water Years.

Exceedance curves indicate differences in redd dewatering between the PA and NAA as examined using the mean percentages of redds dewatered in each river segment for each month of spawning under each water type and all water year types combined (Table 2-139), which may indicate an adverse effect to spring-run Chinook salmon. During August, the mean percent of redds dewatered would be 5 and 8% greater under the PA than under the NAA in wet and above normal water years, respectively. During October, the mean under the PA would be 5% lower in wet years and 6% higher in below normal years. During September of below normal water years, the mean percent of redds dewatered would be up to 3% lower under the PA than under the NAA. The percent differences between the PA and the NAA in the percent of redds dewatered are generally large, but for many months and water year types this is an artifact of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes.

Table 2-139. Spring-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
August	Wet	10.0	15.0	5 (50%)
	Above Normal	13.0	21.4	8 (64%)
	Below Normal	27.9	29.4	1 (5%)
	Dry	27.1	29.4	2 (9%)
	Critical	30.9	29.7	-1 (-4%)
	All	20.1	23.6	3 (17%)
September	Wet	30.2	31.9	2 (6%)
	Above Normal	17.9	16.5	-1 (-8%)
	Below Normal	5.6	2.7	-3 (-52%)
	Dry	3.1	1.9	-1 (-38%)
	Critical	6.0	4.4	-2 (-26%)
	All	14.8	14.2	-0.6 (-4%)
October	Wet	14.5	9.9	-5 (-32%)
	Above Normal	12.4	13.1	1 (5%)
	Below Normal	9.1	15.4	6 (70%)
	Dry	7.9	9.9	2 (26%)
	Critical	6.7	6.1	-1 (-9%)
	All	10.7	10.6	-0.1 (-1%)

The BA also used the SALMOD model to provide predicted flow-related mortality of spring-run Chinook salmon spawning, eggs and alevins in the Sacramento River. The SALMOD results for flow-related mortality are presented in BA Table 5.4-54 in Appendix C of this Opinion together with results for the other sources of mortality of spring-run Chinook salmon predicted by SALMOD. The flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins is divided into “incubation” (which refers to redd dewatering and scour) and "superimposition" (which refers to redd overlap) mortality (see BA Attachment 5.D.2, SALMOD Model, for full model description).

The annual exceedance plot of flow-related mortality of spring-run Chinook salmon spawning, eggs and alevins is presented in Figure 2-72. These results indicate that there would be increases in flow-related mortality of spring-run Chinook salmon spawning, eggs and alevins from incubation-related factors under the PA relative to the NAA for all water year types except dry years. The largest increases, about 30%, would be for wet, above normal and below normal water year types. Under the PA, the number of spring-run Chinook salmon eggs and alevins predicted to die from redd dewatering and scour during incubation ranges from 1,509 in above normal years to 3,422 in dry years; under the NAA mortality ranges from 1,162 in above normal years to 3,652 in dry years.

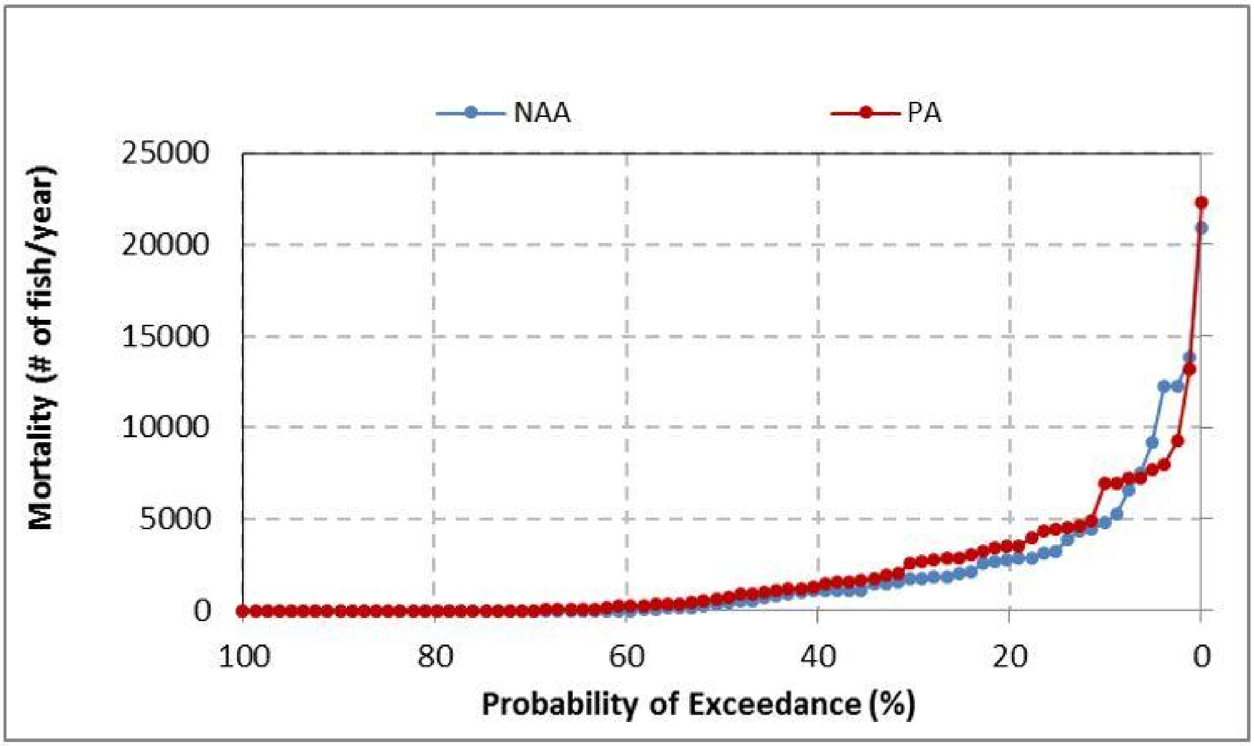


Figure 2-72. Exceedance Plot of Annual Flow-Based Mortality (#of Fish/Year) of Spring-run Chinook Salmon Spawning, Egg Incubation, and Alevins.

Redd dewatering results under the PA for spring-run Chinook salmon show that at least a small percentage ranging up to 32% of redds will be dewatered in every water year type during peak spawning and egg incubation months. The is certainty in the analysis given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale as well as some difficulty in quantifying adverse effects when considering the uncertainties of spring-run Chinook salmon spawning in the upper Sacramento River.

2.5.1.2.2.3 Steelhead Exposure and Risk

2.5.1.2.2.3.1 Sacramento River

Adult migration from the ocean to spawning grounds occurs during much of the year, with peak migration occurring in the fall or early winter Figure 2-73 below (figures A and B from McEwan (2001)). Migration through the Sacramento River mainstem begins in July, peaks at the end of September, and continues through February or March (Bailey 1954; Hallock et al. 1961, both as cited in McEwan and Jackson 1996). Counts made at RBDD from 1969 through 1982 (Hallock 1989, as cited in McEwan and Jackson 1996 and McEwan 2001) and on the Feather River (Painter et al. 1977) follow the pattern described above, although some fish were counted as late as April and May. Weekly counts at Clough Dam on Mill Creek during a 10-year period from 1953 to 1963 showed a similar migration pattern as well. The migration peaked in mid-November and again in February. This second peak is not reflected in counts made in the Sacramento River mainstem (Bailey 1954; Hallock et al. 1961, both as cited in McEwan and Jackson 1996 or at RBDD (Hallock 1989), as cited in McEwan and Jackson 1996, and McEwan 2001).

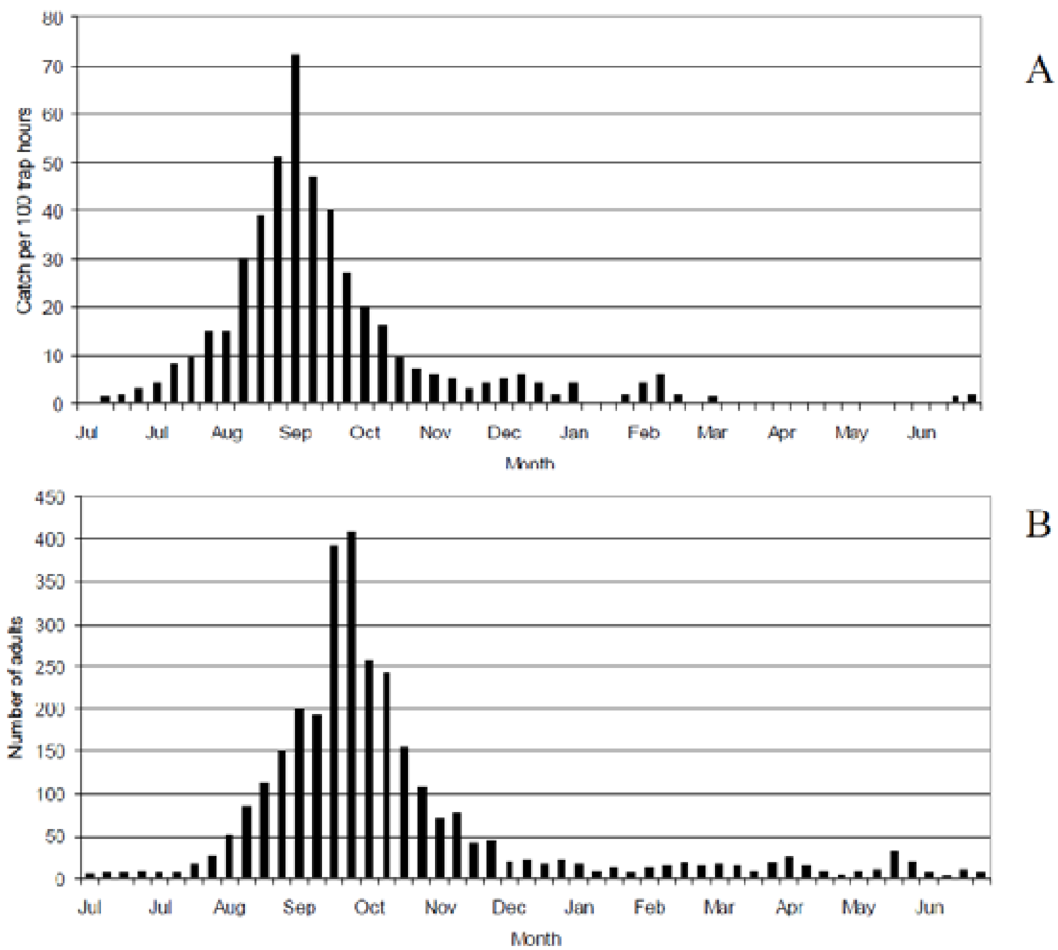


Figure 2-73. Time Pattern of Sacramento River Adult Steelhead Migration.

Plot A shows migration timing from July through June of 1953 through 1959, determined by trapping upstream migrants in the Sacramento River just upstream of the confluence with the Feather River (Hallock et al. (1961) and others). Plot B shows the weekly average number of adult steelhead counted at Red Bluff Diversion Dam from July through June of 1983 through 1986 (from Figure 2, McEwan 2001). The plots are compared to show that steelhead are approximately two to three weeks later in their arrival in the "upper river" (RBDD, Figure B) compared to their exit from the Delta (Figure A). An alternative explanation for these two patterns is that there was a slight shift in migration timing with steelhead in the 1950s immigrating a little earlier than in the 1980s. Both plots show that the bulk of steelhead are immigrating through the Sacramento River from August through November.

Historically, Central Valley steelhead spawned primarily in upper stream reaches and smaller tributaries, although steelhead spawn in most available channel types in unimpounded stream reaches of the Pacific Northwest (Montgomery et al. 1999). Because of water development projects, most spawning is now confined to lower stream reaches below dams. In a few streams, such as Mill and Deer Creeks, steelhead still have access to historical spawning areas. Peak spawning generally occurs from December through April (McEwan and Jackson 1996, McEwan 2001), but spawning can extend into spring and possibly early summer months (McEwan 2001).

Recent steelhead monitoring data are scarce for the Upper Sacramento River system, but population numbers are considered to be low, relative to historic levels (McEwan 2001). Counts at Red Bluff Diversion Dam averaged 1,400 fish from 1991 to 1993, compared to counts in excess of 10,000 fish in the late 1960s (McEwan 2001). There is a strong resident component to the population (referred to as rainbow trout) that interacts with the steelhead population and produces both resident and anadromous offspring. Little is known about steelhead spawning locations in the Sacramento River below Keswick Dam. It was assumed for the analysis of the PA that, because of constraints on water temperature and other habitat features, individuals spawn between Keswick Dam and Red Bluff Diversion Dam, where nearly all Chinook salmon spawn. After spawning, steelhead adults either die or emigrate back to the ocean as kelts between February and May (McEwan 2001).

The time required for egg development is approximately four weeks, but is temperature-dependent (McEwan and Jackson 1996). For northern steelhead populations, optimal egg development occurs at 48 to 52°F. Egg mortality may begin at temperatures above 56°F in northern populations (Bovee 1978; Reiser and Bjornn 1979; and Bell 1986, all as cited in McEwan and Jackson (1996)). After hatching, the yolk-sac fry or alevins remain in the gravel for another four to six weeks (Shapovalov and Taft 1954, as cited in McEwan and Jackson 1996). At 50°F steelhead, fry emerge from the gravel about 60 days after egg fertilization (Leitritz and Lewis 1980).

CCV steelhead eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins in November through the end of alevin emergence in May. The BA provided modeled results on the estimated percentage of steelhead redds dewatered by reductions in Sacramento River flow using CALSIM II estimates of mean monthly flows during the three months following each of the months that steelhead spawn (Section 5.D.2.2, Spawning Flows Methods, Table SFM-1). This analysis employed functional relationships developed in field studies by USFWS (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows. The analysis estimated steelhead redd dewatering under the PA and NAA for the three upstream river segments (Segments 4, 5 and 6). River Segment 4 stretches

8 miles from Battle Creek to the confluence with Cow Creek; Segment 5 reaches 16 miles from Cow Creek to the A.C.I.D. Dam; and Segment 6 covers 2 miles from A.C.I.D. Dam to Keswick Dam. Segment 5 CALSIM II flows were used for the effects analysis to estimate redd dewatering under the PA and NAA. Because the CALSIM II flows for Segments 4 and 6 are similar to those for Segment 5, redd dewatering estimates using the Segment 4 and Segment 6 flows differ little from those for Segment 5 (Appendix 5.D, Section 5.D.2.6, Redd Dewatering Results, Sacramento River Segments 4 and 6). Further information on the redd dewatering analysis methods is provided in Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods.

Differences in steelhead redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for the months that steelhead spawn (November through February) (Figure 2-74 through Figure 2-79).

Exceedance curves for wet and above normal water years indicate that frequencies of dewatering in the middle of the range of redd dewatering percentages would be lower under the PA than under the NAA, but that the frequencies would be similar under the two scenarios for the high and low portions of the range. For the other water year types, frequencies would be similar throughout the range of percentages. The differences for wet years show that under both scenarios approximately 50% of the time, 10% of the redds will be dewatered. Between 50% exceedance and 15% exceedance, the difference between the NAA and PA is about 10 to 15%, with the PA having a lower incidence of redd dewatering. Both scenarios start tracking together again at 15% exceedance when the percentage of redds dewatered reaches approximately 50%. In 10% of the years, the percentage of redds dewatered can reach approximately 75%. The difference between the NAA and PA in above normal years is even greater than in wet years, reaching a maximum of about 30% at about 25% exceedance. Like the wet years, 10% of the redds are dewatered about 50% of the time for both scenarios. At 25% exceedance, the NAA scenario model has about 50% of the redds dewatered, while the PA has approximately 22% of the redds dewatered. By 20% exceedance, both scenarios are again tracking together and approximately 55% of the redds are dewatered. About 75% of the redds will be dewatered 15% of the time, based on the modeling for both scenarios. In the remaining water year types, typically less than 10% of the redds are dewatered for about 80% of the time. Overall, redd dewatering under the PA is expected to be the same or lower than the NAA over most hydrologic conditions.

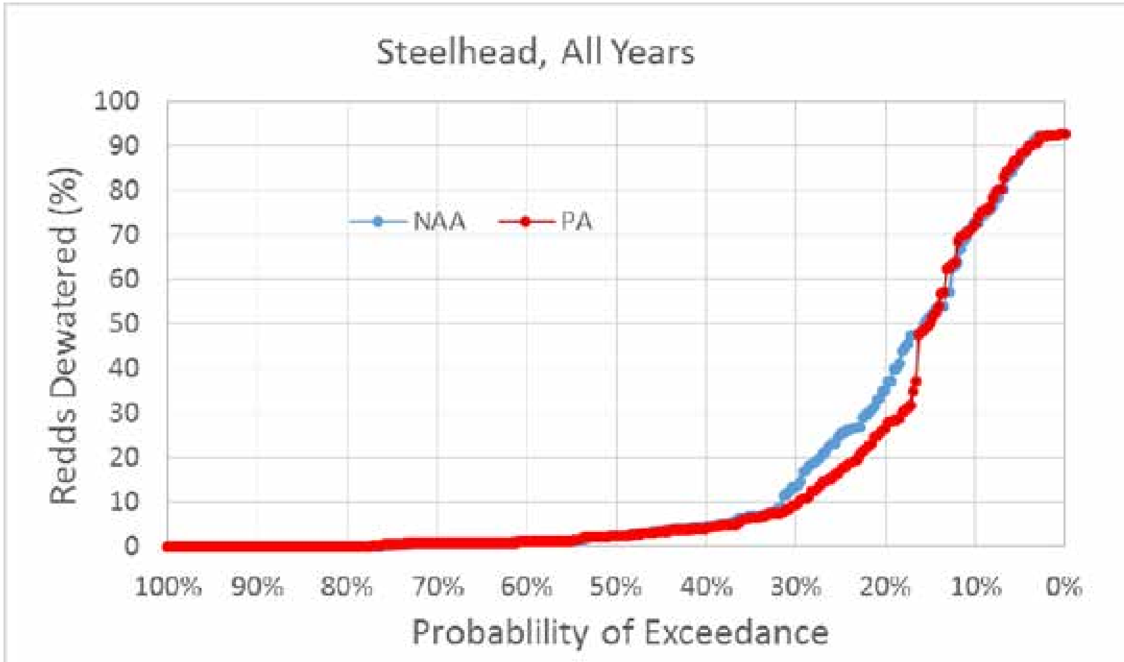


Figure 2-74. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, All Water Years.

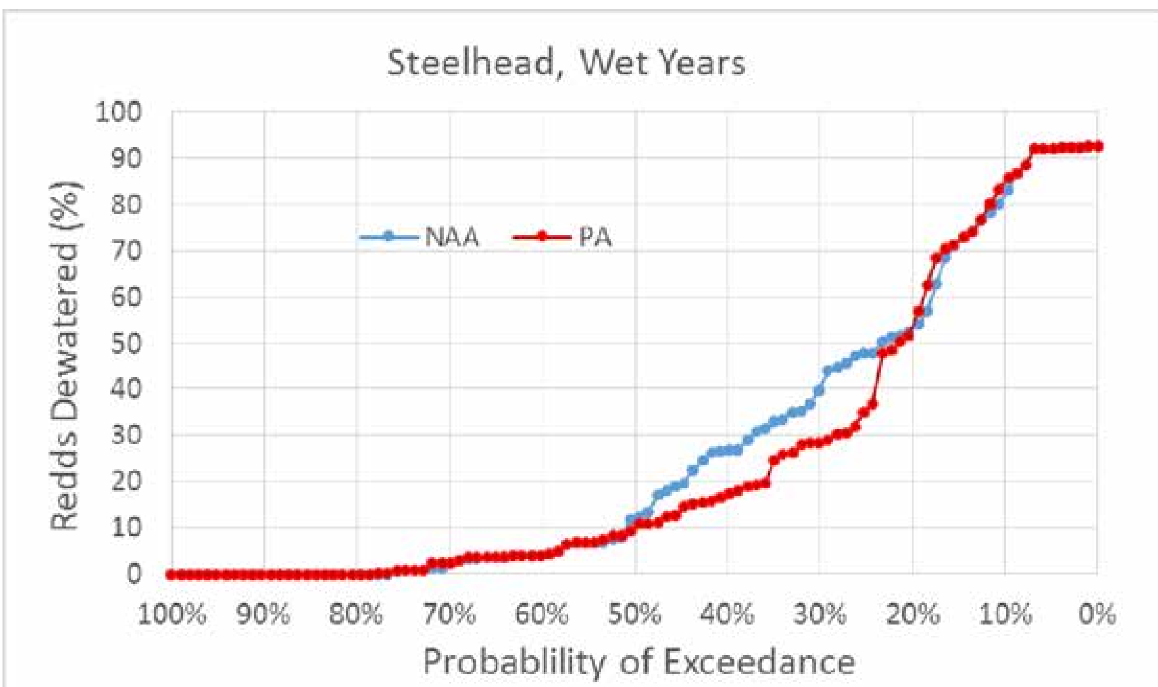


Figure 2-75. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Wet Water Years.

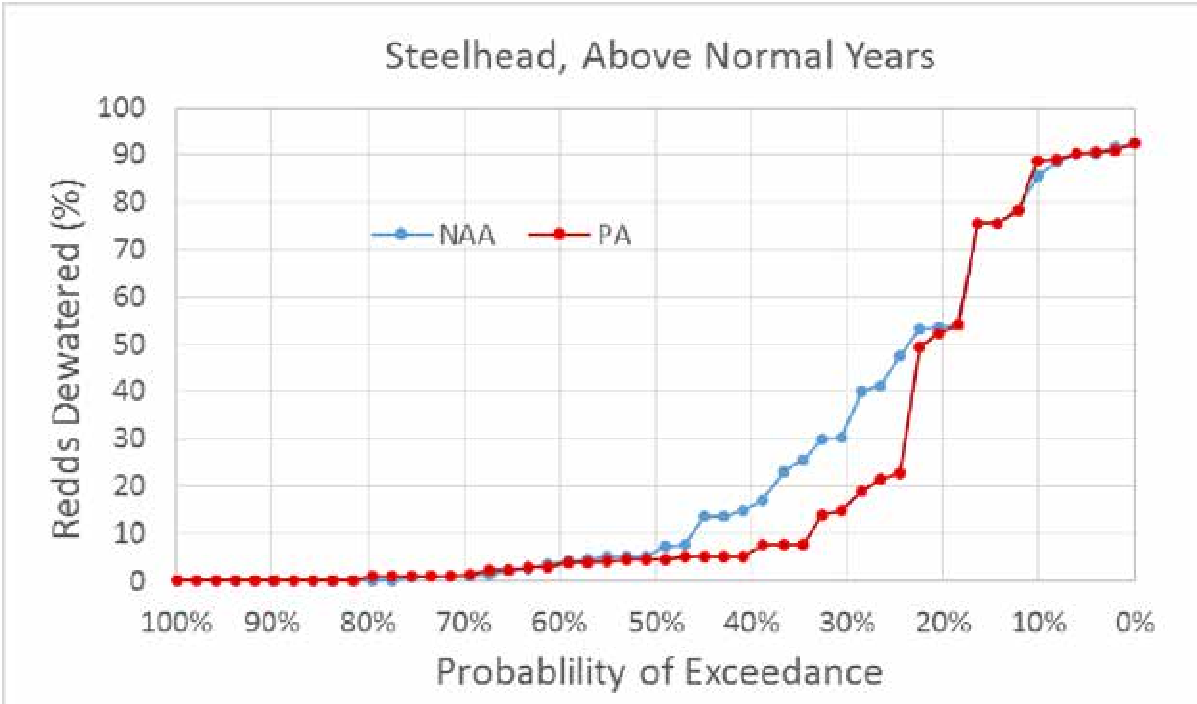


Figure 2-76. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Above Normal Water Years.

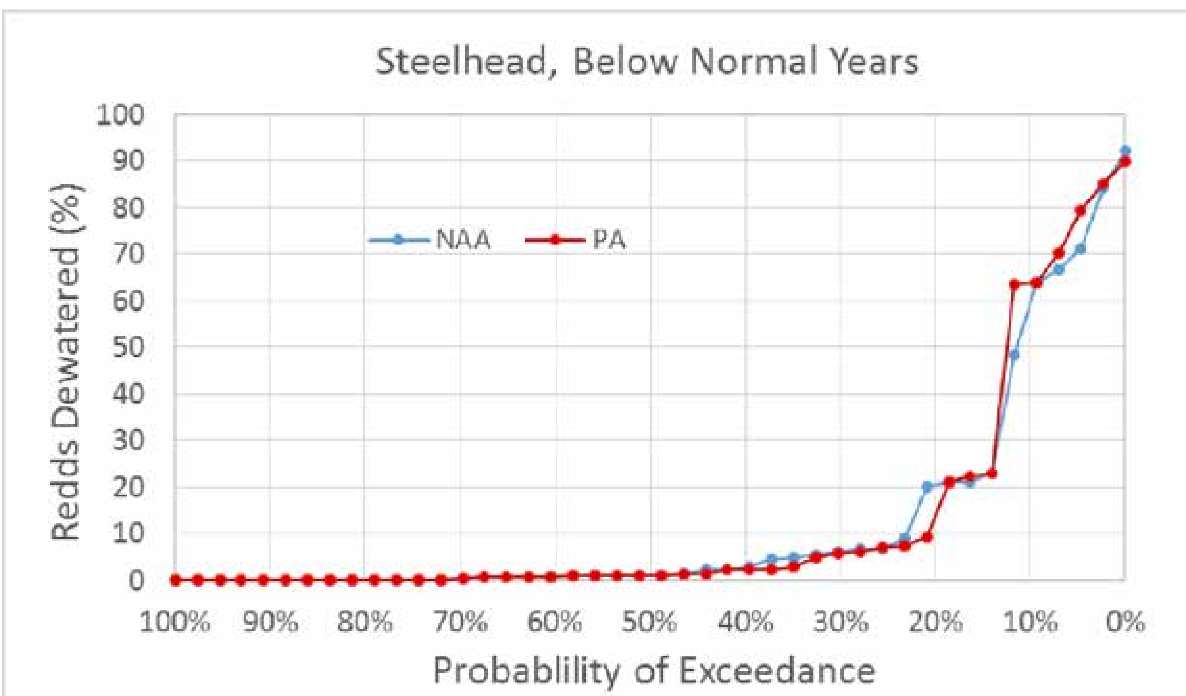


Figure 2-77. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Below Normal Water Years.

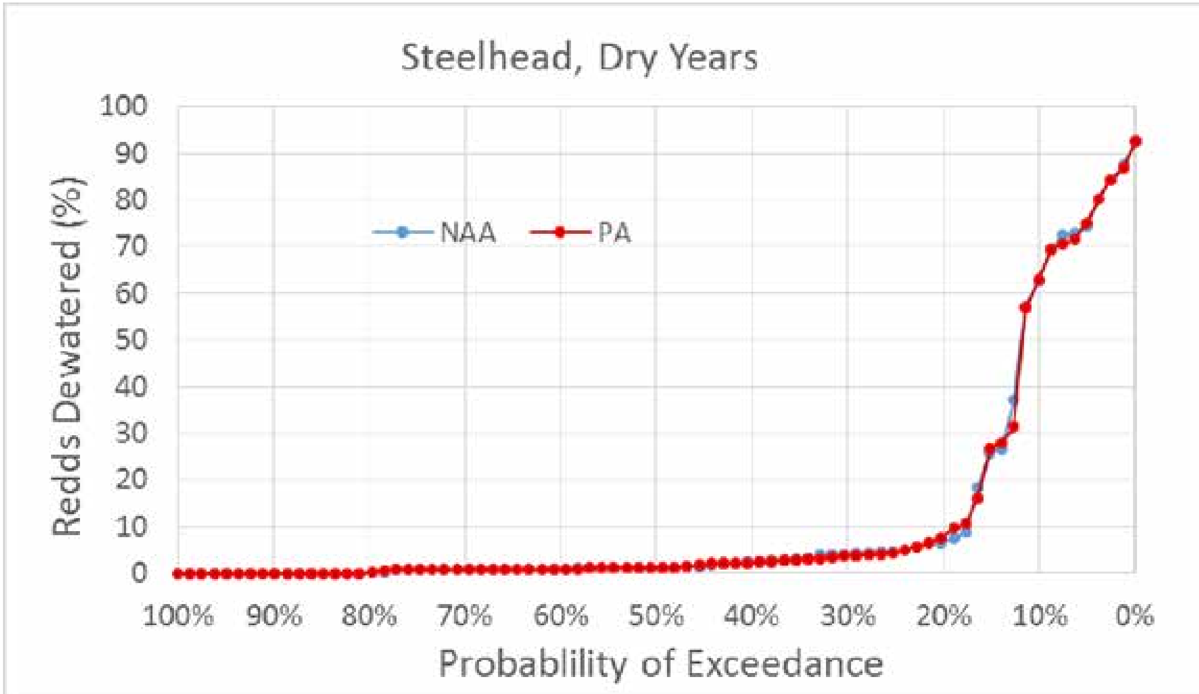


Figure 2-78. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Dry Water Years.

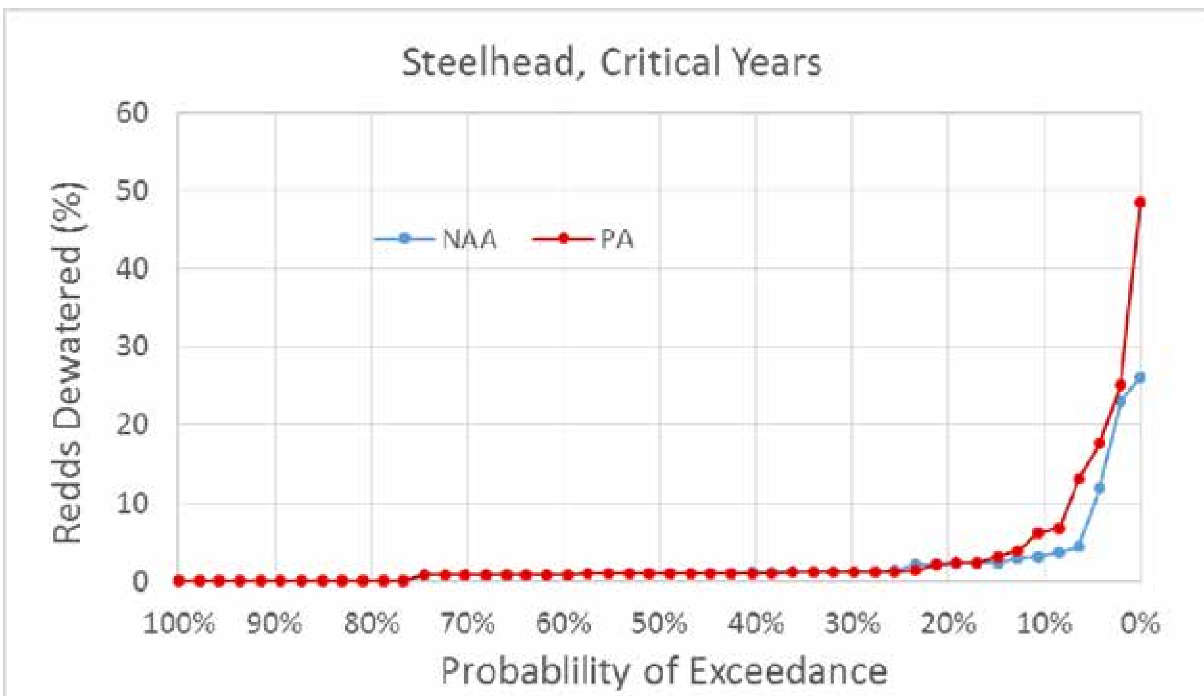


Figure 2-79. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Critical Water Years.

Differences in the mean percentage of redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined also indicate that the PA would minimally affect steelhead redd dewatering, except for reductions in the mean percent of redds dewatered during November of wet and above normal water year types (Table 2-140). The percent differences between the PA and the NAA in the percent of redds dewatered range up to a 158% increase under the PA for January of critical water years, but this increase and many of the large relative changes in percent of redds dewatered are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes.

Table 2-140. Central Valley Steelhead Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
November	Wet	29.4	15.6	-13.8 (-47%)
	Above Normal	29.1	15.5	-13.55 (-47%)
	Below Normal	6.6	5.0	-1.6 (-24%)
	Dry	4.5	3.4	-1.1 (-24%)
	Critical	1.9	4.7	2.8 (153%)
	All	16.0	9.5	-6.5 (-41%)
December	Wet	14.0	14.7	0.7 (5%)
	Above Normal	10.2	8.9	-1.3 (-13%)
	Below Normal	11.8	11.7	-0.1 (-1%)
	Dry	22.2	22.3	0.1 (1%)
	Critical	1.1	1.0	-0.1 (-11%)
	All	13.3	13.3	0 (0%)
January	Wet	22.6	26.0	3.5 (15%)
	Above Normal	14.2	14.3	0.1 (1%)
	Below Normal	14.7	14.2	-0.6 (-4%)
	Dry	21.5	21.9	0.4 (2%)
	Critical	2.6	6.7	4.1 (158%)
	All	17.0	18.8	1.8 (10%)
February	Wet	43.5	44.2	0.8 (1.8%)
	Above Normal	47.7	47.9	0.1 (0%)
	Below Normal	18.8	21.8	3 (16%)
	Dry	1.0	1.1	0.1 (12%)
	Critical	3.6	0.6	-3.1 (-84.1%)
	All	24.6	24.9	0.2 (1%)

2.5.1.2.2.3.2 American River

CCV steelhead eggs and alevins in the American River are vulnerable to dewatering from the time when spawning begins in December through the end of alevin emergence in May. The BA provided modeled results on the estimated percentage of steelhead redds dewatered by reductions in American River flow using CALSIM II estimates of mean monthly flows during the 3 months following each of the months that steelhead spawn. No model for predicting percentages of redds dewatered, such as that developed for the Sacramento River (USFWS 2006), has been developed for the American River. Therefore, the maximum reduction in American River flow for the three months following each of the months during which steelhead spawn was used as a proxy for percent of redds dewatered. CALSIM II flows at Nimbus were used for this analysis. Larger maximum reductions are assumed to increase the percent of redds dewatered and, therefore, to have a negative effect on steelhead. Further information on redd dewatering analysis methods is provided in Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods.

Differences in maximum flow reductions under the PA and NAA were examined using exceedance plots of mean monthly maximum flow reductions, expressed as a percentage of the spawning flows, for the months that American River steelhead spawn (December through February) (BA Figures 5.4-254 through 5.4-259; Figure 2-80 through Figure 2-85).

Exceedance curves for all water year types combined (BA Figure 5.4-254; Figure 2-57) and those for wet, above normal, below normal, and dry water years (BA Tables 5.4-255 through 5.4-258; Figure 2-81 through 2-84) indicate that the PA would generally have slightly greater flow reductions than the NAA. These differences are typically minor, with a magnitude of approximately 5 to 15%. The exceedance curve for critical years appears to indicate a pronounced increase in flow reductions for the PA of up to approximately 40% (Figure 2-85).

However, further inspection, as referenced in the BA, reveals that increased reductions result from differences in only three months out of the 36 critical water year months of the CCV steelhead spawning period in the American River, with all of these months occurring in the same year (1933). The large magnitude of reduced flows in March 1933 under the PA appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs, resulting in higher releases from Keswick Dam and lower releases from Folsom for this month.

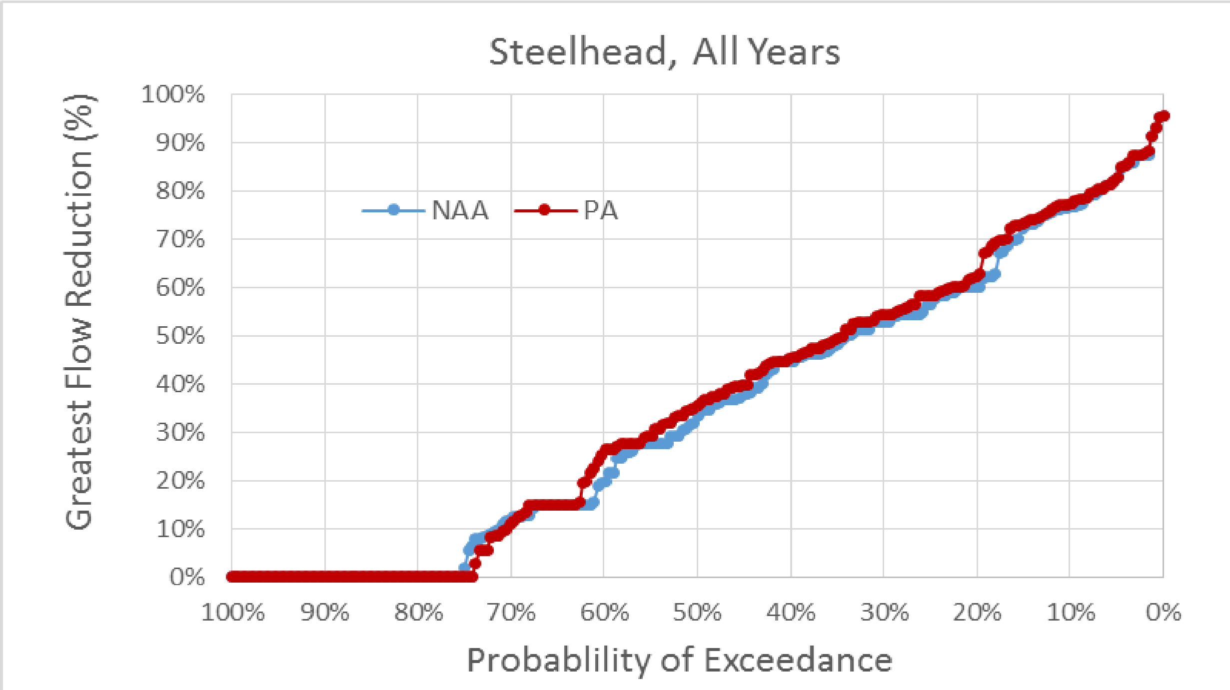


Figure 2-80. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, All Water Years.

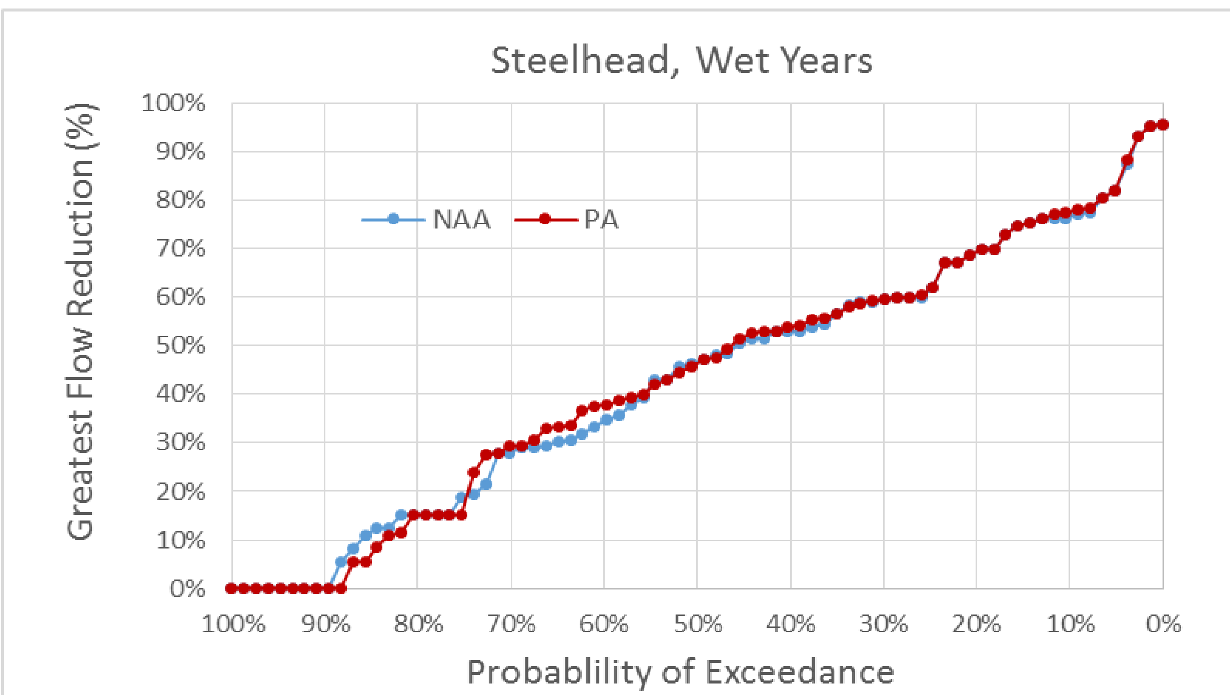


Figure 2-81. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Wet Water Years.

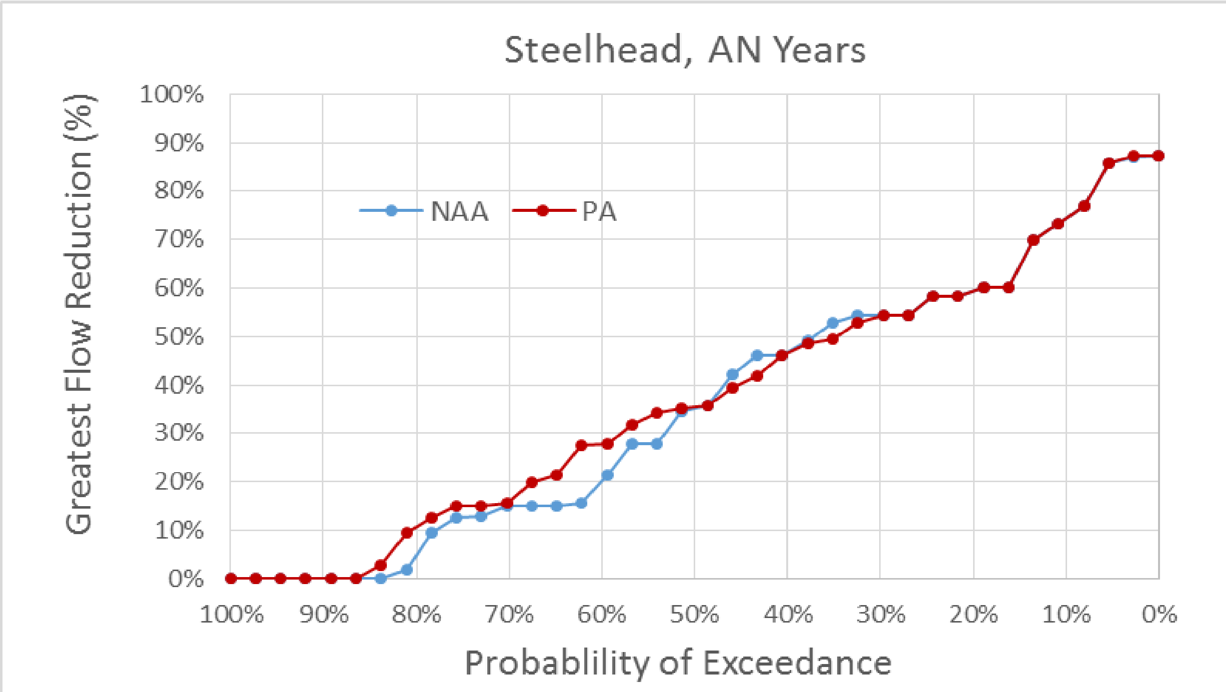


Figure 2-82. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Above Normal Water Years.

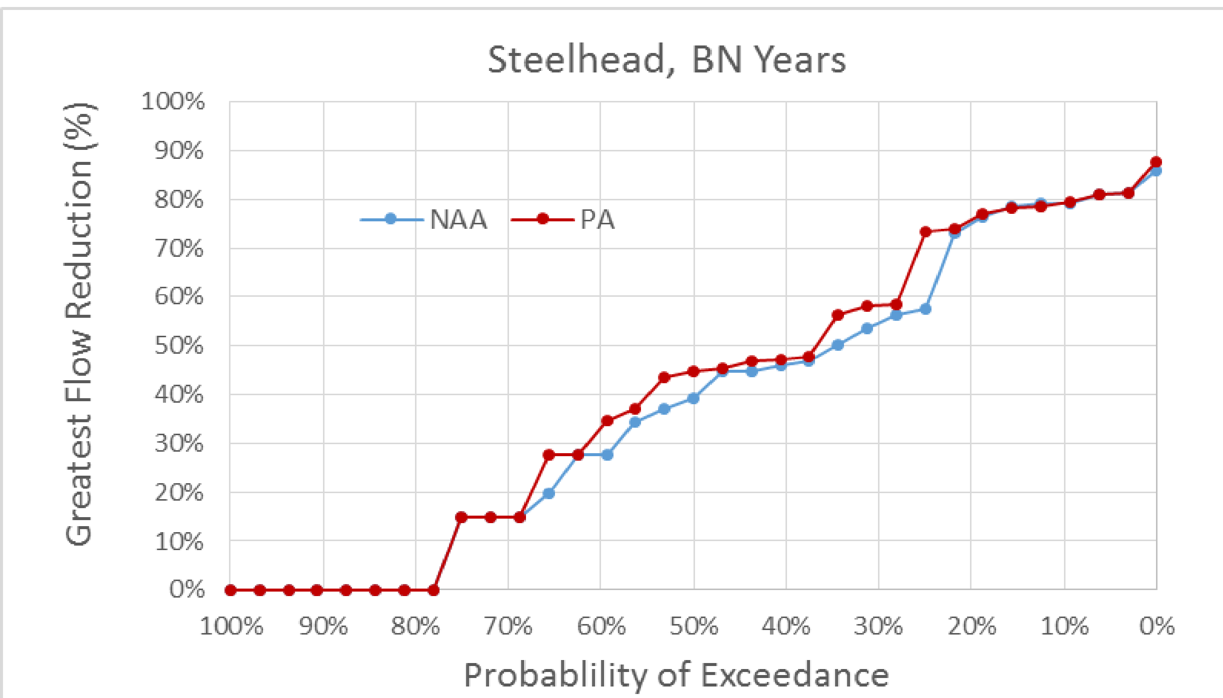


Figure 2-83. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Below Normal Water Years.

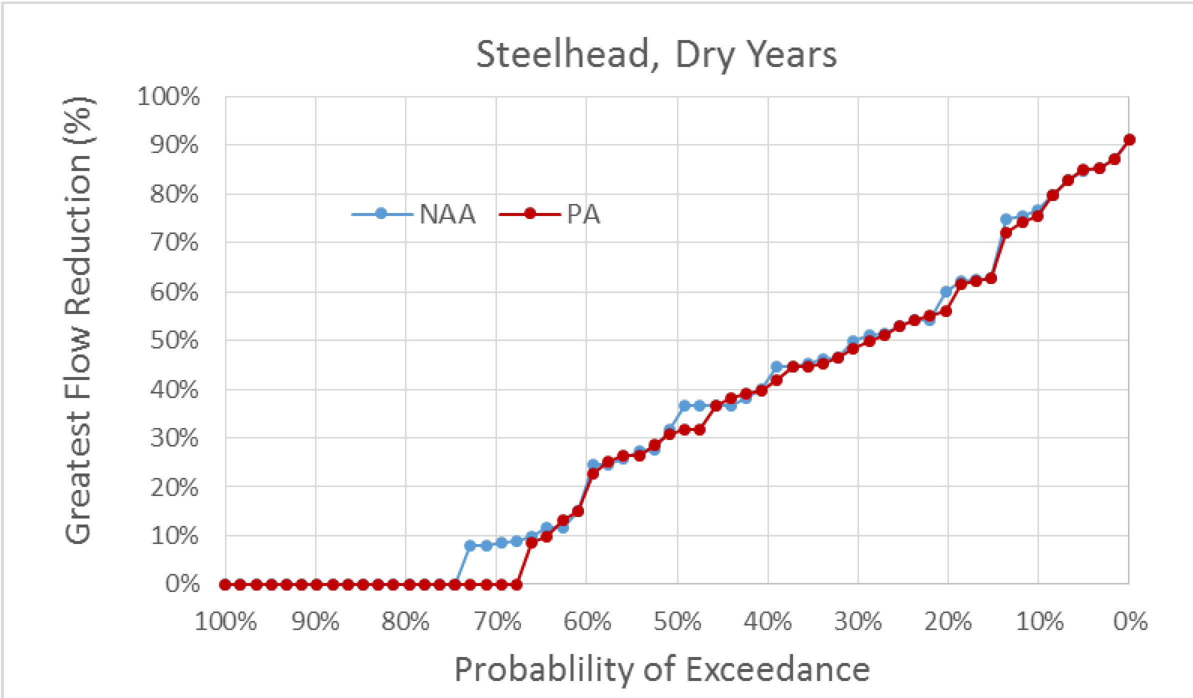


Figure 2-84. Exceedance Plot of Maximum Flow Reductions for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Dry Water Years.

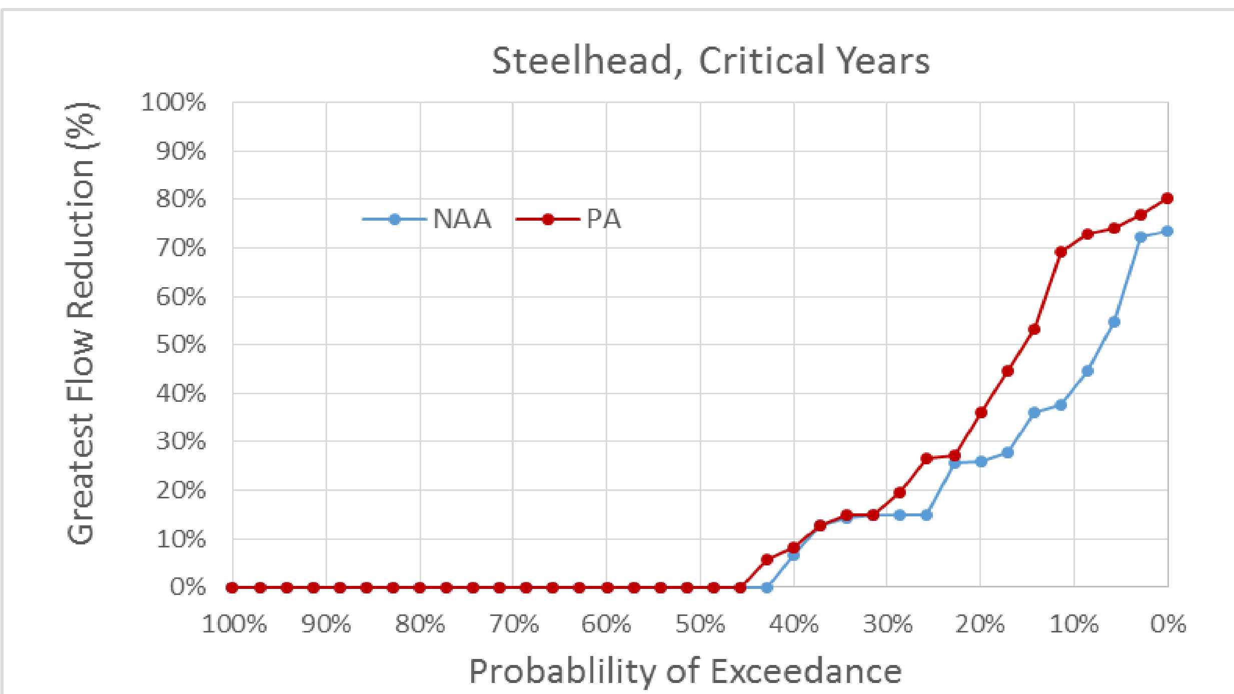


Figure 2-85. Exceedance Plot of Maximum Flow Reductions for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Critical Water Years.

Differences in the mean maximum flow reduction, expressed as a percentage of the spawning flow, for each month of spawning under each water year type and all water year types combined indicate that steelhead redd dewatering would generally be little affected by the PA (less than 5% raw difference), except for a 5% increase in the maximum flow reduction for January of critical years and 6 and 7% increases for February of below normal and critical years, respectively. As previously noted, increases in flow reduction are assumed to increase redd dewatering, negatively affecting steelhead (Table 2-141).

Table 2-141. Maximum Flow Reductions (cfs) for 3-Month Period after Central Valley Steelhead Spawning, and Differences in the Maximums (Percent Differences) Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher[1].)

		Mean Greatest Flow Reduction, as Percent		Raw Difference	Relative (Percent) Difference
Month	WYT	NAA	PA	PA vs. NAA	PA vs. NAA
December	Wet	33.3%	33.5%	0.2%	0.7%
	Above Normal	29.1%	29.0%	-0.1%	-0.2%
	Below Normal	24.3%	24.3%	0.0%	-0.2%
	Dry	35.8%	32.9%	-2.9%	-8.2%
	Critical	15.8%	17.1%	1.3%	8.2%
	All	29.5%	29.0%	-0.5%	-1.6%
January	Wet	42.4%	42.3%	0.0%	-0.1%
	Above Normal	27.0%	26.9%	-0.2%	-0.6%
	Below Normal	40.2%	40.3%	0.1%	0.2%
	Dry	35.8%	36.1%	0.2%	0.6%
	Critical	8.1%	13.2%	5.0%	61.8%
	All	33.0%	33.8%	0.8%	2.3%
February	Wet	53.5%	54.3%	0.8%	1.4%
	Above Normal	50.7%	54.6%	3.9%	7.7%
	Below Normal	50.5%	56.5%	6.0%	11.9%
	Dry	28.1%	27.7%	-0.4%	-1.3%
	Critical	15.8%	22.8%	7.0%	44.5%
	All	41.0%	43.6%	2.6%	6.4%

[1] Increased flow reduction is assumed to increase redd dewatering, negatively affecting steelhead.

2.5.1.2.2.4 Green Sturgeon Exposure and Risk

As previously described, green sturgeon spawning primarily occurs in deep pools containing small to medium sized gravel, cobble or boulder substrate in cool sections of the upper mainstem Sacramento River. Because green sturgeon spawn in deep pools, they are not vulnerable to redd dewatering as a result of flow management in the upper Sacramento River (Benson et al. 2007, Erickson and Webb 2007, Heublein et al. 2008, Poytress et al. 2015).

2.5.1.2.2.5 Fall/Late Fall-run Species Exposure and Risk

2.5.1.2.2.5.1 Sacramento River

2.5.1.2.2.5.1.1 Fall-run Chinook Salmon

Fall-run Chinook salmon eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins in September through fry emergence in January (Vogel and Marine 1991). Nearly all fall-run Chinook salmon redds are constructed upstream of Woodson Bridge, with 61% of redds occurring upstream of the Battle Creek confluence (Table 2-3). The redd dewatering analysis presented in the BA and below relies upon the relationships between flow fluctuations and redd dewatering for Chinook salmon in the Sacramento River between Keswick Dam and Battle Creek (USFWS 2006). The flow fluctuation-redd dewatering relationship downstream of Battle Creek is not available, and as such, the analysis covers the Sacramento River upstream of the Battle Creek confluence. Based on the spatial distribution of redds from 2003-2014 (Table 2-102), therefore, 60% of the habitat used for Sacramento River fall-run Chinook salmon spawning and egg incubation was analyzed for potential risks from dewatering, while the remaining 40% spawning habitat downstream of the Battle Creek confluence was not. As described below, the results for redd dewatering for areas of the Sacramento River upstream of the Battle Creek under the PA are in most cases similar to redd dewatering under the NAA. NMFS expects that a similar result would be seen for redds occurring downstream of the Battle Creek.

The percentage of fall-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated using CALSIM II estimates of monthly mean flows during the three months following each month of spawning combined with the functional relationships developed in field studies by U.S. Fish and Wildlife Service (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows (BA Appendix 5D.2.2, Spawning Flows Methods). The analysis estimated fall-run Chinook salmon redd dewatering under the PA and NAA for the three upstream river segments (Segments 4, 5 and 6). River Segment 4 stretches 8 miles from Battle Creek to the confluence with Cow Creek; Segment 5 reaches 16 miles from Cow Creek to the A.C.I.D. Dam; and Segment 6 covers 2 miles from A.C.I.D. Dam to Keswick Dam. Detailed information on redd dewatering analysis methods is provided in the BA in Appendix 5D.2.2, Spawning Flows Methods.

Differences in fall-run Chinook salmon redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for the September through November months of spawning. Because river Segment 5 is the longest segment and includes the bulk of the analyzed fall-run Chinook salmon spawning area, those results are described in more detail here. The exceedance curves for the PA generally show consistently similar or lower redd dewatering percentages than those for the NAA for all water year types combined, and for wet and above normal water year types (Figure 2-92 through Figure 2-94). The biggest differences in the dewatering curves are predicted for wet water years, with about 61% of all months having greater than 20% of redds dewatered under the NAA, but only 40% of all months having greater than 20% of redds dewatered under the PA (Figure 2-93). Results for Segment 6 (Figure 2-86) through (Figure 2-91) and Segment 4 (Figure 2-97 through Figure 2-103) are similar to those for Segment 5 (BA) in that the PA generally shows consistently similar or lower redd dewatering percentages than for the NAA for all water year types combined, and for wet and above normal water year types.

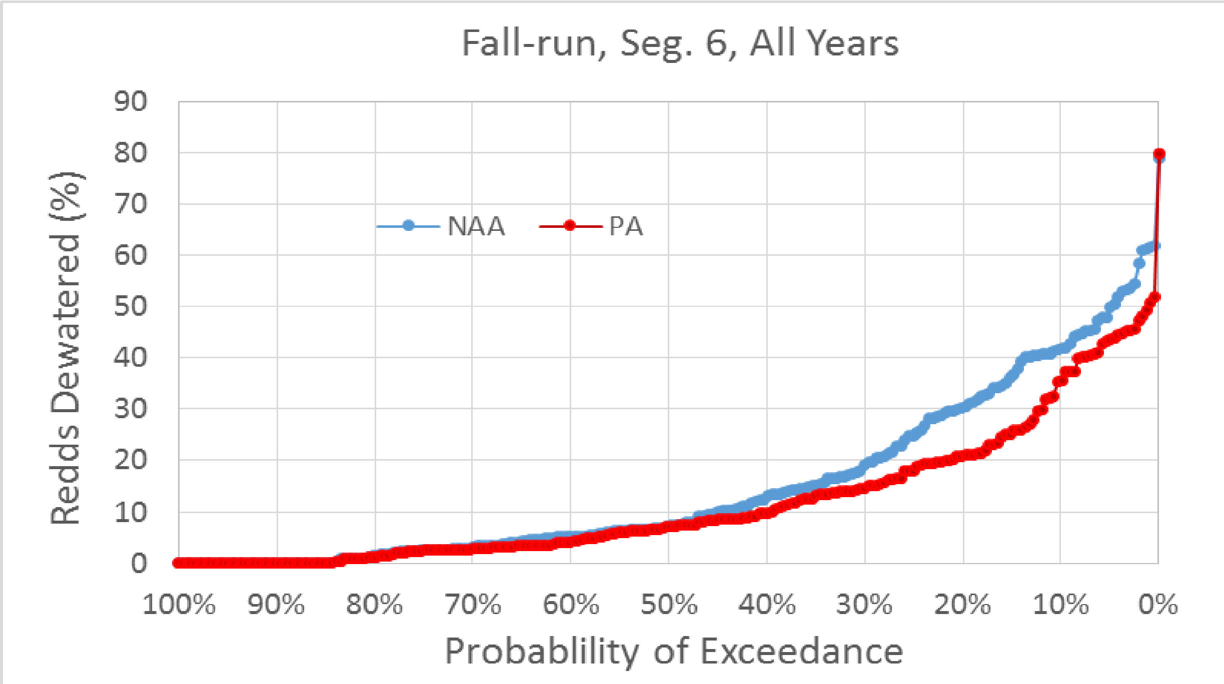


Figure 2-86. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, All Water Years.

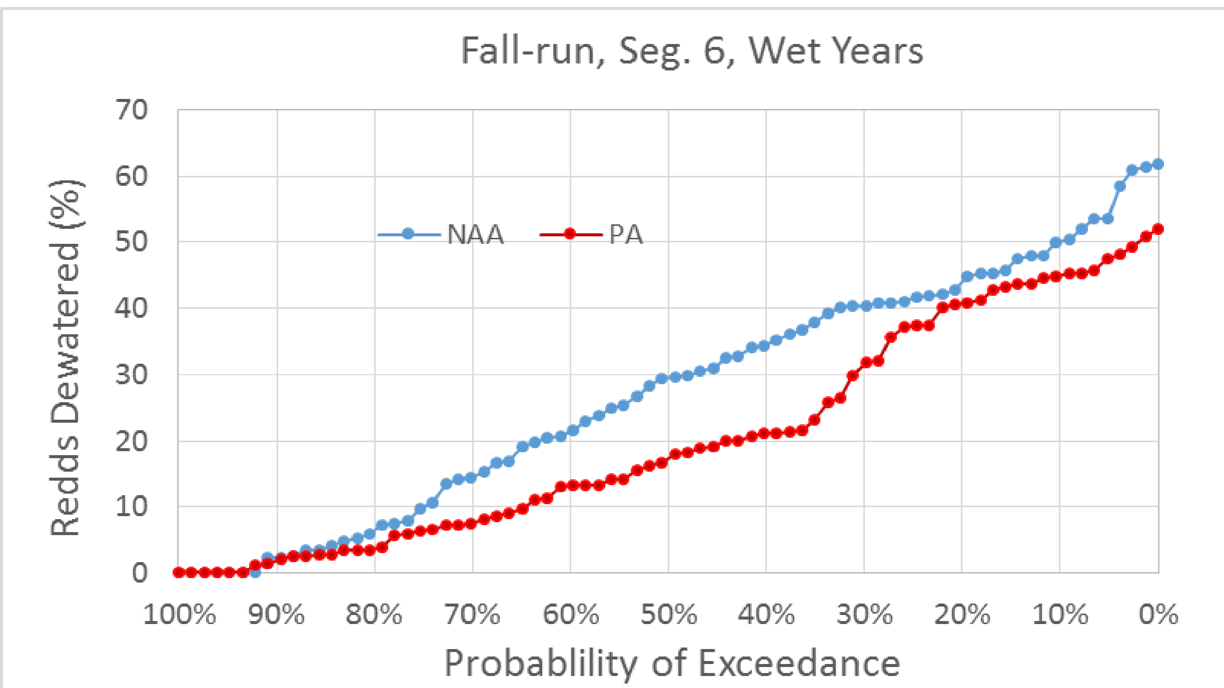


Figure 2-87. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Wet Water Years.

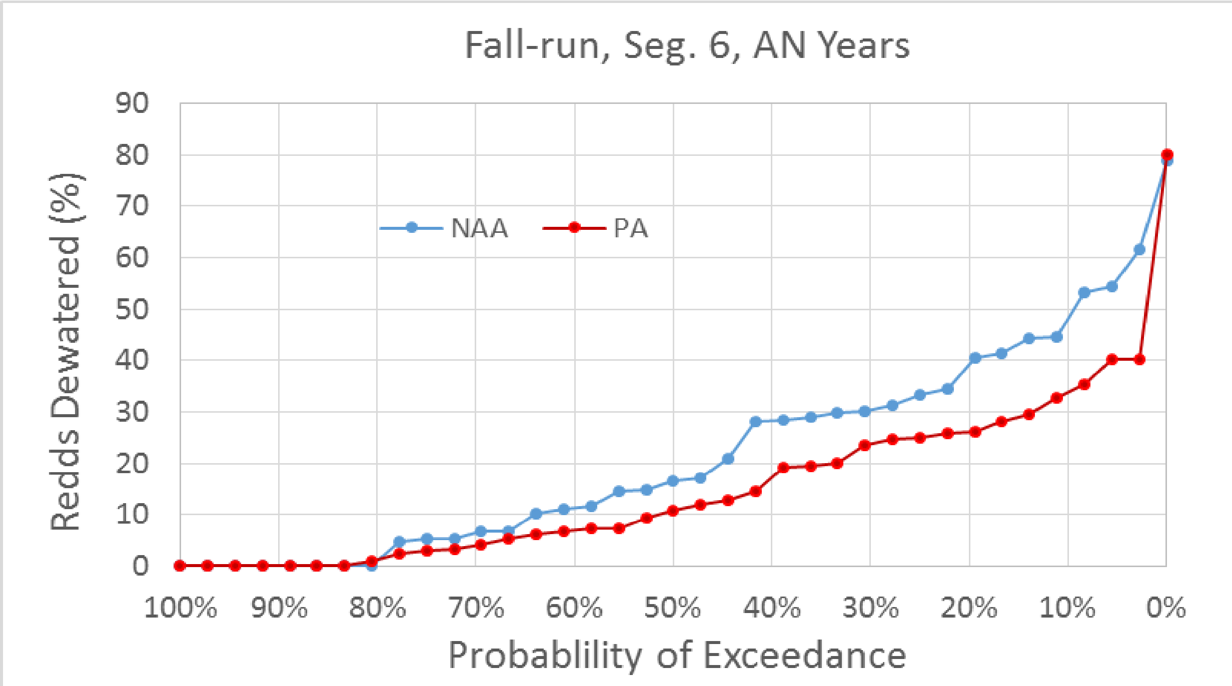


Figure 2-88. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years.

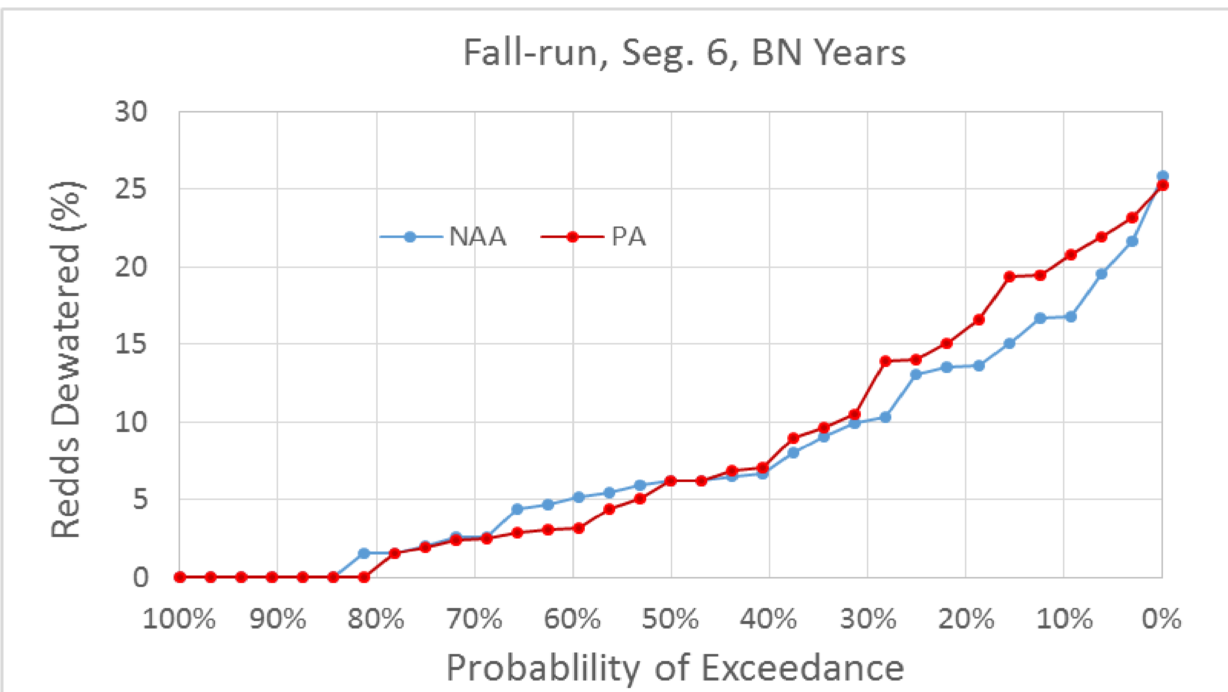


Figure 2-89. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years.

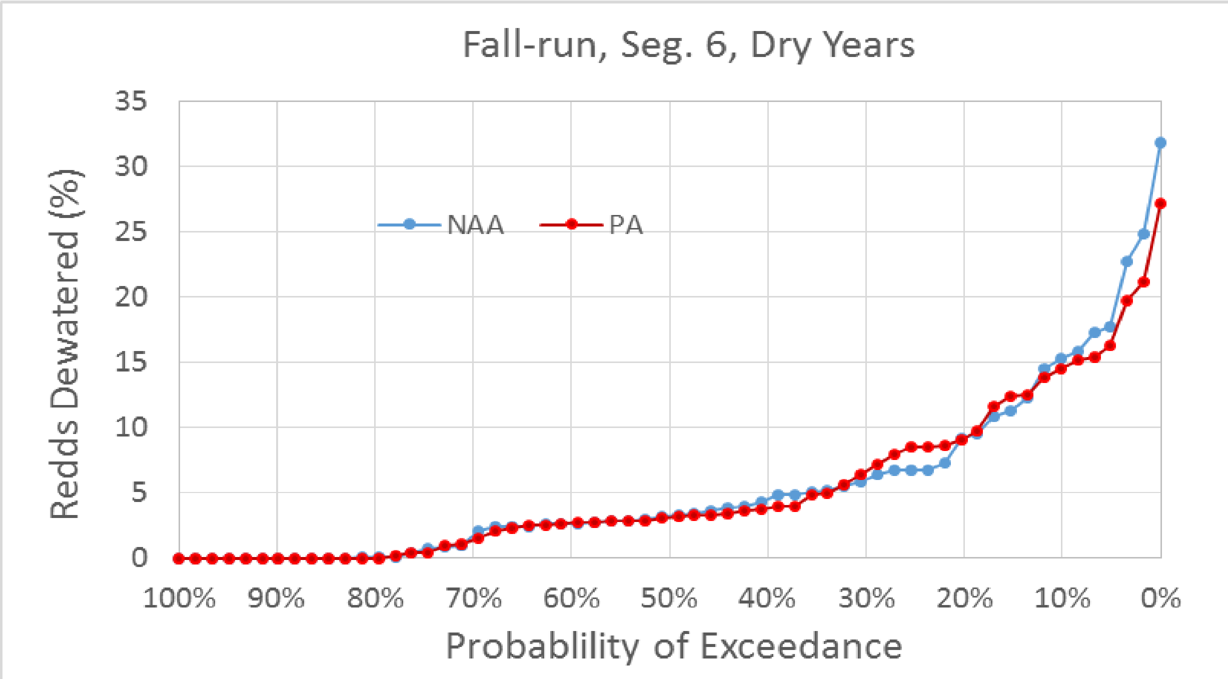


Figure 2-90. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Dry Water Years.

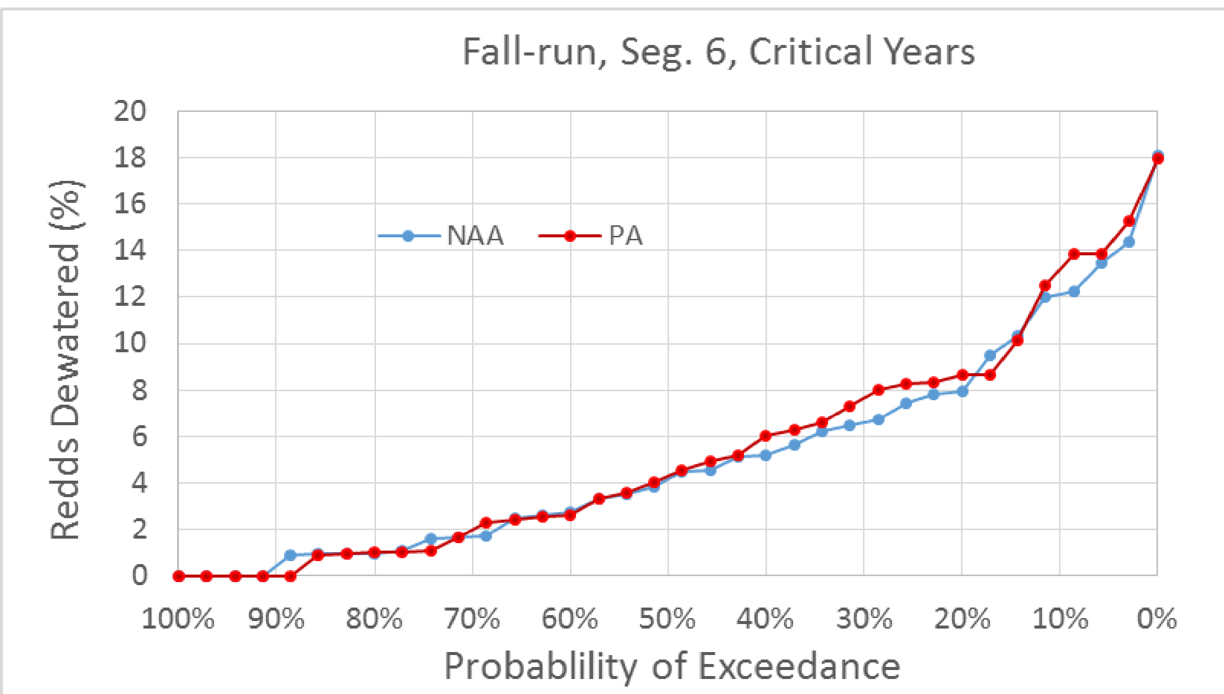


Figure 2-91. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Critical Water Years.

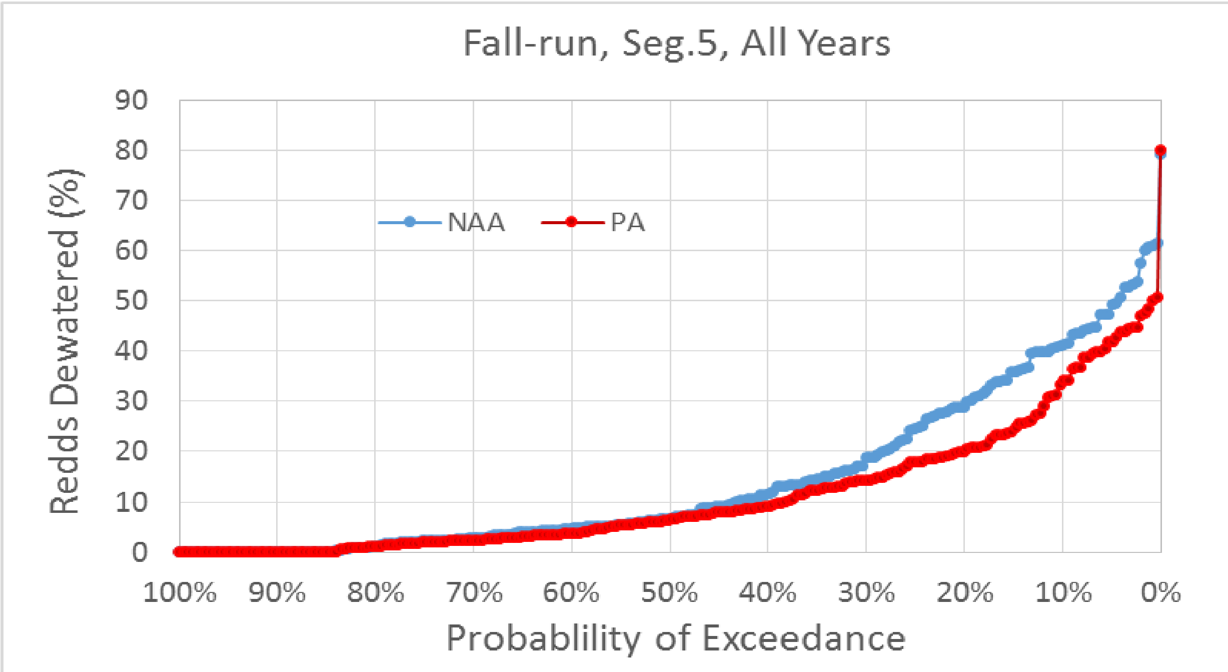


Figure 2-92. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, All Water Years.

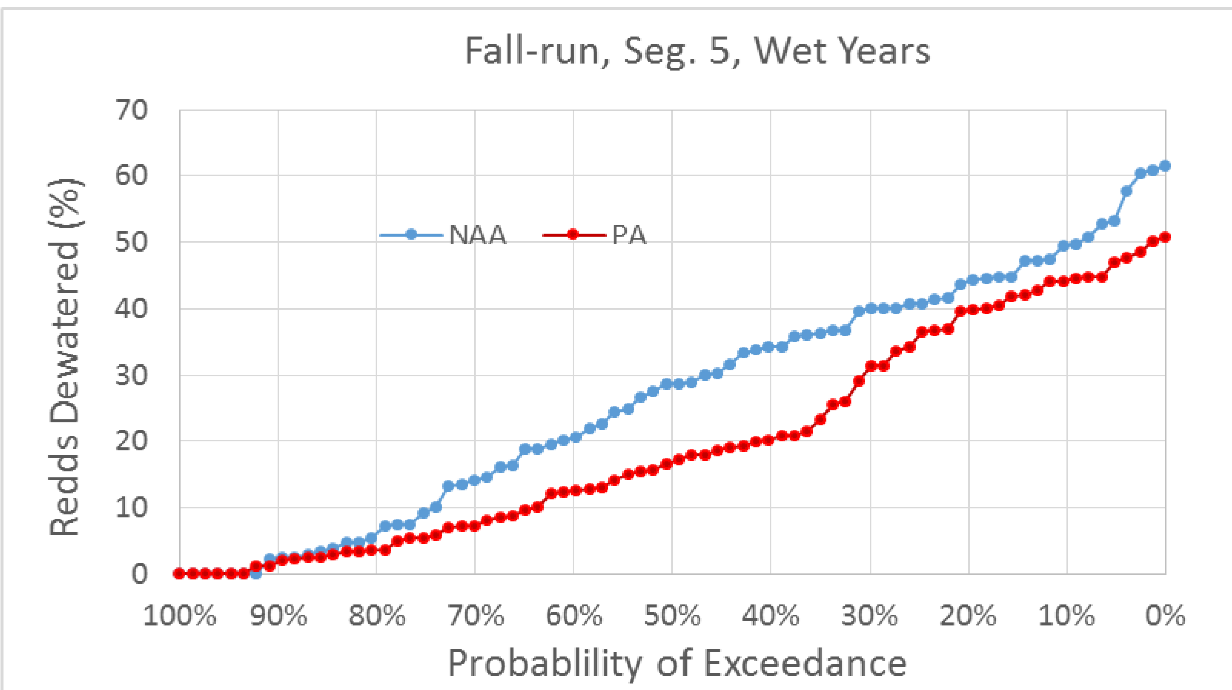


Figure 2-93. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Wet Water Years.

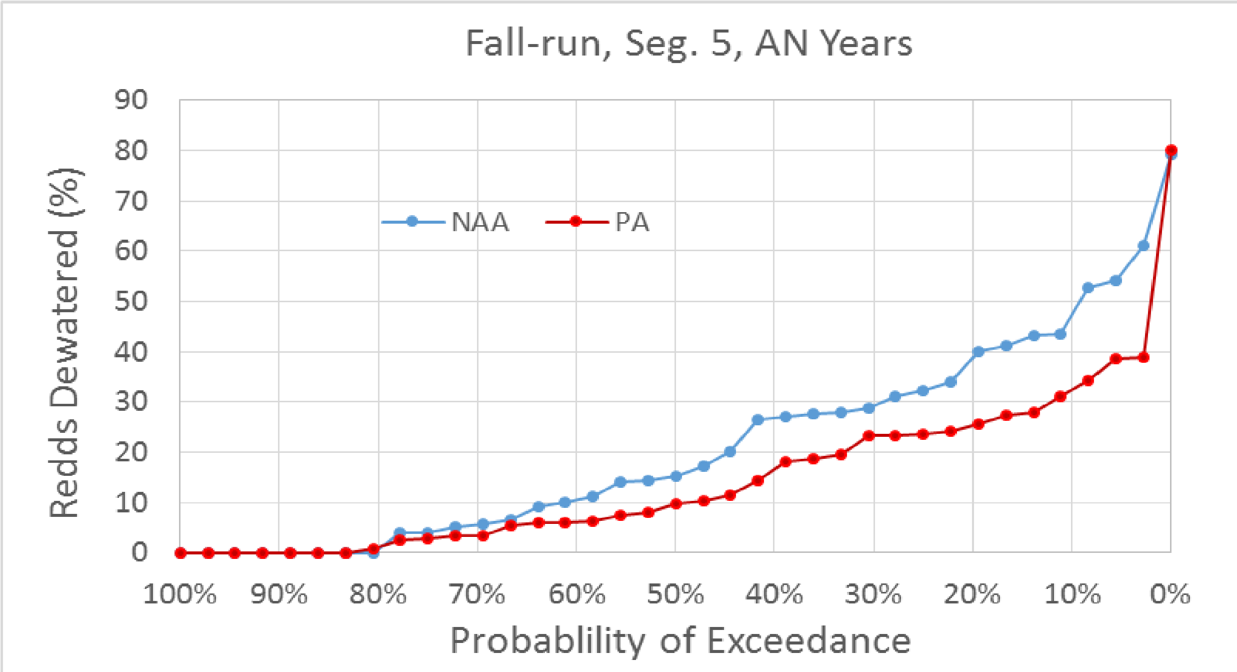


Figure 2-94. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years.

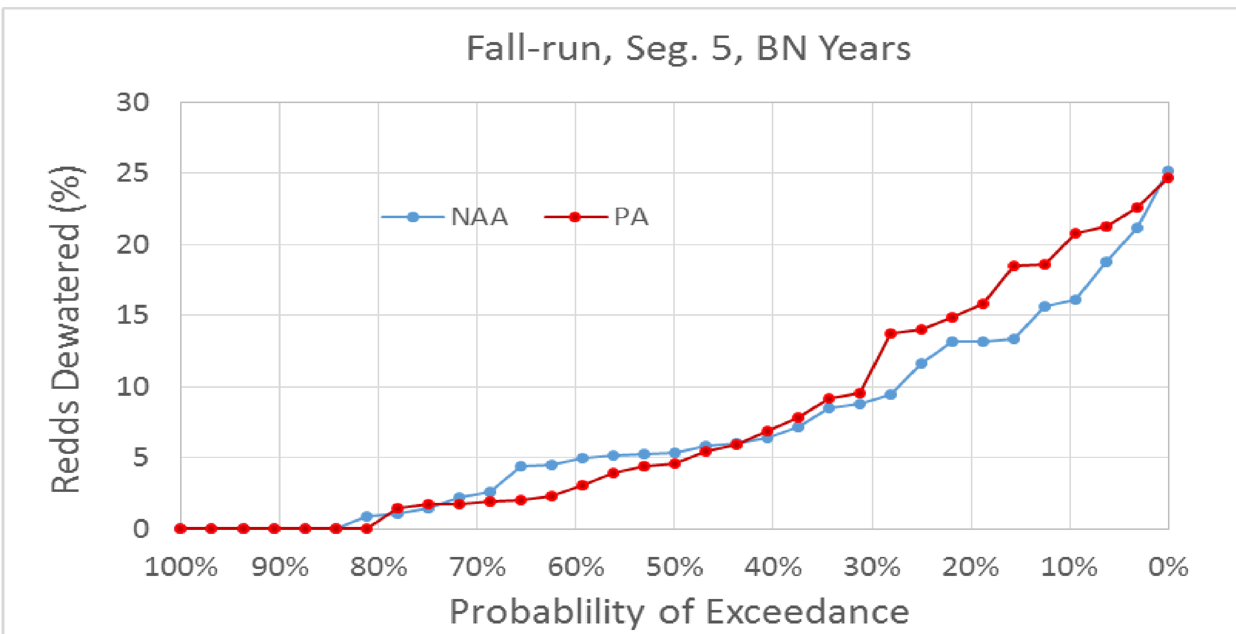


Figure 2-95. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years.

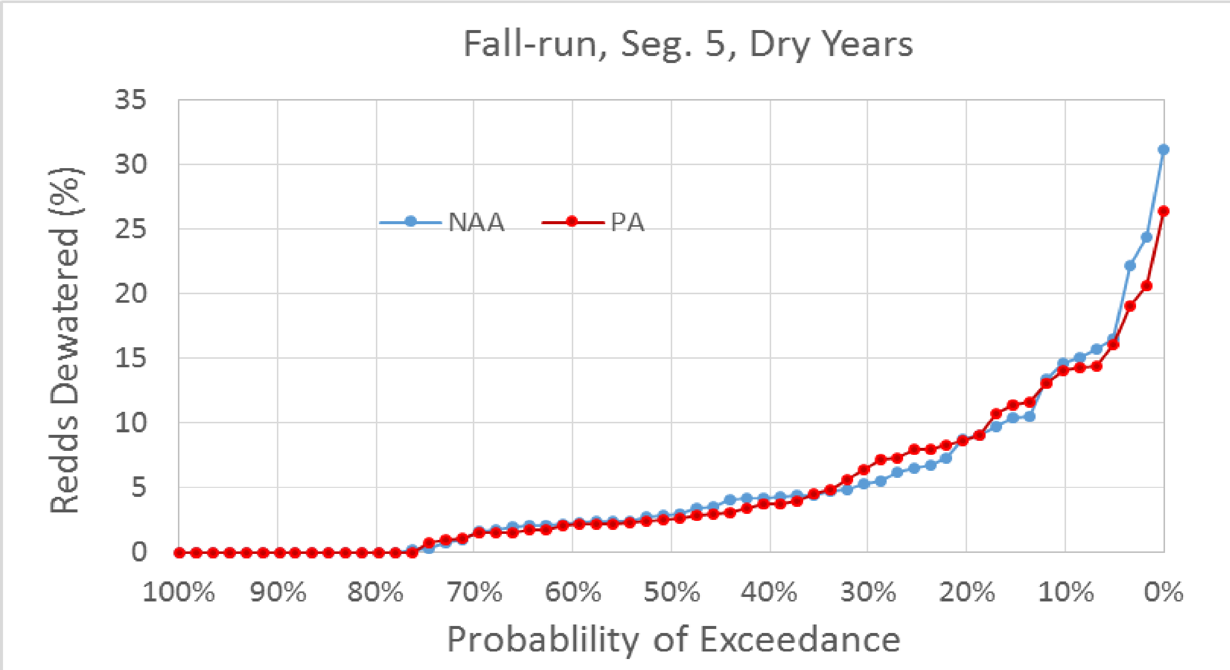


Figure 2-96. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Dry Water Years.

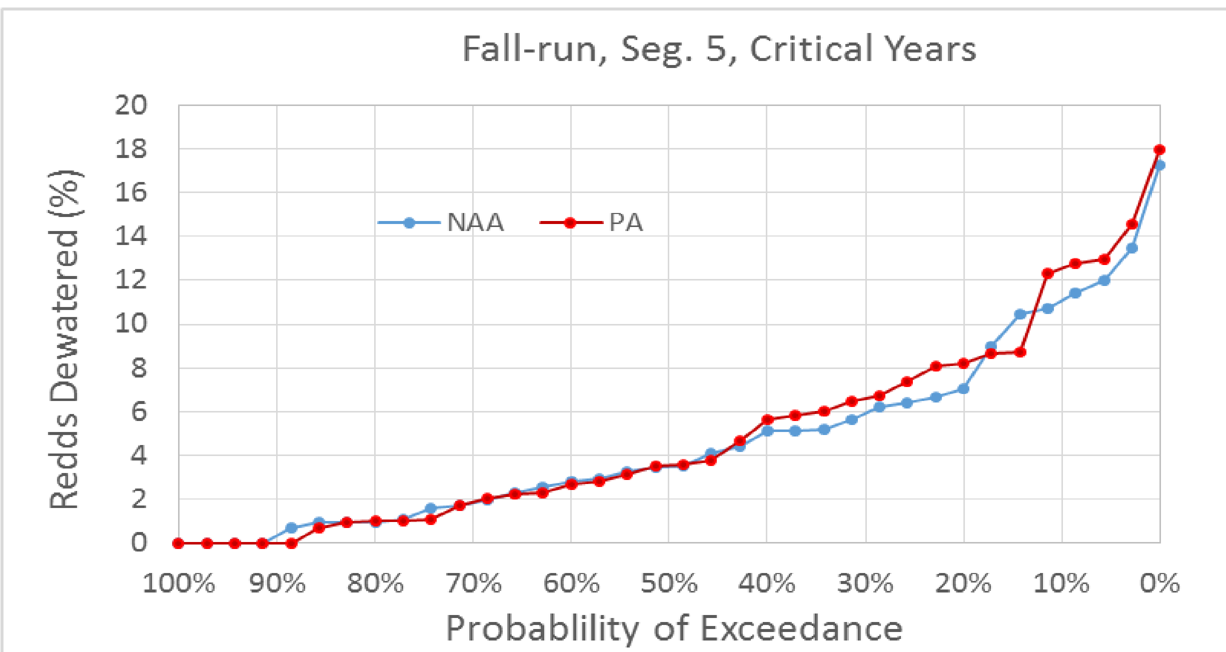


Figure 2-97. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Critical Water Years.

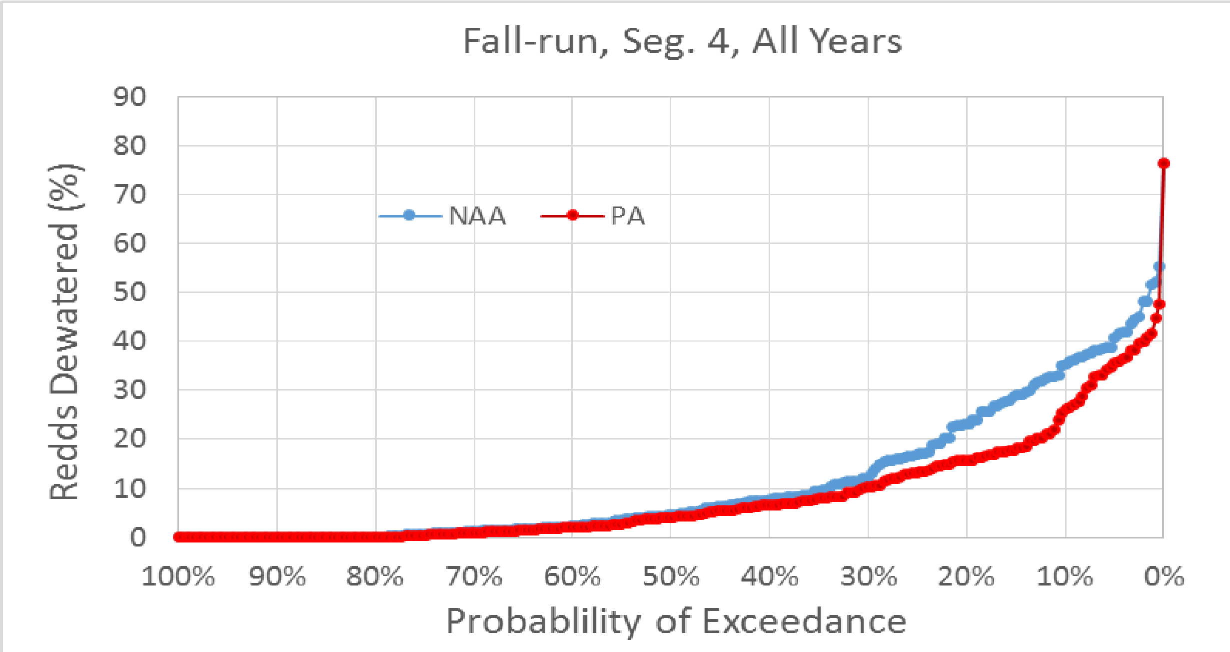


Figure 2-98. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, All Water Years.

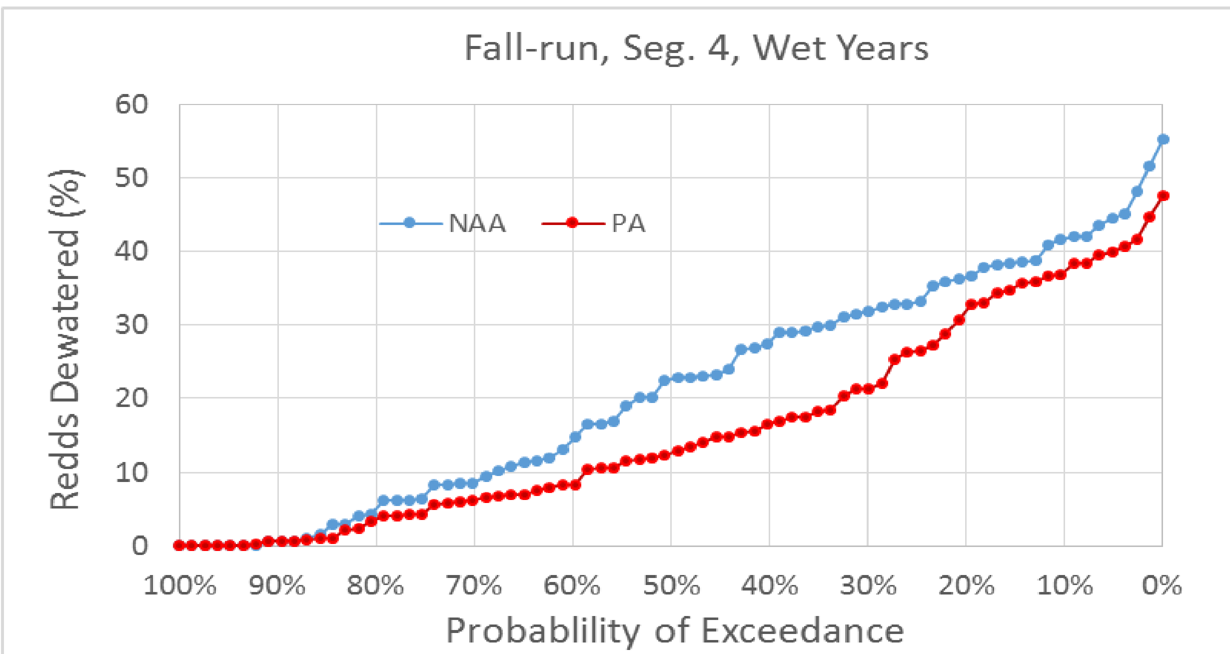


Figure 2-99. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Wet Water Years.

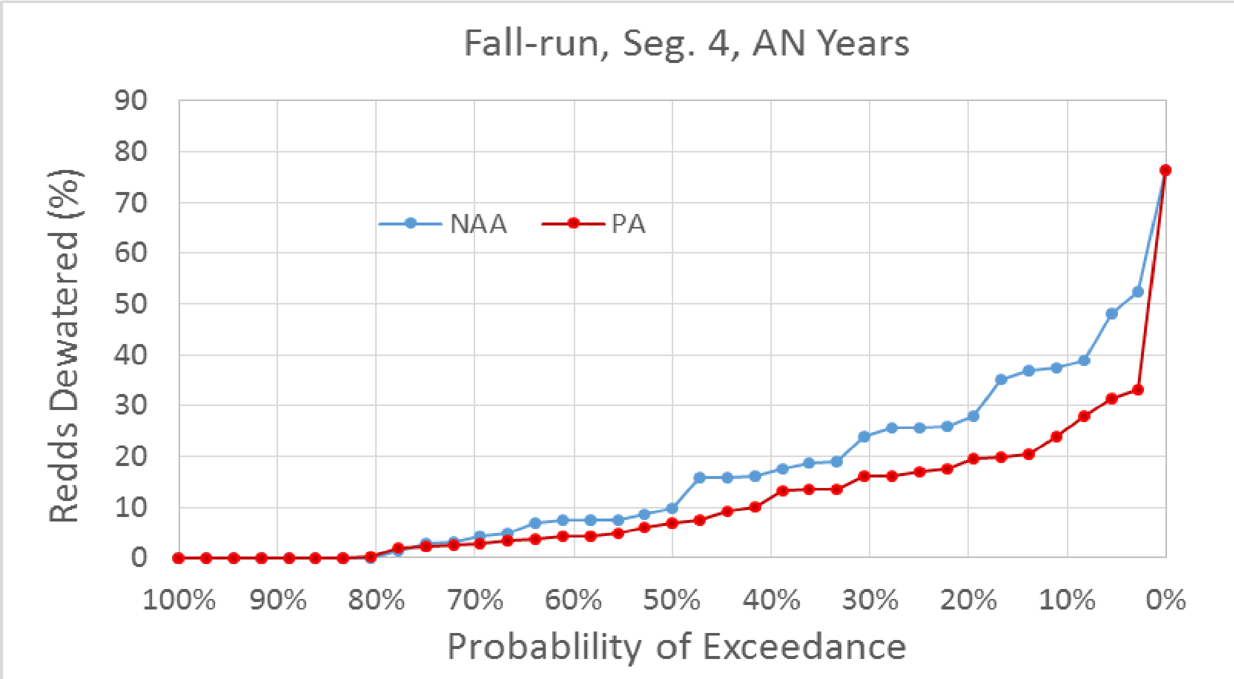


Figure 2-100. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years.

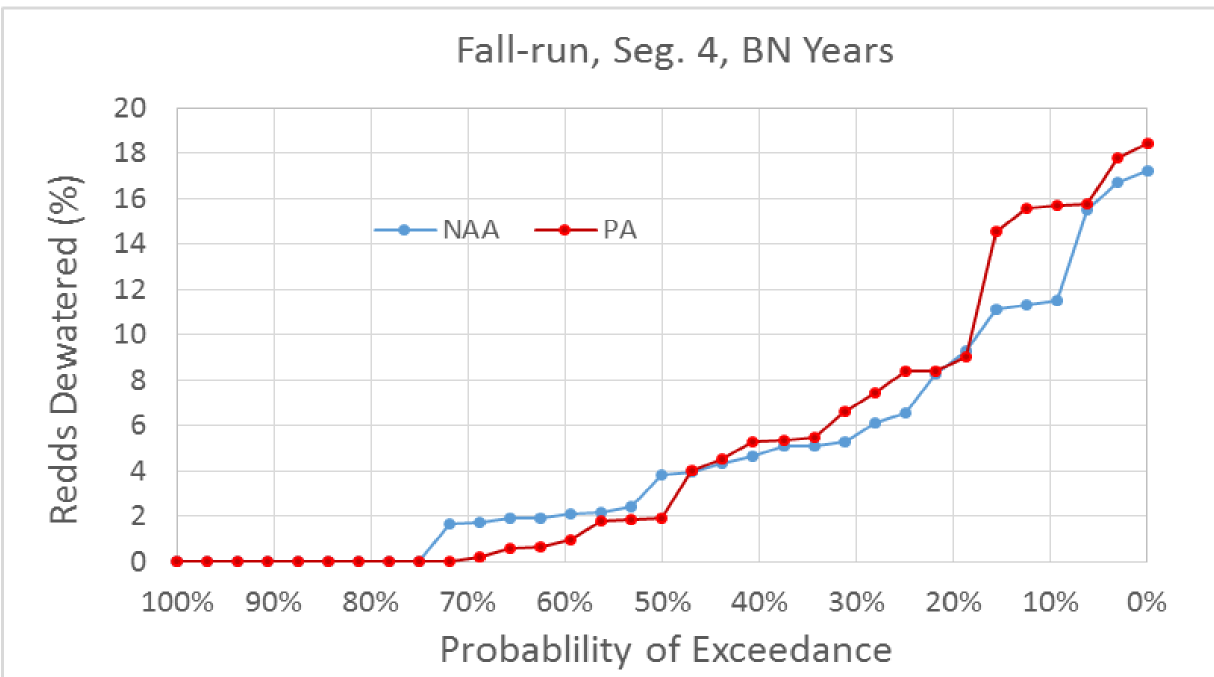


Figure 2-101. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years.

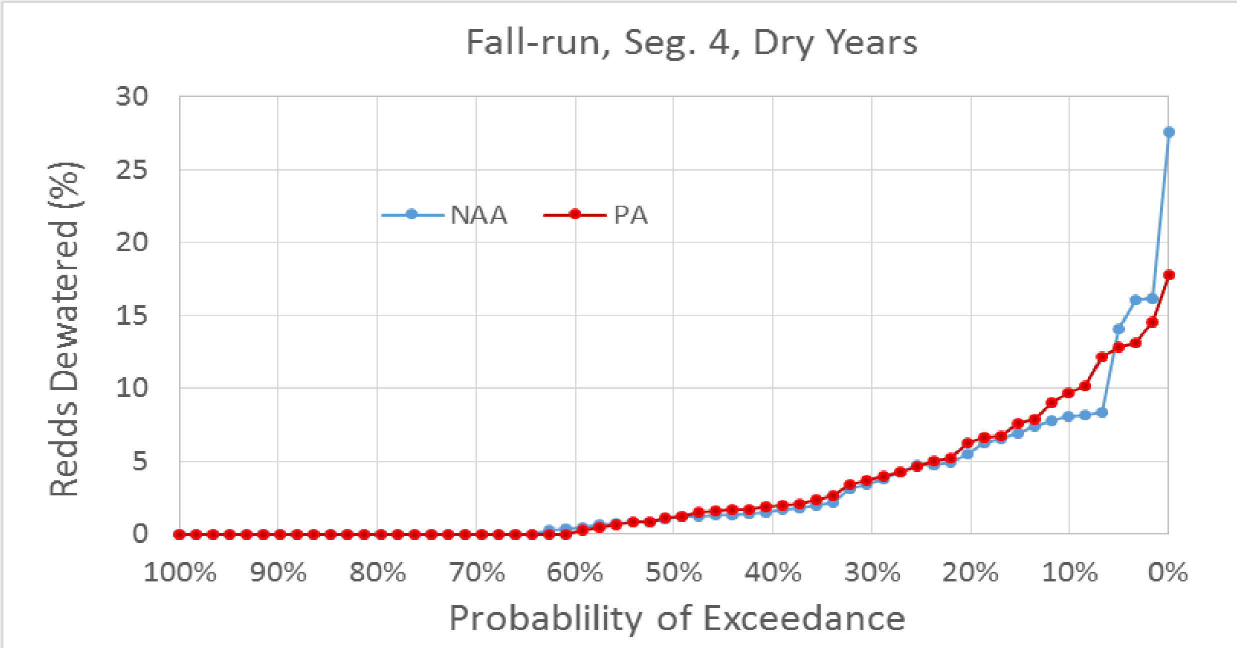


Figure 2-102. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Dry Water Years.

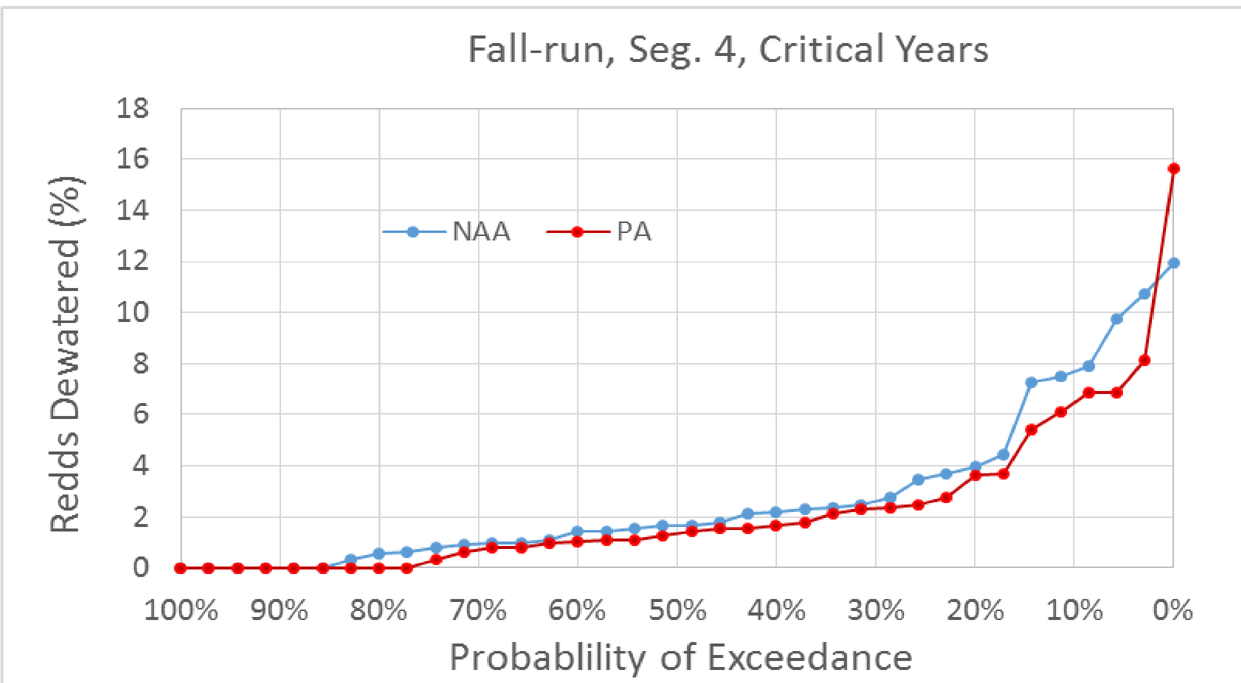


Figure 2-103. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Critical Water Years.

The exceedance curves show that the PA would not increase redd dewatering under most water year types relative to the NAA.

Tabular results from the BA show that differences between the PA and NAA in the mean percentage of redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined would be minimal. The exception is moderate reductions in the mean percent of redds dewatered during November of wet and above normal water year types in all three river segments and a small increase in October of below normal years in river segments 5 and 6 (Table 2-142 through Table 2-143). The percent differences between the PA and the NAA in the percent of redds dewatered range up to a 208% increase under the PA for November of critical water years in Segment 4 (Table 2-144). However, this increase and most of the large relative changes in percent of redds dewatered are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes.

Similar to the redd dewatering exceedance plots, the tabular results show little difference in redd dewatering risk between the PA and NAA. However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the impact to fall-run Chinook salmon is a concern, particularly in wet years. During November of wet years, the percentage of dewatered redds ranges between 15 and 36% across all river segments for the PA. Redd dewatering under the PA in November of dry years is much lower compared to wet years, ranging between just 3 and 5%.

Table 2-142. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 6 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	31.1	33.0	2 (6%)
	Above Normal	19.0	17.7	-1.25 (-7%)
	Below Normal	6.5	3.4	-3 (-47%)
	Dry	3.9	2.6	-1.3 (-33%)
	Critical	6.9	5.3	-1.6 (-24%)
September	All	15.7	15.2	-0.5 (-3%)
October	Wet	15.0	10.3	-4.7 (-32%)
	Above Normal	13.0	13.6	0.7 (5%)
	Below Normal	9.5	15.9	6.4 (67%)
	Dry	8.2	10.3	2.1 (25%)
	Critical	7.0	6.4	-0.6 (-8%)
	All	11.1	11.0	-0.1 (-1%)
November	Wet	35.9	18.7	-17.2 (-48%)
	Above Normal	33.9	15.2	-18.7 (-55%)
	Below Normal	7.2	5.4	-1.8 (-25%)
	Dry	4.7	3.2	-1.5 (-31%)
	Critical	1.6	4.5	2.9 (176%)
	All	18.9	10.4	-8.5 (-45%)

Table 2-143. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 5 between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	30.2	31.9	1.7 (6%)
	Above Normal	17.9	16.5	-1.5 (-8%)
	Below Normal	5.6	2.7	-2.9 (-52%)
	Dry	3.1	1.9	-1.2 (-38%)
	Critical	6.0	4.4	-1.6 (-26%)
September	All	14.8	14.2	-0.6 (-4%)
October	Wet	14.5	9.9	-4.6 (-32%)
	Above Normal	12.4	13.1	0.6 (5%)
	Below Normal	9.1	15.4	6.3 (70%)
	Dry	7.9	9.9	2 (26%)
	Critical	6.7	6.1	-0.6 (-9%)
	All	10.7	10.6	-0.1 (-1%)
November	Wet	35.6	18.5	-17.1 (-48%)
	Above Normal	33.7	15.2	-18.5 (-55%)
	Below Normal	7.0	5.2	-1.8 (-25%)
	Dry	4.7	3.3	-1.4 (-30%)
	Critical	1.6	4.5	2.9 (178%)
	All	18.8	10.4	-8.4 (-45%)

Table 2-144. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 4 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	24.9	26.5	1.6 (6%)
	Above Normal	13.5	12.2	-1.39 (-10%)
	Below Normal	3.1	1.2	-1.9 (-63%)
	Dry	1.0	0.6	-0.4 (-37%)
	Critical	3.5	1.7	-1.8 (-51%)
September	All	11.2	10.9	-0.3 (-3%)
October	Wet	9.3	6.6	-2.7 (-29%)
	Above Normal	8.9	10.0	1.1 (12%)
	Below Normal	6.4	10.9	4.4 (69%)
	Dry	5.0	6.2	1.3 (25%)
	Critical	4.0	2.8	-1.3 (-31%)
	All	7.0	7.0	0 (0%)
November	Wet	29.8	15.3	-14.5 (-49%)
	Above Normal	28.2	12.6	-15.6 (-55%)
	Below Normal	5.1	3.5	-1.6 (-31%)
	Dry	3.4	2.5	-0.9 (-27%)
	Critical	0.8	2.6	1.7 (208%)
	All	15.4	8.2	-7.2 (-46%)

SALMOD results presented in the BA (Error! Reference source not found.) are another source of information suggesting that redd dewatering in the Sacramento River is a concern for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, especially in wet years comes. The SALMOD model provides predicted flow-related mortality of fall-run Chinook salmon spawning, eggs and alevins in the Sacramento River. The SALMOD results for flow-related mortality are presented in Error! Reference source not found.. The flow-related mortality of fall-run Chinook salmon spawning, eggs, and alevins is divided into "incubation" (which refers to redd dewatering and scour) and "superimposition" (which refers to redd overlap) mortality (see Attachment 5.D.2, SALMOD Model). The number of fall-run Chinook salmon eggs and alevins predicted to die from redd dewatering and scour during incubation ranges from 94,913 in above normal years to 4,066,702 in wet years, with an average over all water year types of 1,477,164 (Reclamation 2016).

Collectively, the estimated percentage of redd dewatering presented in the exceedance plots (Figure 2-86 through Figure 2-103) and (Table 2-142 through Table 2-144) indicate that Sacramento River redd dewatering under the PA is a high magnitude stressor to fall-run Chinook salmon in wet years and a medium stressor under relatively dry conditions. The SALMOD results show that the combined effect of redd dewatering and scour under the PA places a high magnitude stress on fall-run Chinook salmon in the Sacramento River. The certainty of these magnitude rankings is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale. In addition, only 61% of the spawning habitat was evaluated which leaves uncertainty about the red dewatering impacts to the remaining 40% of spawning habitat.

2.5.1.2.2.5.1.2 Late Fall-run Chinook Salmon

Late fall-run Chinook salmon eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins in December through June when fry emergence from the streambed ends (Vogel and Marine 1991, U.S. Department of the Interior 2016). The vast majority of late fall-run Chinook salmon redds are distributed in the upper portion of the Sacramento River, with 68% occurring upstream of ACID Dam and 94% occurring upstream of Red Bluff Diversion Dam (BA Table 5.D.1-1 in Appendix 5D Attachment 1).

The percentage of late fall-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated from CALSIM II estimates of monthly mean flows during the 3 months following each month of spawning (BA Appendix 5.D.2.2, Spawning Flows, Methods, Table 5-4-2). This analysis employed functional relationships developed in field studies by the U.S. Fish and Wildlife Service (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows. CALSIM II flows for the three upstream river segments (segments 4, 5 and 6) were used to estimate redd dewatering under the PA and NAA. Note that unlike the analyses used to model weighted usable area, the analysis used to model redd dewatering combines the field observations of water depth, flow velocity, and substrate from the three river segments and, therefore, differences in redd dewatering estimates among the segments result only from differences in the CALSIM II flows. Further information on redd dewatering analysis methods is provided in the BA in Appendix 5.D.2.2, Spawning Flows, Methods.

Differences in late fall-run Chinook salmon redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent dewatered for the December through April spawning months[8] (see Figures 5.E-168 through 5.E-185 in the BA). Because 67% of late fall-run Chinook salmon spawning occurs in river Segment 6 and the results for segments 4 and 5 are similar to those for Segment 6, conclusions regarding effects are primarily based on the Segment 6 results (Figure 2-104 through Figure 2-109). The exceedance curves show little difference between the PA and the NAA in the percentage of redds dewatered for all water years combined or for individual water year types, except for marginally greater redd dewatering under the PA for wet years (Figure 2-105).

[8] Analyzing redd dewatering for three months following December through April covers the full time period (i.e., December through June) that eggs and alevins are in the streambed and thus vulnerable to redd dewatering.

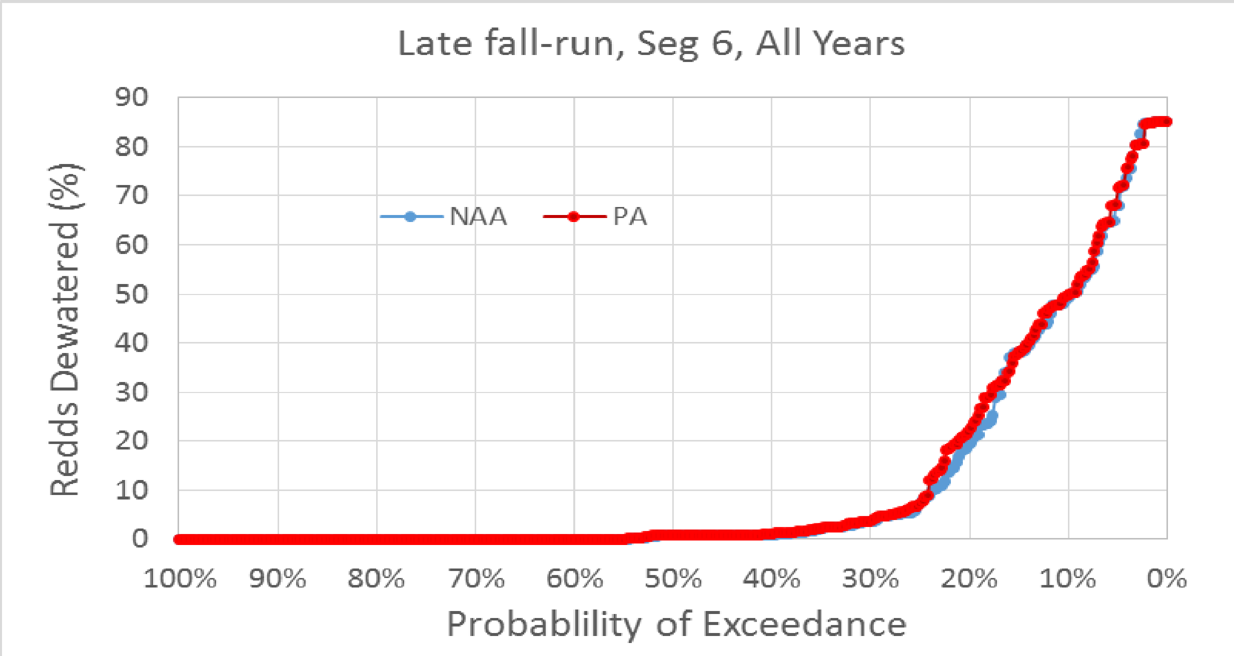


Figure 2-104. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, All Water Years.

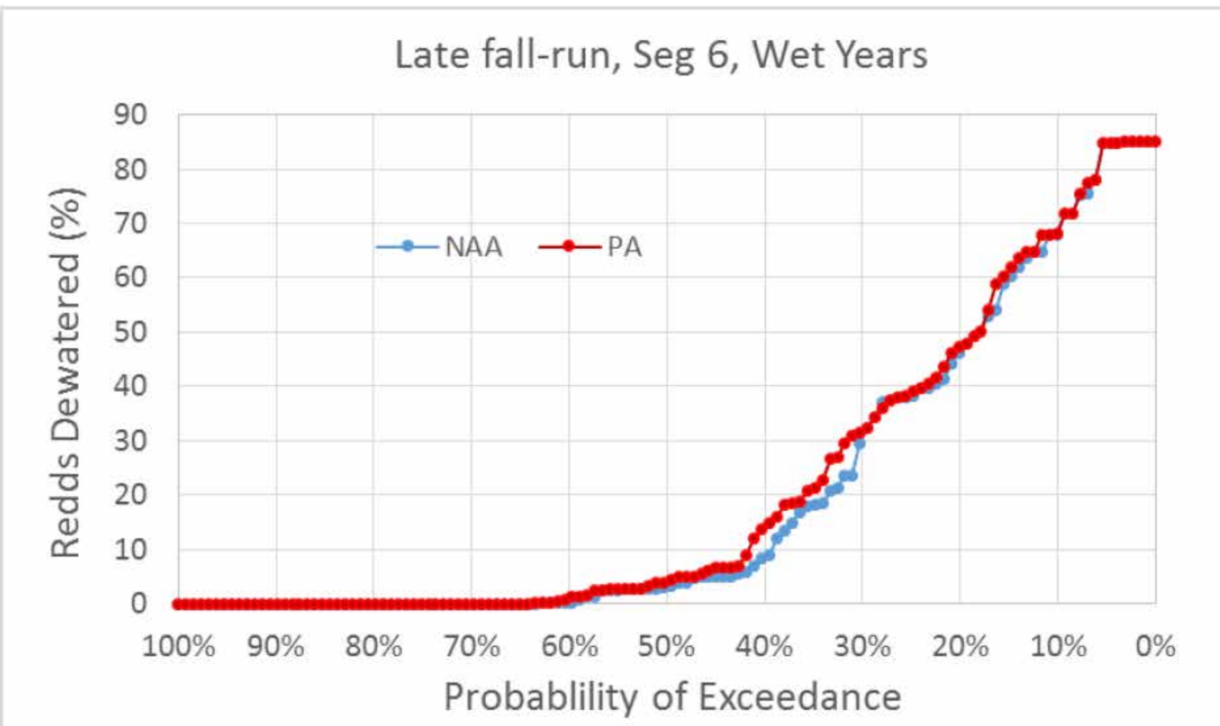


Figure 2-105. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Wet Water Years.

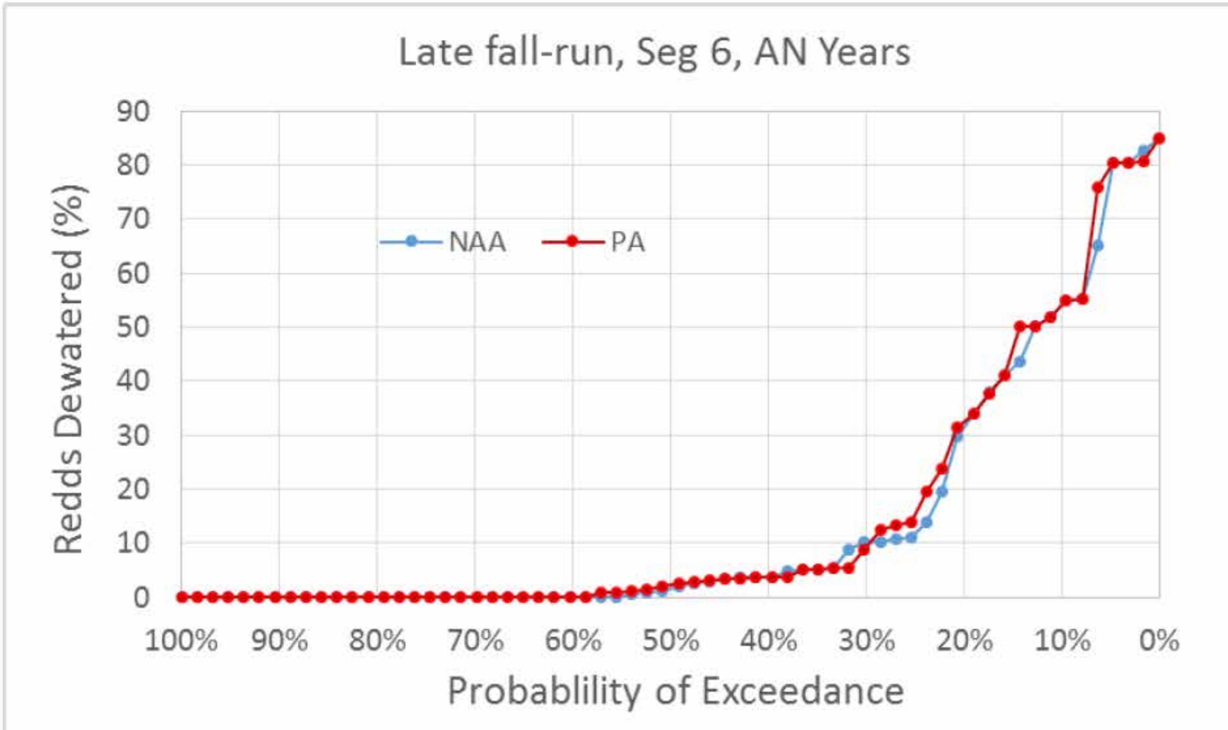


Figure 2-106. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years.

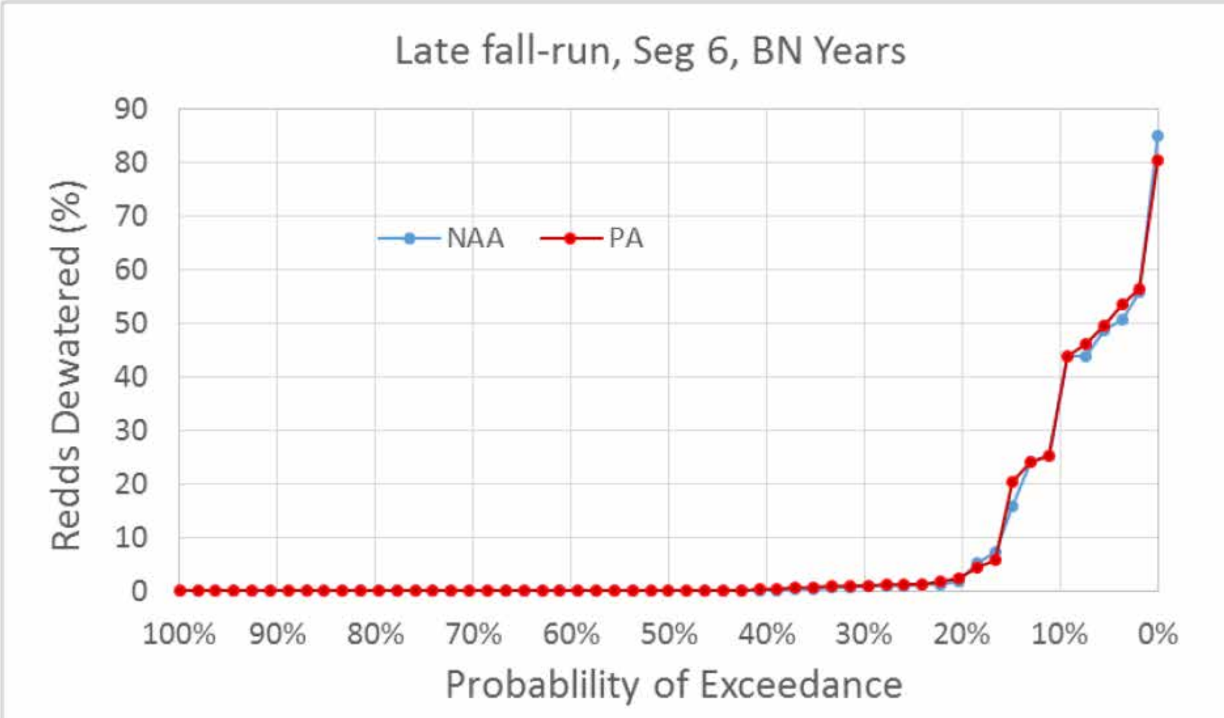


Figure 2-107. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years.

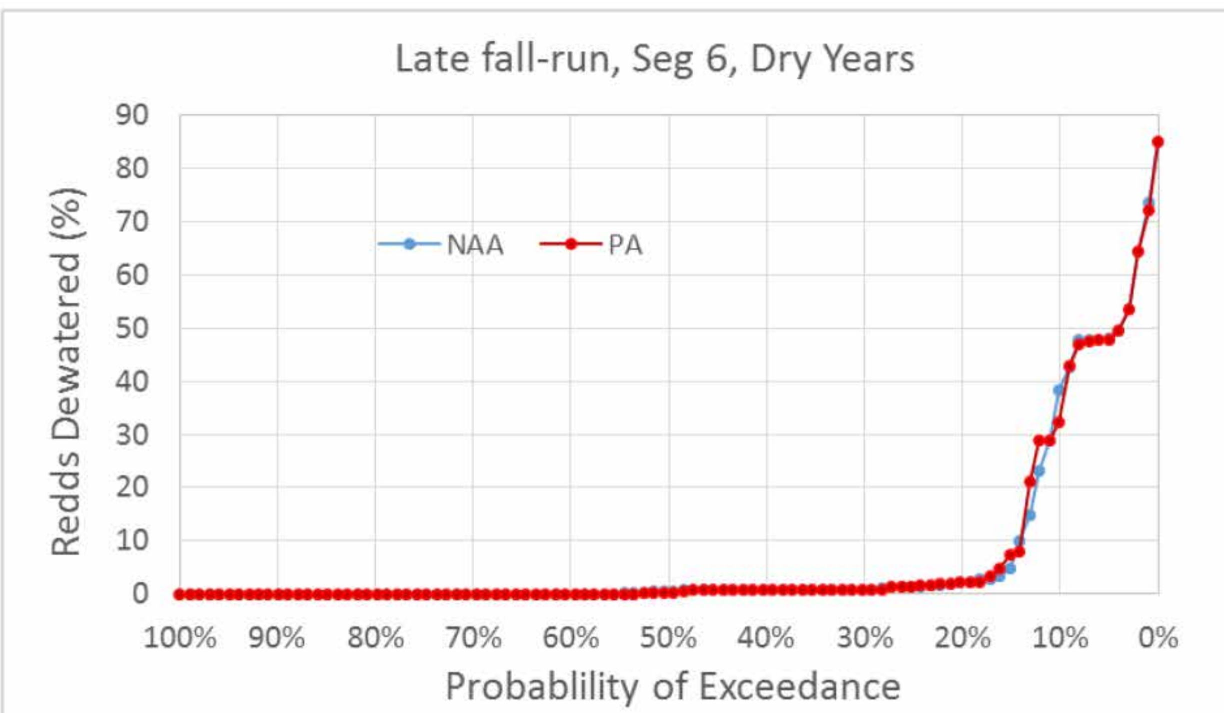


Figure 2-108. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Dry Water Years.

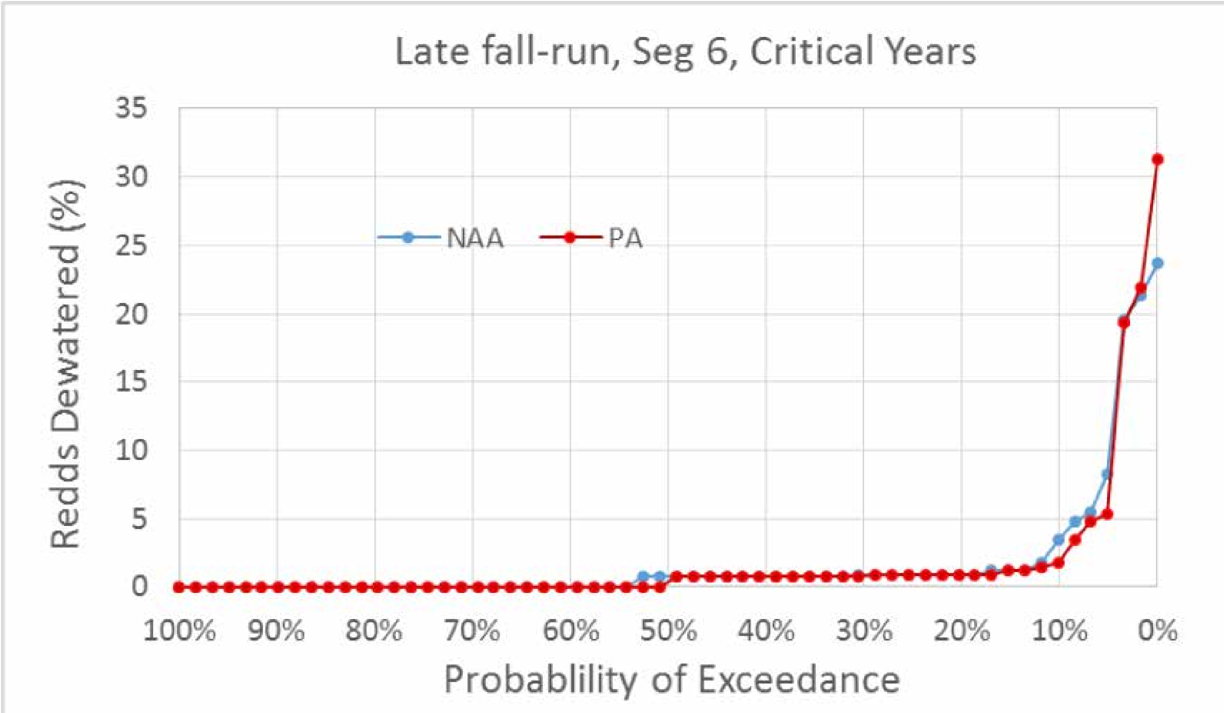


Figure 2-109. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Critical Water Years.

The exceedance curves show that the PA would not increase redd dewatering under most water year types relative to the NAA.

The following description and tabular results from the BA show that differences between the PA and NAA in the mean percentage of late fall-run Chinook salmon redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined would minimal (Tables 5.E-51 through 5.E-53). The percent of redds dewatered under the PA was little different from that under the NAA for all months and water year types, ranging up to 2.9% greater under the PA for January of wet years in Segment 5 (Table 5.E-52). The percent differences in the percent of redds dewatered between the PA and the NAA range up to a 130% increase under the PA for January of critical water years in Segment 6 (Table 5.E-51), but this increase and the other large relative changes in percent of redds dewatered are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent differences.

Similar to the redd dewatering exceedance plots, the tabular results show little difference between the PA and NAA. However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the impact to late fall-run Chinook salmon is a concern, particularly in wet and above normal years. During February of wet and above normal years under the PA the percentage of dewatered redds ranges between 37% and 39% across river segments 4, 5, and 6. Redd dewatering under the PA in February of dry years is much lower (than wet years) ranging between just 0.6% and 2%. However, the bulk of the redd dewatering in dry years occurs in January, with 17% to 18% of all redds being dewatered across river segments 4, 5, and 6.

Table 2-145. Late Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 6 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	11.1	12.0	0.9 (8%)
	Above Normal	7.4	6.3	-1.1 (-15%)
	Below Normal	11.1	10.7	-0.4 (-3%)
	Dry	16.4	16.8	0.4 (2%)
	Critical	0.8	0.6	-0.2 (-22%)
December	All	10.3	10.5	0.1 (1%)
January	Wet	18.7	21.5	2.8 (15%)
	Above Normal	11.3	11.4	0.1 (1%)
	Below Normal	11.3	10.9	-0.5 (-4%)
	Dry	16.9	17.2	0.4 (2%)
	Critical	2.1	4.8	2.7 (130%)
	All	13.7	15.0	1.3 (10%)
February	Wet	36.7	37.5	0.8 (2%)
	Above Normal	37.5	38.2	0.7 (2%)
	Below Normal	13.7	14.8	1 (7%)
	Dry	0.6	0.6	0.1 (10%)
	Critical	3.0	0.4	-2.6 (-87%)
	All	20.0	20.1	0.1 (1%)
March	Wet	29.0	28.9	-0.1 (-0.2%)
	Above Normal	13.6	16.1	2.5 (18%)
	Below Normal	1.4	2.1	0.6 (45%)
	Dry	1.5	1.3	-0.2 (-12%)
	Critical	0.1	0.1	0 (0%)
	All	11.9	12.4	0.4 (4%)
April	Wet	6.7	6.7	0 (0%)
	Above Normal	1.6	1.8	0.2 (11%)
	Below Normal	0.1	0.0	-0.1 (-69%)
	Dry	0.9	0.4	-0.4 (-50%)
	Critical	3.1	3.0	0 (-2%)
	All	3.1	3.0	-0.1 (-3%)

Table 2-146. Late Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 5 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	11.1	12.0	0.9 (8%)
	Above Normal	7.5	6.5	-1.01 (-14%)
	Below Normal	11.0	10.6	-0.4 (-3%)
	Dry	16.5	16.8	0.3 (2%)
	Critical	0.8	0.7	-0.1 (-7%)
December	All	10.4	10.5	0.2 (2%)
January	Wet	18.8	21.7	2.9 (15%)
	Above Normal	11.5	11.6	0.1 (1%)
	Below Normal	11.4	10.9	-0.5 (-4%)
	Dry	17.0	17.3	0.3 (2%)
	Critical	2.2	5.0	2.8 (125%)
	All	13.8	15.1	1.4 (10%)
February	Wet	37.1	37.9	0.8 (2%)
	Above Normal	37.7	38.5	0.8 (2%)
	Below Normal	13.9	14.9	1 (7%)
	Dry	0.7	0.8	0.1 (14%)
	Critical	3.1	0.4	-2.7 (-86%)
	All	20.2	20.4	0.2 (1%)
March	Wet	29.6	29.6	-0.1 (-0.2%)
	Above Normal	14.0	16.5	2.6 (19%)
	Below Normal	1.5	2.2	0.7 (47%)
	Dry	1.7	1.5	-0.2 (-10%)
	Critical	0.1	0.1	0 (0.2%)
	All	12.2	12.7	0.5 (4%)
April	Wet	7.2	7.2	0 (-0.2%)
	Above Normal	1.7	1.9	0.2 (11%)
	Below Normal	0.1	0.0	-0.1 (-65%)
	Dry	0.9	0.5	-0.5 (-49%)
	Critical	3.0	3.0	-0.1 (-2%)
	All	3.2	3.1	-0.1 (-3%)

Table 2-147. Late Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 4 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	11.1	12.2	1 (9%)
	Above Normal	6.9	6.5	-0.45 (-6%)
	Below Normal	10.4	10.4	0 (0%)
	Dry	17.4	17.6	0.1 (1%)
	Critical	1.4	1.4	-0.1 (-4%)
December	All	10.5	10.8	0.3 (3%)
January	Wet	19.1	21.7	2.6 (13%)
	Above Normal	11.9	12.0	0 (0%)
	Below Normal	13.9	13.3	-0.6 (-4%)
	Dry	17.3	17.7	0.4 (2%)
	Critical	3.4	6.1	2.7 (79%)
	All	14.6	15.8	1.2 (8%)
February	Wet	37.4	38.1	0.7 (2%)
	Above Normal	36.8	37.2	0.4 (1%)
	Below Normal	14.0	15.1	1.1 (8%)
	Dry	1.9	2.0	0.1 (5%)
	Critical	3.6	0.9	-2.7 (-74%)
	All	20.6	20.6	0.1 (0%)
March	Wet	28.5	28.4	-0.1 (-0.3%)
	Above Normal	14.9	17.4	2.6 (17%)
	Below Normal	1.5	2.4	0.8 (53%)
	Dry	3.2	2.8	-0.3 (-10%)
	Critical	0.5	0.5	0 (1.6%)
	All	12.4	12.9	0.4 (3%)
April	Wet	6.8	6.8	0 (-0.1%)
	Above Normal	2.0	2.2	0.2 (8%)
	Below Normal	0.2	0.1	-0.1 (-70%)
	Dry	1.1	0.7	-0.4 (-38%)
	Critical	2.5	2.4	-0.1 (-5%)
	All	3.1	3.0	-0.1 (-4%)

Collectively, the estimated percentage of redd dewatering presented in the exceedance plots (Figure 2-104 through Figure 2-109) and tables (Table 2-145 through Table 2-147) indicate that Sacramento River redd dewatering under the PA is a high magnitude stressor to late fall-run Chinook salmon in wet and above normal years and a medium stressor under dry conditions. The certainty of these magnitude rankings is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale.

2.5.1.2.2.5.2 American River

Only fall-run Chinook salmon redd dewatering is evaluated in this section because late-fall Chinook salmon do not spawn in the American River.

2.5.1.2.2.5.2.1 Fall-run Chinook salmon Risk and Exposure

Fall-run Chinook salmon eggs and alevins in the American River are vulnerable to dewatering from the time when spawning begins in October through February when fry emergence from the streambed ends (Vogel and Marine 1991, Bratovich 2005). The vast majority of fall-run Chinook salmon spawning (i.e., 90%) in the American River occurs upstream between Ancil Hoffman Park at river mile 16 to Nimbus Dam at RM 3 (BA Table 5.D.1-4 in Appendix 5D Attachment 1).

The analysis of fall-run Chinook salmon redd dewatering for the American River relies on the analysis presented in the BA. In the BA, the percentage of fall-run Chinook salmon redds dewatered by reductions in American River flow was estimated from CALSIM II estimates of monthly mean flows during the 3 months following each of the months that fall-run Chinook salmon spawn (Section 5.D.2.2, Spawning Flow Methods, Table 5-4-2). No model for predicting percentages of redds dewatered, such as that developed for the Sacramento River (USFWS 2006), has been developed for the American River. Therefore, the maximum reduction in American River flow for the 3 months following each of the months during which fall-run Chinook salmon spawn was used as a proxy for percent of redds dewatered. CALSIM II flows at Nimbus were used for this analysis. Larger maximum flow reductions during the spawning, egg, and alevin life stages are assumed to increase the percent of redds dewatered and, therefore, to have a negative effect on fall-run Chinook salmon. Further information on the redd dewatering analysis is provided in the BA in Appendix 5.D.2.2, Spawning Flow Methods.

As described in the BA, differences in maximum flow reductions under the PA and NAA were examined using exceedance plots of mean monthly maximum flow reductions, expressed as a percentage of the spawning flows, for the months that American River fall-run Chinook salmon spawn (October and November) (Figure 2-110 through Figure 2-115). The exceedance curves for all water year types combined (Figure 2-110) and those for wet and above normal years (Figure 2-111 through Figure 2-112) indicate that the PA would generally have lower flow reductions than the NAA. Differences for the other three water year types would be minor (Figure 2-114 through Figure 2-115).

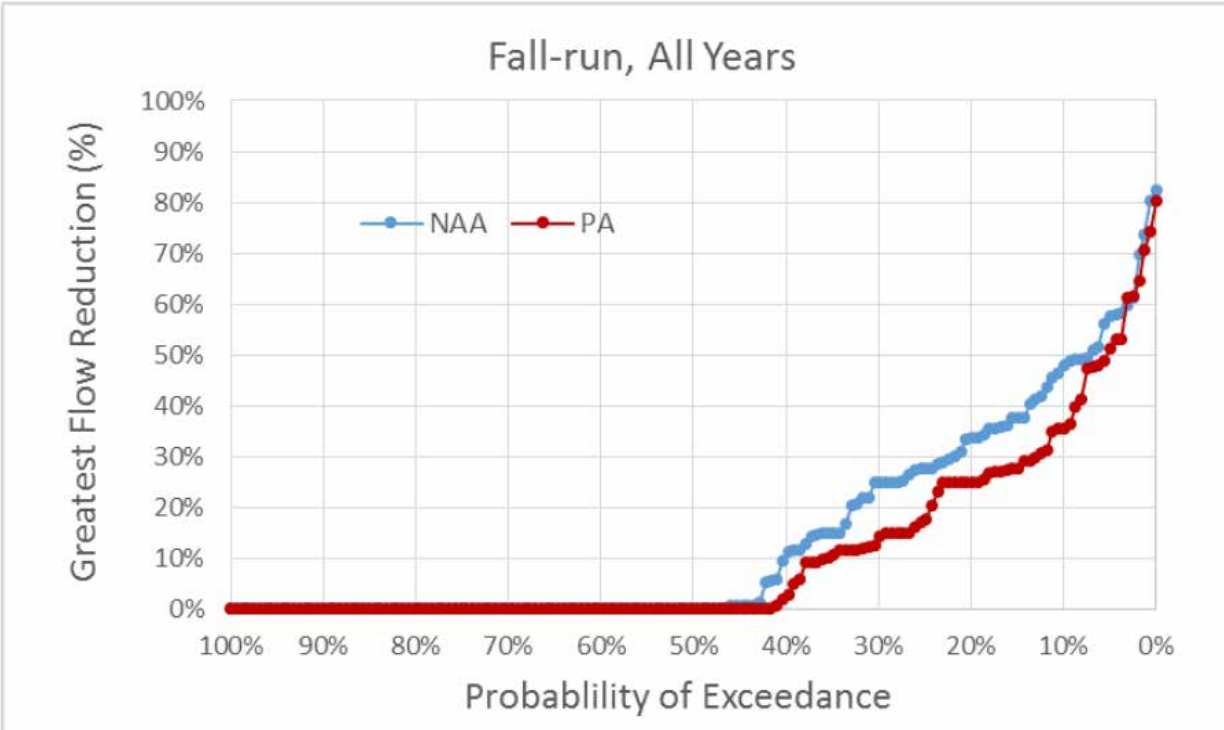


Figure 2-110. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, All Water Years.

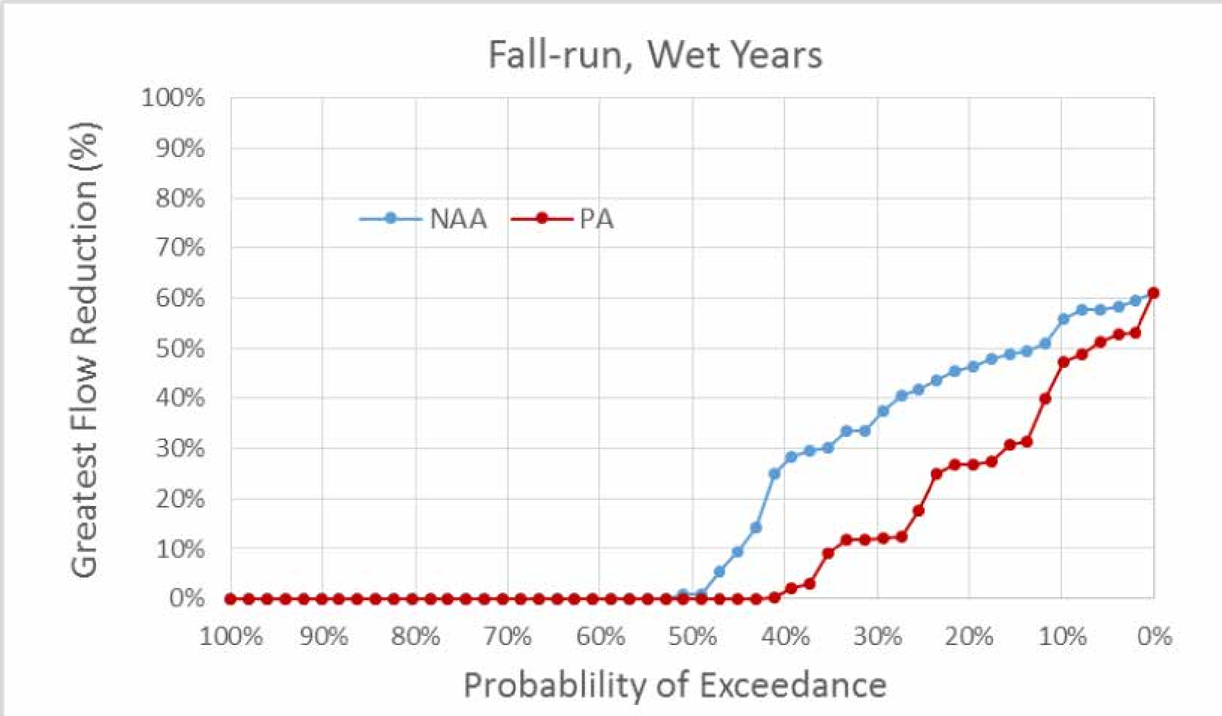


Figure 2-111. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Wet Water Years.

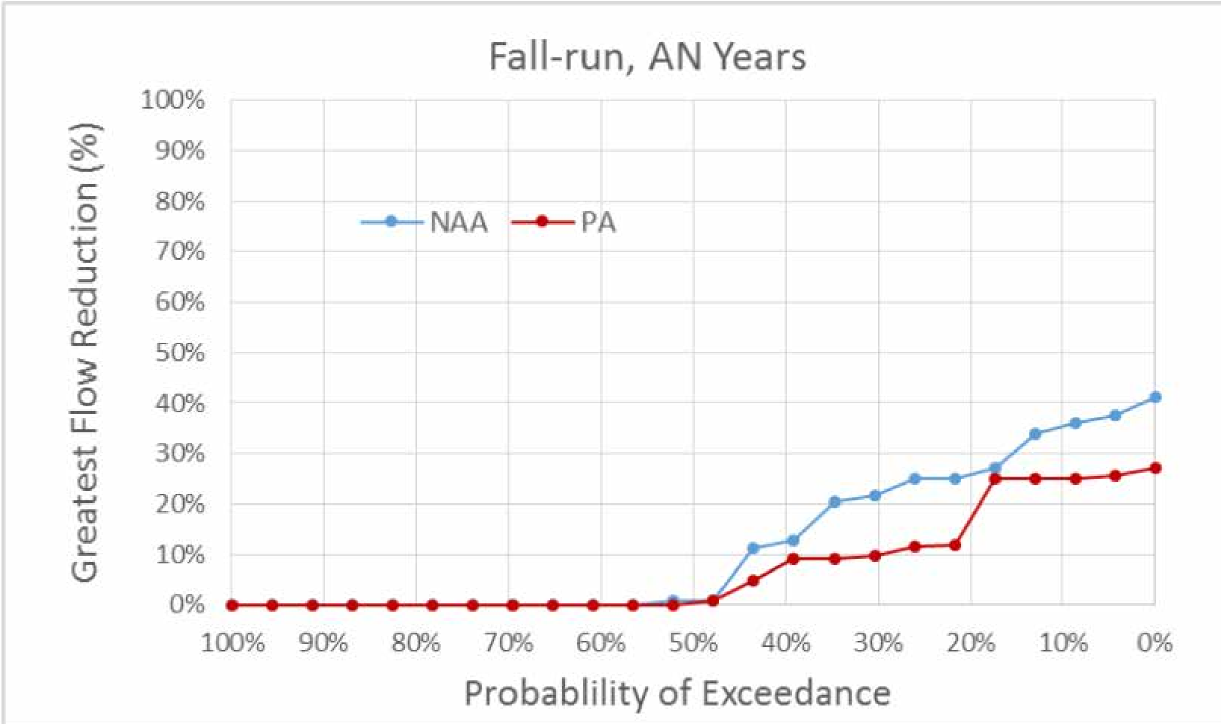


Figure 2-112. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Above Normal Water Years.

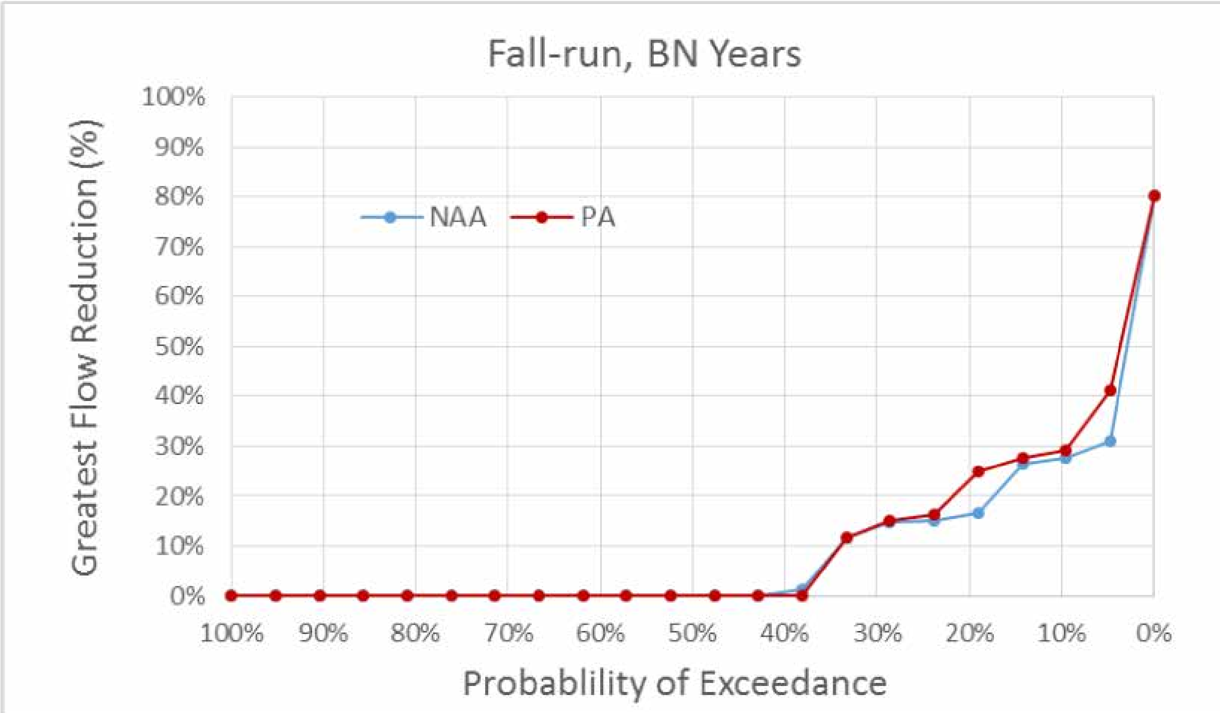


Figure 2-113. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Below Normal Water Years.

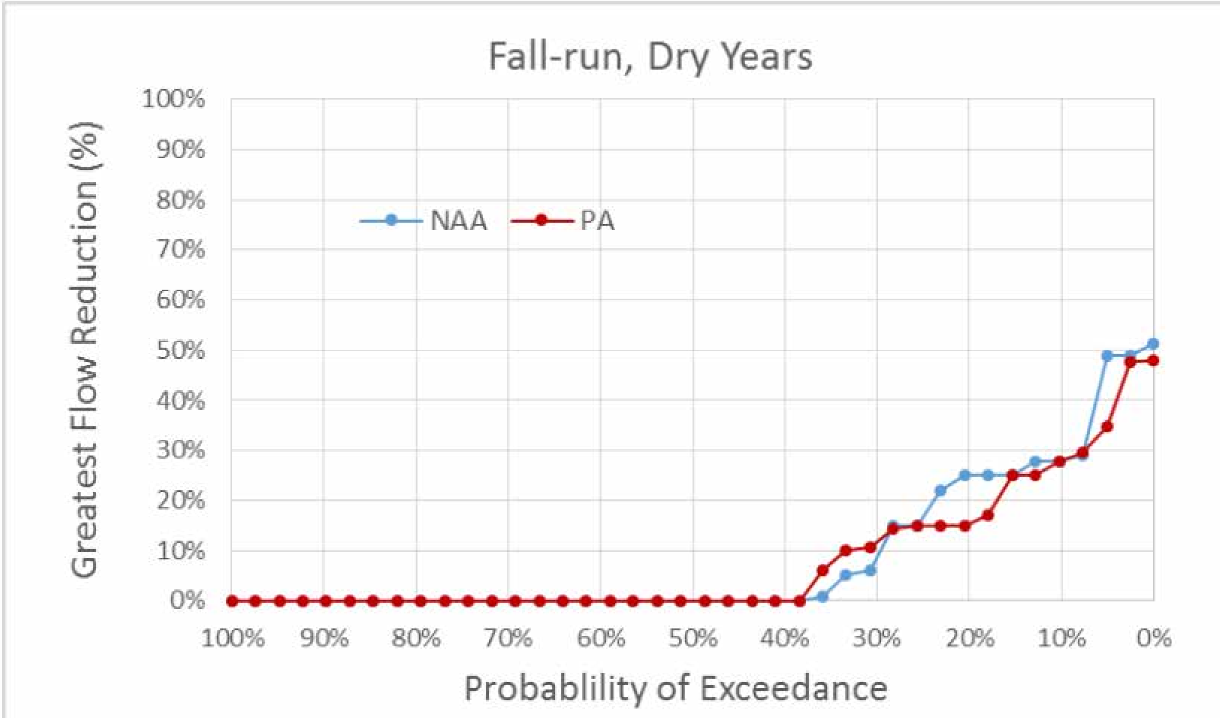


Figure 2-114. Exceedance Plot of Maximum Flow Reductions for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Dry Water Years.

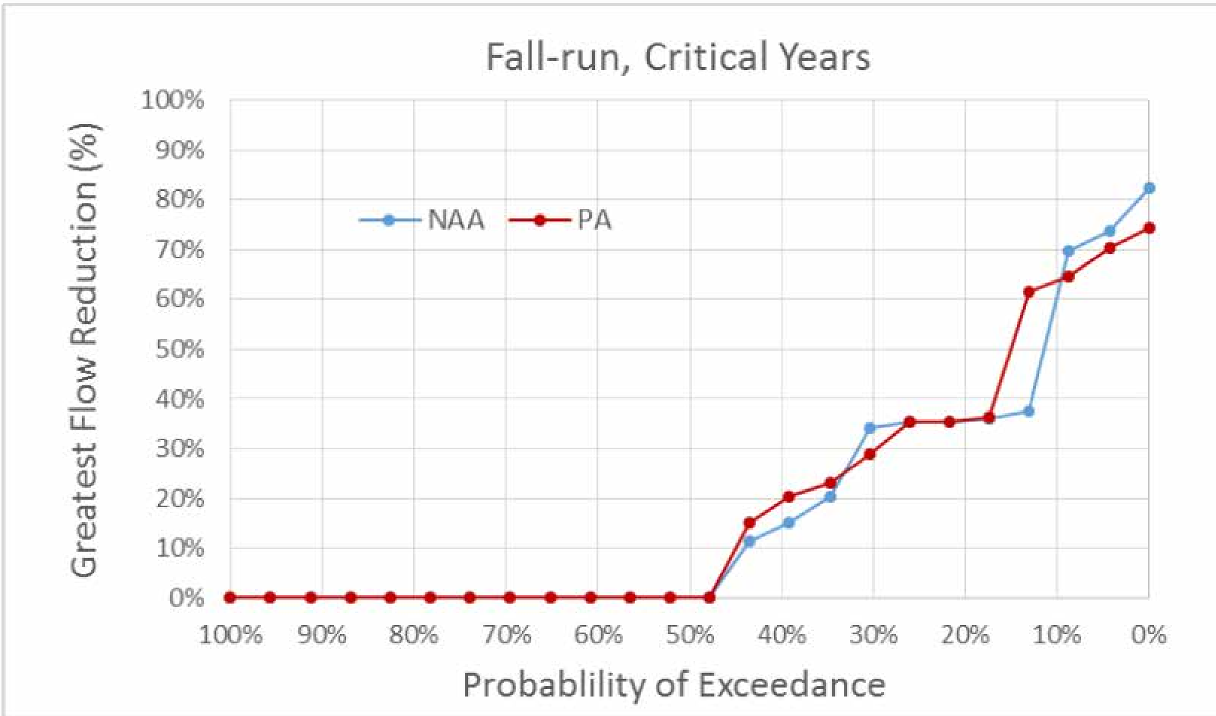


Figure 2-115. Exceedance Plot of Maximum Flow Reductions for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Critical Water Years.

For the redd dewatering analysis in this Opinion, we take things one step further than the BA by assuming that a 25% reduction from the spawning flow will result in at least some redd dewatering, and a 50% reduction from the spawning flow will result in extensive redd dewatering. Making these general assumptions provides additional context for understanding how redd dewatering under the PA may impact fall-run Chinook salmon in the American River. These assumptions were made because: (1) fall-run Chinook salmon often spawn in shallow areas, which are more susceptible to being dewatered with a reduction in flow than deep areas; and (2) they are generally supported by the relationship between redd dewatering and flow for fall-run Chinook salmon on the Sacramento River with the ACID Dam boards out (Table 5.D-57 in the Appendix 5D of the BA). For example, 30% of all fall-run Chinook salmon redds would be dewatered on the Sacramento River if spawning flows of 10,000 cfs were reduced to 5,000 cfs after spawning (a 50% reduction from the spawning flow). In other words, a 50% flow reduction resulted in 30% redd dewatering, which fits a characterization of “extensive” redd dewatering. A 25% drop in spawning flows would dewater 9% of all redds (Table 5.D-57 in the Appendix 5D of the BA), which fits a characterization of “at least some” redd dewatering. The percentage of time that 25% (at least some redd dewatering) or 50% (i.e., extensive redd dewatering) reductions in spawning flow would occur under the PA by water year type are shown in Table 2-148.

Table 2-148. Percentage of Time that 25% (at Least Some Redd Dewatering) or 50% (i.e., Extensive Redd Dewatering) Reductions in American River Fall-run Chinook Salmon Spawning Flow Would Occur During the Egg and Alevin Life Stages Under the PA by Water Year Type.

Water Year Type	At Least Some Redd Dewatering	Extensive Redd Dewatering
Wet	24%	8%
Above Normal	18%	0%
Below Normal	19%	4%
Dry	15%	0%
Critical	34%	16%
All Years	23%	6%

At least some fall-run Chinook salmon redd dewatering is expected to occur in the American River in approximately 23% of all water years combined. Extensive redd dewatering is expected in 6% of the years. The most redd dewatering is expected in critical water years, with at least some dewatering occurring in 34% of critical years and extensive dewatering occurring in 16% of critical years. The least amount of redd dewatering is expected in dry years. Overall, the magnitude of redd dewatering is medium given that at least some redd dewatering is expected in 15 to 34% of years, and extensive redd dewatering has a relatively low frequency of occurrence. The certainty of this medium magnitude ranking is low given that the specific relationship between American River flow and fall-run Chinook salmon redd dewatering is unknown, and there are limitations of using results based on monthly flows to understand the magnitude of impacts that occur over a daily time scale.

2.5.1.2.3 Redd Scour

Streambed scour resulting from high flows is a physical factor that can reduce salmonid egg survival and limit population productivity. High flows can mobilize sediments in the river bed causing direct egg mortality if scour occurs to the depth of the top of the egg pocket. Scour can also increase fine sediment infiltration and indirectly decrease egg survival (DeVries 1997).

This redd scour analysis directly incorporates the methods and results presented in the BA. The redd scour analysis primarily relies upon a flow analysis whereby the probability of flows occurring under the PA and the NAA that would be high enough to mobilize sediments and scour Chinook salmon and steelhead redds was estimated from CALSIM II estimates of mean monthly flows by applying a relationship determined from the historical record between actual mean monthly flow and maximum daily flow (BA Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods). The actual monthly and daily flow data used in the analysis are from gage records just below Keswick Dam and at Bend Bridge. CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Keswick Dam and Red Bluff locations. As discussed in Appendix 5.D, Section 5.D.2.2, Spawning Flow Methods of the BA, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the Sacramento River. Analysis of the Keswick Dam gage data shows that for months with a mean monthly flow of at least 27,300 cfs, the maximum daily flow in that month is always at least 40,000 cfs. The Bend Bridge gage data show that for months with a mean flow of at least 21,800 cfs, the maximum daily flow in that month is always 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 27,300 cfs at Keswick Dam or greater than 21,800 cfs at Red Bluff during the respective spawning and incubation periods for winter-run Chinook salmon, spring-run Chinook salmon, steelhead, fall-run Chinook salmon, and late fall-run Chinook salmon. Further information on the redd scour analysis methods is provided in the BA in Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods.

Secondarily, redd scour impacts were assessed through SALMOD, which predicts “incubation” mortality as a combination of redd scour and dewatering. Because it is impossible to evaluate redd scour and dewatering independently through SALMOD, conclusions as to whether redd scour under the PA would adversely affect each species are based more so on the redd scour flow thresholds analysis.

2.5.1.2.3.1 Winter-run Exposure and Risk

The redd scour analysis suggests there is little risk to winter-run Chinook salmon resulting from high PA flows during the April through October spawning and egg incubation period. Table 2-149 shows that less than 1% of months in the CALSIM II record during the winter-run Chinook salmon spawning and incubation period would have flows of more than 27,300 cfs at Keswick Dam or more than 21,800 cfs at Red Bluff. Only one water year and month with mean monthly flow greater than 27,300 cfs was predicted at Keswick Dam for the winter-run spawning and incubation period (Table 2-150), and several water years and months with mean monthly flow greater than 21,800 cfs were predicted at Red Bluff (Table 2-151) under both the NAA and PA. For winter-run Chinook salmon, there would be no differences between the PA and the NAA in the percentage of scouring flows at either location.

Table 2-149. Percent of Months during Spawning and Incubation Periods with CALSIM II Flow Greater than Redd Scouring Threshold Flow at Keswick Dam (27,300 cfs) and Red Bluff (21,800 cfs) Between Model Scenarios.

Species/Race	Keswick Dam			Red Bluff		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Winter-run Chinook salmon	0.2	0.2	0 (0%)	0.7	0.7	0 (0%)

Table 2-150. Water Year and Month with Mean Flow > 27,300 cfs at Keswick Dam During the Winter-run Chinook Salmon Spawning and Incubation Period.

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1963	April	Wet	30,893	30,893

Table 2-151. Water Years and Months with Mean Flow > 21,800 cfs at Red Bluff During the Winter-run Chinook Salmon Spawning and Incubation Period.

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1941	April	Wet	24,464	24,464
1958	April	Wet	22,228	22,228
1963	April	Wet	42,184	42,182
1982	April	Wet	33,884	33,885

The SALMOD model provides predicted flow-related mortality of winter-run Chinook salmon eggs and alevins in the Sacramento River (see BA Attachment 5.D.2, SALMOD Model for a full description). The SALMOD results for this type of mortality are presented in BA Table 5.4-38 in Appendix C of this Opinion together with results for the other sources of mortality of winter-run Chinook salmon predicted by SALMOD. The flow-related mortality of winter-run Chinook salmon eggs and alevins is split up as “incubation” (which refers to redd dewatering and scour) and “superimposition” (of redds) mortality. The annual exceedance plot of flow-related mortality of winter-run Chinook salmon eggs and alevins is presented in Figure 2-116. These results indicate that there would be increases in flow-related mortality of winter-run Chinook salmon eggs and alevins from incubation-related factors under the PA relative to the NAA for all water year types (increase in average annual mortality of 61,712 eggs and alevins, or 17%, for all water year types combined). Because the redd scour flow threshold analysis discussed above suggests that redd scour is expected to have little effect on winter-run Chinook salmon under either project scenario, the incubation-related mortality predicted by SALMOD, which combines redd scour and dewatering, is likely primarily attributable to redd dewatering.

Overall, redd scour under the PA is not expected to adversely affect winter-run Chinook salmon eggs, except for very rare cases (less than 1% of months).

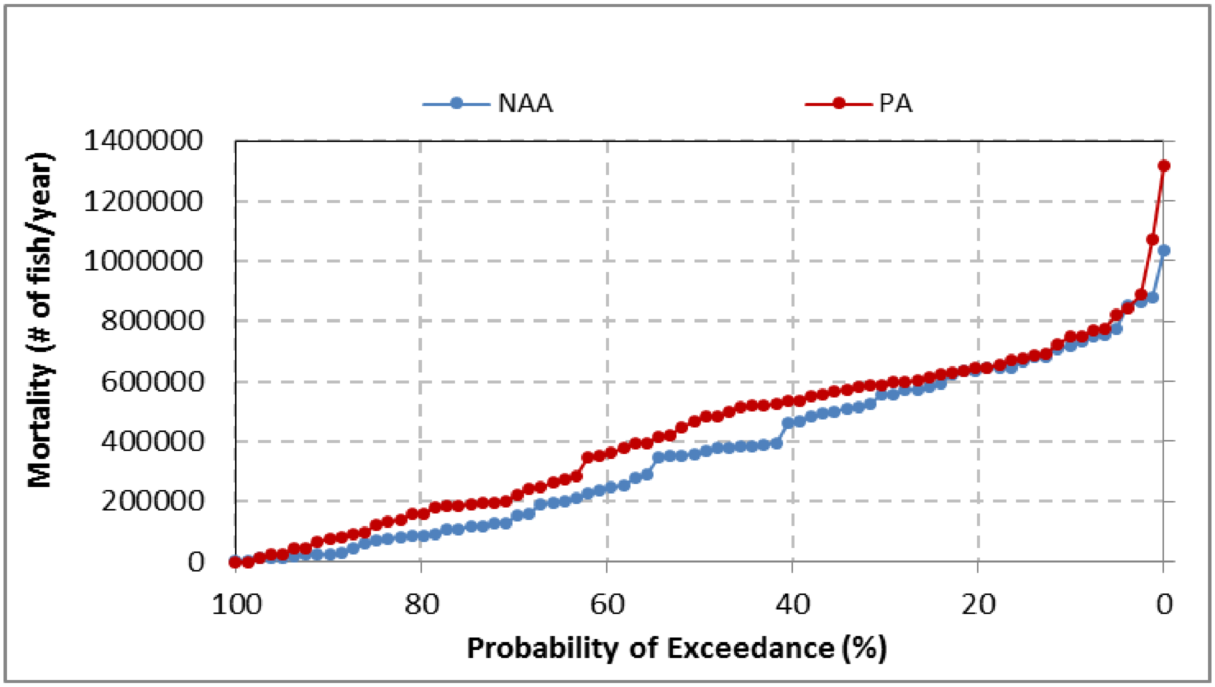


Figure 2-116. Exceedance Plot of Annual Flow-Based Mortality (#of Fish/Year) of Winter-run Chinook Salmon Spawning, Egg Incubation, and Alevins.

2.5.1.2.3.2 Spring-run Exposure and Risk

Table 2-152 shows that fewer than 3% of months in the CALSIM II record during the spawning and incubation period of spring-run Chinook salmon (August through December) would have flows of more than 27,300 cfs at Keswick Dam or more than 21,800 cfs at Red Bluff. This was expected, given that all of the months of the spring-run spawning and incubation period except December rarely experience such high flows. The difference between the PA and the NAA in the percentage of months with scouring flows is 0.2% at both locations.

Table 2-152. Percent of Months During Spawning and Incubation Periods with CALSIM II Flow Greater than Redd Scouring Threshold Flow at Keswick Dam (27,300 cfs) and Red Bluff (21,800 cfs) Between Model Scenarios.

Species/Race	Keswick Dam			Red Bluff		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Spring-run Chinook salmon	0.7	0.5	-0.2 (-25%)	2.6	2.8	0.2 (7%)

The SALMOD model provides predicted flow-related mortality of spring-run Chinook salmon eggs and alevins in the Sacramento River (see BA Attachment 5.D.2, SALMOD Model for a full description). The SALMOD results for this type of mortality are presented in BA Table 5.4-54 in Appendix C of this Opinion, together with results for the other sources of mortality of spring-run Chinook salmon predicted by SALMOD. The flow-related mortality of spring-run Chinook salmon eggs and alevins is split up as "incubation" (which refers to redd dewatering and scour) and "superimposition" (of redds) mortality. Egg and alevin mortality attributable to redd scour and dewatering across all water year types is 2,118 under the PA, 212 higher than under the NAA. (See BA Table 5.4-54 in Appendix C of this Opinion).

The annual exceedance plot of flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins is presented in Figure 2-117. These results indicate that there would be increases in flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins from incubation-related factors under the PA relative to the NAA for all water year types except dry years. The largest increases, about 30 percent, would be for wet, above normal and below normal water year types. Because the redd scour flow threshold analysis discussed above suggests that redd scour is expected to have little effect on spring-run Chinook salmon under either project scenario, the incubation-related mortality predicted by SALMOD, which combines redd scour and dewatering, is likely primarily attributable to redd dewatering.

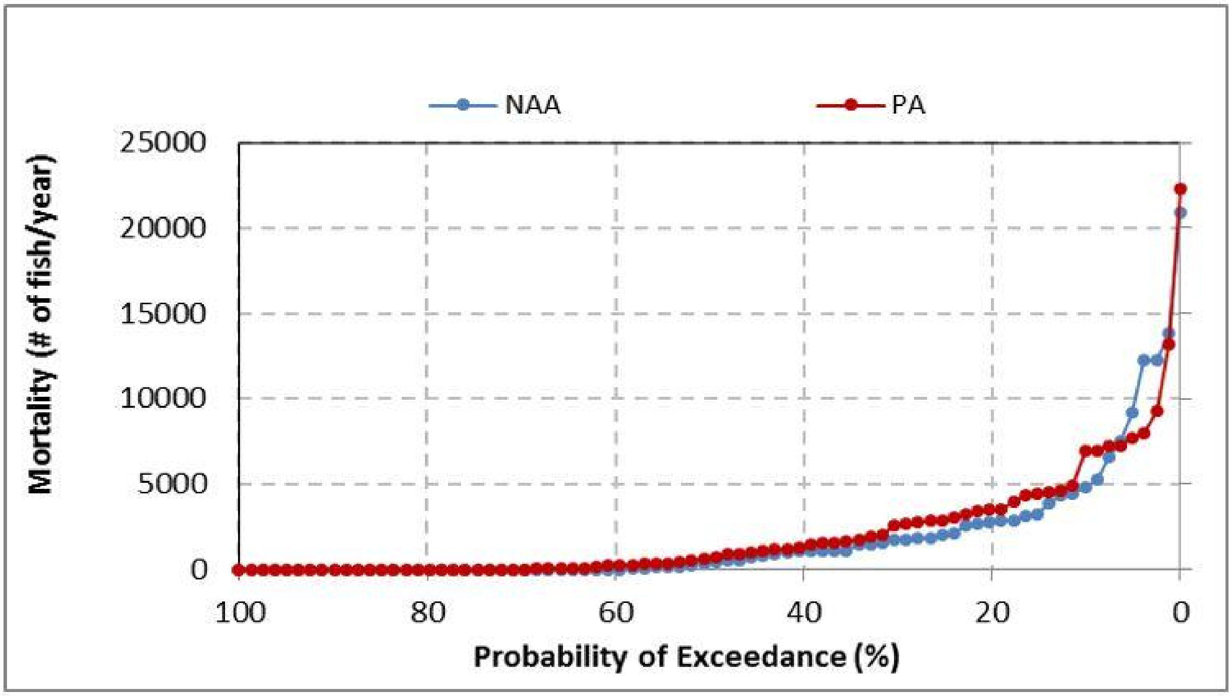


Figure 2-117. Exceedance Plot of Annual Flow-Based Mortality (# of Fish/Year) of Spring-run Chinook Salmon Spawning, Egg Incubation, and Alevins.

Overall, redd scour under the PA is not expected to adversely affect spring-run Chinook salmon eggs, except for rare cases (less than 3% of months).

2.5.1.2.3.3 Steelhead Exposure and Risk

2.5.1.2.3.3.1 Sacramento River

Table 2-153 shows that about 5% of months at Keswick Dam and about 15% of months at Red Bluff would have flows above the redd scouring thresholds during the November through April spawning and incubation period of CCV steelhead. The relatively high percentage of months with scouring flows in the steelhead spawning and incubation period is expected, given that the period encompasses the wettest months of the year. There would be no difference between the PA and the NAA in the percentage of months with scouring flows at Keswick Dam. The percentage of months with scouring flows at Red Bluff would be 1% higher under the PA than under the NAA.

Table 2-153. Percent of Months during Spawning and Incubation Periods with CALSIM II Flow Greater than Redd Scouring Threshold Flow at Keswick Dam (27,300 cfs) and Red Bluff (21,800 cfs) between Model Scenarios.

Species/Race	Keswick Dam			Red Bluff		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
CCV Steelhead	5.3	5.3	0 (0%)	14.6	15.7	1 (7%)

2.5.1.2.3.3.1 American River

The probability of flows in the American River occurring under the PA and the NAA that would be high enough to mobilize sediments and scour Central Valley steelhead redds was estimated from CALSIM II estimates of mean monthly flows, using a relationship determined from the historical record between actual mean monthly and maximum daily flow (BA Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods).

Actual monthly and daily flow data used in the analysis are from gage records at Hazel Avenue and the CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Nimbus Dam location.

As discussed in the BA in Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the American River. Analysis of Hazel Avenue gage data shows that for months with a mean monthly flow of at least 19,350 cfs, the maximum daily flow in that month is always at least 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 19,350 cfs at Nimbus during the steelhead December through May spawning and incubation period (Table 2-154). Further information on the redd scour analysis methods is provided in the BA in Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods.

Table 2-154. Water Years and Months with Mean Flow >19,350 cfs at Hazel Avenue during the Central Valley Steelhead Spawning and Incubation Period in the American River.

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1964	December	Dry	21,494	21,414
1968	January	Below Normal	23,260	23,929
1969	January	Wet	25,092	25,092
1983	March	Wet	19,927	19,927
1983	December	Wet	22,909	22,909
1986	February	Wet	37,305	37,305
1995	March	Wet	19,730	19,721
1996	January	Wet	38,218	38,218

As shown in in Table 2-110, the frequency of flows high enough to result in redd scour is the same under the PA and NAA. Therefore, it was concluded that the PA is not expected to result adverse effects from redd scour under the PA, relative to the NAA.

2.5.1.2.3.4 Green Sturgeon Exposure and Risk

As stated previously, because sturgeon spawn in deep pools, the eggs adhere to bottom cobble and gravel substrates or settle into crevices, and their incubation time is relatively short (i.e., seven to nine days), they are less vulnerable to sediment mobilization under high flows than salmonid species. Therefore, it is assumed that green sturgeon would experience little to no impacts from scour of their spawning areas.

2.5.1.2.3.5 Fall/Late fall-run Exposure and Risk

2.5.1.2.3.5.1 Sacramento River

2.5.1.2.3.5.1.1 Fall-run Chinook Salmon

Table 2-155 shows that about 2% of months at Keswick and about 8% of months at Red Bluff would have flows above the redd scouring thresholds during the September through January spawning and incubation period of fall-run Chinook salmon. The moderately high percentage of scouring flows in the fall-run spawning and incubation period (relative to winter- and spring-run Chinook salmon) is expected, given that the period includes December and January, two of the wettest months of the year. The percentage of months with scouring flows under the PA would be about 0.2% lower at Keswick and 0.5% greater at Red Bluff.

Table 2-155. Percent of Months during Fall-run Chinook Salmon Spawning and Incubation Period with CALSIM II Flow Greater than Redd Scouring Threshold Flow at Keswick (27,300 cfs) and Red Bluff (21,800 cfs) Between Model Scenarios.

Species/Race	Keswick			Red Bluff		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Fall-run Chinook salmon	2.2	2.0	-0.2 (-11%)	7.8	8.3	0.5 (6%)
Late fall-run Chinook salmon	4.4	4.4	0 (0%)	12.4	13.1	0.7 (6%)

The SALMOD model provides predicted flow-related mortality of fall-run Chinook salmon eggs and alevins in the Sacramento River (see BA Attachment 5.D.2, SALMOD Model for a full description). The SALMOD results for this type of mortality are presented in BA Table 5.4-37 in Appendix C of this Opinion, together with results for the other sources of mortality of fall-run Chinook salmon predicted by SALMOD. The flow-related mortality of fall-run Chinook salmon eggs and alevins is split up as "incubation" (which refers to redd dewatering and scour) and "superimposition" (of redds) mortality. Egg and alevin mortality attributable to redd scour and dewatering across all water year types is 1,477,164 under the PA, 25,504 higher than under the NAA BA Table 5.4.-37 in Appendix C of this Opinion.

Considering the results and discussion above, redd scour is not expected to adversely affect fall-run Chinook salmon eggs and alevins, relative to the NAA.

2.5.1.2.3.5.1.2 Late Fall-run Chinook Salmon

Table 2-111 shows that late fall-run Chinook salmon redd scour under the PA is expected to be the same (Keswick) or slightly higher (Red Bluff) than under the NAA. At Red Bluff, the percentage of months that are expected to have flows above the redd scouring thresholds during the late fall-run Chinook salmon spawning and incubation period identified in the BA (December through June) is 13% under the PA and 12% under the NAA. The moderately high percentage of scouring flows in this period is expected, given that it includes the wettest months of the year.

The SALMOD model provides predicted flow-related mortality of late fall-run Chinook salmon eggs and alevins in the Sacramento River (see BA Attachment 5.D.2, SALMOD Model for a full description). The SALMOD results for this type of mortality are presented in Table 5.E-54, together with results for the other sources of mortality of late fall-run Chinook salmon predicted by SALMOD. The flow-related mortality of late fall-run Chinook salmon eggs and alevins is split up as “incubation” (which refers to redd dewatering and scour) and “superimposition” (of redds) mortality. Egg and alevin mortality attributable to redd scour and dewatering across all water year types is 172,486 under the PA, 2,072 higher than under the NAA. See Appendix C in this Opinion, BA Table 5.E-54.

Overall, late fall-run Chinook salmon redd scour resulting from changes to upstream operations as a result of the PA is expected to result in adverse effects, relative to the NAA, but those effects would be minimal (only slightly greater than under the NAA).

2.5.1.2.3.5.2 American River

The probability of flows in the American River occurring under the PA and the NAA that would be high enough to mobilize sediments and scour fall-run Chinook salmon redds was estimated from CALSIM II estimates of mean monthly flows, using a relationship determined from the historical record between actual mean monthly and maximum daily flow (BA Appendix 5.D.2.2, Spawning Flow Methods). Actual monthly and daily flow data used in the analysis are from gage records at Hazel Avenue, and the CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Nimbus Dam location. As discussed in the BA in Appendix 5.D.2.2, Spawning Flow Methods, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the American River. Analysis of the Hazel Avenue gage data shows that for months with a mean monthly flow of at least 19,350 cfs, the maximum daily flow is always at least 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 19,350 cfs at Nimbus during the fall-run Chinook salmon October through January spawning and incubation period. Further information on the redd scour analysis methods is provided in the BA in Appendix 5.D.2.2, Spawning Flow Methods.

Of the months in the CALSIM II record during the spawning and incubation period of fall-run Chinook salmon in the American River (December through April), 1.5% would have flows of more than 19,350 cfs at Hazel Avenue under both the PA and the NAA.

Overall, fall-run Chinook salmon redd scour resulting from changes to American River operations as a result of the PA is not expected to result in adverse effects, relative to the NAA.

Late fall-run Chinook salmon do not spawn in the American River and therefore no effects analysis was conducted for them in the American River.

2.5.1.2.4 Isolation and Stranding

Rapid reductions in flow can adversely affect fish. Juvenile salmonids are particularly susceptible to isolation or fry stranding during rapid reductions in flow. Isolation can occur when the rate of reductions in stream flow inhibits an individual's ability to escape an area that becomes isolated from the main channel or dewatered (USFWS 2006). The effect of juvenile isolation on production of Chinook salmon and steelhead populations is not well understood, but isolation is frequently identified as a potentially important mortality factor for the populations in the Sacramento River and its tributaries (Jarrett and Killam 2014, 2015, Cramer Fish Sciences 2014, NMFS 2009, Bureau of Reclamation 2008, Water Forum 2005, CDFG 2001, USFWS 2001).

Juveniles typically rest in shallow, slow-moving water between feeding forays into swifter water. These shallower, low-velocity margin areas are more likely than other areas to dewater and become isolated with flow changes (Jarrett and Killam 2015). Accordingly, juveniles are most vulnerable to isolation during periods of high and fluctuating flow when they typically move into inundated side channel habitats. Isolation can lead to direct mortality when these areas drain or dry up or to indirect mortality from predators or rising water temperatures and deteriorating water quality.

Different water management and water use actions can cause isolation. High, rapidly changing flows that then quickly decrease may result from flow release pulses to meet Delta water quality standards, from flood control releases, or from tributary freshets following rain events (Jarrett and Killam 2015, Bureau of Reclamation 2008). Isolation may also occur during periods of controlled flow reductions, such as when irrigation demand declines in the fall (NMFS 2009) or following gate removal at the ACID dam in November (NMFS 2009).

Isolation is currently a potential stressor in the upper Sacramento River, though mechanisms such as ramping restrictions exist that are intended to reduce the risk of occurrence. The upper Sacramento River has numerous side channel-like gravel bars that are used by juveniles as resting stops when inundated by higher flows. These areas can become isolated pools or even completely dewatered when reservoir releases are reduced. Although the NMFS biological opinion on the long-term operations of the CVP/SWP (NMFS 2009) includes ramping restrictions for reservoir releases, CDFW rescues fish from these channel margin pools every year (CDFW 2013, 2014, 2015, 2016). CDFW monitoring reports show a range of numbers of different species and runs of anadromous fish observed and rescued in these efforts. The dependence of isolation risk on factors such as rate of sediment mobilization, rate of sediment settling in channel margin areas, and timing and rate of flow reductions makes the quantification of stranding risk difficult.

Juvenile isolation risk would likely remain during operations of the proposed action, but the magnitude is difficult to predict. Juvenile isolation generally results from reductions in flow that occur over short periods of time. The isolation analysis in the biological assessment uses the monthly flow results provided by CALSIM modeling of PA operations. This monthly time step is too coarse for a meaningful analysis of the short-term drivers of juvenile isolation and fry stranding. Though all ramping restrictions for dams on the Sacramento River and its tributaries would not change under the PA, reservoir releases may vary from year to year in timing of flow fluctuations. There is therefore uncertainty to the level of effect of possible isolation and stranding on fish. Continued monitoring will be vital to understanding the level of effect and identifying if additional minimization measures are needed.

2.5.1.2.4.1 Winter-run Exposure and Risk

Timing and distribution of juvenile winter-run presence in the upper Sacramento River is described in section 2.5.1.2.1 Increased Upstream Temperature.

Juvenile winter-run Chinook salmon have the potential to be isolated and thus adversely affected if resting in channel margin pools of the upper Sacramento River when flows are reduced. In order to preserve carry-over storage in the CVP reservoir, releases are reduced October through April based on the CVPIA Anadromous Restoration Plan which targets minimum flows between 3,250 and 5,500 cfs in the fall. Between 1998 and 2000, and as part of the CVPIA Instream Flow Investigations, the USFWS identified 92 locations between Keswick Dam and Battel Creek which would potentially become isolated from the main channel at flows ranging from 3,250 cfs to 15,000 cfs (USFWS 2006). Modeled Keswick/ Shasta reservoir operations under the PA are not substantially different from the NAA scenario. Therefore, the PA is unlikely to increase the risk of stranding to winter-run Chinook salmon on the Sacramento River. However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the risk of flow fluctuations in the river reaches below Keswick Dam that can strand winter-run would continue. The potential for juvenile isolation and fry stranding would also persist as operations continue to target lower reservoir releases in the fall and winter to maximize carry-over storage. For operation of the CVP, this potential stranding has been largely mitigated by maintaining flows above 3,750 cfs and by implementing gradual ramping rates. However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, NMFS expects that stranding of at least a small proportion of winter-run juveniles will continue with PA implementation due to reservoir operations under the environmental baseline that will adversely affect exposed individuals.

2.5.1.2.4.2 Spring-run Exposure and Risk

Timing of juvenile spring-run presence in the upper Sacramento River has previously been described in section 2.5.1.2.1 Increased Upstream Temperature.

Juvenile spring-run Chinook salmon may potentially be isolated and thus adversely affected if resting in channel margin pools of the upper Sacramento River when flows are reduced. Annual aerial redd surveys on the Sacramento River (CDFW unpublished data 2016) in September indicate some spring-run Chinook salmon spawning on the mainstem of the river, though numbers are low; surveys suggest from zero to 100 individuals. The majority of spring-run Chinook salmon hatch in the tributaries to the Sacramento River and then use the Sacramento River as a migratory corridor on route to the ocean. CDFW monitoring of fish in isolated pools on the Sacramento River often cannot identify stranded juvenile spring-run Chinook salmon from fall-run Chinook salmon because of the spatial and temporal overlap of the two runs' spawning and subsequent juvenile outmigration. Mid-summer through winter monitoring indicates that Chinook salmon identified as spring-run/fall-run (based on length-at-date criteria) have been stranded. Six stranded spring-run were documented in 2015/2016 (CDFW 2013, 2014, 2015, 2016). Because the fall-run Chinook salmon ESU abundance is much greater than the CV spring-run Chinook salmon ESU, total numbers of stranded spring-run/fall-run are likely comprised of proportionately more fall-run Chinook salmon than spring-run Chinook salmon. The PA is unlikely to increase the risk of stranding to spring-run Chinook salmon on the Sacramento River.

2.5.1.2.4.3 Steelhead Exposure and Risk

Juvenile and adult steelhead have the potential to be isolated from the main channel of the Sacramento River or American River in side channels as river flows fluctuate and these waterbodies become separated from the main channel flow. Potential for stranding is typically greater for juveniles than for adults because of behavioral use of these habitats for rearing. Survival of juveniles and adults in stranding sites on these rivers depends on many factors. The connectivity to the river changes as reservoir releases change or as tributary flows change so each stranding site is a dynamic balance of environmental inputs at any given time. On the Sacramento River, the farther upstream the site, the less likely that downstream tributary flows will contribute to connectivity changes and stranding events are closely tied to reservoir releases. In the lower survey reaches, tributaries are influenced by precipitation events, and mainstem river levels can fluctuate quickly in response to these tributary flows even when reservoir releases are stable at Keswick. On the American River, there are no tributaries of significant size that would substantially influence river flow levels compared to reservoir releases from Folsom and Nimbus dams.

Annual surveys are conducted by fisheries agencies from Keswick Dam downstream to Tehama on the Sacramento River, a distance of 73 river miles (Killiam and Revnak 2016, Jarrett and Killiam 2015, 2014). Approximately 75 surveys are conducted each year and potential redd dewatering and stranding sites are identified during each survey. Over the past three seasons (2013–2014, 2014–2015, and 2015–2016) approximately 170-190 potential stranding locations have been identified each season in the 73-mile survey area. Typically about 30 of these locations are completely isolated from the main channel and have had salmonids entrapped in them.

Fish rescues conducted in these isolated waterbodies have recovered rainbow trout/ steelhead juveniles. The numbers of rainbow trout/steelhead rescued in the following seasons are:

- 2015–2016 season 15 fish,
- 2014–2015 season 515 fish, and
- 2013–2014 season 153 fish (CDFW 2014, 2015, 2016).

The actual numbers of fish stranded in these isolated pools and waterbodies are potentially much greater because of the inefficiency of the rescues in habitats that are not conducive to the rescue techniques (trees, rocks, and debris interfere with the seine nets, electroshocking, etc.) and the potential for predation and scavenging of trapped and dying fish isolated in these waterbodies.

For purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation with added to the environmental baseline and modeled climate change impacts, it is expected that under the PA and NAA, reservoir releases on the American River from Folsom and Natomas reservoirs will create the potential for stranding of steelhead fry and juveniles in side channels and isolated pools on the American River. Under both the NAA and PA scenarios, reservoir releases increase substantially from January to February and then decline substantially from March through April, creating the potential for stranding and isolation in side channels and pools of newly emerged steelhead alevins and fry and older juvenile steelhead.

Modeled reservoir releases on the American River from Nimbus Dam indicate that there is a tendency for greater reductions in flow under the PA in certain months and water year types than under the NAA scenario. This has the potential to enhance the vulnerability to stranding of steelhead in the lower American River due to the PA.

Overall, steelhead fry stranding and juvenile isolation in the American River resulting from changes to upstream operations as a result of the PA is expected to result in adverse effects, relative to the NAA, but those effects are expected to be minimal (only slightly greater than under the NAA).

2.5.1.2.4.4 Green Sturgeon Exposure and Risk

Stranding of green sturgeon does not occur in the mainstem Sacramento River. Under the environmental baseline (current conditions), green sturgeon stranding in the Yolo Bypass does occur. However, relative to the NAA, the PA is not expected to increase or decrease flow levels such that the amount of stranding of juveniles and post-spawn adults on the seasonally inundated Yolo Bypass would change. Adverse effects resulting from green sturgeon stranding on the Yolo Bypass under the PA are not expected, relative to the NAA.

2.5.1.2.4.5 Fall/Late fall-run Exposure and Risk

2.5.1.2.4.5.1 Sacramento River

Fall-run Chinook salmon juveniles in the Sacramento River are vulnerable to becoming isolated in off channel habitats following flow reductions during their December through June fry and juvenile rearing period; late fall-run Chinook salmon juveniles are vulnerable during March through January. Juvenile stranding of fall-run and late fall-run Chinook salmon has been documented in the Sacramento River under current operations, despite the existence of criteria intended to slow flow reduction rates and allow juveniles to avoid being stranded.

CDFW has implemented juvenile stranding surveys in recent years in part to observe and report on locations that could potentially contain stranded salmonids that were isolated to varying degrees by flow reductions. Fish rescues have become an essential component of these surveys. During monitoring in the summer of 2015 through spring of 2016, 180 stranding locations between the Keswick Dam (the uppermost limit of anadromy on the Sacramento River) and the Tehama Bridge (a total of 73 river miles) were observed. A total of 6,748 fall/spring-run Chinook and late fall-run Chinook juveniles were observed stranded and rescued by crews during the 2015-2016 season (Stompe et al. 2016). During the 2013 through 2014 monitoring season, 188 stranding locations between the Keswick Dam and the Tehama were observed (Jarrett and Killam 2014). An estimated 6,360 naturally spawned Chinook juveniles were observed stranded in isolated sites. Of these, crews estimated that 232 fall-run juveniles were unlikely to survive their stranding due to environmental conditions. Crews were uncertain of the survival of the remaining fish. Rescue efforts were initiated beginning in January 2014 after CDFW rescue permitting was granted. Several thousand fish were successfully rescued including 6,551 juvenile Chinook salmon and rainbow trout/steelhead (Jarrett and Killam 2014). This monitoring shows that the stranding of thousands of juvenile salmonids, many of which are fall-run Chinook salmon, is a regular occurrence in the Sacramento River under the environmental baseline. As the monthly modeled flow results suggest, the adverse effects on fry and juveniles related to flow reductions are expected to be similar between the PA and NAA. Therefore, the PA is unlikely to increase the risk of stranding to spring-run Chinook salmon on the Sacramento River. However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, NMFS expects that stranding of at least a small proportion of fall- and late-fall Chinook salmon spring-run juveniles will continue with PA implementation due to reservoir operations under the environmental baseline that will adversely affect exposed individuals.

2.5.1.2.4.5.2 American River

Fall-run Chinook salmon fry and juveniles occur in the American River from December through June. During that time they are vulnerable to fry stranding on dewatered gravel bars and juvenile isolation in off-channel habitats following reductions in flow. Numerous occurrences of both fall-run Chinook salmon fry stranding and juvenile isolation have been documented in the American River (CDFW 2001; Water Forum 2005). The PA does not include operational changes beyond existing ramp down criteria designed to minimize the rate of flow reductions within the American River. Given that the expected flows in the American River under the PA and NAA are largely similar, as the monthly modeled flow results suggest, the adverse effects on fry and juveniles related to flow reductions are expected to be similar between the PA and NAA. Therefore, the PA is unlikely to increase the risk of stranding to fall-run Chinook salmon on the American River. However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, NMFS expects that stranding of at least a small proportion of fall-run juveniles will continue with PA implementation due to reservoir operations under the environmental baseline that will adversely affect exposed individuals.

2.5.1.2.5 North Delta Diversion Intake Screen Impingement and Entrainment

The PA includes construction of three north Delta diversion (NDD) intakes on the east bank of the Sacramento River between Clarksburg and Courtland, in Sacramento County, California. The intakes are designed as on-bank screens that would minimize the risk of fish entrainment into the intakes. Water will be diverted from the Sacramento River by gravity into the screened intake bays and routed from each bay through multiple parallel conveyance box conduits to sedimentation basins. Flow meters and flow control sluice gates will be located on each box conduit to ensure limitations on approach velocities and that flow balancing among the three intake facilities is achieved.

The screen length is 1,350 ft each at two (Intakes 2 and 5) of the three intakes and 1,110 ft at the third intake (Intake 3) (Table 2-156), with a combined total of 3,810 ft. When fish migrate past the fish screens, there are three general sources of potential impacts that may be caused by the new diversion structures and their operations. The first category of impacts, which is discussed in this section, are those that can typically result from the operation of large diversions such as entrainment and impingement of fish that come in contact with the facility as water is being diverted, possibly resulting in fish injury or mortality. The second category, which is discussed in Section 2.5.1.2.6 Increased Predation, includes those impacts that may result from the existence of large concrete/steel structures in the river, such as increased predation and loss of shoreline habitat features (see Section 2.5.2 Effects to Critical Habitat). The third category of impacts, which is discussed in Section 2.5.1.2 Operations, are those associated with the diversion of large quantities of water from the river, which can affect flow patterns, hydrodynamics, and habitat features or ecological processes that are dependent on river flows.

Table 2-156. Fish Screen Dimensions at the North Delta Diversion Intakes.

Intake	Location on Sacramento River	Screen Height (ft)	Screen Width (ft)	Number of Screens	Total Length of Screens (ft)
Intake 2	RM 41.1 38.40541, -121.51452	12.6	15.0	90.0	1,350.0
Intake 3	RM 39.4 38.38209, -121.51991	17.0	15.0	74.0	1,110.0
Intake 5	RM 36.8 38.35057, -121.53302	12.6	15.0	90.0	1,350.0

2.5.1.2.5.1 Monitoring and Studies Prior to Operations and Following Construction of the North Delta Diversion Intakes

The PA includes that prior to construction of the NDD, specific studies will be developed in collaboration with USFWS, CDFW, and NMFS that are focused on pre-construction conditions and on design of the diversions. Because these studies will be designed after the issuance of this Opinion, the effects of those studies are addressed in this Opinion at a programmatic level (see Section 2.5.1.3 Future Monitoring). These monitoring efforts prior to operations will build off the work done by the Fish Facilities Technical Team (FFTT 2013), which identified monitoring associated with the NDD intakes and their effects. The pre-construction studies identified by this group were focused on specific key questions rather than general monitoring needs and are listed in Table 2-157. These studies and their projected timeframes will be revisited as the final monitoring plan is developed.

Table 2-157. Preconstruction Studies at the North Delta Diversions.

Potential Research Action[1]	Key Uncertainty Addressed	Timeframe
1. This action includes preconstruction study 1, *Site Locations Lab Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to develop physical hydraulic models to optimize hydraulics and sediment transport at the selected diversion sites.	What is the relationship between proposed North Delta Diversions (NDD) intake design features and expected intake performance relative to minimization of entrainment and impingement risks?	Ten months to perform study; must be complete prior to final intake design.
2. This action includes preconstruction study 2, *Site Locations Numerical Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to develop site-specific numerical studies (mathematical models) to characterize the tidal and river hydraulics and the interaction with the intakes under all proposed design operating conditions.	How do tides and diversion rates affect flow conditions at the NDD intake screens and at the Georgiana Slough junction?	Eight months to perform study; must be complete prior to final intake design.
3. This action includes preconstruction study 3, *Refugia Lab Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to test and optimize the final recommendations for fish refugia that will be incorporated in the design of the north Delta intakes.	How should NDD intake refugia be designed in principle to achieve desired biological function?	Nine months to perform study; must be complete prior to final intake design.
4. This action includes preconstruction study 4, *Refugia Field Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to evaluate the effectiveness of using refugia as part of north Delta intake design for the purpose of providing areas for juvenile fish passing the screen to hold and recover from swimming fatigue and to avoid exposure to predatory fish.	How do alternative NDD intake refugia designs perform with regard to desired biological function?	Two years to perform study; must be complete prior to final intake design.
5. This action includes preconstruction study 5, *Predator Habitat Locations* as described by the Fish Facilities Working Team (2013). The purpose of this study is to perform field evaluation of similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District) and identify predator habitat areas at those facilities.	Where is predation likely to occur near the new NDD intakes?	One to two years to perform study; must be complete prior to final intake design.
6. This action includes preconstruction study 6, *Baseline Fish Surveys* as described by the Fish Facilities Working Team (2013), somewhat modified based on discussions with NMFS during 2014. The purpose of this study is to perform literature search and potentially field evaluations at similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District), to determine if these techniques also take listed species of fish, and to assess ways to reduce such by-catch, if necessary.	What are the best predator reduction techniques, i.e., which techniques are feasible, most effective, and best minimize potential impacts on listed species?	Two years to perform study; must be complete prior to final intake design.

Potential Research Action[1]	Key Uncertainty Addressed	Timeframe
7. This action includes preconstruction study 7, *Flow Profiling Field Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to characterize the water velocity distribution at river transects within the proposed diversion reaches for differing flow conditions. Water velocity distributions in intake reaches will identify how hydraulics change with flow rate and tidal cycle, and this information will be used in fish screen final design and in model-based testing of fish screen performance (preconstruction study 8, below).	What is the water velocity distribution at river transects within the proposed intake reaches, for differing river flow conditions?	One year to perform study; must be complete prior to final intake design.
8. This action includes preconstruction study 8, *Deep Water Screens Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to use a computational fluid dynamics model to identify the hydraulic characteristics of deep fish screen panels.	What are the effects of fish screens on hydraulic performance?	Nine months to perform study; must be complete prior to final intake design.
9. This action includes preconstruction study 9, *Predator Density and Distribution* as described by the Fish Facilities Working Team (2013); and includes post-construction study 9, *Predator Density and Distribution*, as described by the Fish Facilities Technical Team (2013). The purpose of this study is to use an appropriate technology (to be identified in the detailed study plan) at two to three proposed screen locations; the study will also perform velocity evaluation of eddy zones, if needed. The study will also collect baseline predator density and location data prior to facility operations, compare that to density and location of predators near the operational facility; and identify ways to reduce predation at the facilities.	What are predator density and distribution in the north Delta intake reaches of the Sacramento river?	Start in 2016 to collect multiple annual datasets before construction begins. The post-construction study will cover at least 3 years, sampling during varied river flows and diversion rates.
10. This action includes preconstruction study 10, *Reach-Specific Baseline Juvenile Salmonid Survival Rates* as described by the Fish Facilities Working Team (2013); and includes post-construction study 10, *Post-Construction Juvenile Salmon Survival Rates* as described by the Fish Facilities Technical Team (2013). The purpose of this study is to determine baseline rates of survival for juvenile Chinook salmon and steelhead within the Sacramento River near proposed north Delta diversion sites for comparison to post-project survival in the same area, with sufficient statistical power to detect a 5% difference in survival. Following initiation of project operations, the study will continue, using the same methodology and same locations. The study will identify the change in survival rates due to construction/operation of the intakes.	How will the new north Delta intakes affect survival of juvenile salmonids in the affected reach of the Sacramento River?	The pre-construction study will cover at least 3 years and must be completed before construction begins. The post-construction study will cover at least 3 years, sampling during varied river flows and diversion rates.

Potential Research Action[1]	Key Uncertainty Addressed	Timeframe
11. This action includes preconstruction study 11, *Baseline Fish Surveys* as described by the Fish Facilities Working Team (2013) and includes post-construction study 11, *Post-Construction Fish Surveys* as described by the Fish Facilities Technical Team (2013). The purpose of this study is to determine baseline densities and seasonal and geographic distribution of all life stages of delta and longfin smelt inhabiting reaches of the lower Sacramento River where the north Delta intakes will be sited. Following initiation of diversion operations, the study will continue sampling using the same methods and at the same locations. The results will be compared to baseline catch data to identify potential changes due to intake operations.	How will the new north Delta intakes affect delta and longfin smelt density and distribution in the affected reach of the Sacramento River?	Pre-construction study will cover at least 3 years. Post-construction study will be performed for duration of project operations (or delisting of species), with timing and frequency to be determined.

Notes:
[1]All research actions listed in this table are part of the PA. For all proposed research actions, a detailed study design must be developed prior to implementation. The study design will be reviewed and approved by CDFW, NMFS, and USFWS prior to implementation.

Monitoring and studies related to CVP and SWP Delta operations, which must occur after operations of the new facilities has commenced, broadly consists of four types of monitoring, performed to assess system state and effects on listed species: monitoring addressing the operation of the proposed new facilities, monitoring related to species condition and habitat that may be influenced by operations of the new facilities, monitoring to evaluate the effectiveness of the proposed facilities, and monitoring addressing the habitat protection and restoration sites (Table 2-158).

Table 2-158. Monitoring Actions for Listed Species of Fish for the North Delta Intakes.

Monitoring Action(s)	Action Description[1]	Timing and Duration
1. Fish screen hydraulic effectiveness	This action includes post-construction study 2, *Long-term Hydraulic Screen Evaluations*, combined with post-construction study 4, *Velocity Measurement Evaluations,* as described by the Fish Facilities Technical Team (2013). The purpose of this monitoring is to confirm screen operation produces approach and sweeping velocities consistent with design criteria, and to measure flow velocities within constructed refugia. Results of this monitoring will be used to "tune" baffles and other components of the screen system to consistently achieve compliance with design criteria.	Approximately 6 months beginning with initial facility operations.
2. Fish screen cleaning	This action includes post-construction study 3, *Periodic Visual Inspections* as described by the Fish Facilities Technical Team (2013). The purpose of this monitoring is to perform visual inspections to evaluate screen integrity and the effectiveness of the cleaning mechanism, and to determine whether cleaning mechanism is effective at protecting the structural integrity of the screen and maintaining uniform flow distribution through the screen. Results of this monitoring will be used to adjust cleaning intervals as needed to meet requirements.	Initial study to occur during first year of facility operation with periodic re-evaluation over life of project.

Monitoring Action(s)	Action Description[1]	Timing and Duration
3. Refugia effectiveness	This action includes post-construction study 5, *Refugia Effectiveness* as described by the Fish Facilities Technical Team (2013). The purpose is to monitor refugia to evaluate their effectiveness relative to design expectations. This includes evaluating refugia operation at a range of river stages and with regard to effects on target species or agreed proxies. Results of this monitoring will be used to "tune" the screen system to consistently achieve compliance with design criteria.	Approximately 6 months beginning with initial facility operations.
4. Fish screen biological effectiveness	This action includes post-construction study 7, *Evaluation of Screen Impingement* as described by the Fish Facilities Technical Team (2013). The purpose of this monitoring is to observe fish activity at the screen face (using technology to be identified in the detailed study plan) and use an appropriate methodology (to be identified in the detailed study plan) to evaluate impingement injury rate. Results of this monitoring are to be used to assess facility performance relative to take allowances, and otherwise as deemed useful via the collaborative adaptive management process.	Study to be performed at varied river stages and diversion rates, during first 2 years of facility operation.
5. Fish screen entrainment	This action includes post-construction study 8, *Screen Entrainment* as described by the Fish Facilities Technical Team (2013). The purpose of this monitoring is to measure entrainment rates at screens using fyke nets located behind screens, and to identify the species and size of entrained organisms. Results of this monitoring are to be used to assess facility performance relative to take allowances, and otherwise as deemed useful via the collaborative adaptive management process.	Study to be performed at varied river stages and diversion rates, during first 2 years of facility operation.
6. Fish screen calibration	Perform hydraulic field evaluations to measure velocities over a designated grid in front of each screen panel. This monitoring will be conducted at diversion rates close to maximum diversion rate. Results of this monitoring will be used to set initial baffle positions and confirm compliance with design criteria.	Initial studies require approximately 3 months beginning with initial facility operations.
7. Fish screen construction	Document north Delta intake design and construction compliance with fish screen design criteria (note, this is simple compliance monitoring).	Prior to construction and as-built.
8. Operations independent measurement	Document north Delta intake compliance with operational criteria, with reference to existing environmental monitoring programs including (1) Interagency Ecological Program Environmental Monitoring Program: Continuous Multi-parameter Monitoring, Discrete Physical/ Chemical Water Quality Sampling; (2) DWR and Reclamation: Continuous Recorder Sites; (3) Central Valley RWQCB: NPDES Self- Monitoring Program; and (4) USGS Delta Flows Network and National Water Quality Assessment Program. The purpose of this monitoring is to ensure compliance and consistency with other relevant monitoring programs, and to ensure that this information is provided to CDFW, NMFS, and USFWS in association with other monitoring reporting.	Start prior to construction of water diversion facilities and continue for the duration of the PA.
9. Operations measurement and modeling	Document north Delta intake compliance with the operational criteria using flow monitoring and models implemented by DWR. The purpose of this monitoring is to ensure and demonstrate that the intakes are operated consistent with authorized flow criteria.	Start prior to completion of water diversion facilities and continue for the duration of the PA.

Monitoring Action(s)	Action Description[1]	Timing and Duration
10. North Delta intake reach salmonid survivorship	Determine the overall impact on survival of juvenile salmonids through the diversion reach, related to the operation of the new north Delta intakes. Use mark/recapture and acoustic telemetry studies (or other technology to be identified in the detailed study plan) to evaluate effects of facility operations on juvenile salmonids, under various pumping rates and flow conditions. Results of this monitoring are to be used to assess whether survival objectives for juvenile salmonids traversing the diversion reach are being met, to determine whether take allowances are exceeded, and otherwise as deemed useful via the collaborative adaptive management process	Study to be performed at varied river flows and diversion rates, during first 2 to 5 years of facility operation.

Note:
[1]All monitoring actions are part of the PA. For all proposed monitoring actions, a detailed study design must be developed prior to implementation. The study design will be reviewed and approved by CDFW, NMFS, and USFWS prior to implementation.

Implementation of these studies and monitoring efforts will assist in informing the technical teams of the potential for meeting the fish screen criteria during design and development, and the compliance of the screens with the expected performance criteria after construction and operations commence. Although these studies and monitoring efforts are designed to achieve the fish screening criteria needed to protect the listed species evaluated in this Opinion, there is a high degree of uncertainty about whether the NDD can be built to meet the fish screen criteria due to large extent of the screens. Therefore, because the results of these studies and monitoring efforts are not known at this time, any additional species protection that may be garnered from the study/monitoring process is not incorporated into our current effects analysis. The expectation is that the study/monitoring results will inform the NDD design and initial operations. Once those designs and operations are complete, NMFS will evaluate them to ensure that the impacts fall within the range of impacts evaluated in this Opinion. For the reasons described above, NMFS has taken a worst-case scenario approach to the analysis in this section consistent with the general principle of institutionalized caution.

The PA does provide assurance that the NDD will precede to full operations with a phased test period during which DWR, as project applicant, in close collaboration with NMFS and CDFW, will develop detailed plans for appropriate tests and use those tests to evaluate facility performance across a range of pumping rates and flow conditions. This phased testing period will include biological studies and monitoring efforts to enable the measurement of survival rates (both within the screening reach and downstream to Chipps Island), and other relevant biological parameters which may be affected by the operation of the new intakes.

The PA provides that the fish and wildlife agencies (i.e., USFWS, NMFS, and CDFW) retain responsibility for determination of the operational criteria and constraints (i.e., which pumping stations are operated and at what pumping rate) during testing. The fish and wildlife agencies are also responsible for evaluating and determining whether the diversion structures are achieving performance standards for listed species of fish over the course of operations. Consistent with the experimental design, the fish and wildlife agencies will also determine when the testing period should end and full operations consistent with developed operating criteria can commence. In making this determination, fish and wildlife agencies expect and will consider that, depending on hydrology, it may be difficult to test for a full range of conditions prior to commencing full operations. Therefore, tests of the facility to ensure biological performance standards are met are expected to continue intermittently after full operations begin, to enable testing to be completed for different pumping levels during infrequently occurring hydrologic conditions.

2.5.1.2.5.2 Juvenile Salmonid Entrainment through Screens

The proposed fish screens are based on the NMFS fish screen criteria (NMFS 1997, 2011) for waters which may contain salmonid fry (<60 mm in total length), and consist of vertical profile bars made from stainless steel, having a maximum gap between bars of 0.069 in. (1.75 mm). These screens are designed to minimize the entrainment of alevins, fry, juvenile, and larger salmonids into waterways or areas of concern (i.e., the NDD intakes). Juvenile fish with a head width of less than or slightly greater than 1.75 mm have the potential to pass through screen openings and get entrained into the intakes. It is possible that juvenile fish with heads larger than the 1.75 mm screen openings may pass through the fish screen if they become impinged on the fish screen and, during the process of trying to free themselves, change their orientation and are pulled through the fish screen openings by the current passing through the slot openings of the fish screen. The plasticity of the cranium, opercular, and axial skeletal structures of fish larvae and fry may allow these bony structures to deform and thus allow the fish to pass through the screens. Ossification of the bones is not yet complete at these early life stages of teleost fish (van den Boogaart et al 2012; Mork and Crump 2015; Witten and Hall 2015). Also, juvenile fish that exceed the minimum size criteria for exclusion and that are impinged on the fish screen may pass through the fish screen if they are pushed through by the screen cleaner brushes (ICF International 2015; Greenwood 2016). It is expected that all fish that are entrained through the screen will be lost to the population, as there is no attempt to salvage any of these fish from behind the screens. These fish are effectively considered as mortalities, even if they survive their entrainment through the screens.

Evidence that suggests that fish with head widths wider than the gap between the vertical screen openings can pass through the screens is presented in the following cases. It has been observed that a 32 mm Chinook salmon fry and a 41-mm lamprey ammocoete were entrained through the fish screens to the Freeport water intakes which have the 1.75 mm opening vertical profile bar screens (ICF International 2015). Using estimated head width values for Chinook salmon derived from the fork length and head width measurements provided by (Mueller et al. 1995), the entrained 32 mm Chinook salmon would have a 3.8 mm head, which is much larger than the 1.75 mm width of the screen openings. It should be noted that the Chinook salmon fry recovered was from a location 14 miles downstream of the Freeport fish screens, in a canal leading to the Vineyard Surface Water Treatment Plant, and thus the fish in question may have reared for a period of time before recovery in the inlet canal leading to the location of capture. In a laboratory study (Zydlewski and Johnson 2002), one out of 25 trout fry (bull trout; *Salvelinus confluentas*) exposed to an experimental fish screen was entrained through the 1.75 mm opening of a vertical profile bar screen, implying a 4% entrainment rate. However, this fish was the smallest (23.0 mm) tested in the vertical profile bar screen experiment. The size range for bull trout fry for the entire suite of experimental screens was 22.5 to 31.0 mm total length with a median size of 25.0 mm (Zydlewski and Johnson 2002). The larger study specimens were effectively screened. From a field study using NMFS fish screen criteria, 2% of the juvenile cutthroat trout (*O. clarki*) (20-40-mm total length) passing downstream were entrained through a flat plate fish screen on irrigation canals in the Bitterroot River basin, Montana (Gale et al. 2008).

The proposed fish screens, when meeting specific design criteria for screen materials, sweeping flows, and approach velocities described in the NMFS fish screen criteria (NMFS 1997, 2011), have shown guidance efficiencies of greater than 98% for juvenile salmonids (i.e., less than 2% entrainment). Since the location of the NDD fish screens are considerably downstream of any spawning locations in the mainstem Sacramento River, and downstream of the numerous tributary rivers and streams that join the mainstem, it is unlikely that newly emerged alevins or fry from listed salmonids that are small enough to be vulnerable to entrainment will be present. The only scenario that is likely to create conditions in which recently emerged alevins and fry are present at the NDD location is under flood conditions when high flows in the tributaries and main stem of the river sweep these fish downstream into the Delta. However, these fish are likely to belong to the unlisted late fall/fall-run Chinook salmon populations, which have later spawning periods than the listed salmon populations, and therefore would have greater overlap with their alevin and fry life history stages and winter flood events.

Examination of the catch records from the Sacramento Trawl (https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm) for the period between 2012 and 2016 indicates that only fall-run and late fall-run Chinook salmon were captured that were smaller than 32 mm; the size of the fish recovered at the Freeport diversion site. The following table presents the size distributions for Chinook salmon and steelhead/rainbow trout collected in the Sacramento trawl monitoring activities from the 5-year period between 2012 and 2016 (Table 2-159). Fish that do not have their adipose fin clipped (unclipped) are considered natural-origin, not hatchery origin; the unclipped fish monitoring data are used for this analysis to represent the natural-origin fish that may be impacted by the NDD screens.

Table 2-159. Percentage of Unclipped Chinook Salmon and Rainbow Trout/Steelhead Less than 32 mm Captured in the Sacramento Trawl, 2012–2016.

ESU/DPS	Fork length (FL) range (mm)	Average FL (mm)	Number ≤ 32 mm	% of Total Captured	Cumulative # Caught[1]
Fall Run Chinook Salmon (FRCS)	23-107	51.55	443	2.98	14,855
Spring Run Chinook Salmon (SRCS)	34-108	78.2	0	0	1,695
Winter Run Chinook Salmon (WRCS)	44-143	82.9	0	0	208
Late Fall Run Chinook Salmon (LFRCS)	30-143	105.8	1	5.5	18
Rainbow Trout (RBT)/California Central Valley Steelhead (CCVSH)	36-350	191	0	0	21

Note:
[1] Cumulative number refers to the total number of fish captured and measured for fork length. Actual numbers of fish captured during monitoring are greater due to the subsampling of large catch events.

Additional information is also available for beach seine monitoring sites in the region of the proposed NDD locations (Sacramento River from Discovery Park to Isleton) between 2012 and 2016. Similar to the Sacramento trawl data above, the greatest risk is to fall-run Chinook salmon. Only 378 (2.9%) of the 13,078 fish captured and measured for fork length in the regional beach seines were fall-run Chinook salmon ≤ 32 mm fork length. Only 0.2% of the fish identified as spring-run by length at date captured in these monitoring efforts were ≤ 32 mm (2 fish out of 877 fish captured). No winter-run Chinook salmon sized fish were captured at these locations which were ≤ 32 mm (0 fish out of 222 fish captured). In comparison, approximately 32% of the late fall-run Chinook salmon captured in these monitoring efforts were ≤ 32 mm (12 fish out of 38 fish captured). Of the 12 wild *O. mykiss* juveniles captured in the beach seines, 2 were ≤ 32 mm.

Therefore, based on the evidence discussed above that fish equal to 32 mm or less in fork length are vulnerable to entrainment through the 1.75 mm gap in the vertical bar screens, fall-run and late fall run Chinook salmon appear to be at a greater risk of entrainment at the NDD fish screens than other salmonids. The very infrequent capture of spring-run Chinook salmon that are 32 mm or smaller indicates that these early life stages are at very low risk of entrainment at the location of the NDD fish screens. Winter-run Chinook salmon also appear to be at very low risk of entrainment since no fish were captured that were 32 mm or smaller, although some winter-run were captured in the beach seines that were just slightly larger (35 to 39 mm).

NMFS will use an entrainment rate of 2% to assess the probability of fish less than or equal to 32 mm in fork length being entrained through the fish screen vertical bars based on the field study by (Gale et al. 2008) for the entrainment of cutthroat trout (*O. clarki*). This study examined fish screen operations in the field and covered a broader range of fish sizes (20-40 mm total length) than the Zydlewski and Johnson (2002) study which looked at laboratory conditions and exposed smaller and fewer fish to the effects of entrainment.

2.5.1.2.5.3 Juvenile Salmonid Impingement on Screens

Impingement may occur when the approach velocity exceeds the swimming capability of a fish, creating substantial body contact with the surface of the fish screen. Whether or not impingement would occur depends on screen approach velocity, screen sweeping velocity, and the swimming capacity of juvenile fish. Injury resulting from impingement may be minor and create no long-term harm to the fish, or result in injuries leading to mortality either directly or at some time in the future after contact with the screen, including predation or infections from wounds and abrasions associated with the screen contact.

Approach velocity is the vector component of the channel's water velocity immediately adjacent to the screen face that is perpendicular to and upstream of the vertical projection of the screen face, calculated by dividing the maximum screened flow by the effective screen area. All intakes in the PA will be required to meet specific performance standards, and will be sized to provide approach velocities at the fish screen of less than or equal to 0.20 feet per second (ft/sec) at a diversion rate of 3,000 cfs per screen location when operated at night, which is targeted to protect delta smelt, a more stringent approach velocity criterion than for the daytime operations to protect juvenile Chinook salmon in California (i.e., 0.33 ft/sec) (National Marine Fisheries Service 1997). Fish screens with approach velocities less than or equal to 0.33 ft/sec would minimize screen contact and impingement of juvenile salmonids (FFTT 2013). In order for the approach velocity to effectively protect juvenile fish, the screen design must provide for nearly uniform flow distribution over the entire screen surface. Uniform flow distribution avoids localized areas of high velocity, which have the potential to impinge fish. Uniformity of approach velocity is defined as being achieved when no individual approach velocity measurement exceeds 110% of the criteria (National Marine Fisheries Service 2011b).

Sweeping velocity is the vector component of channel flow velocity that is parallel and adjacent to the screen face, measured as close as physically possible to the boundary layer turbulence generated by the screen face. The (FFTT 2013) concluded that the sweeping velocities at the NDD fish screens should follow a sweeping flow velocity/approach velocity ratio of at least 1:1 to protect Delta smelt when present. Delta smelt have been shown in laboratory studies to have greater survival at lower sweeping velocities (Swanson et al. 2005). In contrast, the screening criteria from (CDFW 2000) requires a sweeping flow velocity/approach velocity of 2:1 for on-river fish screens while (NMFS 2011) recommends that for screens longer than 6 feet, the sweeping velocity should optimally be at least 0.8 ft/sec and less than 3 ft/sec, with sweeping velocity not decreasing along the length of the screen. This will reduce exposure time of fish to the screen as they move past it. The PA was modeled using an approach velocity of 0.2 ft/sec and a sweeping velocity of 0.4 ft/sec (BA Appendix 5.B. DSM2 Modeling and Results). This analysis used a combination of the required approach velocity for Delta smelt (0.2 ft/sec) and the (CDFW 2000) sweeping velocity criterion for streams and rivers (i.e., at least two times the allowable approach velocity, thus a minimum value of 0.4 ft/sec). This modeling was used to determine the conditions under which the screens could be operated with sweeping flows meeting the minimum 0.4 ft/sec criteria.

Several studies examined the behavior of juvenile Chinook salmon in relation to screened diversions and different combinations of approach velocities and sweeping velocities. (Swanson et al. 2004b) conducted laboratory studies with an annular fish “treadmill” using different combinations of approach and sweeping velocities, as well as temperature and illumination (day/night). They found that juvenile Chinook salmon swimming velocity increased with increasing sweeping flows, with an increase in the degree of positive rheotaxis (i.e., turning to face oncoming current) response (swimming upstream) for most fish tested, although the sweeping flows tended to move them downstream in relation to the screen face when the flows exceeded their swimming ability to hold station. The exception to this was exhibited by larger juvenile Chinook salmon tested at 19°C. These larger fish exhibited negative rheotaxis (swam downstream) at the intermediate sweeping flows. Changes in approach velocity did not affect these swimming behaviors. The location of fish relative to the screen face during the day was not affected by the approach velocity. Larger fish tended to position themselves closer to the face of the fish screen compared to smaller fish, and fish in general moved away from the screen as the sweeping velocity increased during daytime experiments. During the nighttime experiments, fish position relative to the screen face was not affected by changes in the flows. Chinook salmon experienced frequent contacts with the 2.3 mm vertical wedge wire screen face used in this study, particularly at night and with reduced sweeping velocities. However, few of these contacts with the screen resulted in impingement on the screen in which the fish was unable to free itself. Most of the contacts were tail contacts, only 20% of the total contacts observed being body contacts. However, the relative proportions of body contacts increased significantly with increases in sweeping velocity for all fish tested at 12°C. During the course of the study (164 experiments), no more than 0.3% of the test fish were impinged (defined as prolonged screen contacts greater than 2.5 min), and the overall mortality rate was less than 1%. However, the authors note that these studies were conducted in a controlled environment without predators or exposure to pathogens or diminished water quality, which could affect the outcome of screen contacts in the natural environment. Manipulation of the sweeping flow component of screen flow criteria by increasing the flow velocity appears to offer an effective strategy for facilitating the passage of exposed fish (salmonids) by the screen (reduced duration for passage past the screen) as well as minimizing the probability of screen contact by shortening the exposure time to the screen in which contact may occur (Swanson et al. 2004a).

Another laboratory experiment using a vertical profile bar screen (1.75 mm openings) and newly emerged bull trout fry (25.0 mm median total length) showed an impingement rate of 12% and survival rate of 100%. In this study, impingement was defined as extended contact (greater than one second) with the test screen (Zydlewski and Johnson 2002). This is a comparatively less stringent definition of impingement than used in the previous study by (Swanson et al. 2004a).

In a field study, juvenile salmonid injury and mortality were examined for vertical profile bar screens (1.75 mm opening) at John Day Dam. Note that these screens consist of a different configuration than those proposed for the NDDs because they guide fish upward toward the bypass orifice. The study results indicated an average injury rate of 2.8% as defined by greater than 20% descaling and an average mortality rate of 3.5% for yearling Chinook salmon, and 2.2% injury and 3.9% mortality rate for sub yearling Chinook salmon (Brege et al. 2005), with an overall average of 2.5% for injury and 3.7% for mortality. These results likely represent the high end of juvenile fish injury and mortality rates at vertical profile bar screens.

2.5.1.2.5.4 Salmonids Exposure and Risk

2.5.1.2.5.4.1 Temporal Distribution of Juvenile Salmonids

2.5.1.2.5.4.1.1 Winter-run Chinook Salmon

Juvenile winter-run will migrate from the Sacramento River and pass the NDD intakes from mid-October to mid-April. There are two juvenile migration peaks: late November to late December and early February to late March. As indicated above, the vulnerability to entrainment is greatest for fish less than 32 mm in total length. Winter run juveniles entering the location of the NDDs are typically greater than this length, having reared in upstream locations following their emergence from the gravel weeks to months earlier. A very small number of fish may potentially enter the area of risk at this size if early fall storms are encountered from September through October and sweep rearing fry downstream into the Delta. Based on the Delta model for length-at-date race determination criteria which is used by the DJFMP to determine race of Chinook salmon in the Delta, the latest that winter-run fry would be 32 mm or smaller is October 21. It should be noted that true genetic winter-run that are smaller than 32 mm may continue to enter the Delta after this date, but would be classified as spring-run fry by the Delta model for length at date. No winter-run fry identified by length-at-date criteria were 32 mm or smaller out of the 208 fish captured in the trawls or the 222 fish captured in the beach seines for the period 2012 to 2016. Due to the small number of winter-run recovered in the monitoring, the same proportion of fish 32 mm or less in fork length from the spring-run sized Chinook salmon population (0.1%) will be used for the winter-run Chinook salmon population; which will be used as an estimate of the percentage of the winter-run Chinook salmon population that is vulnerable to entrainment at the NDD fish screens. However, larger winter-run fry and juveniles entering the Delta would continue to be vulnerable to the effects of the fish screens at the three NDD locations through mid-April, when it is expected that the emigrating winter-run juveniles would have finished their downstream migration and entered the Delta below this location. These other screen related effects include impingement, body contacts with the screen, abrasions, and reduced fitness due to injuries and infections.

2.5.1.2.5.4.1.2 Spring-run Chinook Salmon

Juvenile spring-run from the Sacramento River basin enter the Delta as early as December, and migration continues through early May. The peak migration of spring-run juveniles into the Delta occurs from mid-March to late April (He and Stuart 2016). Spring-run Chinook salmon fry 32 mm or smaller total length are vulnerable to entrainment through the fish screens of the NDDs. Based on the Delta model length-at-date, spring-run fry would be larger than 32 mm by December 1. Similar to winter-run fry, fall storms would be expected to flush some immature fry out of their upstream rearing areas and downstream into the Delta. Based on recent data from the (DJFMP 2012-2016); https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm), only 2 spring-run sized fry ≤ 32 mm were collected in beach seine monitoring efforts in the region surrounding the NDD fish screen locations. This is equivalent to 0.2% of the total number of spring-run juveniles as determined by length captured during this period (877 fish). No spring-run ≤ 32 mm were captured in the Sacramento Trawl during this same period (1,695 fish). However, this is not surprising given that the trawl samples the middle of the channel where smaller fry are less likely to be present, compared to the river’s edge where beach seine monitoring occurs and smaller fish are expected to rear. Therefore, approximately 0.1% of spring-run Chinook salmon captured in the Sacramento trawl and the regional beach seines were 32 mm or smaller, which will be used as an estimate of the percentage of the spring-run Chinook salmon population that is vulnerable to entrainment at the NDD fish screens. Larger juvenile spring-run Chinook salmon are expected to remain vulnerable to the other effects of the fish screens, such as impingement and associated predation, through early May when their downstream emigration in the area of the NDD is expected to be completed, with the fish completing their movements through the lower Delta to the marine environment.

2.5.1.2.5.4.1.3 Fall-run Chinook Salmon

Juvenile fall-run Chinook salmon from the Sacramento River basin are expected to be present in the Delta from December through August, based on Sacramento trawl data for RM 55 (https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm). These fish would likely be smaller sub-yearlings that may migrate more slowly than larger smolts. Fall-run Chinook salmon fry 32 mm or smaller total length are vulnerable to entrainment through the fish screens of the NDD. Based on the Delta model length-at-date, fall-run fry would be larger than 32 mm by April 1. Late fall and winter storms would be expected to flush some immature fry out of their upstream rearing areas, including the mainstem Sacramento River and its numerous tributaries. These fry would be carried subsequently downstream into the Delta if they were unable to find protective waters to hold in during the high flows. Based on recent data from the DJFMP monitoring efforts (2012-2016), 443 out of 14,855 fish captured in the Sacramento trawl and identified as fall-run by size were 32 mm or smaller (2.98 %). An equivalent percentage of fall-run captured in the beach seines were 32 mm or smaller (378 fish out of 13,078 identified as fall-run by size; 2.9%). Therefore, approximately 2.94% of fall-run Chinook salmon captured in the Sacramento trawl and regional beach seines were 32 mm or less in fork length, which will be used as an estimate of the percentage of the fall-run Chinook salmon population that is vulnerable to entrainment at the NDD fish screens. Larger juvenile fall-run Chinook salmon are expected to remain vulnerable to the other effects of the fish screens, such as impingement and associated predation, through August when their downstream emigration in the area of the NDD is expected to be completed.

2.5.1.2.5.4.1.4 Late Fall-run Chinook Salmon

Juvenile late fall-run Chinook salmon are present at the NDD intake locations year-round, but in relatively low numbers compared to the other runs. The smallest fry can start appearing in early April at approximately 20 to 30 mm. Fish tend to get larger as the year progresses, with the largest fish (yearlings) arriving in late fall and winter based on Sacramento trawl data for RM 55 and beach seine data (https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm). Late fall-run Chinook salmon fry 32 mm or smaller total length are vulnerable to entrainment through the fish screens of the NDD. Based on the Delta model length-at-date criteria, late fall-run fry would be larger than 32 mm by approximately July 1. Late winter and early spring storms, as well as high flows due to snow melt runoff would be expected to flush some immature fry out of their upstream rearing areas (March through April). These fry would be carried subsequently downstream into the Delta if they were unable to find protective waters to hold in during the high flows. Based on recent data from the DJFMP monitoring efforts (2012-2016; https://www.fws.gov/lodi/juvenile_fish_monitoring_program/jfmp_index.htm), 1 out of 18 fish captured in the Sacramento trawl and identified as late fall-run by size were 32 mm or smaller (5.5 %). A greater percentage of late fall-run captured in the beach seines were 32 mm or smaller (12 fish out of 38 fish identified as late fall-run by size; 32%). Therefore, approximately 23% of late fall-run Chinook salmon captured in both the Sacramento trawl and the regional beach seines were 32 mm or less in fork length, which will be used as an estimate of the percentage of the late fall-run Chinook salmon population that is vulnerable to entrainment at the NDD fish screens. Larger juvenile late fall-run Chinook salmon are expected to remain vulnerable to the other effects of the fish screens, such as impingement and associated predation, throughout the remainder of the year (through March) when their downstream emigration occurs within the area of the NDD.

2.5.1.2.5.4.1.5 Steelhead

Juvenile steelhead from the Sacramento River basin enter the Delta in late January and their emigration continues through April and May. There are two peaks of juvenile steelhead migration: one from mid-February to mid-March and the other in April (He and Stuart 2016); unpublished data. There are occasional catches of *O. mykiss* fry in the Sacramento trawl and regional beach seines. There were no fish 32 mm or smaller in the trawl captures during the period between 2012 and 2016. The smallest fish recovered in the trawl was a 36-mm individual. The next two smallest fish were approximately 60 mm and 100 mm in fork length. Only two fish were 32 mm or smaller in those captured by the beach seines during the same period of time (26 and 30 mm in fork length). Of the 33 *O. mykiss* captured in the monitoring efforts, only 2 were 32 mm or smaller (6%), which will be used as an estimate of the percentage of the CCV steelhead population that is vulnerable to entrainment at the NDD fish screens. The vast majority of *O. mykiss* recovered in the trawls and beach seines were of smolt size, and would not be vulnerable to screen entrainment. These larger fish are expected to remain vulnerable to the other effects of the fish screens, such as impingement and associated predation, throughout the remainder of the year when their downstream emigration occurs within the area of the NDDs.

2.5.1.2.5.4.2 Vertical Distribution of Juvenile Salmonids

Both laboratory and field studies have shown that emigrating juvenile salmonids tend to be surface-oriented and often concentrate in water less than 49 ft deep, but can occur throughout the water column. Yearling Chinook salmon tend to emigrate deeper than steelhead (Carter et al. 2009; Smith et al. 2010). (Klimley et al. 2010) observed a positive correlation between the frequency of salmonid smolt detections and depths ranging from 3.3–37 ft. This relationship was not evident, however, in waters deeper than 37 ft. During 2007–2008, Chinook salmon and steelhead smolts were detected in water ranging from 20–26 feet in depth along the eastern span of the San Francisco-Oakland Bay Bridge. Three dimensional positioning from mobile tracking Juvenile Salmon Acoustic Telemetry System (JSATS) fish in the Columbia River estuary indicated that Chinook salmon migrated through the lower Columbia River at 13.5–34.4 ft for yearlings and 15–90 ft for subyearlings (Carter et al. 2009). The water depth in the river channel at Intake 5 would be expected to be 26 ft or more 10% of the time, 20 ft or more 50% of the time, and 17 ft or more 80% of the time (Greenwood 2016). This implies that emigrating juvenile salmonids from the Sacramento River could be impacted by the entire height of the intake screens in the PA.

In a study using hydroacoustic detections of juvenile salmonids near the DCC location on the Sacramento River, (Horn and Blake 2004) found that almost all fish released were located in the upper half of the water column; the highest fish densities occurred between –13 ft and –3 ft with an average vertical depth of -6.5 ft (referenced to North America Vertical Datum (NAVD) 88). Average water surface elevation of the Sacramento River near the DCC location is +2 ft (referenced to NAVD 88). The draft designs for the NDD fish screens indicate that the screens are located at depths that overlap with the distribution of juvenile salmonids based on the work conducted by (Horn and Blake 2004).

2.5.1.2.5.4.3 Horizontal Distribution of Juvenile Salmonids

The horizontal distribution of emigrating juvenile salmonids varies with the size of juvenile fish. Capture studies in the Columbia River (both the free flowing section and the estuary) have documented use of deeper offshore main channel habitats by larger yearling Chinook salmon and steelhead, whereas smaller juvenile fish, such as subyearling Chinook salmon, use the shallower water closer to shore (Carter et al. 2009; Smith et al. 2010).

It has been observed in the Sacramento River (within the Delta) that at night when juvenile salmon were actively moving downstream, the horizontal distribution of juvenile salmon was more concentrated in the outside bend of the river, which presumably resulted from secondary circulation along the outside bend of the river (Horn and Blake 2004; Burau et al. 2007). However, during the daytime when juvenile salmon were likely to be holding, they tended to distribute more on the inside of the river bend, as illustrated at Clarksburg Bend (Burau et al. 2007; Greenwood 2016). This indicates that at night, when fish are actively moving downstream, more than 50% of the population will be associated with the bank of the outside river bend, whether on the east or west side of the river. This estimate is based on the shift of the center of mass of fish detections from the centerline of the river to the outside bank of the river as measured by hydroacoustic detections of migrating fish in the river channel cross section (Horn and Blake 2004). During the day, when juvenile fish are predicted to hold within the slower waters associated with the inside of the river bends, the majority of the fish will be located in these waters as demonstrated by the tracking of acoustically tagged salmon (Burau et al. 2007).

Few fish during the day were associated with protracted downstream movement, with most fish exhibiting holding and milling behavior in the nearshore waters. With nightfall, these holding fish again moved into the higher flows of the channel and moved downstream along the outside bends. The three diversion intakes in the PA are located within straight reaches of the river transitioning to river bends or mild outside bends to minimize complex flow patterns, sedimentation, and excessive scour on the eastern bank of the Sacramento River. Based on the locations of the screens in relation to the bathymetry of the river reaches, it is likely that juvenile salmonids will be in close proximity to the screens due to secondary circulation patterns, particularly at night during their downstream migrations when they are susceptible to these hydrodynamic conditions.

Although there are no available data that address how on-bank water diversions influence or change the horizontal distribution of emigrating salmonid juveniles passing large diversion intakes, we assume that a substantial proportion of the emigrating juveniles would be drawn to the diversion intakes because of large volumes (up to 3,000 cfs) of water pulling to each of the diversion intakes at velocities up to 0.2 ft/sec when Delta smelt are present, and up to 0.33 ft/sec at all other times for approximately 56 minutes of transit time past each intake location (Table 2-160). Using these values, along with the sweeping flows (0.4 ft/sec) described in the BA, a rough estimate of the potential lateral distance travelled by a passive particle in the river channel over the course of time it takes to move past the entire length of the screen can be made (Table 2-161). However, these transit time estimates may underestimate the actual time that fish are exposed to the screens. Exposure times presented in the BA (Figures 5.4-1 and 5.4-2, based on the equations in (Swanson et al. 2004b) predict that a 44 mm standard length (SL) Chinook salmon in 12°C water will take upwards of ~40 to 60 minutes to pass the entire length of the intake screen at night and ~105 to 108 minutes during the day at a sweeping velocity of 0.4 ft/sec and an approach velocity of 0.2 ft/sec. A larger fish, as represented by a 79 mm SL Chinook salmon at the same approach and sweeping velocities, will take between ~80 to 100 minutes at night and considerably longer during the day. The BA states that there is considerable uncertainty regarding these exposure times.

Therefore, a passive particle has the potential to be drawn across the river channel width to the screens under both anticipated approach velocities assuming simple linear flow fields. Actual circulation is more complicated and the secondary circulation patterns may draw particles (or fish) to the screens more quickly or frequently than described here.

Table 2-160. Fish Screen Transit Time.

Intake #	Total screen length (ft)[1]	# Bays per Intake[2]	# screens/intake	# screens/ bay	Length of bay (ft)[3]	Time to transit each Bay @ 0.4 ft/sec sweeping velocity[4]
Intake #2	1350	6	90	15	225	562.5 seconds
Intake #3	1110	6	74	12	180	450 seconds
Intake #5	1350	6	90	15	225	562.5 seconds

Notes:
[1]From BA table 3.2-6.
[2]From BA Appendix 3.B table 6-1.
[3]Assumes standard screen width of 15 feet.
[4]Assumes a passive drift at the speed of the sweeping velocity

Table 2-161. Lateral Approach Assessment: Distance Covered under the Two Approach Velocities.

Intake #	Time to travel length of Intake screen (secs) @ 0.4 ft/sec[1]	Lateral distance travelled[2]	
		Approach velocity (0.2 ft/sec)	Approach velocity (0.33 ft/sec)
Intake #2	3375 secs	675 ft	1114 ft
Intake #3	2775 secs	555 ft	916 ft
Intake #5	3375 secs	675 ft	1114 ft

Notes:
[1]Total screen length divided by sweeping velocity of 0.4 ft/sec, passive drift
[2]Total travel time multiplied by approach velocity. Assumes uniform sweeping flow across river channel cross section and unidirectional flow

2.5.1.2.5.4.4 Risk of Entrainment of Juvenile Salmonids at the North Delta Diversion

As previously discussed, an entrainment rate of 2% will be used to assess the probability of fish 32 mm or smaller being entrained through the fish screen vertical bars based on (Gale et al. 2008). The percentages of Chinook salmon belonging to the four different runs as well as *O. mykiss* captured in the Sacramento trawls and regional beach seines from 2012 to 2016 that were 32 mm or smaller will be used as estimates of the percentages of the population that are vulnerable to entrainment at the NDD fish screens. Data from the Sacramento trawl and regional beach seines is the best available information about the presence of salmonids that are 32 mm or smaller in the vicinity of the NDD fish screens. Entrainment rates are calculated for each individual bay of screens (180 to 225 feet long), for each screen location (6 bays per diversion location), and for the three diversion locations (18 bays total) (Table 2-162).

Table 2-162. Cumulative Fish Screen Entrainment Rates.

Species/ Run	% Population ≤ 32 mm	% Entrainment Rate	% Population Entrained	% Population Not Entrained per Bay	% Population Not Entrained per Intake (6 bays)	% Population Not entrained per 3 Intakes (18 bays)
WRCS	0.1	2	0.002	99.998	99.988	99.964
SRCS	0.1	2	0.002	99.998	99.988	99.964
FRCS	2.94	2	0.059	99.941	99.646	98.943
LFRCS	23	2	0.46	99.54	97.271	92.036
RBT/SH	6	2	0.12	99.88	99.282	97.862

2.5.1.2.5.4.5 Risk of Impingement of Juvenile Salmonids at the North Delta Diversion

NMFS used the information provided by Brege et al. (2005) to inform our analysis of injury and mortality associated with fish contacting the proposed screens, but not being entrained through the screens. Information from Brege et al. (2005) is used for this analysis because the study uses the same vertical bar screening material as the currently proposed screen. However, the alignment of the screen in the study is at an angle to the direction of flow and not perpendicular to the flow line (vertical 90^0) as is the proposed NDD. Thus, this analysis is probably a "worst case" scenario for fish interacting with this type of screen material consistent with the general principle of institutionalized caution. Using the average (which represents the overall impact to a population over time) of the values derived from the study for yearling and sub-yearling Chinook salmon released into the turbine intakes of the John Day Dam, 2.5% of the fish recovered showed signs of injury (represented by >20% descaling) and 3.7% of the fish recovered were dead (mortality) after interacting with the vertical bar screens being tested. NMFS will also assume that 50% of the emigrating juvenile salmonids will be subject to the impact of the screens. We do not have data regarding the percentage of the population that will be exposed to the NDD screens; 50% was chosen as a reasonable expectation for this analysis given the hydrodynamics of the river relative to juvenile salmon migration patterns. Based on this assumption, the proportion of juvenile salmonids that will be injured or killed by screen impingement is 1.25% and 1.85%, respectively, of a population per each intake location. This equates to a proportion of non-injury to exposed fish of 98.75 % and a survival rate of exposed fish of 98.15%.

2.5.1.2.5.4.6 Risk of Juvenile Salmonid Injury and Mortality due to Exposure to North Delta Diversion

To arrive at the proportion of the exposed populations of salmonids that would neither be injured by contact with the screens, lost by entrainment through the screens, nor killed by contact with the screens requires that each probability be multiplied together. The final probability that a fish would pass all three intakes without incident is the value from one intake raised to the third power, assuming all intakes are equal in their potential to cause entrainment, and injury or death due to impingement or contact with the screen materials (Table 2-163).

Table 2-163. Estimated Proportion of No Adversely Impacts at the NDD Intake Screens on Juvenile Salmonids (50% of Population Exposed to Screens).

Run/Species	Probability of no entrainment at one screen	Probability of no screen injury at one screen	Probability of no screen mortality at one screen	One Intake: probability of no injury or mortality occurring	Three Intakes: Probability of no injury or mortality occurring
WRCS	99.988%	98.75%	98.15%	96.91%	91.02%
SRCS	99.988%	98.75%	98.15%	96.91%	91.02%
FRCS	99.646%	98.75%	98.15%	96.58%	90.09%
LFRCS	97.271%	98.75%	98.15%	94.28%	83.80%
RBT/SH	99.28%	98.75%	98.15%	96.22%	89.10%

Since it is not certain how large a percentage of the population will be within a close enough proximity to the screen face to actually be affected by the screens themselves, NMFS has calculated estimates of no injury or mortality related to contact with the screens at two additional population percentiles (e.g., 33% or 25%). For a lower proportion of a population subject to the screen impacts, lower adverse effects on a population would be expected (Table 2-164).

Table 2-164. Analysis of Population Proportion Screen Exposure.

Run/Species	Probability of no entrainment at one screen (%)	Probability of no screen injury at one screen (%)		Probability of no screen mortality at one screen (%)		One Intake: probability of no injury or mortality occurring (%)		Three Intakes: Probability of no injury or mortality occurring (%)	
		33%[1]	25%[1]	33%	25%	33%	25%	33%	25%
WRCS	99.988	99.175	99.375	98.779	99.075	97.95	98.44	93.98	95.40
SRCS	99.988	99.175	99.375	98.779	99.075	97.95	98.44	93.98	95.40
FRCS	99.646	99.175	99.375	98.779	99.075	97.62	98.11	93.02	94.43
LFRCS	97.271	99.175	99.375	98.779	99.075	95.29	95.77	86.53	87.84
RBT/SH	99.28	99.175	99.375	98.779	99.075	97.26	97.75	92.00	93.39

Notes:
[1]Percentage of population exposed to screens

Incorporation of refugia areas along the length of the screens is part of the PA. The refugia design and effectiveness are part of the future monitoring studies proposed, so NMFS cannot quantify the exact benefit of these refugia in this analysis. Hydraulic lab testing of fish screen refugia indicates that under certain hydraulic conditions, small fish can avoid being impinged on the screen by using the refugia areas (Reclamation 2013). Therefore, NMFS expects that these refugia will reduce the exposure of salmonids to the NDD and reduce the potential of impingement to an unknown degree.

2.5.1.2.5.5 Green Sturgeon Exposure and Risk

Green sturgeon eggs and larvae are not likely to be present near the NDD intakes, while juveniles, subadults, or adults may pass within the area during their migrations and be exposed to potential interactions with the NDD intake screens (Seesholtz 2016, Heublein *et al.* 2017).

The spatial distribution of green sturgeon is not well documented. Juvenile green sturgeon (200-580 mm) were sampled in water depths from 3 to 8 ft in the Delta at Santa Clara Shoal (Radtke 1966 cited in Seesholtz 2016). An acoustic telemetry study by Kelly et al. (2007 cited in Seesholtz 2016) on sub-adult and adult sturgeon found the majority of movements were non-directional and closely associated with the bottom, whereas directional movements occurred in the top 20% of the water column. Kelley et al. (2007) also indicated that subadults regularly utilized depths in the estuary of less than 33 ft.

2.5.1.2.5.5.1 Green Sturgeon Entrainment through Screens

Entrainment of any life stages of green sturgeon into the NDD intakes is unlikely. Although green sturgeon larvae are not expected to be present near the NDD intakes, to fully assess the potential for screen entrainment, the body morphometrics were used to derive the body depth based on their length and hence their vulnerability to passing through the gap between the vertical bars of the screen. Green sturgeon larvae hatch at about 12.6–14.5 mm in length and at 10-day post-hatch (dph) are about 23-25.2 mm in length (Deng et al. 2002; Wang 2006 cited in Seesholtz 2016). Seesholtz (2016) evaluated Figure 2 in Deng at al. (2002) to obtain a rough measure of length and body depth. The 0-dph green sturgeon larvae from the figure was estimated to be about 14.6 mm long and had a depth of 3.9 mm which equates to a ratio of 3.7. The 10-dph green sturgeon larvae was estimated to be about 24.2 mm long and had a depth of 3.4 mm which equates to a ratio of 7.1. The potential accuracy of projected body depth was confirmed by R. Reyes (USBR 2016) from width measurements taken on approximately 40 lab-cultured fishes, but not reported in Wang (2006). Based on these size calculations, entrainment of green sturgeon is unlikely to occur through the intake screens even for larvae. For green sturgeon juveniles that are likely present near the NDD intakes, their body depth would be expected to be larger than larvae since most green sturgeon recovered at the SWP and CVP export facilities are greater than 200 mm in fork length which would also prevent their entrainment (ftp://ftp.dfg.ca.gov/salvage/).

2.5.1.2.5.5.2 Green Sturgeon Impingement on Screens

Injury or mortality could result from fish impingement with the proposed NDD fish screens. The following studies are evaluated to determine the potential for sturgeon to be in the vicinity of the diversions and how they will behave around them.

While the following studies do not account for impingement since the diversions were unscreened, the studies at least provide information on the potential of sturgeon to be within the area of influence of a diversion. A study by Mussen et al. (2014 as cited in Seesholtz 2016) indicated that juvenile green sturgeon (350-mm mean fork length) appear to lack avoidance behavior when encountering unscreened water-diversion structures. Fish entrainment ranged from 26–61% and they estimated green sturgeon entrainment of up to 52% if they passed within 5 ft of an active diversion three times. The studies examined the rate of entrainment with different intake flows through the pipe inlet and sweeping flows past the unscreened diversions. There did not appear to be significant differences in the entrainment risk at different sweeping velocities of 0.4, 1.2, and 2.0 ft/s; however, there was a trend towards less entrainment at higher sweeping flows. This appeared to be related to the swimming behavior of the experimental fish. Fish were more actively swimming at lower sweeping flows, and thus encountered the inlet to the pipe more frequently. Therefore, at lower sweeping flows, the fish are more likely to come into contact with the inlet to the NDD intakes, which are protected by the fish screens, rather than moving past the screen or holding at the bottom of the channel against the higher flows. In contrast, very low numbers of sturgeon were entrained in a monitoring project that sampled 12 unscreened diversions (<150 cfs) on the Sacramento River between Colusa and Knights Landing (Vogel 2013 as cited in Seesholtz 2016). During Vogel's study, green sturgeon were entrained at the South Steiner diversion during the irrigation seasons in 2010 (n=3 [extrapolated]; FL = 86 mm; approach velocity = 2.17 ft/sec) and 2011 (n=1; FL = 70 mm; approach velocity = 0.08 ft/sec); and at the Tisdale diversion in 2011 (n=1; FL = 106 mm; approach velocity = 0.40 ft/sec) but not in the 2012 (n=0) irrigation season. All entrainments occurred in July. Sturgeon passing or residing around the NDDs would likely be larger than those sampled further upstream during the Vogel study.

A study by Poletto et al. (2014 as cited in Seesholtz 2016) conducted 15-minute trials on lab-raised green sturgeon (296 mm FL) in a flume containing a fish screen with 2-mm bar spacing at two water approach velocities (0.67 ft/s and 1.22 ft/s). Green sturgeon contacted the screens on average 61 times and occurred more frequently during the day (62 versus 58). Green sturgeon contacted the screens more often at the higher water velocity (1.22 ft/sec versus 0.67 ft/sec). Approximately 17% of the total green sturgeon tested became impinged (when more than two thirds of the body of the fish remained flush against a screen for >10 s) at least once, and of those fish, 11.3% became impinged more than once. Note that the maximum velocity at the NDD when delta smelt are present is planned to be 0.2 ft/s and therefore falls well below those studied for green sturgeon in this study. At all other times the approach velocity will meet the NMFS criteria for 0.33 ft/sec for juvenile salmonids. It should be noted that at the proposed sweeping velocity of 0.4 ft/sec, it will take approximately 9 minutes to pass one bay of screens, and nearly an hour to pass one entire screened diversion (6 bays).

2.5.1.2.5.5.3 Adverse Effects of the Three North Delta Diversion on Green Sturgeon

Since larval and early life stage green sturgeon are very unlikely to be present in the Sacramento River adjacent to the locations of the proposed NDD intakes, green sturgeon entrainment is unlikely to occur. As previously described, green sturgeon less than 200 mm are typically found in upstream reaches of the Sacramento River closer to the areas in which they were spawned, while fish larger than 200 mm are more typical in Delta waters and the lower Sacramento River. Fish of this size would not be at risk for entrainment through the proposed fish screens due to the cross section of their bodies. However, fish that are larger than 200 mm may become impinged on the screens at the NDD intakes (Polletto et al. 2014), especially when they migrate or reside near these long fish screens. The short-term and long-term effects of multiple contacts with and impingements upon screens have not been evaluated in juvenile sturgeon. It is likely that repeated contact or impingements may reduce swimming performance, possibly because of increased physiological stress from the encounter, exhaustion and metabolic disturbance elicited during escape attempts, or physical damage to skin and fin structure. Reductions in the physiological status of the impinged fish may lead to latent morbidity or mortality. Another potential impact may be increased predation risk, either during or immediately following impingements (Poletto et al. 2014). NMFS expects a medium proportion of the green sturgeon population would be subjected to adverse effects as a result of screen impingement because all juvenile green sturgeon will migrate through this section of the Sacramento River and those that are within the size range susceptible to impingement on the screen may be adversely affected.

2.5.1.2.6 Increased Predation Risk

2.5.1.2.6.1 Permanent In-Water Structures [Present Post-Construction]

The PA will result in new permanent structures in the river channel at the three NDDs and at the HOR gate, which will include fish screens, bulkheads, pilings and other over- and in-water structures. The effects of bulkheads, piers, pilings, and other over- and in-water structures on salmonids in the northwest were reviewed by (Kahler et al. 2000) and (Carrasquero 2001). (Kahler et al. 2000) described how shoreline alterations could potentially increase the rate of predation on juvenile Chinook salmon by 1) reducing prey refuge habitat by modifying the structure of the shoreline; 2) providing concealment structures for ambush predators such as bass and sculpin; 3) creating enough structure to reduce bass home range sizes; 4) providing artificial lighting that allows for around-the-clock foraging by predators; 5) increasing migration route lengths and therefore predator exposure for smolts and rearing fry; and 6) increasing the bass population by increasing the amount of potential bass spawning habitat. Adult migrants are not expected to be adversely affected because they are less vulnerable to predation from resident predators in the Delta system.

Vertical bulkheads or retaining wall sites tend to be deeper, primarily because the structures are usually placed below the ordinary high water mark and then backfilled (Kahler et al. 2000;

Carrasquero 2001). This effectively pushes the shoreline out from its original location, which results in a corresponding increase in water depth along the face of the structure outside the shallow littoral zone. Given that out-migrating juvenile salmonids (particularly Chinook salmon) use shallow-water habitats for rearing, foraging, and migration, retaining walls may potentially disrupt juvenile salmonid migration, reduce prey resource availability, and increase exposure to predators found in deeper water.

Vertical bulkheads or retaining walls also alter the flows along the bank, enhancing scour along the foot of the structure. This can create depressions along the outer margin of the in-water structure which may attract predators and provide holding areas for larger predatory fish. Prey fish may attempt to avoid the shallow-water increased predation risk by moving into deeper water where there is increased vulnerability to predation by larger predators and less refuge habitat (Kahler et al. 2000; Carrasquero 2001).

Vertical bulkheads and retaining walls also create shaded areas along their face during certain periods of the day which create hiding areas for predators and prey that conceal them from fish in the lighted zone outside of the area impacted by the shaded area. Such behavior by fish creates a temporal and spatial overlap of predators and prey in the shaded zone, as well as enhancing the success of predator ambush attacks on prey outside of the shaded zone (Kahler et al. 2000; Carrasquero 2001).

Vertical pilings will provide alterations to the local flow field by disrupting the flow, creating eddies downstream of the piling and other microhabitats where predatory species may preferentially hold (Carrasquero 2001). These pilings also attract juvenile salmonids trying to avoid the local river currents. Therefore, pilings can create and increase the overlap of predator and prey in a localized area, increasing the predation risk for the prey species that are not provided local refuge habitat. Similar to bulkheads and walls, pilings can create shade that attracts predators (Kahler et al. 2000; Carrasquero 2001).

2.5.1.2.6.1.1 North Delta Intakes

By the very nature of being permanent, the in-water infrastructure of the NDDs will be present throughout the year and will overlap with the occurrence of several life stages of listed fish species that are present in that region of the Sacramento River channel.

The permanent in-water infrastructure for the three NDDs include sheet pile training walls extending from the levee face to the intake screens; cut-off sheet pile wall running the length of the screen forming the edge of the sill; fish screens with refuge areas located between screen bays; floating debris boom along outside face of the fish screens; and debris boom piles to support floating debris boom. These structures create habitat that provides holding and cover for predators.

The footprint of each intake structure, including cofferdams, transition wall structures, and bank protection (riprap), would result in the permanent loss of approximately 6.6 acres of tidal perennial habitat and 1.02 linear miles of shoreline and associated riparian vegetation. At each intake location, these structures would encompass 1,600-2,000 linear feet of shoreline and 35 feet (5-7 percent) of the total channel width. In addition, riprap and artificial structures provide physical and hydraulic conditions that may attract certain predatory fish species such as striped bass, largemouth bass, smallmouth bass, and Sacramento pikeminnow and potentially increase their ability to ambush juvenile salmonids and other fishes.

The sheet pile training wall and vertical fish screens at the NDD constitute a permanent vertical bulkhead or retaining wall structure. Vertical bulkhead retaining walls lack habitat complexity, offering little refuge from predators. The NDD fish screen design described in the PA includes refuge areas between each set of screen bays; these are hypothesized to provide shelter to prey species such as juvenile salmonids from co-occurring predators. Hydraulic lab testing of fish screen refugia indicates that under certain hydraulic conditions, small fish can avoid being impinged on the screen by using the refugia areas (Reclamation 2013).

The NDD fish screen design described in the PA includes a debris boom to deflect floating debris from the screens, particularly during high flow events. The debris boom consists of a floating boom anchored in place by vertical pilings that run the length of the intake structure several feet outboard of the screen face. The project will have three log booms ranging from 1,300-1,700 feet long, depending on intake location. Booms will be supported by 32-40 pilings at each intake location. Each piling and the associated floating log boom will provide both structure and shade in an offshore environment. This will likely attract both predators and prey.

Because the debris booms are designed to intercept floating debris and prevent damage to the fish screens, they can potentially accumulate debris to create a larger, more complex structure than the boom and pilings alone. During high flow periods, debris mass is expected to attract both predators and prey, and will continue to do so until the debris is removed. It is during these high flow events that juvenile salmonids will be moving downstream through the NDD locations, creating an overlap between predator and prey presence and increasing predation risk.

The BA presents a predation study that was conducted at the GCID facility but acknowledges that those results do not transfer well to the NDD due to the size and location of the NDD compared to GCID and also the size of fish used in the study are smaller than what is expected at the NDD location. As described in BA Section 5.4.1.3.1.1.1, the main near-field effects of the NDD on juvenile salmonids may include screen contact (resulting in risk of injury), long screen passage times (increasing the risk of screen contact or predation), and predation (giving risk of mortality). These effects pose some risk to juvenile salmonids, although there is uncertainty in the extent of the risk.

An analysis of potential predation of juvenile Chinook salmon using a bioenergetics approach (see the public draft BDCP's Appendix 5.F, Biological Stressors on Covered Fish, Section 5.F.3.2.1 [California Department of Water Resources 2013]) suggests that loss along the NDD would be an order of magnitude lower than estimated at the GCID facility (e.g., for winter-run Chinook salmon the bioenergetics estimates were considerably less than 0.3%). As noted in in BA Section 5.4.1.3.1.1.1.3, indicators of the risk of predation vary between the lower estimates suggested by previous bioenergetics modeling (e.g., 0.3% for winter-run Chinook salmon) to higher estimates (5%) from the study conducted at the GCID fish screen (Vogel 2008b), although in neither case did these estimates consider the baseline rate of predation that might occur without the NDD.

Although NMFS has considered these estimates of predation in the winter-run life cycle modeling (see Section 2.5.1.2.7.5.2 Sacramento River Winter-run Chinook Salmon Life Cycle Model), the analysis in this section of the Opinion does not rely on these estimates because they are uncertain due to the various assumptions in the modeling and the estimates do not provide context for how such losses would compare to baseline losses without the NDD.

2.5.1.2.6.1.1.1 Winter-run Exposure and Risk

Detailed timing and spatial occurrence of winter-run Chinook salmon presence is described in Section 2.5.1.1 Construction Effects. Juvenile winter-run Chinook salmon can be found in the Delta near the NDD starting in October and continuing through April.

The location of the NDD is found along the migratory corridor for all winter-run Chinook salmon juveniles and adults. As described above, the permanent NDD structures will create habitat and opportunity for larger predators, which is expected to result in adverse effects to juvenile winter-run Chinook salmon. It is difficult to quantify the extent of impacts to juvenile winter-run Chinook salmon expected to occur at the NDD especially given the uncertainty related to the efficacy of proposed refugia and predator cover areas. Although all of the juvenile winter-run Chinook salmon migrate through the NDD area, NMFS expects that a small proportion of the population will be affected due to implementation of structure design elements intended to reduce suitable predator areas. Therefore, studies and monitoring at these sites will be important to improve understanding of the potential extent of impacts.

2.5.1.2.6.1.1.2 Spring-run Species Exposure and Risk

Detailed timing and spatial occurrence of spring-run Chinook salmon presence have previously been described in Section 2.5.1.1 Construction Effects. Juvenile spring-run Chinook salmon can be found in the Delta near the NDDs from November through May.

The location of the NDDs serve as a migratory corridor for all Sacramento River basin-produced spring-run Chinook salmon juveniles and adults. As described above, the permanent NDD structures will create habitat and opportunity for larger predators, which is expected to result in adverse effects to juvenile spring-run Chinook salmon. It is difficult to quantify the extent of impacts to juvenile spring-run Chinook salmon expected at the NDDs; therefore, studies and monitoring at these sites will be important to improve understanding. Although all of the juvenile spring-run Chinook salmon from the Sacramento River basin migrate through the NDD area, NMFS expects that a small proportion of the population will be affected due to implementation of structure design elements intended to reduce suitable predator areas.

2.5.1.2.6.1.1.3 Steelhead Exposure and Risk

Detailed timing and spatial occurrence of CCV steelhead presence have previously been described in Section 2.5.1.1 Construction Effects. Juvenile CCV steelhead are present in the Delta from November through June, with peak occurrence from January through March.

Juvenile steelhead will be exposed to predators at the NDDs. The distribution and timing of predatory fish, including striped bass, largemouth bass, smallmouth bass and Sacramento pikeminnow, overlap with the presence of juvenile steelhead at the NDDs; all of these predatory fish are resident in the Sacramento River year round. Juvenile steelhead are expected to have similar responses to predation risks as described for salmon in Kahler et al. (2000), although outmigrating steelhead smolts are typically larger than outmigrating juvenile Chinook salmon and may have a slight reduction in risk. However, steelhead are expected to be adversely effected as they encounter an increased predation risk at the NDD. It is difficult to quantify the extent of impacts to juvenile steelhead expected at the NDDs; therefore, studies and monitoring at these sites will be important to improve understanding. Although all of the juvenile steelhead migrate through the NDD area, NMFS expects that a small proportion of the population will be affected due to implementation of structure design elements intended to reduce suitable predator areas.

2.5.1.2.6.1.1.4 Green Sturgeon Exposure and Risk

Detailed timing and spatial occurrence of sDPS green sturgeon presence has previously been described in Section 2.5.1.1 Construction Effects. Juvenile green sturgeon can occur in the Delta at all times of the year.

Generally speaking, juvenile sDPS green sturgeon are much more likely to experience increased predation throughout the Delta than adults or sub-adults owing to the difference in size. It is also worth noting, however, that juvenile green sturgeon may be inherently less susceptible to predation than other fishes because of the deterrence afforded them by the presence of protective scutes on their skin. Nevertheless, juvenile green sturgeon have the potential to be present in all waters of the Delta during every month of the year, and all of the green sturgeon migrate through the NDD area. NMFS expects that a small proportion of the population will be affected due to implementation of structure design elements intended to reduce suitable predator areas.

2.5.1.2.6.1.1.5 Fall/Late fall-run Exposure and Risk

Detailed timing and spatial occurrence of fall- and late fall-run Chinook salmon presence have previously been described in Section 2.5.1.1 Construction Effects. Juvenile fall-run Chinook salmon are present at the NDD intake locations from December through August, with a peak from February through May. Juvenile late fall-run Chinook salmon are present at the NDD intake locations from July through January, peaking in December.

The location of the NDDs serve as a migratory corridor for all Sacramento River basin-produced fall- and late fall-run Chinook salmon juveniles and adults. As described above, the permanent NDD structures will create habitat and opportunity for larger predators, which is expected to result in adverse effects to juvenile fall- and late fall-run Chinook salmon. It is difficult to quantify the extent of impacts to juvenile spring-run Chinook salmon expected at the NDDs; therefore, studies and monitoring at these sites will be important to improve understanding. Although all of the juvenile fall- and late fall-run Chinook salmon migrate through the NDD area, NMFS expects that a small proportion of the population will be affected due to implementation of structure design elements intended to reduce suitable predator areas.

2.5.1.2.6.1.2 HOR Gate

An operable gate will be constructed at the HOR to prevent migrating juvenile salmonids (San Joaquin River-origin steelhead, spring-run Chinook salmon, and fall-run Chinook salmon) from entering Old River from the San Joaquin River, and thereby minimize their exposure to the CVP/SWP pumping facilities. The gate will be located in Old River approximately 400 feet downstream of the junction of Old River with the San Joaquin River. The gate will be 210 feet long and 30 feet wide, with a top elevation of +15 feet and include seven bottom-hinged gates, a fish passage structure, a boat lock, a control building, a boat lock operator’s building, and a communications antenna.

Elements of the HOR gate construction will lead to adverse effects upon listed salmonids over the course of its operations. The base of the gate structure will consist of a concrete foundation poured over steel foundation piles set into the channel bottom during construction. It is anticipated that the steel sheet piles used to construct the cofferdam will be cut off above the channel invert at the level of the concrete foundation surface to create a raised sill, similar to the NDD fish screens. When the gate is operated the gates are raised either by hydraulic pistons or by a pneumatic bag to block the flow of water through the gate location. When the gates are not in operation they are lowered and lay flat on the concrete foundation. In this closed position, when the gates are lying flat on the bottom, there will be a turbulent layer of water flow adjacent to the surface of the gates caused by irregularities in the surface of the gate structure. The raised sill is anticipated to create a rotating eddy in front of and behind the foundation of the gates as the ambient river flow goes over the top of the gate structure when the gates are in their lowered position and flat against the foundation floor. This will allow fish, including predators, to “sit” in this eddy and hold station both in front of and behind the foundation structure. In addition, as flow moves over the gate panels, the flow is anticipated to speed up, much like air moving over the curved surface of a wing, and then slow down and separate once it reaches the trailing edge of the gate structure, creating a series of small eddies along the shear line between moving water and stationary water behind the gate structure. It is anticipated that this will result in an adverse effect upon salmonid survival by increasing the vulnerability to predation of any salmonids moving through the location of the gates due to the nature of the velocity discontinuities and rotational eddies found in this flow field.

Flow along the edges of the boat lock channel and levee embankment where the gate structure ties into the levee face will have small fields of turbulent flow and eddies associated with the sheet pile walls used to construct these structures. As stated earlier in the CCF section regarding pile driving, the sheet pile identified for use in this project will have large indentations in the constructed wall. The individual sheet piles are interlocking and will create a depression 18 inches deep by approximately 40 inches long for every two interlocking piles. Within each indentation, there will be a small eddy allowing fish to hold, including predators, but will not provide suitable habitat that would form refugia for small fish such as juvenile salmonids to hide from predators. The sheet pile walls will enhance the vulnerability of listed salmonids to predation from predators holding along these walls. Thus, the sheet pile walls as proposed, are likely to adversely affect the survival of salmonids passing through this location.

The operation of the boat lock may lead to the “accidental” passage of juvenile salmonids in the San Joaquin River into the channel of Old River below the location of the gates. Passage into Old River will expose these fish to predators in the Old River corridor and, eventually, the potential entrainment into the SWP and CVP export facilities and their associated predation and survival effects. When the gate is operating and flows from the San Joaquin River are blocked, the flows downstream of the gates on Old River are reduced, and the local hydraulics immediately downstream of the gate would create conditions that are expected to enhance predation. Lowered velocities and eddies created by the gate structure and boat locks would slow down passage of any juvenile salmonid in this reach and increase the exposure time to any predators holding immediately below the dam-like gate structure thus increasing the vulnerability to predation and enhancing the success of a predation event (Sabal et al. 2016; Blackwell and Juanes 1998; Tucker et al. 1998).

The docks and pilings associated with the upstream and downstream sides of the boat lock will also create habitat which may adversely affect the survival of juvenile salmonids passing these structures. As previously discussed in the predation risks for interim structures (Section 2.5.1.1.6.3 Interim In-water Structures (Present During Construction)), pilings and the shaded areas beneath docks can create habitat that attracts both predators and prey, thus increasing the overlap of the predator's presence with their prey. However, this structure does not create habitat that can serve as protective refugia for the smaller prey fish and thus enhances the interaction between predator and prey and likely increases the success of the predation event leading to an adverse outcome in terms of salmonid survival.

The physical location of the gate structure may increase predation risks for emigrating juvenile salmonids from the San Joaquin River basin. As designed, the gate location is set back approximately 400 feet into Old River from the junction between the San Joaquin River and Old River. When the gates are raised, and the flow into Old River is blocked, it is expected that the flow from the San Joaquin River will form a large eddy in front of the closed gate. This large eddy will create hydraulic conditions that will aggregate both predators and prey and increase the period of overlap between the two groups. By increasing the likelihood of spatial and temporal co-occurrence, the risk of successful predation events increases. Furthermore, there is a known scour hole adjacent to the HOR gate location just downstream of the junction on the left bank of the San Joaquin River that attracts predators and creates a significant predation hotspot for emigrating salmonids. Thus, the pre-existing predation hotspot, combined with a new area that is likely to aggregate predators and prey, will exacerbate the predation risk in this confined area as predators can easily move from one spot to the other. Moving the gate location closer to the junction to alleviate the size of the eddy circulation would reduce both the temporal and spatial area of overlap between predators and prey, thus reducing the likelihood of successful predation events occurring. The interagency technical team will evaluate how to implement design elements intended to reduce predator areas, such as; 1) gate location, and 2) refugia areas incorporated into boat dock, piling and sheet pile designs.

2.5.1.2.6.1.2.1 Winter-run Exposure and Risk

There are no winter-run Chinook salmon in the vicinity of the HOR, so there is no exposure or risk to this species at this location from increased predation risk as a result of the proposed action.

2.5.1.2.6.1.2.2 Spring-run Exposure and Risk

Detailed timing and spatial occurrence of spring-run Chinook salmon presence have previously been described in Section 2.5.1.1 Construction Effects. Juvenile spring-run Chinook salmon can be found in the Delta near the HOR gate from November through May. The location of the HOR gate serves as a migratory corridor for all San Joaquin River basin-produced spring-run Chinook salmon juveniles and adults.

The HOR gate structure is expected to prevent fish from entering the Old River migratory corridor and reduce the potential for increased predation and mortality associated with these waterways and the operations of the SWP and CVP export facilities. As described above, the permanent HOR gate structure (and boat lock) will create habitat and opportunity for larger predators, which is expected to result in adverse effects to juvenile spring-run Chinook salmon. It is difficult to quantify the extent of impacts to juvenile spring-run Chinook salmon expected at the HOR gate; therefore, monitoring at these sites will be important to improve understanding. Although all San Joaquin River basin-produced juvenile spring-run Chinook salmon migrate through the HOR area, NMFS expects that a small proportion of the population will be affected due to implementation of structure design elements intended to reduce suitable predator areas.

2.5.1.2.6.1.2.3 Steelhead Exposure and Risk

The timing and spatial distribution of CCV steelhead has already been discussed in Section 2.5.1.1 Construction Effects. Since the HOR gate is a permanent structure that, once constructed, will be present year round, it will coincide with the presence of any CCV steelhead in adjacent waterways. Only steelhead originating in the San Joaquin River basin upstream of the Delta are expected to be exposed to the HOR gate and associated structures because of the gate location. Fish from the Sacramento River basin and east side tributaries are not expected to be present at the HOR gate location.

The HOR gate is expected to affect steelhead in the south Delta. The structure is expected to prevent fish from entering the Old River migratory corridor and reduce the potential for increased predation and mortality associated with these waterways and the operations of the SWP and CVP export facilities. As described above, the permanent HOR gate structure (and boat lock) will create habitat and opportunity for larger predators, which is expected to result in adverse effects to juvenile steelhead. It is difficult to quantify the extent of impacts to juvenile steelhead expected at the HOR gate; therefore, monitoring at these sites will be important to improve understanding. Although all of the juvenile steelhead originating in the San Joaquin River basin upstream of the Delta migrate through the HOR area, NMFS expects that a small proportion of the population will be affected due to implementation of structure design elements intended to reduce suitable predator areas.

2.5.1.2.6.1.2.4 Green Sturgeon Exposure and Risk

There are no green sturgeon in the vicinity of the HOR, so there is no exposure or risk to this species at this location from increased predation risk as a result of the proposed action.

2.5.1.2.6.1.2.5 Fall/Late fall-run Exposure and Risk

There are no late fall-run Chinook salmon in the vicinity of the HOR, so there is no exposure or risk to this species at this location from increased predation risk as a result of the proposed action.

Detailed timing and spatial occurrence of fall-run Chinook salmon presence have previously been described in Section 2.5.1.1 Construction Effects. Juvenile fall-run Chinook salmon can be found in the Delta near the HOR gate from January through May.

The location of the HOR gate serves as a migratory corridor for all San Joaquin River basin-produced fall-run Chinook salmon juveniles and adults. As described above, the permanent HOR gate structure (and boat lock) will create habitat and opportunity for larger predators, which is expected to result in adverse effects to juvenile fall-run Chinook salmon. It is difficult to quantify the extent of impacts to juvenile fall-run Chinook salmon expected at the HOR gate; therefore, monitoring at these sites will be important to improve understanding. Although all San Joaquin River basin-produced juvenile fall-run Chinook salmon migrate through the HOR area, NMFS expects that a small proportion of the population will be affected due to implementation of structure design elements intended to reduce suitable predator areas.

2.5.1.2.7 Reduced In-Delta Flows

The Sacramento-San Joaquin Delta is an inverted Delta that consists of many channels and distributaries before funneling into the Bay at Carquinez Strait. Delta inflow and tidal excursion counteract each other in the lower part of the estuary to influence channel velocity and proportional flow in the channels and distributaries anadromous fish rear and migrate through. Riverine flow is a key component of aquatic habitat and juvenile migratory success in the Delta. Flow affects several aspects of anadromous species behavior and survival given that the timing and quantity of flow influences spawning behavior, migration events, habitat use, predator evasion, and ultimately survival (Perry et al. 2010; Michel et al. 2013; del Rosario et al. 2013; Fish et al. 2010).

Studies have highlighted that there is a strong relationship between river flow and through-Delta survival, particularly in transition reaches; where tidal influence begins to encroach on the mostly riverine areas of the lower Sacramento River during periods of low inflow (Perry 2016 in prep; Perry et al. 2010). These studies are extremely useful in providing insight into the mortality risk for Chinook salmon migrating through the Delta. Predation is believed to be a major source of mortality in the Delta for juvenile salmon and many factors such as temperature, predator and prey density, flow regimes, turbidity and habitat complexity can influence predator and prey interactions (Anderson et al. 2005; Lindley and Mohr, 2003). One migratory trait that can be linked to increased predation risk is travel time and distance (Anderson et al. 2005; Cavallo et al. 2012). Within the tidal Delta, the transition reaches are where the flow survival relationships have been most evident (Perry 2016), where flows shift from unidirectional to bidirectional influencing travel time and overall distance travelled. A study conducted on the Mokelumne River (Cavallo et al. 2012) supports a similar mechanism where increasing flow and decreasing tidal effect decreased juvenile salmon emigration time and significantly increased survival through the study reach. When habitat conditions are poor and predators can be encountered several times when flow is reduced in transition reaches, mortality is expected to be higher for migrating smolts.

Assessing survival and migratory changes for juvenile Chinook salmon in the Delta with the operations of the PA relies on understanding inflows into and hydrodynamics of the Delta. The three CWF intakes are located in the Freeport to Hood region of the Sacramento River from river mile (RM) 41.1 to RM 36.8. Many of the CWT and acoustic tag studies conducted in the Delta released Chinook salmon smolts into the Sacramento River just above or below the Freeport area. Flow-related survival for such studies often use Sacramento River flows at Freeport (USGS gauge 1447650) and just downstream of the junction with Georgiana Slough (USGS gauge 11447905) as well as the Delta Outflow Index (DWR Dayflow_DOI). In this Opinion, flow at Freeport is also used as a metric to assess differences in juvenile salmon survival, migration routing, travel time, and occurrence of reverse flow in the junction of the Sacramento River just below Georgiana Slough (Perry et al. 2016 in review; Perry et al. 2015). This is because the observed flow at Freeport influences the magnitude of flows detected in the lower reaches of the system downstream of the proposed NDD locations, and the proportion of observed Freeport flows in these downstream reaches is reduced under the PA compared to the NAA due to diversions that occur from the three new intakes. Analyses used in this Opinion will include assessment of Delta hydrodynamics as drivers or correlates to juvenile salmonid migration route selection and flow-related survival. Although this analysis is specific to juvenile Chinook salmon, the analysis can also inform the impacts to migrating juvenile steelhead because juvenile steelhead migrate at similar times as Chinook salmon.

2.5.1.2.7.1 Travel Time

Patterns of anadromous fish migration are influenced by a number of variables, including flow velocity, direction, volume, and source. When velocities along migratory corridors are reduced, juvenile outmigration takes longer and smolts are more likely to be vulnerable to increased predation risk (Anderson et al. 2005; Muthukumarana et al. 2008; Cavallo et al. 2013). The amount of time outmigrating juvenile salmonids spend traveling through migratory corridors in the Delta is one indicator of predation risk, with longer travel time through the Delta often resulting in higher mortality rates. Table 2-165 provides a summary of the modeling tools used to assess the impacts of travel time changes caused by the PA on juvenile salmonid survival and green sturgeon.

Table 2-165. Models Used to Assess Changes in Velocities and Juvenile Salmonid Outmigration Travel Time Under the PA.

Model	Source	Method	Applicability	Analysis
Channel Velocity Analysis	CWF BA Section 5.4.1.3.1.2.1.1	DSM2 hydrodynamic modeling	Juvenile salmonids and sturgeon migratory patterns	Hydrological changes between PA and NAA at key channels throughout the north, central, and south Delta
NDD bypass flows and smolt entrainment model	Perry et al. (2016)	Historical flow at Freeport (USGS gage 11447905) and Sacramento River downstream of Georgiana Slough (USGS gage 11447650) to predict velocities under NDD proposed bypass rules	Juvenile salmonids and sturgeon migratory patterns	Velocities below NDD intakes due to written bypass rules as compared to NAA (no diversions)
Perry Survival Model (Travel Time component)	Perry 2016	Statistical analysis of travel time over eight distinct reaches based on Delta inflow and a five-year study of the travel time of acoustic tagged Chinook salmon smolts applied to the PA operational scenarios in comparison with the NAA.	Chinook salmon smolts (i.e., >70 mm)	Calsim simulations of scenarios to determine through Delta and route specific travel times based on relationships from acoustic tag studies.

Note: The unlimited pulse protection scenario is not evaluated with these modeling tools specifically relative to travel time

2.5.1.2.7.1.1 Channel Velocity Analysis

The first component of the travel time analysis is an evaluation of channel velocity changes caused by the PA. The BA provides information on the hydrodynamic conditions that an outmigrating fish will experience and the resultant differences between scenarios, PA and NAA. Because flow velocity can affect fish travel time, and therefore the potential risk of exposure to predation, results from these comparative velocity analyses can indicate whether they facilitate successful juvenile migration and in particular, smolt outmigration. The BA provides analysis of key migration routes and channel junctions in the Delta and the effects of PA operations on the hydrodynamics of those routes and junctions (BA Section 5.4.1.3.1.2.1.1 Channel Velocity).

Table 2-166 describes the channels used in the velocity analysis, as well as the hypothesized importance of a particular channel on salmonid migration and survival. The analysis in the BA uses DSM2 modeling to evaluate the NAA and PA for differences in:

1. Magnitude of channel velocities,
2. Magnitude of negative velocities, and
3. Proportion of each day that velocity was negative in the study channels.

Table 2-166. Description of Channels Used in the Velocity Analysis and Their Hypothesized Importance for Fish Migration.

DSM2 Channel	Description	Hypothesized importance
21	San Joaquin River downstream of the head of Old River.	Fish in this region have avoided entering the interior Delta at Head of Old River and are in a potentially higher survival route, where survival may be influenced by river flow (velocity).
45	San Joaquin River near the confluence with the Mokelumne River.	Fish entering the San Joaquin River from the Sacramento River via Georgiana Slough and the DCC experience this area.
94	Old River downstream of the south Delta export facilities.	Fish attempting to move north from the south Delta experience are within the hydrodynamic footprint of the south Delta export facilities and are particularly susceptible to entrainment.
212	Old River upstream of the south Delta export facilities.	Fish moving through Old River experience conditions in this channel as they approach the facilities.
418	Sacramento River downstream of proposed NDD.	Fish moving down the Sacramento River could experience operational effects in this region (flow-survival relationships).
421	Sacramento River upstream of Georgiana Slough.	This region is where fish may enter the interior Delta from the Sacramento River, and there may be flow-survival relationships.
423	Sacramento River downstream of Georgiana Slough.	This region is where fish may enter the interior Delta from the Sacramento River, and river flow (velocity) may affect survival (i.e., there is a significant flow-survival relationship; Perry 2010).
DCC	Delta Cross Channel	Fish from the Sacramento River may enter the interior Delta through this channel.
379	Steamboat Slough	Fish using this route are not exposed to entrainment into Georgiana Slough and the DCC, and river flow (velocity) may affect survival (i.e., there is a significant flow-survival relationship; Perry 2010)
383	Sutter Slough	Fish using this route are not exposed to entrainment into Georgiana Slough and the DCC, and river flow (velocity) may affect survival (i.e., there is a significant flow-survival relationship; Perry 2010)

A limitation to this model, as stated in the BA, is that differences in velocity may not directly correspond to biological outcomes in scenarios. Juvenile salmonids may show a selective tidal-stream transport that does not allow simple differences in velocity to translate into biological outcomes (Delaney et al. 2014). The uncertainty in these results limits their use to general trends in differences, such as decreased overall velocity, increased negative velocity, and a greater proportion of negative velocity as indicators of adverse effects to juvenile salmonids, including delayed migration or advection into migration pathways with higher mortality risk.

Though the operations of the PA have the potential to beneficially change channel flows in the Delta, the changes will depend on the extant conditions and specific PA operational conditions. The velocity analysis can indicate whether operations beneficially increase channel flows in ways that would reduce travel time and decrease the likelihood of exposure of juvenile salmonids to less-suitable migration routes.

BA Tables 5.4-9, 5.4-10, and 5.4-11 in Appendix C of this Opinion show the results of the analyses of median channel velocity, median negative channel velocity, and median daily proportion of negative velocity values at the locations specified in Table 2-166. The effects of channel velocities under the PA on travel time of outmigrating salmonid species are described in the exposure and risk subsections below.

Magnitude of change in channel velocities under the PA

Under the PA, water velocities in the north Delta would be lower by at least 5% in all water years and most months with the exception of April (BA Table 5.4-9 in Appendix C of this Opinion). This would increase migratory travel time and potentially increase the risk of predation for juvenile salmonids. In the South Delta, median velocities generally increase under the PA in all water years and most months with the exception of December. The positive change in velocity would decrease migratory travel time and reduce predation risk for juvenile salmonids migrating through the south Delta. In the Central Delta, there is little difference in magnitude of channel velocities between the NAA and PA for any month or water year type at the DCC, except for June when the median velocity under the PA is more negative in all water years but wet.

Magnitude of change in negative velocities (or reverse flows) under the PA

In the North Delta, reverse flows would increase in most water years and months with the exception of December and January under the PA (BA Table 5.4-10 in Appendix C of this Opinion). In the South Delta, reverse flows occur roughly half of the time (BA Table 5.4-11 in Appendix C of this Opinion) under the PA and NAA, and differences between scenarios are only prevalent in the San Joaquin River downstream of the HOR. During January through June, negative velocities are reduced in the San Joaquin River downstream of the HOR under the PA (BA Table 5.4-10 in Appendix C of this Opinion).

Proportion of each day that velocity was negative under the PA

In the North Delta, the PA had a higher proportion of each day with negative velocities (reverse flow) particularly in Steamboat Slough and Sacramento River downstream of Georgiana Slough (BA Table 5.4-11 in Appendix C of this Opinion). In the South Delta, results were similar between scenarios except for the San Joaquin River downstream of the HOR where the PA had less proportion of the day with negative velocities. In the Central Delta, results showed little difference between scenarios with the DCC having more proportion of day with negative velocities under the PA only during the month of June.

Under the PA, the channel reach in the Old River upstream of the south Delta export facilities had less water moving toward the pumps in most months and water years (BA Table 5.4-9 to 11 in Appendix C of this Opinion). This would result in fewer fish exposed to entrainment in the South Delta pumping facilities. The higher probability of reverse flows and daily proportion of reverse flows in this channel under the PA would reduce the frequency of flows into the South Delta pumping facilities and therefore reduce the number of fish potentially entrained in the facilities (BA table 5.4-9 to 11 in Appendix C of this Opinion).

2.5.1.2.7.1.2 NDD Bypass Flows and Smolt Entrainment Analysis

In order to more thoroughly evaluate the impact of reverse flows on migrating salmon, NMFS undertook an additional analysis. The likelihood of juvenile fish entering migratory routes with reduced survival increases with the daily probability of flow reversal, or with increases in the proportion of each day with flow reversals. The probability of juvenile Chinook salmon getting entrained into migratory routes of lower survival like Georgiana Slough and the Delta Cross Channel is highest during reverse-flow flood tides (Perry et al. 2015). In addition, the proportion of fish entrained into Georgiana Slough on a daily basis increases with the proportion of a day that the Sacramento River downstream of Georgiana Slough flows in reverse (Perry et al. 2010). Consequently, diverting water from the Sacramento River could increase the frequency and duration of reverse-flow conditions, thereby increasing travel time as well as the proportion of fish entrained into the interior Delta where survival probabilities are lower than in the Sacramento River (Perry et al., 2010 and 2015).

Using the proposed NDD bypass rules described in the BA (AppendixA1B Table 3.3-2 of this Opinion), we undertook an analysis to quantify how the NDD bypass rules would increase the frequency and duration of flow reversals on the Sacramento River at the junction of Georgiana Slough compared to NAA. The proposed NDD bypass rules are the governing criteria on how much could be diverted for a given flow at Freeport. The Calsim and DSM2 hydrodynamic simulations of the CWF are only a predictor of what actual diversions and bypass flows would occur on any given day under the NDD bypass rules; therefore, analyzing the proposed operating criteria of the NDD bypass rules is important to understand potential bypass flows. This is because the Calsim and DSM2 simulations may not always divert the maximum allowed under the proposed NDD bypass rules as other unrelated criteria may control how much is diverted such as water quality criteria and whether there is storage room at reservoirs.

The proposed NDD bypass rules include a commitment to an operational constraint that the amount of flow withdrawn at the NDD cannot exacerbate reverse flows (i.e., increase the frequency, magnitude, or duration of negative velocities) at the Georgiana Slough junction from December through June beyond what would occur in NAA. However, the BA does not describe the methods or the modeling that would show how this would be achieved. Specifically, the BA does not describe:

1. The extent that the proposed NDD bypass rules may affect the frequency, magnitude and duration of reverse flows in the lower Sacramento River;
2. The description of how real-time monitoring could be implemented to meet the criteria of not increasing reverse flows;
3. The modeling simulations that would show how this criteria is being met and therefore provide reasonably accurate bypass flow levels.

In the absence of that information, this Opinion relies on the NDD bypass evaluation in the smolt entrainment model to evaluate the likelihood of reverse flows and proportion of daily reverse flows in the Sacramento River downstream of Georgiana Slough under the PA without extensive real-time operations adjustments. Unlimited pulse protections, which as described in the PA would be implemented through real-time operations at the NDD, cannot be modeled with the tools described here but are evaluated with a different level of analysis discussed in Section 2.5.1.2.7.4 Delta Survival. In addition, in the June 2017 Revised PA, DWR committed to additional Delta habitat restoration that is expected to change the tidal prism so that the operational commitment of not exacerbating reverse flows in the north Delta can be met.

As illustrated in the public draft Bay Delta Conservation Plan (BDCP), tidal habitat restoration's redirection of tidal energy away from the Sacramento River–Georgiana Slough junction has the potential to more than offset NDD effects on reverse flow relative to a no action alternative (reflecting continuation of the environmental baseline) that does not include either the NDD or tidal habitat restoration (DWR 2013: Appendix 5.C Flow, Passage, Salinity, and Turbidity, Section 5C.5.3.8 Sacramento River Reverse Flows Entering Georgiana Slough). Several hypothetical restoration scenarios were considered as part of initial BDCP discussions, which included around 6,750 acres, 13,000 acres, and 20,000 acres of restoration in the Cache Slough complex (see Appendix G Habitat Restoration of this Opinion). The PA adds 1,800 acres of Delta tidal habitat restoration to the existing commitments for 9,000 acres of Delta tidal habitat restoration, which in total according to DSM2-HYDRO modeling will mute reverse flows to varying degrees depending on Sacramento River outflow (see Figures 1 and 2 in Appendix G Habitat Restoration of this Opinion).

In addition to the 1,800 acres, the PA states, " DWR and Reclamation also commit to providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration and magnitude of reverse flows caused by NDD operations…Furthermore, DWR and Reclamation commit as part of the AMP to a monitoring program to assess the performance of these actions and modify the mitigation approach as necessary to offset the effects of the project as they are better understood." Therefore, Reclamation and DWR are not only commiting to an additional 1,800 acres, but are also committing to a new program of Delta habitat restoration that will be driven by the PA objective of the project not exacerbating reverse flows in the North Delta/Lower Sacramento River area, and be based on science, monitoring and adaptive management.

NMFS expects that tidal habitat restoration (both the additional 1,800 acres and the new objective-driven program) in combination with reductions in NDD diversions due to real-time operation pulse protection actions will prevent the exacerbation of reverse flows in the north Delta. Therefore, the Calsim modeling for the PA represents a worst-case scenario analysis. The Calsim modeling for the PA does not account for the prevention of additional reverse flows in the north Delta that is expected with proposed NDD operations. Therefore, the analysis presented here, which is based on the Calsim modeling, includes an increase in flow reversals and the subsequent impacts to migrating salmonids, but the increase is expected to be prevented or reduced to some degree under the PA.

Hydrodynamic analysis conducted by Perry et al. (2016) (hereafter referred to as NDD bypass evaluation and smolt entrainment model) provides information on the potential influence of the PA operations on Sacramento River flow reversals. This analysis helps to highlight when real-time adjustments would be needed to meet the criteria of not increasing reverse flows at the junction of Georgiana Slough under the proposed NDD bypass rules. The analysis uses historical flow data to estimate the effect of Sacramento River discharge at Freeport (USGS gage 11447650) on two hydrodynamic conditions just downstream of Georgiana Slough (USGS gage 11447905): (1) the daily probability of a flow reversal, and (2) the proportion of each day with reverse flow.

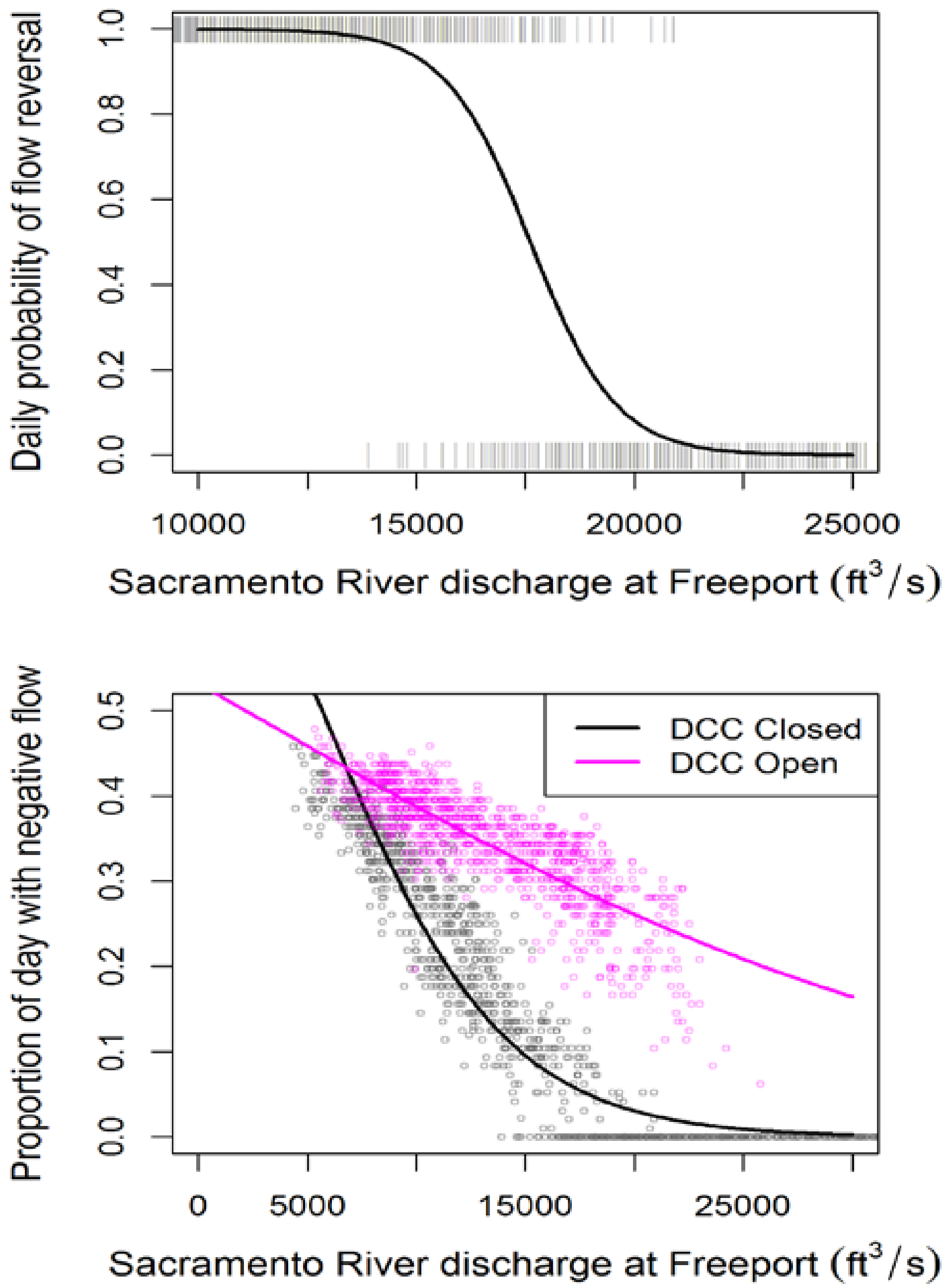


Figure 2-118. Effect of discharge at Freeport on frequency of reverse flow in the Sacramento River downstream of Georgiana Slough with DCC closed (top) and on duration of flow reversals when DCC is open and closed. The top panel shows the effect of the mean daily discharge (cfs; cubic feet per second) in the Sacramento River at Freeport on the probability of a flow reversal occurring on a given day at the USGS gage in the Sacramento River just downstream of Georgiana Slough with the Delta Cross Channel (DCC) gate closed. The bottom panel shows the fraction of each day with reversing flow as a function of DCC gate position and mean daily discharge at Freeport.

The probability of a flow reversal in the Sacramento River downstream of Georgiana Slough occurring at some time during a 24-hour period is one hundred percent when Sacramento River flows at Freeport are less than 13,000 cfs (Figure 2-118 top panel). Likewise, when flows are greater than 23,000 cfs, flow reversals are not expected to occur at the Georgiana Slough junction. For the range of flows between 13,000 and 23,000 cfs at Freeport, reverse flows can be expected to occur, but the probability decreases with increasing Freeport flow. Under near term conditions, real-time management would be needed within the Freeport flow range of 13,000 cfs to 23,000 cfs to ensure NDD diversions are not the cause of flow reversals. Below 13,000 cfs, flow reversals at Georgiana Slough are certain to occur so any substantial diversion could increase the magnitude or duration of reverse flows.

The proportion of the day with flow reversals downstream of Georgiana Slough is approximately 45 percent when Sacramento River flow at Freeport is about 6,000 cfs regardless of the DCC gate position (Figure 2-118, bottom panel). As Freeport discharge increases over 6,000 cfs, however, the percentage of the day with flow reversals decreases much more sharply with the DCC closed relative to open.

The NDD bypass evaluation and smolt entrainment model estimated the frequency and duration of reverse-flow conditions on the Sacramento River downstream of Georgiana Slough under each of the prescribed minimum bypass flows described in the NDD bypass rules (BA Table 3.3-2 in Appendix A2 of this Opinion).The NDD bypass rules are applied to a Freeport discharge range of 5,000 to 35,000 cfs, which brackets empirical flows covering the full range of reverse flow probabilities (i.e., 0 to 100 percent probability of reverse flow).

The following assumptions were used:

1) the NDD bypass rules are applied based on mean daily Sacramento River discharge at Freeport, and 2) water is diverted at a constant rate over an entire day such that the bypass flow is constant over the day. The analysis adheres to a strict interpretation of the NDD bypass rules and does not include flow variations at sub-daily timescales.

Additionally, the analysis was conducted with recent historical flow hydrodynamics and would need to be recalibrated as sea level rise or hydrodynamic conditions (i.e., tidal restoration) change in the estuary.

The analysis modeled: (1) the probability of flow reversal, and (2) proportion of each day with flow reversals, comparing the scenarios of no diversion (NAA) and diversion under the NDD bypass rules (PA). The difference between no diversion and diversion prescribed under the NDD bypass rules were calculated to assess the magnitude of increase in the frequency and duration of reverse flows.

The NDD bypass rules prescribe a series of minimum allowable bypass flows that vary depending on the following: (1) month of the year and (2) progressively decreasing levels of bypass flow following a pulse flow event.

Results are separated into time periods corresponding to NDD bypass rules (Appendix A2 Table 3.3-2):

1. Constant low-level pumping (pulse protection for December–June)
2. October–November bypass rules

3. Level 1, 2, and 3 post-pulse operations for December–April
4. Level 1, 2, and 3 post-pulse operations for May
5. Level 1, 2, and 3 post-pulse operations for June
6. July–September bypass rules

Based on the results of the NDD bypass evaluation and smolt entrainment model, the proposed NDD bypass rules would increase the frequency and duration of reverse flows of the Sacramento River downstream of Georgiana Slough. The magnitude of increase varies depending on the operational time period (e.g., December-June constant low-level pumping; Level 1, 2, and 3 post-pulse operations for December-April). The most protective bypass rule, constant low-level pumping during December-June, has the smallest increase in probability of and duration of flow reversals (Figure 2-119).

October-November operations can greatly increase the probability of reverse flow; for example, when flows at Freeport are between 20,000 to 25,000 cfs there would be ~100% increase in flow reversals under the PA (Figure 2-124).

For December through June, the months to which post-pulse bypass rules govern the NDD operational level, Level 1 always results in the least increase in the probability of flow reversal (30 to 50 percent probability), while Level 3 results in the greatest increase in probability of flow reversal (100 percent probability). For all of these months, the peak increase in probability occurs in the range of 20,000-25,000 cfs flow at Freeport (Figure 2-120 through Figure 2-122).

The December-April bypass flow rules were developed with the intent to be the most protective of bypass flows to help protect the majority of juvenile winter-run Chinook salmon outmigration. The December-April rules (Figure 2-120) contribute to that objective by producing a lower probability of increased reverse flows than the rules developed for May and June (Figure 2-121 and Figure 2-122).

For example, the increase in probability of flow reversal at Level 2 pumping for December-April peaks at approximately 0.8 (Figure 2-120), while for May it peaks at 0.9 (Figure 2-121). Even at Level 2 pumping for these more protective December-April constraints, the proportion of the day during which reverse flow conditions exist can increase by an additional 5 percent of the day, and the probability of reverse flow occurring increases by 80 percent (Figure 2-120).

Similar results, though with greater degrees of change, result for May (Figure 2-121) and June (Figure 2-122). July through November (Figure 2-123) and (Figure 2-124) show similarly high increases in probability of flow reversals and proportion of the day that reverse flow conditions exist. These months are not governed by the different levels (i.e., pulse protections) that apply to December through June, but instead have static bypass flow requirements.

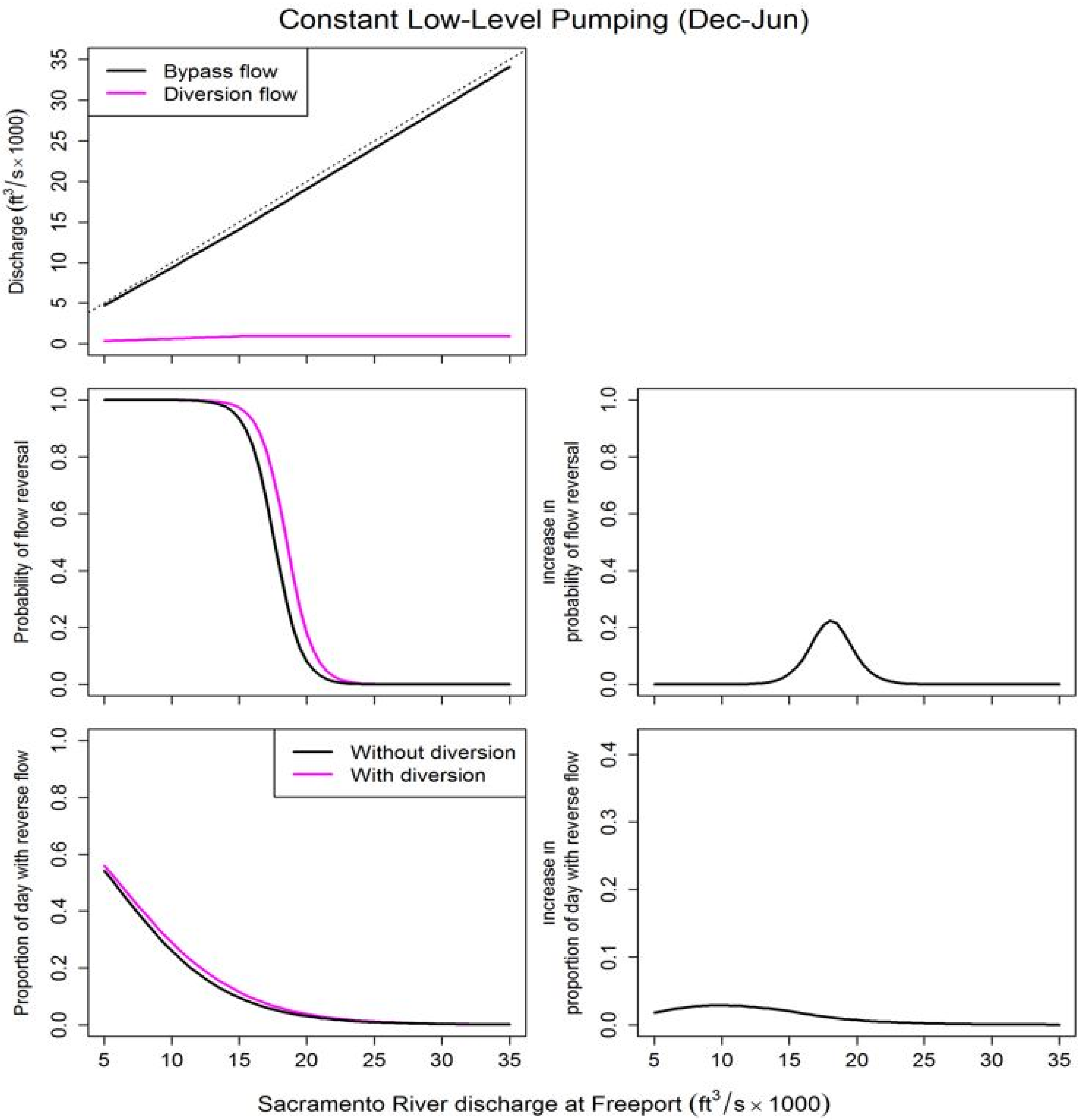
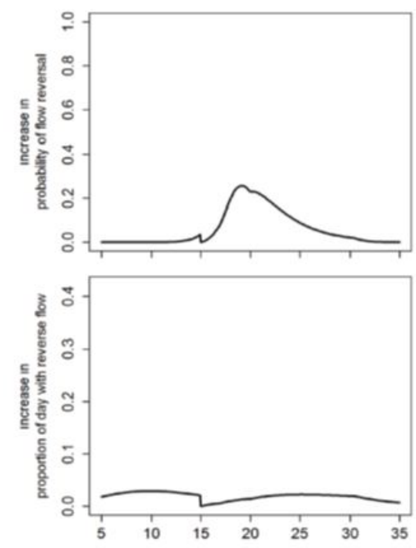
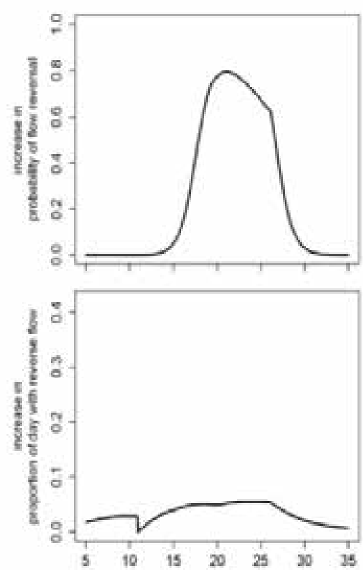


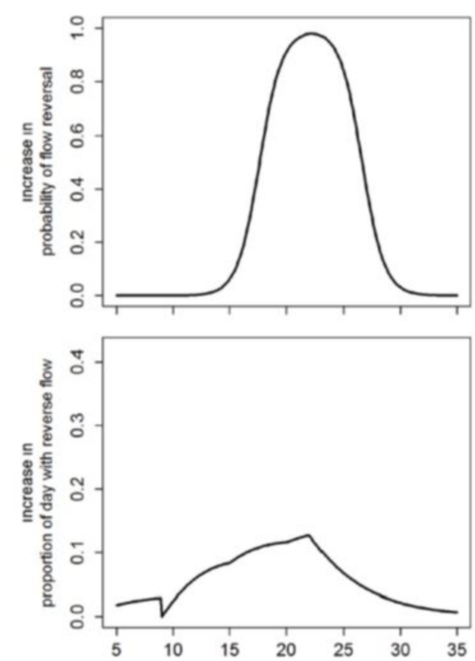
Figure 2-119. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for constant low-level pumping as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.



Dec-April Level 1 Bypass Rules



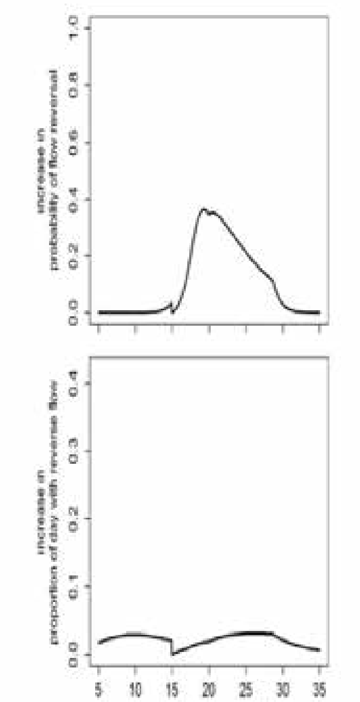
Dec-April Level 2 Bypass Rules



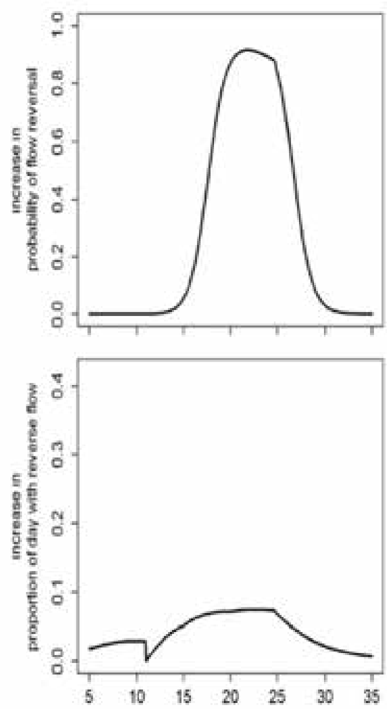
Dec-April Level 3 Bypass Rules

Sacramento River Discharge at Freeport (ft^3 /s x 1000)

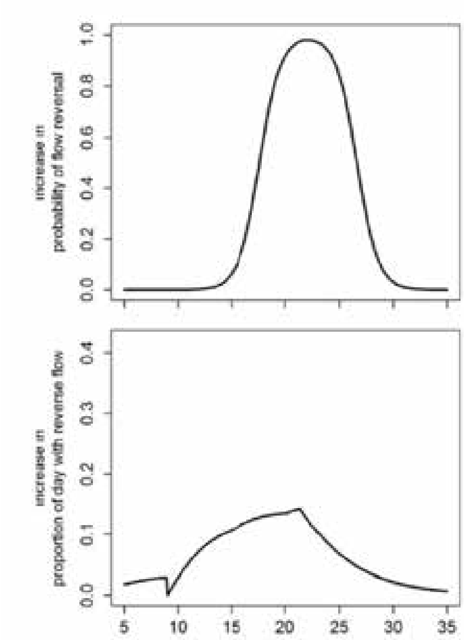
Figure 2-120. Dec-April Levels 1-3 Bypass Rules



May Level 1 Bypass Rules



May Level 2 Bypass Rules



May Level 3 Bypass Rules

Sacramento River Discharge at Freeport (ft^3 /s x 1000)

Figure 2-121. May Levels 1-3 Bypass Rules.

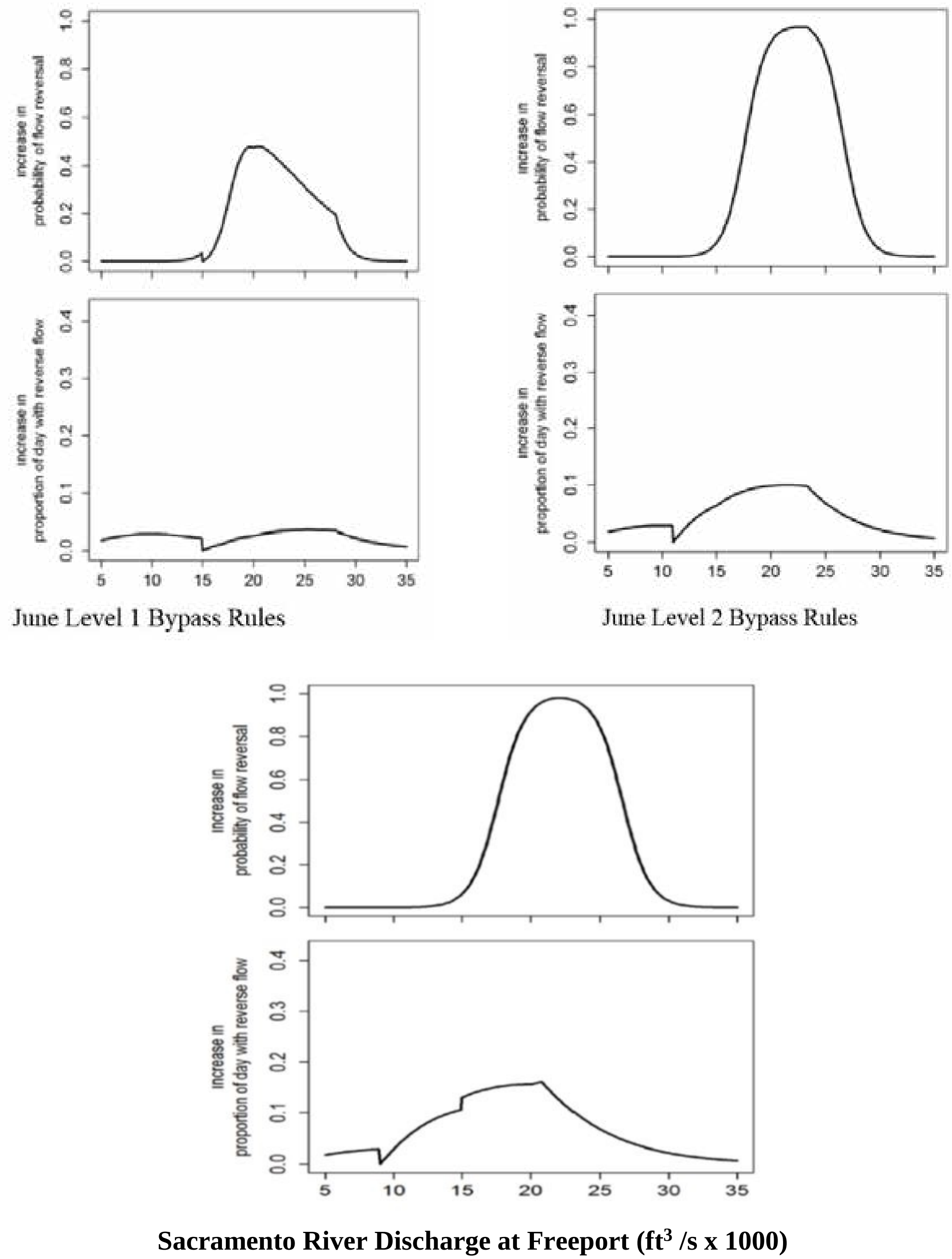


Figure 2-122. June Levels 1-3 Bypass Rules.

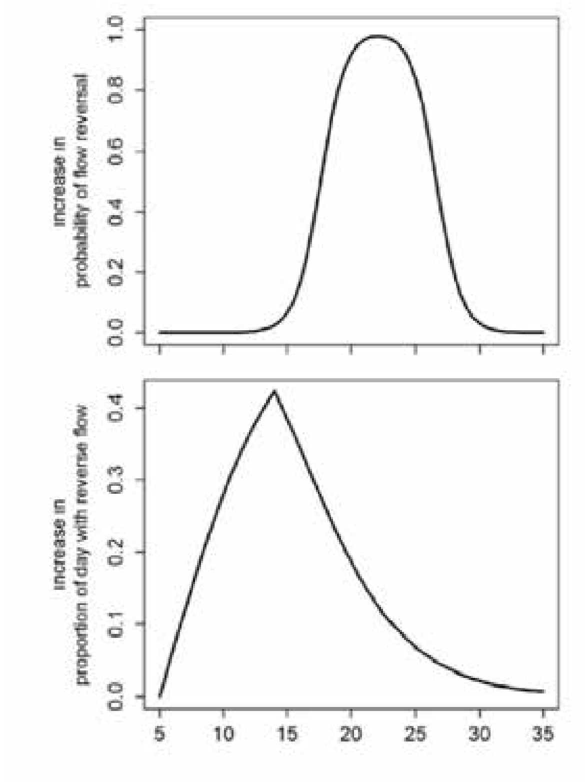


Figure 2-123. Jul-Sept Bypass Rules.

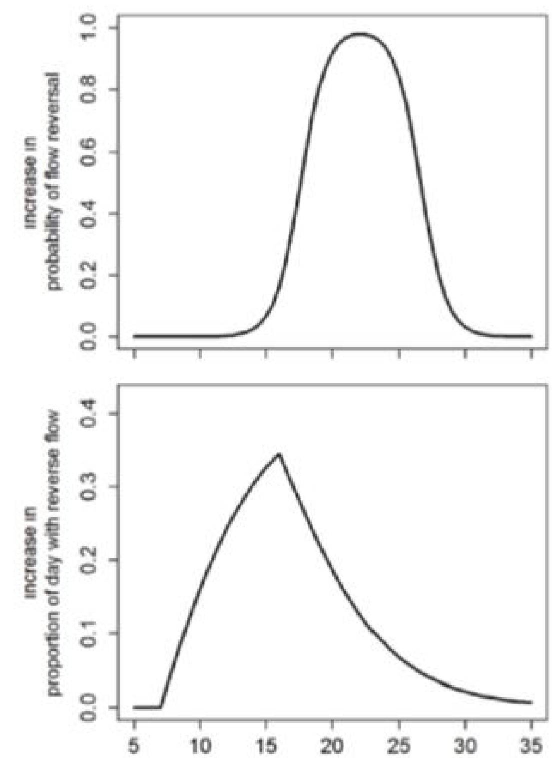


Figure 2-124. Oct-Nov Bypass Rules.

Sacramento River Discharge at Freeport (ft^3 /s x 1000)

As described above in this section, the Calsim and DSM2 modeling completed for analysis of PA operations does include constraints to diversions at the north Delta intakes imposed by other requirements such as positive sweeping velocities and D-1641 water quality and outflow constraints. Therefore, results from the PA modeling are likely a closer approximation of actual allowable diversions and resultant bypass flows. The modeling runs are more suited as long-term predictors of how operations would commence, however, and do not capture real-time management that may alter diversion amounts on any given day. Additionally, the PA modeling also does not attempt to limit increases in negative velocities below the diversion screens or at Sacramento River downstream of Georgiana Slough (USGS gage 11447905) as stated in the NDD bypass rules criteria. Absent information in the PA on how the proposed NDD bypass flows may increase the frequency and duration of reverse flows and absent the description or modeling on how the PA would achieve the commitment to an operational constraint of not increasing the frequency, magnitude or duration of reverse flows above baseline, this analysis was conducted in the BO to help inform this data gap. As described above, modeling of the PA scenario with strict implementation of the NDD bypass rules and without real-time management represents a worst-case scenario. Unlimited pulse protections, which as described in the PA would be implemented through real-time operations at the NDD, cannot be modeled with the tools described here but were evaluated with a different level of analysis discussed in Section 2.5.1.2.7.4 Delta Survival.

2.5.1.2.7.1.3 Perry Survival Model (Travel Time Component)

The survival model (Perry 2016) estimates the relationship of Sacramento River inflows (measured at Freeport) on reach-specific travel time, routing, and survival of acoustic-tagged late-fall Chinook salmon smolts. The survival model evaluates the travel time of daily cohorts (i.e., groups) of migrating smolts at eight discrete reaches through the Delta under the PA and NAA scenarios.

We discuss throughout this section how the different diversion levels (Level 1, 2, 3) in the proposed NDD bypass rules (described in Appendix A2 Project Description of this Opinion) affect velocities downstream of the intakes. The PA scenario contains diversions at all three levels. In addition, a scenario that restricts diversions to no greater then Level 1 (L1 scenario) during December to June is included in this analysis. The UPP scenario is not evaluated here relative to juvenile Chinook salmon travel time specifically; however, the Perry Survival Model is applied to the UPP scenario evaluation relative to overall juvenile survival (see Section 2.5.1.2.7 Delta Survival). The L1 scenario offers the most protection of the three levels due to higher Freeport inflows before diversions can occur. NMFS has evaluated this scenario to provide context for the range of effects that may be experienced by migrating salmonids given that the PA states that post-pulse bypass flow operations will remain at Level 1 pumping, unless specific criteria have been met to increase to Level 2 or Level 3, but the specific criteria to transition to or among different levels are not developed yet (Appendix A2 Project Description of this Opinion). Monitoring and criterion to detect salmonids that are migrating and rearing in the north Delta is not fully described in the PA and will be further developed in the Adaptive Management Program (Appendix A2 Project Description of this Opinion). For this reason, the L1 scenario provides a best-case scenario of flows salmonids would experience under the NDD bypass rules.

The Perry Survival Model provides analysis of differences in travel time between the following scenarios: NAA and PA, NAA and Level 1 only (L1), and PA and L1. The model provides five categories of simulation outputs for each daily cohort, as listed below; however, this section focuses only on the categories median travel time by route and over all routes, and daily difference in median travel time between PA and NAA scenarios because the focus of this section is on juvenile Chinook salmon travel time. Later sections will focus on the other categories of simulation outputs.

- Median travel time by route and over all routes.
- The proportion of fish using each unique migration route.
- The mean survival for each unique migration route.
- Overall survival through the Delta, calculated as the mean survival over all individuals.
- Daily difference in survival and median travel time between PA and NAA scenarios.

More detail on the Perry Survival Model is provided in Section 2.5.1.2.7.4.2 Perry 2017 Flow-Survival Model (Delta Survival) and in Appendix F and Appendix G.

Each year of the 82-year CALSIM hydro-modeling scenario was input into the Perry Survival Model to track differences in migratory travel time between scenarios. Using BN water year type 1923 as an example, Figure 2-125 illustrates how Freeport discharge and corresponding bypass flow levels influence daily salmonid migratory travel time through the Delta.

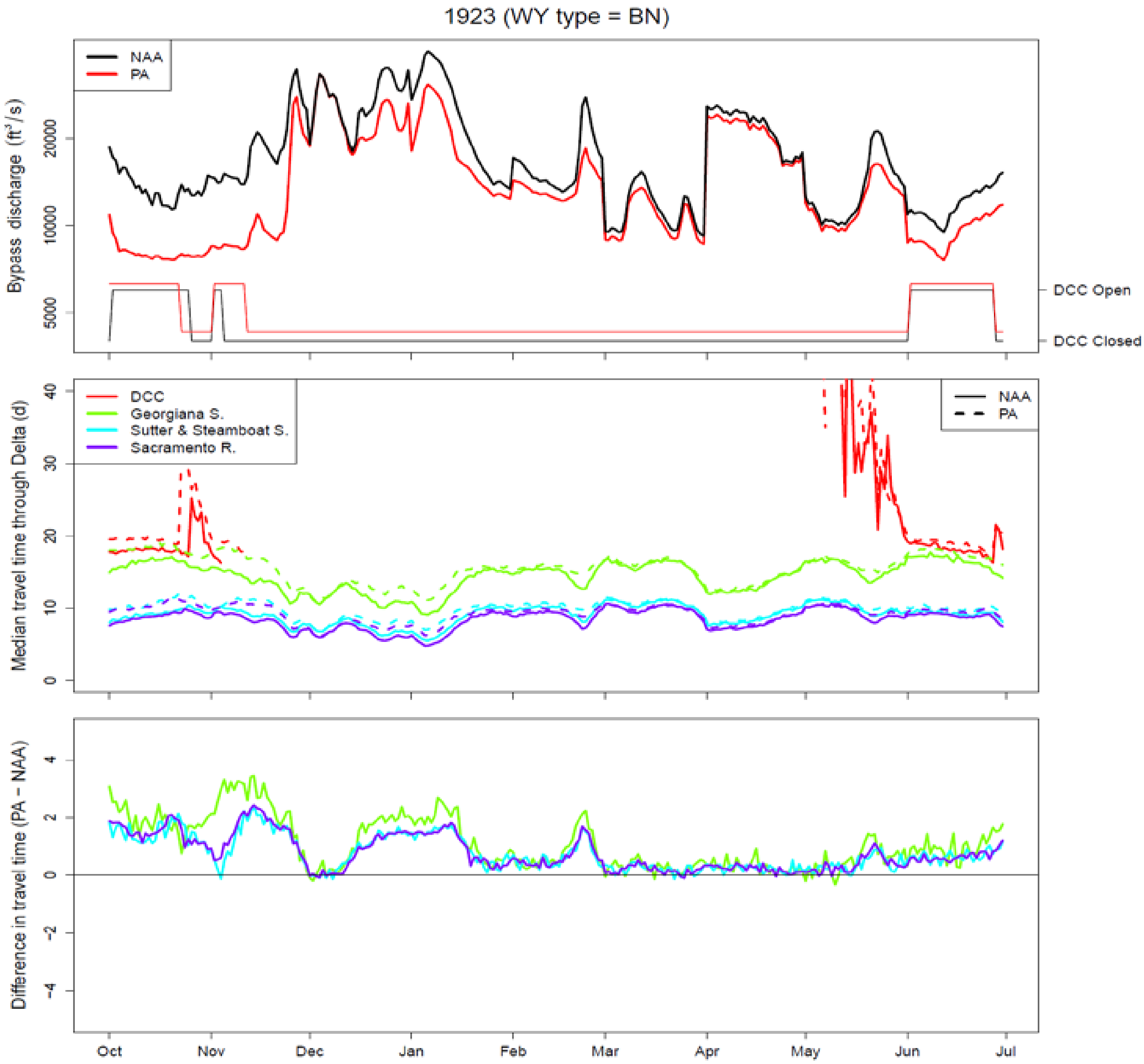


Figure 2-125. Travel time under the scenarios for BN water year 1923.

The top panel illustrates bypass flow in the Sacramento River at Freeport under the NAA (black line) and bypass flow after diversions under the PA (red line). The middle panel illustrates median travel time through Delta for all migratory routes in each scenario. The bottom panel illustrates median difference (PA-NAA) in travel time for each route.

During at least 75% of the years, juvenile Chinook salmon travel time will be increased under the PA compared to the NAA for all months of October through June (top panel, Figure 2-126). When comparing NAA to L1, travel time will be increased for at least 75% of the years under L1 (middle panel, Figure 2-126). The months with the largest increases in travel time for both the PA and L1 occur during the off-peak Chinook salmon migratory months of October, November, and June. During the peak Chinook salmon migratory window of December through April, February and March have the largest increases in travel time under the PA. The months with the smallest increase in travel time under the PA occur during April and May. The bottom panel (Figure 2-126) compares differences in travel time between the two PA scenarios and is not discussed further in this effects analysis because the focus for this analysis is on changes from baseline conditions (NAA compared to PA and/or L1).

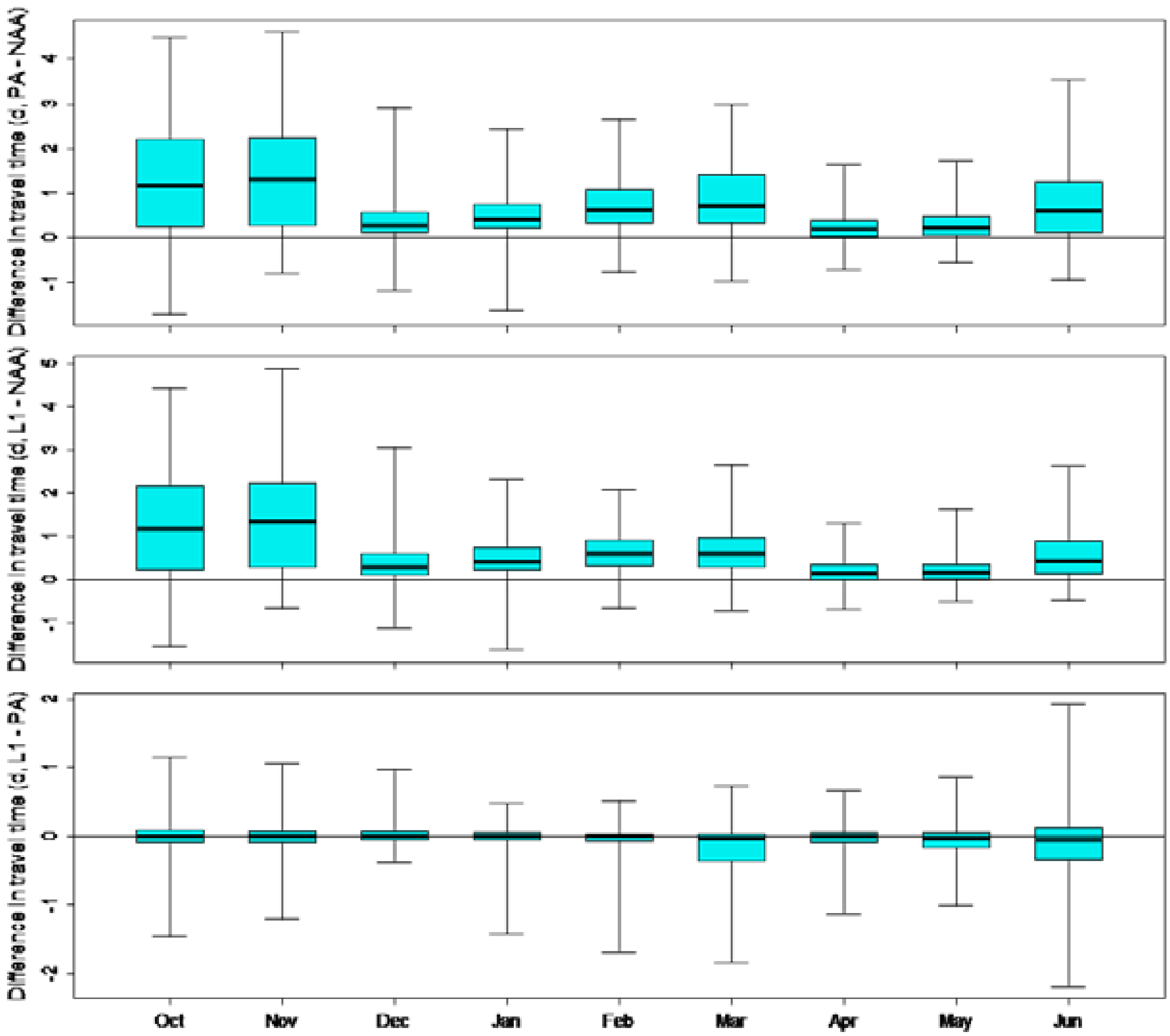


Figure 2-126. Boxplots of differences in median travel time through the Delta between the NAA, PA, and L1 scenario. Each box plot represents the distribution of daily travel time differences among years for a given month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

Lower velocities lead to increase in travel time, which can be an adverse effect on salmonid migration for the following reasons: increased predator encounter (Anderson et al. 2005, Muthukumarana et al. 2008, Cavallo et al. 2013), increased tidal excursion in transition reaches of the lower Sacramento River (Perry et al. 2016, Perry et al.2017b), increased entrainment into lower survival routes of the central Delta (Newman 2008, Kjelson et al. 1981, Perry et al. 2010) and reduced turbidities that likely benefit sight predators. We have examined how the PA is expected to reduce velocities in the north Delta, which will result in some increase in the adverse effects described above. Summaries of the differences in travel time between the NAA and PA are grouped by monthly operation of NDD criteria. October and November (Table 2-167) both fall under minimum bypass flows and December through June (Table 2-168) all fall under Level 1, 2, 3 diversions under the PA or Level 1 diversions only under L1. May and June each have their own unique diversion criteria, based on lowering export restrictions towards the end of the main salmonid migratory window (December through June). Differences in travel time under the PA are shown in Table 2-167 for October and November. Relatively large increases in travel time are experienced in these months because the PA bypass rules allow for greater levels of diversion under certain conditions.

Table 2-167. Change in Travel Time (Expressed as Days) Under the PA as Compared to the NAA Over All Water Year Types for October and November.

Month	Median increase in travel time (days)	Increase in travel time for middle 50% of years (interquartile)	Increase (or reduction) in travel time for 25% of years (minimum to first quartile)	Increase in travel time for 25% of years (third quartile to maximum)
October	1.2	0.24 to 2.2	0.24 to (-1.7)	2.2 to 4.5
November	1.3	0.28 to 2.2	0.28 to (-0.82)	2.2 to 4.6

Table 2-168. Change in Travel Time (Expressed as Days) Under the PA and L1 as Compared to the NAA Over All Water Year Types for December Through June.

Month	Median increase in travel time (days)	Increase in travel time for middle 50% of years (interquartile)	Increase (or reduction) in travel time for 25% of years (minimum to first quartile)	Increase in travel time for 25% of years (third quartile to maximum)
December (PA)	0.29	0.11 to 0.59	0.11 to (-1.2)	0.59 to 2.9
December (L1)	0.29	0.12 to 0.61	0.12 to (-1.1)	0.61 to 3.0
January (PA)	0.41	0.22 to 0.76	0.22 to (-1.6)	0.76 to 2.4
January (L1)	0.41	0.22 to 0.74	0.22 to (-1.6)	0.74 to 2.3
February (PA)	0.63	0.34 to 1.1	0.34 to (-0.76)	1.1 to 2.6
February (L1)	0.6	0.33 to 0.91	0.33 to (-0.66)	0.91 to 2.1
March (PA)	0.73	0.33 to 1.4	0.33 to (-0.97)	1.4 to 3.0
March (L1)	0.6	0.28 to 0.96	0.28 to (-0.7)	0.96 to 2.7
April (PA)	0.19	0.02 to 0.39	0.02 to (-0.73)	0.39 to 1.6
April (L1)	0.14	0.01 to 0.33	0.01 to (-0.68)	0.33 to 1.3

Month	Median increase in travel time (days)	Increase in travel time for middle 50% of years (interquartile)	Increase (or reduction) in travel time for 25% of years (minimum to first quartile)	Increase in travel time for 25% of years (third quartile to maximum)
May (PA)	0.23	0.05 to 0.47	0.05 to (-0.54)	0.47 to 1.7
May (L1)	0.17	0.02 to 0.33	0.02 to (-0.51)	0.33 to 1.6
June (PA)	0.62	0.12 to 1.3	0.12 to (-0.93)	1.3 to 3.5
June (L1)	0.43	0.14 to 0.89	0.14 to (-0.48)	0.89 to 2.6

The trends seen in through-Delta travel time are very similar to trends evident in travel time specific to each juvenile Chinook salmon migratory route: Sacramento mainstem (top panel, Figure 2-127), Sutter and Steamboat Sloughs (middle panel, Figure 2-127) and Georgiana Slough (bottom panel, Figure 2-127). Travel time under the PA for each migratory route is increased at least 75% of the time with the exception of April for Sutter and Steamboat Sloughs and Georgiana Slough. During April, travel time under the PA for those two migratory routes is increased at least 50% of the time and for 25% of the years travel time is reduced under the PA (Figure 2-127).

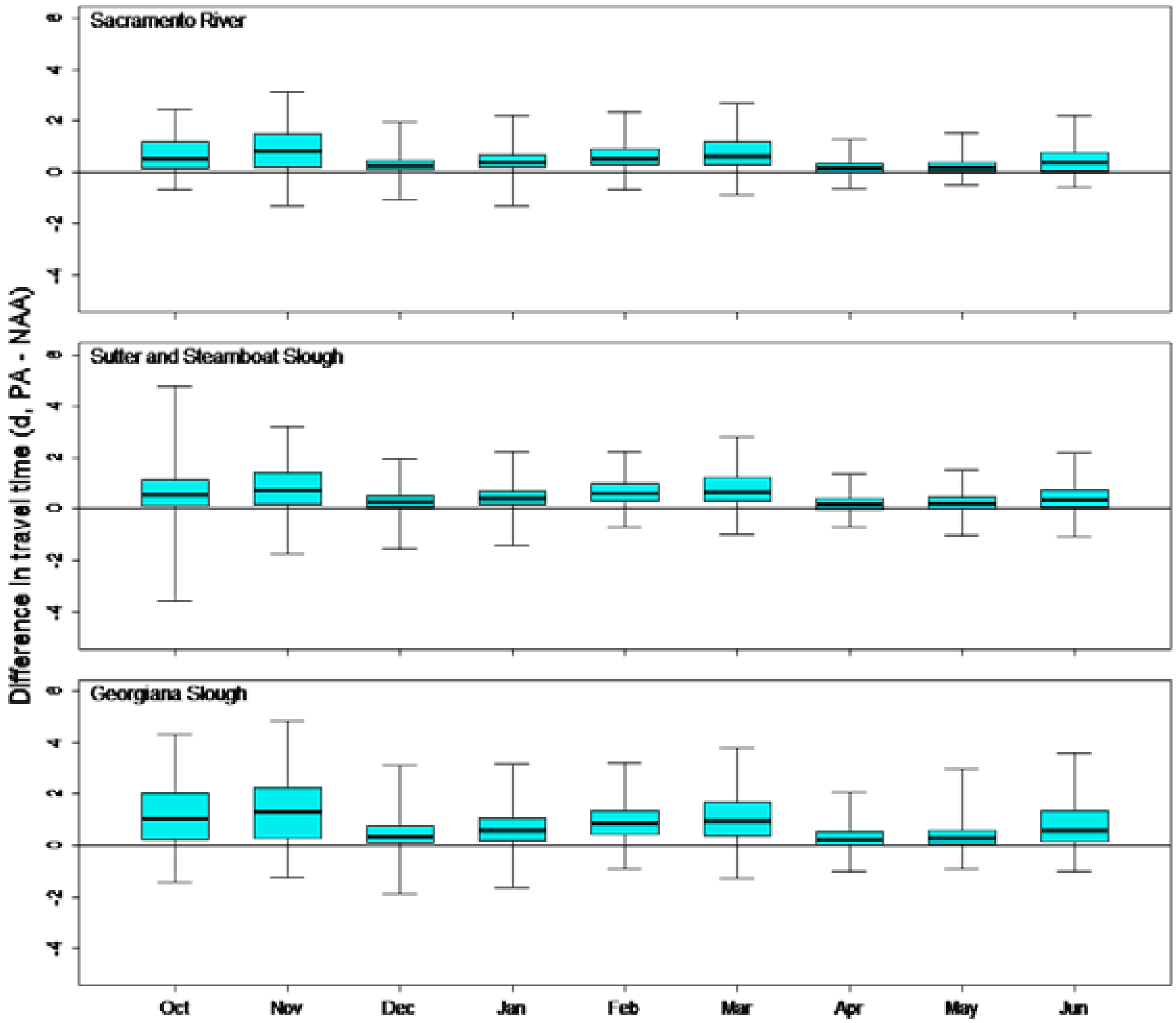


Figure 2-127. Boxplots of differences in median travel time through the Delta between the NAA and PA scenario for fish using different migration routes through the Delta.

Each box plot represents the distribution of daily travel time differences among years for a given month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

A summary of the travel time analysis is provided in Table 2-169.

Table 2-169. Summary of Travel Time Analysis.

Model	Overall Trends in Results
Channel Velocity Analysis	Under the PA, there were decreased velocities in the north Delta, increased velocities in the south Delta and no change in the DCC except for decreased velocities in June.
NDD bypass flows and smolt entrainment model	Under the PA, velocities were decreased downstream of the NDD resulting in more reverse flows and longer proportion of the day with reverse flows at the junction of Georgiana

Model	Overall Trends in Results
	Slough. Effects of reverse flows increased as operations changed from Level 1 through Level 3 and then to static operations during summer and fall months.
Perry Survival Model (Travel Time component)	Under the PA and L1, travel time increased under all months and was increased most during fall migratory months of October and November. During the common salmonid migratory months of December through June, February and March had the longest change in travel times and April the shortest change in travel times.

2.5.1.2.7.1.3.1 Winter-Run Exposure and Risk

Detailed spatial and temporal occurrence of winter-run Chinook salmon presence in the action area has been previously described in Section 2.4.3 Environmental Baseline and Appendix B. Here we present information specific to winter-run Chinook salmon rearing and migratory patterns in the Delta that better informs species exposure and risk to effects on travel time from the proposed NDD intake operations. We focus on exposure of winter-run juveniles based on their extended temporal and spatial distribution within the Delta both upstream of the NDD intakes (i.e., data from Sacramento trawl) and in the western-most Delta (i.e., data from Chipps Island trawl).

Winter-run Chinook salmon juvenile entrance into the Delta begins as early as October and extends through April. The majority of juveniles enter the Delta as immature smolt-sized fish (i.e., greater than 70 millimeters fork length (FL)). Studies indicate that winter-run Chinook salmon smolts may spend several weeks and/or months rearing in the lower Sacramento River, the Delta, and associated distributaries before outmigrating to the ocean. The largest proportion of outmigrants enter the Delta in November and December and exit the Delta in March at an average fork length of 111 mm (Table 2-170).

Based on sampling from Knights Landing (on the Sacramento River) and the Sacramento Trawl, entrance of winter-run Chinook salmon into the Delta is primarily driven by hydrology. The timing of fall/winter storm pulses that increase Sacramento River flow at Wilkins Slough to 14,000 cfs or greater correspond to observations of large migration events at Knights Landing (del Rosario et al. 2013). This initial migration event has been shown to include over 50 percent of the annual winter-run Chinook salmon population sampled at Knights Landing (del Rosario et al. 2013).

During years with fall or early winter pulse flows, juveniles may enter the Delta or Yolo Bypass at a smaller size (i.e., smaller than 70 millimeters FL). These smaller fish are believed to spend more time rearing in the Delta and floodplain habitats until outmigration to the ocean than their larger migrating counterparts (del Rosario et al. 2013). During these early seasonal storm events, winter-run Chinook salmon juveniles are expected to be in the Delta beginning in November or December in significant numbers. Thirty percent of the winter-run-sized smolt population typically is present in these two months (Figure 2-128).

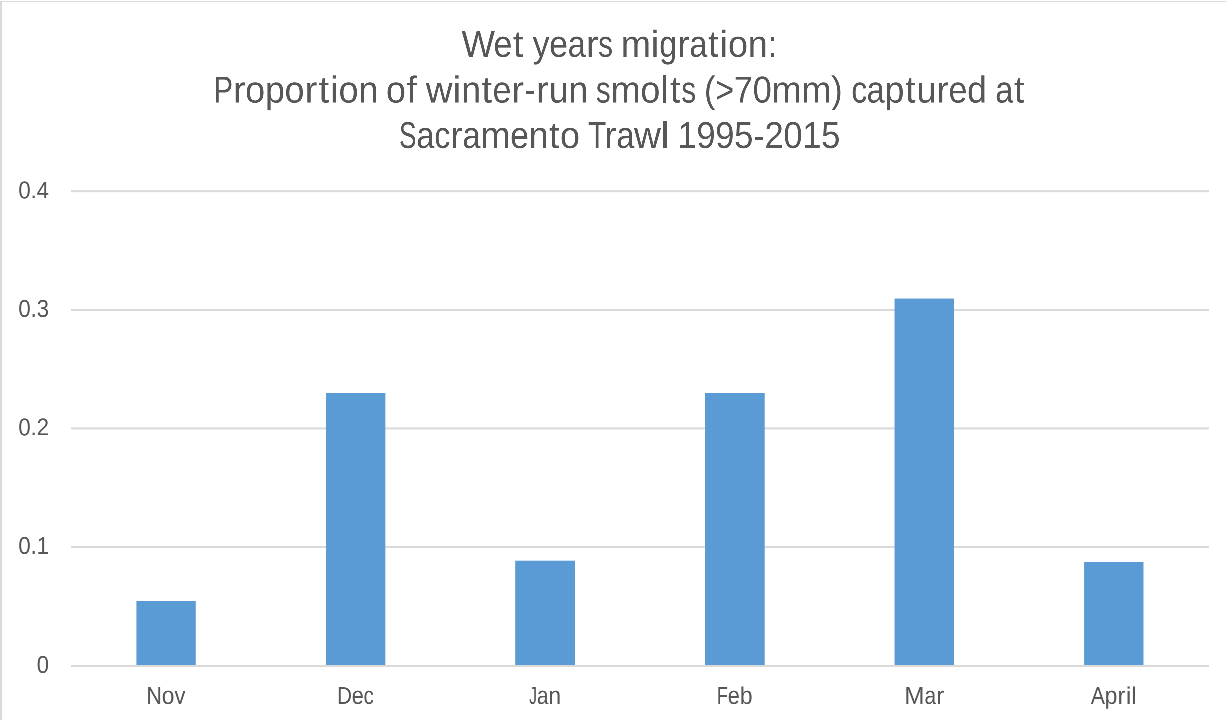


Figure 2-128. Catch of winter run at Sacramento Trawl based on years when a flow pulse upstream (14,000 cfs) occurred after December during wet years.

Juvenile winter-run Chinook salmon migration patterns are different in drier years due to different hydrologic conditions. When late fall/early winter river flows do not approach the 14,000 cfs threshold level, winter-run Chinook salmon rear upstream for several months and are observed further downstream after smaller increases in flow later in the winter. In such drier years, sampling shows that winter-run Chinook salmon juveniles enter the Delta primarily in February (Figure 2-129).

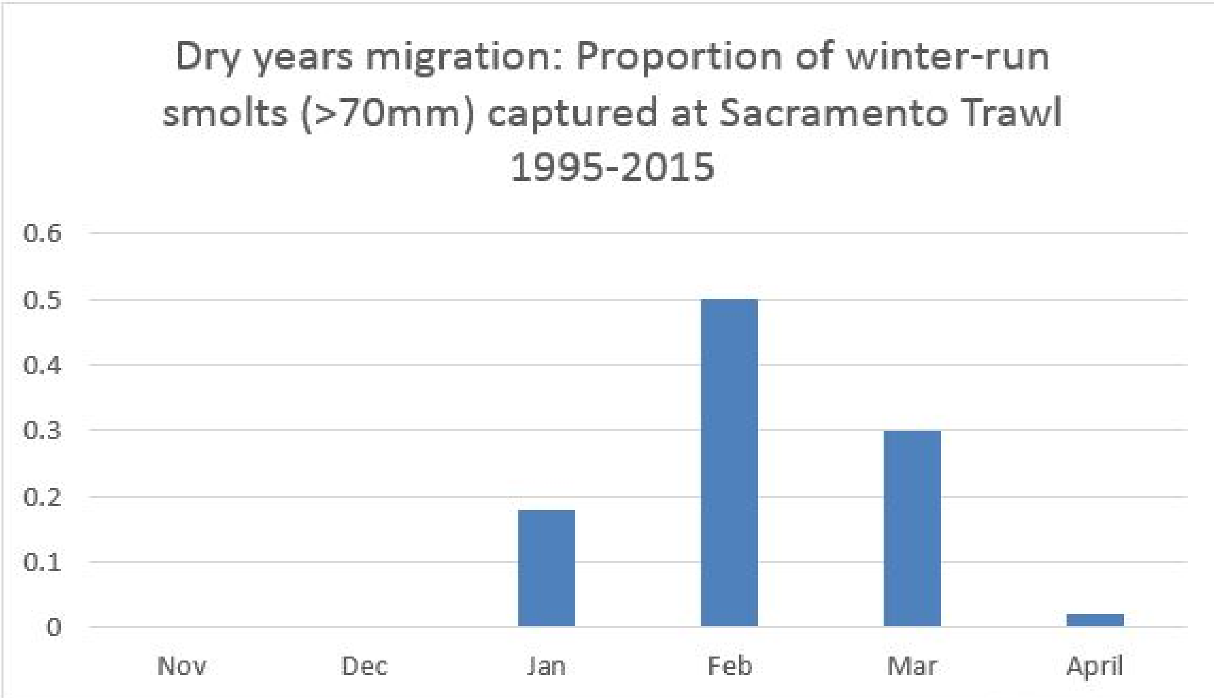


Figure 2-129. Catch of winter run at Sacramento Trawl based on years when a flow pulse upstream (14,000 cfs) occurred after December during dry years.

Table 2-170 shows the proportion of population sampled at Sacramento Trawl and Chipps Island regardless of hydrology or fish size. November is an important month for fry sized winter-run (<70 millimeters) in the Delta as 32% of the inter-annual population is sampled at Sacramento Trawl. This table encompasses the emigration into and out of the Delta for all winter-run sized (based on length criteria) fish and is useful for exposure and risk analysis that is not covered in the biological models that focus on smolt-sized migrants (e.g., DPM, Perry Survival Model, Newman survival model).

Table 2-170. Winter-run Population Based on Catch Per Unit Effort (CPUE) from Midwater Trawl at Chipps Island, Midwater and Kodiak Trawls at Sherwood Harbor Near Sacramento, Conducted by the Delta Juvenile Fish Monitoring Program (DJFMP), Stockton, CA USFWS.

Monitoring data years 1995-2015	High >30%		Medium 10-29%		Low 2-9%		Rare/None	
Sacramento Trawl (RM 55) (proportion of population)	Oct <1%	Nov 31.7%	Dec 31.5%	Jan 7.7%	Feb 14.4%	Mar 12%	Apr 2.7%	May --
Mean Fork Length (mm) (mean FKL range within years)	--	63 (47-73)	75 (62-99)	93 (77-118)	102 (93-115)	102 (93-110)	--	--
Chipps Island (proportion of population)	Oct --	Nov --	Dec <1%	Jan 3.3%	Feb 14.3%	Mar 66%	Apr 15%	May --

Mean Fork Length (mm) (mean FKL range within years)	--	--	87 (77-95)	107 (92-119)	113 (102-123)	111 (103-120)	117 (107-128)	--

Given the information above, the emigration window encompassing the majority of winter-run Chinook salmon spans from November through April. November and December are peak months for winter-run entry into the Delta at Sacramento. March is the month of peak presence regardless of hydrology; 66 percent of the sampled winter-run Chinook salmon population exited the Delta in March during the years 1995-2015 (Table 2-170). In drier years, February is the month of peak entrance into the Delta; 50 percent of the population entered the Delta in February of drier years (Figure 2-129). Overall, November through March are the most important Delta entry and exit months for winter-run Chinook salmon. This includes fry-sized migrants (i.e., smaller than 70 mm FL) which can comprise up to 30 percent of the annual Delta population in November of wet years (Table 2-170). Note that winter-run juveniles are entering the Delta in Sacramento at fairly large sizes (e.g., mean fork length 63 mm in November and continue to grow until they exit at Chipps Island at mean fork length of 117 m in April; Table 2-170). This provides some evidence that a portion of winter run Chinook salmon are likely rearing and smoltifying in the Delta.

Channel Velocity Differences in North Delta

The velocity analysis revealed that, in the north Delta, the median velocities are reduced under the PA throughout the winter-run Chinook salmon emigration period (December through April) and across all water year types (BA Table 5.4-9 in Appendix C of this Opinion). Velocities during the month of November were not examined in this analysis. Changes in migratory and habitat conditions in November are examined with other methods and models within this biological opinion (Section 2.5.1.2.7.1.2 NDD Bypass Flows and Smolt Entrainment Analysis, and Section 2.5.1.2.7.1.3 Perry Survival Model). The reduced velocities in the north Delta suggest outmigrating winter-run smolts will experience longer travel time and, therefore, higher mortality during the entirety of their migration period for which velocity data are available.

Specifically, in the north Delta, results for December in below normal, above normal, and wet water year types show that median velocity for the Sacramento River downstream of the NDD, including Steamboat and Sutter Sloughs, are 5 to 15 percent lower for the PA (BA Table 5.4-9 in Appendix C of this Opinion). December is particularly important for winter-run Chinook salmon in these wetter year types.

During January and February, median velocities are consistently lower by five percent or more under the PA for the Sacramento River downstream of the NDD, including Steamboat and Sutter Slough (BA Table 5.4-9 in Appendix C of this Opinion), with the biggest changes occurring in January of wet and above normal years ranging from a 10 to 18 percent reduction in velocities. These are important migratory and rearing months for winter-run.

The greatest velocity reductions for the December through April period occur in March when velocities are reduced for the Sacramento River downstream of the NDD, including Steamboat and Sutter Sloughs, by 10 percent or more in all water year types except critical years (BA Table 5.4-9 in Appendix C of this Opinion). Velocity reductions in this section of the Delta in March would negatively affect the travel time and increase predation risk of outmigrating smolts during the month of peak abundance of winter-run exiting the Delta.

While the magnitude of velocity reductions in April are not as large as in earlier months, the reductions for PA operations range from 5 to 10 percent for these north Delta locations (BA Table 5.4-9 in Appendix C of this Opinion). This can potentially affect later winter-run Chinook salmon outmigrants, which are an important component of the population diversity.

An analysis was done to look at changes in differences in the magnitude of negative velocities (flow reversing) between scenarios (BA Table 5.4-10 in Appendix C of this Opinion). This analysis recognizes that, in the tidal Delta, velocities are not always seaward and can become slack or negative during the day. This affects fish migration as fish may be advected back upstream during flood tide, hold in the water column or a side bank or exert more energy to continue seaward all affecting travel time during active outmigration.

In the north Delta, increase in flow reversals downstream of Georgiana Slough are of concern for migrating salmonids. The BA velocity analysis indicated increased negative velocities under the PA during important winter run Chinook salmon migratory months of February through April upstream and downstream of Georgiana Slough on the Sacramento River (BA Table 5.4-10 in Appendix C of this Opinion). Increased negative velocity can range up to 98% more during the month of March under the PA, though most increases range between 7% to 30%. Increases in flow reversals would likely reduce the survival probability of outmigrating smolts by moving them back upstream, increasing their exposure to junctions that lead to migratory routes of lower survival, such as in Georgiana Slough. Under the PA, there is no operating criteria to avoid reverse flows in the lower Sacramento River through reservoir releases. Reservoir releases have not historically been used to reduce the occurrence of reverse flow or negative velocities at the junction of Georgiana Slough. There is no water quality or biological opinion mandate to use reservoir releases under baseline conditions to avoid reverse flows in the lower Sacramento River. The proposed action, however, does specify that diversion operations will be managed so that the new north Delta exports cannot increase the frequency, magnitude or duration of reverse flows above baseline in the Sacramento River at the Georgiana Slough junction. As described below, the results of the modeling do not explicitly capture this operational constraint.

The third part of this hydrodynamic analysis looked for differences in modeling results between NAA and PA in the proportion of time each day that velocity was negative in north Delta channels. In the north Delta, the modeling results show that proportion of day with reverse flows increases under the PA especially in Steamboat Slough and downstream of Georgiana Slough (BA Table 5.4-11 in Appendix C of this Opinion). This is yet another analysis that corroborates that operating strictly according to the NDD bypass rules does not meet the PA operational constraint of not increasing the frequency, duration or magnitude of reverse flows and real-time monitoring and operations will be necessary to meet that operational constraint. The BA, however, did not provide any specific information or modeling simulation on how operations would be managed to meet that operational constraint in real time. In addition, a recent review of an independent science panel commented that it is highly unlikely operations could effectively model and control this criteria in real time with operational changes (Independent Review Panel Report 2016). Therefore, we have insufficient information to determine that this operational constraint is reasonably certain to occur. However, in the May 2016 Revised PA, DWR committed to Delta habitat restoration at a level that RMA Bay-Delta modeling indicates could prevent exacerbation of reverse flows in the north Delta due to the PA by changing the tidal prism in the Delta (see Section 2.5.1.2.7.1.2 NDD Bypass Flows and Smolt Entrainment Analysis).

Channel Velocity Differences in Central Delta

In the central Delta at DCC, velocities were very similar between the NAA and PA scenarios in December through April. Based on the velocity analysis, travel time and predation risk for outmigrating smolts in the central Delta are not expected to change under the PA. Velocities in Georgiana Slough were not examined in this analysis though it is an important migratory route that is examined in other models in this biological opinion. Specifically, the NDD bypass and smolt entrainment model assesses changes in proportion of smolts using Georgiana Slough, and the DPM and Perry Survival Model assess differences in survival using this migratory route.

Channel Velocity Differences in South Delta

In the south Delta, median velocities generally increase for PA operations. In the San Joaquin River, velocities for the PA are often substantially greater in most months, typically by at least 15% and up to 54%, depending on month and water year type (BA Table 5.4-9 in Appendix C of this Opinion). This is mainly due to the presence of the HOR in the PA. Results for Old River downstream of the pumping facilities show a similar level of increase in velocity for the PA in December through March due to reduced south Delta pumping (BA Table 5.4-9 in Appendix C of this Opinion). This is expected to affect the proportion of winter-run juveniles that have entered the interior Delta by reducing risk of entrainment into the South Delta facilities. When velocities in Old River are positive (heading seaward), reduced south Delta pumping under the PA has the positive effect of not increasing entrainment risk towards the pumps. April has reduced velocities in Old River downstream of the pumping facilities in the BN to Critical water years (BA Table 5.4-9 in Appendix C of this Opinion). This would mean that winter-run Chinook salmon in the South Delta during April could experience a greater risk of entrainment into the South Delta pumping facilities under the PA for BN to Critical water years.

While these increases in velocity would be expected to decrease the travel time for any outmigrating juvenile salmonids, the San Joaquin River and Old River are not preferred migration routes for winter-run Chinook salmon. Furthermore, only a small portion of the population is expected to benefit from the increased velocity. Acoustic tag studies during 2006 to 2009 showed that approximately 10-35% of outmigrating Chinook salmon smolts from the Sacramento River entered the interior Delta (Perry et al. 2010). Additionally, the small proportion of the population remaining in the Delta after March would not experience velocity increases under the PA since velocities are similar or reduced compared to the NAA in April.

During critical years or any periods when the median velocity is negative (reverse flow), there is little difference in median negative velocity between the scenarios except for less negative velocity in the San Joaquin River downstream of the HOR (BA Table 5.4-10 in Appendix C of this Opinion). In this channel, negative velocities are reduced from 12 to 33% during winter-run outmigration months of January to April. Additionally, there are more negative velocities in Old River upstream of the South Delta export facilities indicating less water being diverted to the pumps; therefore, this is a positive effect under the PA. These are likely effects from having the HOR gate in place under the PA. However, the PA does not offer a benefit or an adverse effect to juvenile winter-run migrants entering the San Joaquin River from Mokelumne River via DCC or Georgiana Slough (i.e., north and interior Delta). This is the likely entry point of winter-run Chinook salmon into the San Joaquin River and there was very little change in negative velocities between the scenarios at this junction (BA Table 5.4-10 in Appendix C of this Opinion). Likewise, when median velocities are negative, the PA does not provide a benefit or adverse effect for winter-run in the Old River downstream of the pumping facilities with the exception of decreased negative velocities (reverse flow) in January and March of wetter water year types. When flow is reversing in north, central or south Delta channels it is generally a negative effect on salmonid migratory success. This analysis indicates that adverse effects of negative velocities are generally not improved under the PA with some minor exceptions (BA Table 5.4-10 in Appendix C of this Opinion).

The third part of the velocity analysis was proportion of day with negative velocities. In the south Delta, the San Joaquin River downstream of the HOR and Old River upstream of the south Delta export facilities both showed positive effects under the PA (BA Table 5.4-11 in Appendix C of this Opinion). There were a couple of water years in January, February, and March where the PA reduced proportion of day with reverse flow by 6% to 16%.

Overall, increases in velocity in the south Delta locations should reduce the risk of entrainment into the south Delta facilities, which would beneficially affect a small proportion of winter-run Chinook salmon.

Effect of the NDD Bypass Rules on Winter-run Chinook Salmon Migration (Perry et al. 2016 NDD Bypass Flows and Smolt Entrainment Model)

As noted in the winter-run temporal information (Figure 2-128 to 2-129 and Table 2-170), the Delta migration period generally occurs between November and April. Under the bypass rules (BA Table 3.3-2 in Appendix A2 of this Opinion), November would not have a protective bypass flow under normal circumstances (i.e., there would generally be no restrictions on NDD diversions other than minimum bypass flows) and hence winter-run Chinook salmon would be subject to reverse flows into migratory routes with reduced survival probabilities. Under the PA, only December through June of the salmonid migratory period have additional restrictions on NDD diversions to provide some degree of flow needed for habitat, rearing and migration. In July through November, there would generally be no restrictions on NDD diversions other than minimum bypass flows to provide for in river flow to meet water quality criteria but not specifically for juvenile salmonid protection. However, if flow in November becomes sufficient through storm runoff events to trigger winter-run emigration towards the Delta, a pulse protection will apply that will limit diversions to low level pumping for a certain amount of days or until fish presence is not detected based on real-time management criteria. Without this protection, early emigrating winter-run would be subject to some of the more extreme diversion levels allowed, probability of reverse flows would increase, and winter-run Chinook salmon would face greater risk of entrainment into interior Delta and overall lowered survival.

December and April represent the rest of the winter-run emigration through the Delta. This block of time falls under identical operations rules once initial pulse protection ends, starting with Level 1 operation, and increasing to Level 2 or Level 3 operations when flow criteria is met. Level 1 operations provide the most protection or least change in riverine flows from the NAA scenario. Under Level 1 operations, the increase in probability of a flow reversal remains under 30% and the increase in the proportion of the day with a flow reversal remains under 5%. Under Level 2, the probability of a flow reversal can be as high as 80% with a ~4-6% increase in the proportion of the day with a flow reversal; while under Level 3, the probability of a flow reversal is up to 100%, with the increase in the proportion of the day with a flow reversal up to 15% (Figure 2-120).

Based on the adverse effects Level 2 and Level 3 diversions have on riverine conditions that influence migration routing, travel time, and overall survival, winter-run would be less impacted under low-level-pumping and Level 1 operations.

Perry Survival Model – Travel Time Component

The Perry Survival Model (Perry 2016) helps to quantify the actual travel time that smolts will experience under the different Delta inflows between scenarios. Travel time through the Delta will be increased under the PA during the migration period for winter-run Chinook salmon. February and March show the largest increase in travel time, which corresponds with when approximately 80% of the overall juvenile migrants are exiting the Delta. For example, travel time under the PA will increase from 0.33 days to 1.4 days during February and March for 50% of the years (Table 2-168). During 25% of the years, travel time will increase during February and March from 1.1 to 3 days under the PA (Table 2-168). Travel times are also increased and much more variable in October and November than in other months (Table 2-167). These results indicate that there may be a wide range of travel time impacts to winter-run Chinook salmon juveniles during important migration months.

Since travel time will affect survival in the Delta, a more thorough look at winter-run survival under the different operating levels by month and water year type is included in the Perry 2017 survival model. The Perry 2017 survival model is best suited to determine overall effects to winter run Chinook salmon due to PA operations in the North Delta. The Perry 2017 survival model encompasses the key stressors that affect overall migratory success in the Delta, travel time, route selection and survival probabilities based on Freeport inflows. While we identify the individual stressors, the effects of the PA on travel time are best evaluated holistically to determine an overall migratory success (survival) or failure (mortality).

Based on the travel time analysis in Section 2.5.1.2.7.1.3 Perry Survival Model (Travel Time Component), operations under the PA would increase travel time throughout the winter-run migratory period with the biggest adverse changes in February and March, which are peak months for winter-run Chinook salmon presence in the Delta. Travel times for winter run Chinook salmon fry sized fish (<70 mm) could be expected to increase particularly in the month of November. NMFS therefore expects that the reduction in flow as a result of the PA will impact rearing habitat and routing for fry sized fish and increase travel time for outmigrating smolts. This will result in an adverse effect to a high proportion of rearing and outmigrating winter-run Chinook salmon.

2.5.1.2.7.1.3.2 Spring-Run Exposure and Risk

Spring-run juveniles enter the Delta as early as December and as late as May based on Sacramento Trawl monitoring over the last 20 years (Table 2-171). Peak entrance into the Delta is in April when 63% of the population enters the Delta based on sampling between 1995 and 2015 (Table 2-171). Monitoring at Chipps Island indicates that exit from the Delta occurs during a smaller window from March through May (Table 2-171). Peak exit from the Delta occurs in April as well and it is assumed the majority of the population (over 60%) migrates quickly through the Delta during the month of April because there is little change in fork length, averaging 86 mm on entrance to Delta and 91 mm upon exit from Delta. Spring run are identified using length at date criteria for juvenile Chinook salmon (Fisher 1992). There is a segment of the population (~16%) that enters earlier from December through March under 70 mm and would likely spend weeks to months rearing in the Delta until exiting during or after the month of March (Table 2-171).

Table 2-171. Spring-run Emigration Through the Delta 1995-2015.

Monitoring Location	Data	Month											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Sacramento Trawl	Percent Population Present	0	0	7	3	6	17	63	5	0	0	0	0
	Mean Size (Fork length) Size Range	NA	NA	38 (36-40)	48 (44-58)	59 (52-65)	75 (68-84)	86 (68-84)	86 (82-92)	NA	NA	NA	NA
Chipps Island Trawl	Percent Population Present	0	0	0	0	0	20	67	13	0	0	0	0
	Mean Size (Fork length) Size Range	NA	NA	NA	NA	NA	83 (74-94)	91 (87-99)	101 (95-103)	NA	NA	NA	NA

KEY	Degree of rearing expected	High >20%	Medium 10-20%	Low 2-10%	Rare to None <2%

Note: Inter-annual proportion of population sampled at Midwater Trawl at Chipps Island, Midwater and Kodiak Trawls at Sherwood Harbor near Sacramento, conducted by The Delta Juvenile Fish Monitoring Program (DJFMP), Stockton, CA, USFWS.

Channel Velocity Differences in North Delta

The velocity analysis revealed that, in the north Delta, the median velocities are reduced under the PA throughout the spring-run Chinook salmon emigration period (December through May) (Table 2-171) and across all water year types (BA Table 5.4-9 in Appendix C of this Opinion). The reduced velocities in the North Delta suggest outmigrating spring-run smolts will experience longer travel time and, therefore, higher mortality during the entirety of their migration period for which velocity data are available.

Specifically, in the North Delta, results for December in below normal, above normal, and wet water year types show that median velocity for the Sacramento River downstream of the NDD, including Steamboat and Sutter Sloughs, are 5 to 15 percent lower for the PA (BA Table 5.4-9 in Appendix C of this Opinion). December is particularly important for spring-run Chinook salmon fry sized fish (<70 mm) that are expected to be present in these wetter year types. USFWS monitoring detects 7% of inter annual migrants during this month (Table 2-171).

During January and February, median velocities are consistently lower by five percent or more under the PA for the Sacramento River downstream of the NDD, including Steamboat and Sutter Slough (BA Table 5.4-9 in Appendix C of this Opinion), with the biggest changes occurring in January of wet and above normal years ranging from a 10% to 18% reduction in velocities. These could be months when spring-run Chinook salmon are rearing in the Delta. Sacramento Trawl detects 9% of spring run inter-annual migrants during January and February (Table 2-171).

The greatest velocity reductions for the December through May spring-run migratory period occur in March when velocities are reduced for the Sacramento River downstream of the NDD, including Steamboat and Sutter Sloughs, (BA Table 5.4-9 in Appendix C of this Opinion) by 10% or more in all water year types except critical years. Velocity reductions in the north Delta during March would increase travel time and predation encounter for 17% to 20% of outmigrating smolts when spring-run Chinook salmon smolts (>70 mm) first enter the Delta (Table 2-171).

The magnitude of velocity reductions in April are not as large as in earlier months (most are under 5%), some of the larger velocity reductions for PA operations in April range from 5% to 10% (BA Table 5.4-9 in Appendix C of this Opinion). This would affect the majority of spring-run Chinook salmon outmigrants as over 60% of the population is detected during April (Table 2-171).

During May, the end of spring-run Chinook salmon migration, velocity reductions are greater and more frequent than April but not as prevalent or extreme as the earlier migratory and rearing months of December through March (BA Table 5.4-9 in Appendix C of this Opinion). USFWS trawls detect 5% to 15% inter-annual migration into and out of the Delta during this month (Table 2-171).

An analysis was done to look at changes in differences in the magnitude of negative velocities (flow reversing) between scenarios (BA Table 5.4-10 in Appendix C of this Opinion). This analysis recognizes that, in the tidal Delta, velocities are not always seaward and can become slack or negative during the day. This affects fish migration as fish may be advected back upstream during flood tide, hold in the water column or a side bank or exert more energy to continue seaward, all affecting travel time during active outmigration. As discussed in Section 2.5.1.2.7.1.2 NDD bypass flows and smolt entrainment analysis, there is insufficient information to analyze the PA operational constraint regarding no increase in reverse flows.

In the north Delta, the velocity analysis indicated increased negative velocities under the PA during important spring run Chinook migratory months of February through May upstream and downstream of Georgiana Slough on the Sacramento River (BA Table 5.4-10 in Appendix C of this Opinion). Increased negative velocity can range up to 98% more during the month of March under the PA though most increases range between 7% to 30%. Increases in flow reversals would likely reduce the survival probability of outmigrating smolts by moving them back upstream, increasing their exposure to junctions that lead to migratory routes of lower survival, such as in Georgiana Slough.

The third part of this hydrodynamic analysis looked for differences in modeling results between NAA and PA in the proportion of time each day that velocity was negative in north Delta channels. In the north Delta, the modeling results show that proportion of day with reverse flows increases under the PA especially in Steamboat Slough and downstream of Georgiana Slough (BA Table 5.4-11 in Appendix C of this Opinion).

The velocity analysis indicates that the majority of spring run Chinook salmon will experience conditions in the north Delta as a result of the PA that will increase travel time resulting in adverse effects.

Channel Velocity Differences in Central Delta

In the central Delta at DCC, velocities were very similar between the NAA and PA scenarios in December through May. Based on the velocity analysis, travel time and predation risk for outmigrating smolts in the central Delta are not expected to change under the PA. Velocities in Georgiana Slough were not examined in this analysis though it is an important migratory route that is examined in other models in this biological opinion. Specifically, the NDD bypass flows and smolt entrainment model assesses changes in proportion of smolts using Georgiana Slough, and the DPM and Perry Survival Model assesses differences in survival using this migratory route.

Channel Velocity Differences in South Delta

In the south Delta, median velocities would generally increase under PA operations. In the San Joaquin River, velocities for the PA are often substantially greater in most months, typically by at least 15% and up to 54%, depending on month and water year type (BA Table 5.4-9 in Appendix C of this Opinion). This is mainly due to the presence of the HOR in the PA. Results for Old River downstream of the pumping facilities show a similar level of increase in velocity under the PA in December through March due to reduced south Delta pumping. This is expected to affect the proportion of spring-run juveniles that have entered the interior Delta by reducing risk of entrainment into the South Delta facilities. When velocities in Old River are positive (heading seaward), reduced south Delta pumping under the PA has the positive effect of not increasing entrainment risk towards the pumps. April and May have reduced velocities in Old River downstream of the pumping facilities in the BN to Critical water years. This would mean that spring-run Chinook salmon in the South Delta during April and May would experience a greater risk of entrainment into the South Delta pumping facilities under the PA for BN to Critical water years.

While these increases in velocity would be expected to decrease the travel time for any outmigrating juvenile salmonids, the San Joaquin River and Old River are not preferred migration routes for spring-run Chinook salmon. Furthermore, only a small portion of the population is expected to benefit from the increased velocity. Acoustic tag studies during 2006 to 2009 showed that approximately 10-35% of outmigrating Chinook salmon smolts from the Sacramento River entered the interior Delta (Perry et al. 2010). Spring run are most prevalent in the Delta during the month of April and the majority would not experience velocity increases under the PA since velocities are similar or reduced compared to the NAA in April and May. The experimental population of spring run and/or spring running fish would sometimes benefit from increased velocities but the majority of outmigrating spring run in the south Delta during April and May would experience more negative velocities in Old River downstream of the pumping facilities about as often as they would experience more positive velocities as it varies by water year type (BA Table 5.4-9 in Appendix C of this Opinion). For those spring run fish that outmigrate from the San Joaquin River, the PA would provide beneficial flows downstream of the HOR in all months and water years.

During critical years or any periods when the median velocity is negative (reverse flow), there is little difference in median negative velocity between the scenarios except for less negative velocity in the San Joaquin River downstream of the HOR (BA Table 5.4-10 in Appendix C of this Opinion). In this channel, negative velocities are reduced from 12 to 33% during spring-run outmigration months of January to May. Additionally, there are more negative velocities in Old

River upstream of the South Delta export facilities indicating less water being diverted to the pumps; therefore, this is a positive effect under the PA. These are likely effects from having the HOR gate in place under the PA and would most benefit spring run juveniles out migrating from the San Joaquin River tributaries. However, for Sacramento basin spring run juveniles, the PA does not offer a benefit or an adverse effect to spring-run migrants entering the San Joaquin River from Mokelumne River via DCC or Georgiana Slough (i.e., north and central Delta). This is the likely entry point of the majority of spring-run Chinook salmon into the San Joaquin River and there was very little change in negative velocities between the scenarios at this junction. Likewise, when median velocities are negative, the PA does not provide a benefit or adverse effect for spring-run in the Old River downstream of the pumping facilities with the exception of decreased negative velocities (reverse flow) in January and March of wetter water year types. When flow is reversing in north, central, or south Delta channels it is generally a negative effect on salmonid migratory success. This analysis indicates that adverse effects of negative velocities are generally not improved under the PA with some minor exceptions.

The third part of the velocity analysis was proportion of day with negative velocities. In the south Delta, the San Joaquin River downstream of the HOR and Old River upstream of the south Delta export facilities both showed positive effects under the PA (BA Table 5.4-11 in Appendix C of this Opinion). There were a couple of water years in January, February, and March when the PA reduced proportion of day with reverse flow by 6% to 16%.

Overall, increases in velocity in certain south Delta locations should reduce the risk of entrainment into the South Delta facilities, which would beneficially affect a small proportion of spring-run Chinook salmon from the Sacramento basin and a larger proportion of spring run juveniles that may enter from the San Joaquin basin. However, when the majority of the spring run Chinook salmon population (60% to 80%) is expected to be in the Delta during April and May (Table 2-171), velocities in Old River downstream of the south Delta facilities are improved in wetter year types but are more negative in drier water year types (BA Tables 5.4-9 to 5.4-11 in Appendix C of this Opinion). This could increase entrainment into the south Delta facilities as hydrologic conditions are more negative in the drier years.

Effect of NDD Bypass Rules on Spring-run Chinook Salmon Migration (Perry et al. 2016 NDD Bypass Rlows and Smolt Entrainment Model)

As noted in the spring-run temporal distribution tables (Table 2-171), the Delta migration period generally occurs between December and May.

Under the PA NDD bypass rules, December and April fall under identical operations rules once initial pulse protection ends; starting with Level 1 operation, and increasing to Level 2 or Level 3 operations when flow criteria are met. Of the three main operating levels, Level 1 operations provide the most protection or least change in riverine flows from the NAA scenario. Under Level 1 operations, the increase in probability of a flow reversal remains under 30% and the increase in the proportion of the day with a flow reversal remains under 5%. Under Level 2, the probability of a flow reversal can be as high as 80% with a ~4-6% increase in the proportion of the day with a flow reversal; while under Level 3, the probability of a flow reversal is up to 100%, with the increase in the proportion of the day with a flow reversal up to 15% (Figure 2-120). The majority of spring run-Chinook salmon will be in the Delta during these months ranging from 87% to 95% (Table 2-171).

May has a unique set of NDD bypass rules that is slightly less protective than the diversion rules in December through April because Level 2 or 3 could be enacted if bypass flow criteria have been met. 5% to 13% of spring run Chinook salmon smolts are expected to be in the Delta during this month (Table 2-171). They may experience slightly longer travel times than smolts traveling during earlier months given the same inflow at Freeport. This would be due to lower velocities that may result from less restrictive diversions as defined by the NDD bypass rules (BA Table 5.4-11 in Appendix C of this Opinion).

Based on the adverse effects Level 2 and Level 3 diversions have on riverine conditions that influence migration routing, travel time, and overall survival, spring-run would be less impacted under low level pumping and Level 1 operations. Additionally, just based on the NDD bypass rules and no other constraints to diversions, spring run Chinook salmon smolts that are in the Delta during May will have slightly longer travel times than smolts who migrate out earlier. This could result in higher mortality rates for the late migrating spring run Chinook salmon smolts that are an important part of the species life history diversity.

Perry Survival Model – Travel Time

The Perry 2017 survival model helps to quantify the actual travel time that smolts will experience under the different Delta inflows between scenarios. Travel time through the Delta will be increased under the PA during the migration period for spring-run Chinook salmon. February and March show the largest increase in travel time, which corresponds with when approximately 20% of the overall juvenile migrants are exiting the Delta. For example, travel time under the PA will increase from 0.33 days to 1.4 days during February and March for 50% of the years (Table 2-168). During 25% of the years, travel time will increase during February and March from 1.1 to 3 days under the PA (Table 2-168). Travel times are also increased in key migratory months of April and May when 68% to 80% of spring run are expected to be in the Delta (Table 2-171). Travel time differences in April and May are less than in the other spring run migration months. In April travel time for 50% of years will increase from 0.02 days to 0.39 days and in May from 0.05 days to 0.47 days (Table 2-168). During 25% of years, travel time will increase from 0.39 days to 1.6 days and 0.47 days to 1.7 days in April and May, respectively (Table 2-168). During the other 25% of years, travel time differences under the PA will range from a slight increase 0.02 to a reduction of 0.73 days and an increase of 0.05 days to a reduction of 0.54 days during April and May, respectively (Table 2-168).

Since travel time will affect spring-run survival in the Delta, a more thorough look at spring-run survival under the different operating levels by month and water year type is included in the Perry Survival Model. The Perry 2017 survival model is best suited to determine overall effects to spring run Chinook salmon due to PA operations in the North Delta. The Perry Survival Model encompasses the key stressors that affect overall migratory success in the Delta, travel time, route selection, and survival probabilities under Freeport inflows. While we identify the individual stressors, the effects of the PA on travel time are best evaluated holistically to determine an overall migratory success (survival) or failure (mortality).

Based on the travel time analysis in Section 2.5.1.2.7.1.3 Perry Survival Model (Travel Time Component), operations under the PA would increase travel times throughout the spring-run migratory period with the biggest increases in February and March, which are important migratory months for spring-run Chinook salmon juvenile diversity in the Delta. Increases in travel times for spring- run Chinook salmon fry sized fish (<70 mm) could be expected particularly in the month of February. April is the main migratory month of spring run Chinook salmon smolts and travel time differences between scenarios in April were modest for 75% of the years ranging from 0.39 days increase to 0.73 days decrease under the PA. The 25% of years with the greatest increase in April under the PA ranged up to 1.6 days (Table 2-168). Likewise, in May, travel time for 75% of years increased under the PA up to 1.7 days. Although the effect of increase in travel time for these key migratory months are not substantial, it is still an adverse effect of the PA. Additionally, when spring run Chinook salmon are mostly present in the Delta during April and May, there was not a substantial benefit in south Delta velocities and sometimes in drier years there was an increase in entrainment risk at the south Delta facilities. NMFS therefore expects that reduction in flow as a result of the PA will increase travel time for the majority of outmigrating spring-run smolts. This will result in an adverse effect to a high proportion of rearing and outmigrating spring-run Chinook salmon.

2.5.1.2.7.1.3.3 Steelhead Exposure and Risk

Wild CCV Steelhead juveniles enter the Delta as early as December and as late as June based on Sacramento Trawl monitoring from 1998 through 2016 (Figure 2-125). All hatchery produced steelhead since 1998 have been adipose fin clipped, allowing discrimination between wild, naturally-produced fish and those produced in Central Valley hatcheries captured in monitoring efforts. Peak entrance into the Delta is in February and again in April based on data from the Sacramento Trawl; however, there is a broad window of entrance between January and June. Monitoring at Chipps Island indicates that exit from the Delta occurs during a broad window from February through June (Figure 2-125). Peak exit from the Delta occurs in May (~28%), but is only slightly greater than the prior three months. Fork length of captured juveniles from both the Sacramento Trawl and Chipps Island Trawl cover a broad range of sizes, but are typically greater than 200 mm in average fork length. The Sacramento Trawl does recover a few individuals that are considerably smaller than this, but their rarity does not alter the average fork length size to any extent. There is also an indication that larger fish are captured in the Chipps Island trawls compared to the Sacramento Trawl, which represent adult fish (~400 – 800 mm).

Table 2-172. CCV Juvenile Steelhead Emigration Through the Delta 1998-2016.

Monitoring Location	Data	Month											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Sacramento Trawl	Percent Population Present	0	0	1.9	17.4	19.6	15.0	21.9	16.0	7.5	0	0	0.7
	Mean Size (Fork length) Size Range			260 (220 - 300)	234 (194-273)	171 (36-300)	234 (183 - 350)	213 (58-310)	207 (96-308)	137 (51-277)			258

Monitoring Location	Data	Month											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Chipps Island Trawl	Percent Population Present	1	0.2	0.2	3.6	14.6	24.2	24.3	27.6	3.4	0.4	0.1	0.5
	Mean Size (Fork length) Size Range	214 (164-517)	195 (147-260)	301 (222-380)	241 (191-428)	230 (172-318)	248 (122-440)	250 (92-515)	233 (132-500)	249 (186-500)	658 (500-800)	500	273 (189-350)

KEY	Degree of rearing expected	High >20 %	Medium 10-20%	Low 2-10%	Rare to None <2%

Note: Inter-annual proportion of population sampled at Midwater Trawl at Chipps Island, Midwater and Kodiak Trawls at Sherwood Harbor near Sacramento, conducted by The Delta Juvenile Fish Monitoring Program (DJFMP), Stockton, CA, USFWS.

Channel Velocity Differences in the North Delta

The BA provided information regarding the hydrodynamic conditions that both adult and juvenile fish migrating through the Delta will be exposed to under the PA and NAA scenarios. A comparison of hydrodynamic conditions in important Delta channels for the NAA and PA scenarios was undertaken based on 15-minute DSM2-HYDRO velocity outputs. Three velocity metrics were assessed: magnitude of channel velocity; magnitude of negative velocity; and proportion of time in each day that velocity was negative. Lower overall velocity, greater negative velocity, and a greater proportion of negative velocity are all indicators of potential adverse effects to juvenile salmonids, e.g., by delaying migration or causing advection into migration pathways with lower survival.

The velocity analysis revealed that, in the North Delta, the median velocities are reduced under the PA throughout the CCV steelhead juvenile emigration period (December through June) (Table 2-172) and across all water year types (BA Table 5.4-9 in Appendix C of this Opinion). The reduced velocities in the North Delta suggest outmigrating steelhead smolts will experience longer travel time and, therefore, higher mortality during the entirety of their migration period for which velocity data are available.

During January and February, when CCV steelhead are beginning to enter the Delta, median velocities are consistently lower by five percent or more under the PA for the Sacramento River downstream of the NDD, including Steamboat and Sutter Slough (BA Table 5.4-9 in Appendix C of this Opinion) with the biggest changes occurring in January of wet and above normal years ranging from a 10% to 18% reduction in velocities. This has the potential to affect approximately 17% of steelhead smolts entering the Delta in January and 20% of smolts entering in February based on data from the Sacramento Trawl (Table 2-172). Velocity reductions may affect approximately 4 to 15% of steelhead smolts exiting the Delta at Chipps Island (Table 2-172).

The velocity reductions that occur in March for the Sacramento River downstream of the NDD, including Steamboat and Sutter Sloughs, are 10% or more in all water year types except critical years (BA Table 5.4-9 in Appendix C of this Opinion). Velocity reductions in the north Delta during March would increase travel time and predation encounter for approximately 15% of outmigrating steelhead smolts entering the Delta and approximately 24% of smolts exiting the Delta at Chipps Island (Table 2-172).

The magnitude of velocity reductions in April are not as large as in earlier months (most are under 5%), some of the larger velocity reductions for PA operations in April range from 5% to 10% (BA Table 5.4-9 in Appendix C of this Opinion). This would affect approximately 22% of steelhead smolts entering the Delta as determined by the Sacramento Trawl data and approximately 24% of smolts exiting the Delta at Chipps Island detected during April (Table 2-172).

During May, velocity reductions are greater and more frequent than April, but not as prevalent or extreme as the earlier migratory months of December through March (BA Table 5.4-9 in Appendix C of this Opinion). USFWS trawls detect ~16% inter-annual migration of steelhead smolts into the Delta and ~28% out of the Delta during this month (Table 2-172).

During June, reductions in velocities are increasing and range from 5 to 24% in the Sacramento River downstream of the NDD, including Steamboat and Sutter Sloughs (BA Table 5.4-9 in Appendix C of this Opinion). During June, USFWS trawls detect approximately 7.5% inter-annual migration of steelhead smolts entering into the Delta and approximately 3.5% emigration out of the Delta (Table 2-172). Velocity reductions in the north Delta during June would increase travel time and predation encounters for the tail end of steelhead smolt emigration through the North Delta.

An analysis was done to look at changes in differences in the magnitude of negative velocities (flow reversing) between scenarios (BA Table 5.4-10 in Appendix C of this Opinion). This analysis recognizes that, in the tidal Delta, velocities are not always seaward and can become slack or negative during the day. This affects fish migration as fish may be advected back upstream during flood tide, hold in the water column or a side bank or exert more energy to continue seaward, all affecting travel time during active outmigration (Horn and Blake 2004; Burau et al. 2007). As discussed in Section 2.5.1.2.7.1.2 NDD Bypass Flows and Smolt Entrainment Analysis, there is insufficient information to analyze the PA operational constraint regarding no increase in reverse flows.

In the north Delta, the velocity analysis indicated increased negative velocities under the PA during important CCV steelhead smolt migratory months of January through May upstream and downstream of Georgiana Slough on the Sacramento River (BA Table 5.4-10 in Appendix C of this Opinion). Increased negative velocity in wet years can range up to 117% more negative during the month of March in Steamboat Slough and 98% in the Sacramento River downstream of Georgiana Slough under the PA though most increases range from 7% to 30%. Increases in flow reversals would likely reduce the survival probability of outmigrating steelhead smolts by moving them back upstream, and increasing their exposure to junctions that lead to migratory routes of lower survival, such as in Georgiana Slough.

The third part of this hydrodynamic analysis looked for differences in modeling results between NAA and PA in the proportion of time each day that velocity was negative in north Delta channels. In the north Delta, the modeling results show that the proportion of the day with reverse flows increases under the PA, especially in Steamboat Slough and downstream of Georgiana Slough (BA Table 5.4-11 in Appendix C of this Opinion).

The velocity analysis indicates that the majority of CCV steelhead smolts will experience conditions in the north Delta as a result of the PA that will increase travel times, leading to increased periods of time for exposure to predators, and increased exposure to advection into river junctions leading to waterways with lower survival rates, resulting in overall adverse effects.

Channel Velocity Differences in Central Delta

In the central Delta at the DCC location, velocities were very similar between the NAA and PA scenarios in the December through May period. However, in June they became more positive in wet years and critical years, but more negative in above normal, below normal, and dry water year types. Based on the velocity analysis, travel time and predation risk for outmigrating steelhead smolts in the central Delta are not expected to change under the PA for the period between December and May, but will increase in the month of June (BA Table 5.4-9 in Appendix C of this Opinion). The magnitude of negative water velocities did not change substantially from December through May. However, in June, the magnitude of negative velocities became more negative in all water year types except for critical water years. In wet years, the magnitude of negative water velocities became 7% more negative in the DCC channel, and was 3% more negative in above normal, below normal, and dry water year types (BA Table 5.4-10 in Appendix C of this Opinion). The proportion of the day in which water velocities were negative remained unchanged between December and May when the DCC gates were closed. In June when the gates become operable again, the proportion of the day in which the flows were negative increased substantially in all water year types. In above normal years, the percentage increase is 100% (BA Table 5.4-11 in Appendix C of this Opinion). CCV steelhead smolts will experience conditions in the Central Delta in June that will increase travel times, leading to increased predation exposure, and increased exposure to advection into river junctions leading to waterways with lower survival rates, resulting in overall adverse effects. Negative velocities in Georgiana Slough were not examined in this analysis though it is an important migratory route that is examined in other models in this biological opinion. Specifically, the NDD bypass flows and smolt entrainment model assesses changes in proportion of smolts using Georgiana Slough, and the DPM and Perry Survival Model assess differences in survival using this migratory route.

Channel Velocity Differences in the South Delta

In the south Delta, the modeling indicates that flow velocities generally increase in the San Joaquin River between the location of the Head of Old River and the Port of Stockton at Channel Point where the confined river channel enters the much larger Stockton DWSC. Under the PA, the HOR gates are operated from January through June to enhance flows in this river reach and keep fish from entering the Old River channel. As modeled, there is little difference in flow velocity in December between the PA and NAA scenarios when the gates are not operated. From January through June the increases in velocity range from 8% (June, wet water year type) to 54% (January, below normal water year type). During key emigration months in the San Joaquin River Basin for CCV steelhead smolts entering the Delta (March through May), increases in flow velocity typically range from 30% to almost 50% under the PA compared to the NAA scenario (BA Table 5.4-9 in Appendix C of this Opinion). This will help steelhead smolts travel faster downstream from the HOR location to the Stockton DWSC. Shortened travel times are anticipated to decrease predation risks by shortening the temporal overlap with predators in this river reach.

The San Joaquin River flow velocity near the mouth of the Mokelumne River (Channel node 45) would also generally be higher under the PA compared to the NAA scenario. Flow velocities would be higher in almost all water year types from December through June. Most of these increases would be greater than 5%. Only in June of critical water year types would the PA and NAA scenarios have equal flow velocities. The increases in flow velocity, as modeled, range between 6% and 31% (BA Table 5.4-9 in Appendix C of this Opinion), and should aid the downstream movement of steelhead smolts through the Stockton DWSC by reducing the temporal exposure to potential predators in this reach of the river. Shorter exposure to predators should enhance survival of steelhead smolts by reducing the duration of predator-prey interactions. Increased flow velocities in December and January should also benefit adult steelhead by having an improved flow cue to attract them upriver into the San Joaquin River basin.

Velocities in the Old River channel also increase under the PA scenario relative to the NAA scenario in most months and water year types, except for the months of April and May. Under the NAA scenario, median 15 minute velocities are typically negative in most water year types during the period between December and March, except for wet water year types when some positive velocities are observed in the modeling output. In Old River, downstream of the south Delta export facilities, the differences were related to less south Delta exports. However, in April and May it was also apparent that in drier years, median velocity was less positive under the PA than the NAA. Although the PA criteria are consistent with the OMR flows and San Joaquin I/E ratio requirements in the current BiOp for the Long Term operations of the CVP and SWP (NMFS 2009), and south Delta export pumping is almost always lower in April and May; the modeling assumption that the HOR gates are closed 50% of the time, combined with differing modeling assumptions for south Delta exports to fill San Luis Reservoir, results in Old River channel velocities that were slightly lower under the PA scenario than the NAA (although both had positive median velocity). Channel velocity in Old River upstream of the south Delta export facilities was less positive under the PA than NAA, reflecting less south Delta exports under the PA (i.e., the export facilities exert some hydrodynamic influence by increasing velocity toward the facilities when pumping) and the operation of the HOR gate, which blocks flow from entering 50% of the time during the January–June period.

Steelhead smolts in the Old River channel corridor would benefit from the more positive flow velocities downstream of the CVP and SWP facilities during the December through March period. These fish could come from anywhere in the Central Valley region. The more positive velocities indicate that there is less net flow towards the facilities since the channel dimensions remain the same. This is a result of anticipated reduced exports in the south Delta under the PA scenario. More positive velocities (even though they are still predominately negative) may mean that steelhead within the Old River channel downstream of the facilities are advected towards the fish salvage facilities at a lower rate under the PA compared to the NAA scenario. In the Old River channel upstream of the project facilities, the reduced median velocity is related to the operations of the HOR gate and the reduction in exports from the facilities under the PA scenario. Under the NAA, more flow is routed into the Old River channel at the HOR and under higher export moves at an increased velocity towards the facilities. This would provide an alternative route for emigrating steelhead smolts from the San Joaquin River basin towards the ocean. However, once in the vicinity of the export facilities, few fish are able to pass the intakes and proceed downstream and are typically entrained into the facilities. Predation is also high in the region surrounding the facilities, particularly in the CCF where predation appears to be approximately 80% for steelhead smolts based on studies conducted in the forebay (DWR 2008). Under the PA, the HOR gates are operated to reduce the routing of steelhead smolts into the Old River channel when emigrating fish are detected in regional monitoring efforts (i.e., Mossdale trawls). Nevertheless, some fish will enter the Old River channel when the gates are lowered during the January through June period or pass through the boat locks or fish ladder when they are in operation. These fish will have slower transit times through the Old River migratory route between the HOR location and the project facilities. Slower transit times related to reduced flow velocity is likely to enhance the risk of predation on steelhead smolts in the channels that make up the Old River migratory route.

The magnitude of negative flow velocity was modeled to compare the changes between the PA and NAA scenarios (BA Table 5.4-10 in Appendix C of this Opinion). Considering only negative velocity estimates under the PA, the median negative velocity in the San Joaquin River downstream of Old River was greater (closer to zero) than under the NAA, with the relative difference decreasing as water years became drier. The muting of the negative velocities (flow velocity becoming more positive) is a reflection of the operation of the HOR gate, which redirects more flow down the San Joaquin River main channel. The greater percentage of river flow moving down the main channel will increasingly offset the influence of the tides in this river reach, and enhance downstream movement of fish. These effects occur in all water year types from January through June and should benefit emigrating steelhead smolts from the San Joaquin River basin. There was little difference between the PA and NAA scenarios farther downstream near the confluence with the Mokelumne River (Channel node 45), reflecting greater tidal influence on flow velocities relative to river inflow. Negative velocity estimates in Old River downstream of the south Delta export facilities under the PA were either less than or similar to those under the NAA scenario (defined as <5% difference in the medians), whereas in Old River upstream of the facilities, the negative velocities were greater (again reflecting less south Delta exports and the influence of the HOR gate, both of which would increase the influence of flood tides in this channel). More negative velocities are believed to be detrimental to downstream migration of steelhead smolts by increasing travel times. As stated above, increased travel times will likely increase the smolts' exposure to predators and reduce survival in those channels.

The third part of the velocity analysis was proportion of day with negative velocities. In the south Delta, the analysis showed positive effects under the PA in the San Joaquin River downstream of the HOR and Old River downstream of the south Delta export facilities (BA Table 5.4-11 in Appendix C of this Opinion) in which a lower percentage of the day had negative flows. There were a couple of water years in January, February, and March when the PA reduced proportion of day with reverse flow by 6% to 16% (BA Table 5.4-11 in Appendix C of this Opinion). Conversely, for reasons already explained, the operations of the HOR gate increased the percentage of the day in which flows were negative upstream of the South delta export facilities from January through May. Emigrating steelhead smolts should benefit with the reduction in the proportion of the day in which negative flows occur in the San Joaquin River downstream of the HOR gate location and in Old River downstream of the South Delta export facilities.

Effect of NDD Bypass Rules on CCV Steelhead Migration (Perry et al. 2016 NDD Bypass Flows and Smolt Entrainment Model)

As noted in the CCV steelhead temporal distribution tables (Figure 2-125), the Delta migration period generally occurs between December and June. Although the modeling was conducted for Chinook salmon, NMFS will use the general findings for its analysis of effects on CCV steelhead as applicable to salmonids in general in the Delta because juvenile steelhead migrate at similar times as Chinook salmon.

December and April fall under identical operations rules once initial pulse protection ends, starting with Level 1 operation, and increasing to Level 2 or Level 3 operations when flow criteria are met. Level 1 operations provide the most protection or least change in riverine flows from the NAA scenario. Under Level 1 operations, the increase in probability of a flow reversal remains under 30% and the increase in the proportion of the day with a flow reversal remains under 5%. Under Level 2, the probability of a flow reversal can be as high as 80% with a ~4-6% increase in the proportion of the day with a flow reversal; while under Level 3, the probability of a flow reversal is up to 100%, with the increase in the proportion of the day with a flow reversal up to 15% (Figure 2-120). The majority of CCV steelhead will be in the Delta during these months (~75% of annual emigration) (Table 2-172).

May has a unique set of NDD bypass rules that is slightly less protective than the diversion rules in December through April. Approximately 16% of CCV steelhead smolts are expected to be entering the Delta during this month (Table 2-172). These steelhead smolts may experience slightly longer travel times than smolts traveling during earlier months given the same inflow at Freeport. This would be due to lower velocities that may result from less restrictive diversions under the NDD bypass rules (BA Table 3.3-2 in Appendix A2 of this Opinion).

Additionally, based solely on the NDD bypass rules and no other constraints to diversions, CCV steelhead smolts that are in the Delta during May will have slightly longer travel times than smolts who migrate out earlier. This could result in higher mortality rates for the late migrating steelhead smolts that are an important part of the species life history diversity. This is exacerbated even more during June, but a smaller proportion of the steelhead annual emigration takes place during this month.

Perry Survival Model – Travel Time

The Perry Survival Model was originally developed for Chinook salmon. NMFS concludes that it should be generally applicable to steelhead when looking at the general trends in travel time through the Delta because juvenile steelhead are migrating at similar times as Chinook salmon. The Perry 2017 survival model helps to quantify the actual travel time that smolts will experience under the different Delta inflows between scenarios. Travel time through the Delta will be increased under the PA during the migration period for salmonids. February and March show the largest increase in travel time which corresponds with when approximately 35% of the overall steelhead migrants are entering the Delta and 39% are exiting the Delta. For example, travel time under the PA will increase from 0.33 days to 1.4 days during February and March for 50% of the years (Table 2-168). During 25% of the years, travel time will increase during February and March from 1.1 to 3 days under the PA (Table 2-168). Travel times are also increased in key migratory months of April and May when 38-50% of steelhead are expected to be in the Delta (Table 2-172). Travel time differences in April and May are less than in the other migration months. During 50% of years, travel times will increase in April from 0.02 days to 0.39 days and in May from 0.05 days to 0.47 days (Table 2-168). During 25% of years, travel time will increase from 0.39 days to 1.6 days and 0.47 days to 1.7 days in April and May, respectively (Table 2-168). During the other 25% of years, travel time differences under the PA will range from a slight increase of 0.02 days to a reduction of 0.73 days and an increase of 0.05 days to a reduction of 0.54 days during April and May, respectively (Table 2-168). In June, travel time under the PA in 50% of years will increase from 0.12 days to 1.3 days (Table 2-168). During the upper 25% of years, travel time will increase from 1.3 to 3.5 days in June under the PA. In the lower 25% of years, travel time differences under the PA in June will range from an increase of 0.12 days to a reduction of 0.93 days.

The Perry Survival Model is best suited to determine overall effects to salmonids due to PA operations in the north Delta. The Perry Survival Model encompasses the key stressors that affect overall migratory success in the Delta, travel time, route selection, and survival probabilities under Freeport inflows. While we identify the individual stressors, the effects of the PA on travel time are best evaluated holistically to determine an overall migratory success (survival) or failure (mortality) to salmonids. The model was developed using Chinook salmon and not steelhead as the test fish. However, the test fish used were late fall-run Chinook salmon, which are fairly similar in size to steelhead smolts and should at least represent predation vulnerability (i.e., survival) of emigrating fish to regional predators. Actual emigration rates are likely to be different between Chinook salmon and steelhead, but the general trends in the travel time, whether increasing or reduced due to operations, should be applicable.

Based on the travel time analysis in Section 2.5.1.2.7.1.3 Perry Survival Model (Travel Time Component), operations under the PA would increase travel times throughout the steelhead migratory period for fish leaving the Sacramento River basin with the biggest increases occurring in February and March, which are important migratory months for Sacramento River basin steelhead in the Delta. Increases in travel times for steelhead smolts are expected throughout their emigration window through the Delta (January through June) and in 50% of years ranges from a delay of 0.02 to 0.39 days in April to a delay of 0.33 to 1.4 days in March. The 25% of years with the greatest increase of travel time under the PA ranged up to 3.5 days in June and 3.0 days in March (Table 2-168). The greatest delays occurred in February, March, and June. Although the effect of increased travel time for these key migratory months are not substantial, it is still an adverse effect of the PA.

Additionally, when steelhead smolts are mostly present in the Delta during the February through May period, there was a substantial benefit in south Delta velocities (more positive velocities) in the waters of the lower San Joaquin River downstream from the location of the HOR gate, the San Joaquin River near the confluence with the Mokelumne River, and Old River downstream of the South Delta export facilities. This is a particular benefit to steelhead smolts leaving the San Joaquin River basin, but should benefit any fish present in those waters regardless of origin. However, since changes in travel time were not modeled in the Perry 2017 Survival Model for fish leaving the San Joaquin River basin, only a qualitative assessment can be made. More positive outflow conditions (more positive flow velocities, more positive magnitude of negative flows and shorter duration of daily negative flows) should reduce travel times for fish leaving the San Joaquin River basin under the PA. NMFS therefore expects that the reduction in flow in the

North Delta as a result of the PA will increase travel time for the majority of outmigrating steelhead smolts originating in the Sacramento River basin. This will result in an adverse effect to a high proportion of rearing and outmigrating CCV steelhead as the majority of the CCV steelhead population originates from this basin. The PA, however, will benefit CCV steelhead from the San Joaquin River basin through reduced travel times due to improved flow conditions.

2.5.1.2.7.1.3.4 Green Sturgeon Exposure and Risk

Detailed information regarding the Southern distinct population segment (sDPS) of North American green sturgeon, their designated critical habitat, life history, and status of the species can be found in Appendix B Rangewide Status of the Species and Critical Habitat. Additional information regarding the specific life history and the spatial and temporal presence of sDPS green sturgeon in the action area is described in Section 2.4.3 Environmental Baseline. Little information is currently available to discern the exact relationship of how hydrology may influence the behavior, abundance, or distribution of sDPS green sturgeon in the Delta. Moreover, there is no information currently available that might be considered predictive of the influence of reverse flows on green sturgeon. In general, however, it appears that elevated flows during the late winter and early spring months may provide an important cue for spawning adults to initiate their upstream migrations to the spawning grounds between February and May (Heublein et al. 2009; Poytress et al. 2011). Elevated flows have also been suggested as an in-migration cue in white sturgeon in the Sacramento River (Shaffter 1997). Similarly, post-spawn adults exhibit a wide variety of outmigration strategies, returning to the ocean just after spawning or up to several months later after over summering in the upper portion of the watershed (Heublein et al. 2009; Mora 2016). The variation between early outmigration from, and extended occupancy in, upstream spawning or holding habitats may also be related to hydrologic cues as well, since increased flow appears to be an outmigration cue (Heublein et al. 2009).

In addition, it has been theorized that there is a positive relationship between annual outflow and larval abundance and distribution in the reaches of the Sacramento River just downstream from sturgeon spawning habitat on the Sacramento River (reviewed in Heublein et al. 2017, in press) although whether the mechanism might be an increased number of spawners, increased egg survival, increased larval dispersal, or some combination of the three remains uncertain. In particular, spring and summer outflow may influence the extent of larval dispersion from spawning habitat where the eggs incubate and hatch. California Department of Fish and Game (1992) and USFWS (1995) found a positive correlation between mean daily freshwater outflow (April to July) and white sturgeon year class strength in the San Francisco Bay Delta Estuary. CDFW has suggested that green sturgeon recruitment was highest in wet years, and sturgeon eggs and larvae have only ever been collected in the Feather River during wet years (Seesholtz et al. 2015). In contrast, low outflow in the spring could influence the late spring and summer water temperatures such that suboptimal conditions exist for adequate incubation or growth, possibly reaching lethal levels in particularly dry years. There may also be a correlation between high outflows and the occurrence of sturgeon stranding on the Yolo and Sutter Bypasses, however, which has only been documented during wet years (Thomas et al. 2013). Whether this is an artifact of increased abundance and distribution throughout the range or a result of spawning adults homing in on a false attractant flow up the bypass has not been determined.

As described above, the frequency, timing, and duration of pulsed flows into and out of the Delta likely has an important effect on the distribution, abundance, and recruitment of the sDPS green sturgeon population by influencing the timing, magnitude, and relative success of each spawning season. However, NMFS has insufficient information to make a conclusion with regard to whether there is an effect on juvenile green sturgeon migration travel time through the Delta relative to change in flow due to the PA.

2.5.1.2.7.1.3.5 Fall-Run Exposure and Risk

Fall run Chinook salmon have a wide emigration window and utilize different life history strategies at the juvenile stage. In wetter years, it is not uncommon to find fall run Chinook salmon fry in the Delta as early as December (Table 2-173). April is when the fall-run hatchery smolts are released at various locations upstream of and within the Delta, contributing to high abundance in the Delta in April for smolt-sized fish. The emigration window can last until August on rare occasions but generally extends from December through June (Table 2-173).

Table 2-173. Fall-run Sacramento and San Joaquin Basin Emigration from 1995 to 2008.

Monitoring Location	Data	Month											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Knights Landing	Mean Size (Fork length) Size Range	NA	NA	35 (34-36)	37 (37-38)	39 (38-40)	43 (37-52)	73 (60-80)	77 (73-81)	78 (72-83)	76	91	87
Sacramento Trawl	Mean Size (Fork length) Size Range	NA	NA	35 (34-36)	37 (35-40)	39 (37-41)	45 (39-53)	72 (69-78)	77 (71-81)	82 (75-90)	85 (78-94)	92 (85-102)	NA
Chipps Island Trawl	Mean Size (Fork length) Size Range	NA	NA	NA	38 (36-43)	39 (37-41)	56 (42-69)	78 (76-82)	81 (78-84)	85 (80-92)	89 (80-96)	NA	NA
Mossdale	Mean Size (Fork length) Size Range	NA	NA	NA	37 (36-38)	39 (36-47)	50 (38-65)	76 (65-80)	86 (78-91)	97 (92-102)	NA	NA	NA

KEY

Degree of rearing expected	High >20%	Medium 10-20%	Low 2-10%	Rare to None <2%

Note: Inter-annual proportion of population sampled at Midwater Trawl at Chipps Island, Midwater and Kodiak Trawls at Sherwood Harbor near Sacramento, conducted by The Delta Juvenile Fish Monitoring Program (DJFMP), Stockton, CA, USFWS.

Channel Velocity Differences in North Delta

The velocity analysis revealed that, in the north Delta, the median velocities are reduced under the PA throughout the fall-run Chinook salmon emigration period (December through June) (Table 2-173) and across all water year types (BA Table 5.4-9 in Appendix C of this Opinion). The reduced velocities in the North Delta suggest outmigrating fall-run smolts will experience longer travel time and, therefore, higher mortality during the entirety of their migration period for which velocity data are available.

Specifically, in the North Delta, results for December in below normal, above normal, and wet water year types show that median velocity for the Sacramento River downstream of the NDD, including Steamboat and Sutter Sloughs, are 5 to 15 percent lower for the PA (BA Table 5.4-9 in Appendix C of this Opinion). December is the start of the fall-run Chinook salmon fry sized fish (<70 mm) emigration and they are expected to be present in these wetter year types. USFWS monitoring detects a low proportion of interannual migrants during this month (Table 2-173).

During January and February, median velocities are consistently lower by five percent or more under the PA for the Sacramento River downstream of the NDD, including Steamboat and Sutter Slough (BA Table 5.4-9 in Appendix C of this Opinion), with the biggest changes occurring in January of wet and above normal years ranging from a 10% to 18% reduction in velocities. These could be months when fall-run Chinook salmon are rearing in the Delta. Sacramento Trawl detects a large proportion of fall run inter-annual fry sized migrants during January and February (Table 2-173).

The greatest velocity reductions for the December through May fall-run migratory period occur in March when velocities are reduced for the Sacramento River downstream of the NDD, including Steamboat and Sutter Sloughs, (BA Table 5.4-9 in Appendix C of this Opinion) by 10% or more in all water year types except critical years. Velocity reductions in the north Delta during March would occur when a large proportion of the fry sized population is rearing and migrating in the Delta (Table 2-173). This could cause adverse effects to habitat availability and increase predator encounters due to increased routing to or greater exposure in higher mortality habitats.

The magnitude of velocity reductions in April are not as large as in earlier months (most are under 5%); some of the larger velocity reductions for PA operations in April range from 5% to 10% (BA Table 5.4-9 in Appendix C of this Opinion). This would affect the majority of fall-run Chinook salmon smolts as most of the population is over 70 mm at this point in the year and hatcheries are releasing millions of smolts during April (Table 2-173).

During May, another peak month of fall-run Chinook salmon smolt migration (Table 2-173), velocity reductions are greater and more frequent than April but not as prevalent or extreme as the earlier migratory and rearing months of December through March (BA Table 5.4-9 in Appendix C of this Opinion). This would increase travel time affecting survival during a peak migratory month.

During June, reductions in velocities are increasing and range from 5 to 24% in the Sacramento River downstream of the NDD, including Steamboat and Sutter Sloughs (BA Table 5.4-9 in Appendix C of this Opinion). During June, the abundance of fall-run Chinook salmon smolts is decreasing in comparison to April and May smolt presence (Table 2-173). Velocity reductions in the north Delta during June would increase travel time and predation encounters for the tail end of fall-run Chinook salmon smolt emigration through the North Delta.

An analysis was done to look at changes in differences in the magnitude of negative velocities (flow reversing) between scenarios (BA Table 5.4-10 in Appendix C of this Opinion). This analysis recognizes that, in the tidal Delta, velocities are not always seaward and can become slack or negative during the day. This affects fish migration as fish may be advected back upstream during flood tide, hold in the water column or a side bank or exert more energy to continue seaward, all affecting travel time during active outmigration. As discussed in Section 2.5.1.2.7.1.2 NDD Bypass Flows and Smolt Entrainment Analysis, there is insufficient information to analyze the PA operational constraint regarding no increase in reverse flows.

In the north Delta, the velocity analysis indicated increased negative velocities under the PA during important fall-run Chinook salmon migratory months of February through May upstream and downstream of Georgiana Slough on the Sacramento River (BA Table 5.4-10 in Appendix C of this Opinion). Increased negative velocity can range up to 98% more during the month of March under the PA though most increases range between 7% to 30%. Increases in flow reversals would likely reduce the survival probability of outmigrating smolts by moving them back upstream, increasing their exposure to junctions that lead to migratory routes of lower survival, such as in Georgiana Slough.

The third part of this hydrodynamic analysis looked for differences in modeling results between NAA and PA in the proportion of time each day that velocity was negative in north Delta channels. In the north Delta, the modeling results show that proportion of day with reverse flows increases under the PA especially in Steamboat Slough and downstream of Georgiana Slough (BA Table 5.4-11 in Appendix C of this Opinion).

The velocity analysis indicates that the majority of fall-run Chinook salmon will experience conditions in the north Delta as a result of the PA that will increase travel time, reduce habitat, and potentially increase predator exposure resulting in adverse effects. These adverse effects are impactful for the fry-sized life stage (due to their increased vulnerability due to their small size) and for the late arriving fall-run smolts in June or July (who will experience overall poor migration and rearing conditions in the Delta). During the peak months of smolt presence in the Delta (April and May), changes in velocities are not as pronounced as in the shoulder months.

Channel Velocity Differences in Central Delta

In the central Delta at the DCC location, velocities were very similar between the NAA and PA scenarios in the December through May period. However, in June they became more positive in wet years and critical years, but more negative in above normal, below normal, and dry water year types. Based on the velocity analysis, travel time and predation risk for outmigrating fall-run Chinook salmon smolts in the central Delta are not expected to change under the PA for the period between December and May, but will increase in the month of June (BA Table 5.4-9 in Appendix C of this Opinion). The magnitude of negative water velocities did not change substantially from December through May. However, in June, the magnitude of negative velocities became more negative in all water year types except for critical water years. In wet years, the magnitude of negative water velocities became 7% more negative in the DCC channel, and was 3% more negative in above normal, below normal, and dry water year types (BA Table 5.4-10 in Appendix C of this Opinion). The proportion of the day in which water velocities were negative remained unchanged between December and May when the DCC gates were closed. In

June when the gates become operable again, the proportion of the day in which the flows were negative increased substantially in all water year types. In above normal years, the percentage increase is 100% (BA Table 5.4-11 in Appendix C of this Opinion). Fall-run Chinook salmon smolts will experience conditions in the Central Delta in June that will increase travel times leading to increased predation exposure, and increased exposure to advection into river junctions leading to waterways with lower survival rates, resulting in overall adverse effects. Negative velocities in Georgiana Slough were not examined in this analysis though it is an important migratory route that is examined in other models in this biological opinion. Specifically, the NDD bypass flows and smolt entrainment model assesses changes in proportion of smolts using Georgiana Slough, and the DPM and Perry Survival Model assesses differences in survival using this migratory route.

Channel Velocity Differences in South Delta

In the south Delta, the modeling indicates that flow velocities generally increase in the San Joaquin River between the location of the Head of Old River and the Port of Stockton at Channel Point where the confined river channel enters the much larger Stockton DWSC. Under the PA, the HOR gates are operated from January through June to enhance flows in this river reach and keep fish from entering the Old River channel. As modeled, there is little difference in flow velocity in December between the PA and NAA scenarios when the gates are not operated. From January through June, the increases in velocity range from 8% (June, wet water year type) to 54% (January, below normal water year type). During key emigration months in the San Joaquin River Basin for fall-run Chinook salmon parr and smolts entering the Delta (March through May), increases in flow velocity typically range from 30% to almost 50% under the PA compared to the NAA scenario (BA Table 5.4-9 in Appendix C of this Opinion). This will help fall run Chinook salmon smolts travel faster downstream from the HOR location to the Stockton DWSC. Shortened travel times are anticipated to decrease predation risks by shortening the temporal overlap with predators in this river reach.

The San Joaquin River flow velocity near the mouth of the Mokelumne River (Channel node 45) would also generally be higher under the PA compared to the NAA scenario. Flow velocities would be higher in almost all water year types from December through June. Most of these increases would be greater than 5%. Only in June of critical water year types would the PA and NAA scenarios have equal flow velocities. The increases in flow velocity, as modeled, range between 6% and 31% (BA Table 5.4-9 in Appendix C of this Opinion), and should aid the downstream movement of fall-run Chinook salmon smolts through the Stockton DWSC by reducing the temporal exposure to potential predators in this reach of the river. Shorter exposure to predators should enhance survival of fall-run Chinook salmon smolts by reducing the duration of predator-prey interactions.

Velocities in the Old River channel also increase under the PA scenario relative to the NAA scenario in most months and water year types, except for the months of April and May. Under the NAA scenario, median 15 minute velocities are typically negative in most water year types during the period between December and March, except for wet water year types when some positive velocities are observed in the modeling output. In Old River, downstream of the south Delta export facilities, the differences were related to less south Delta exports. However, in April and May, it was also apparent that in drier years, median velocity was less positive under the PA than the NAA. Although the PA criteria are consistent with the OMR flows and San Joaquin I/E ratio requirements in the current BiOp for the Long Term operations of the CVP and SWP

(NMFS 2009), and south Delta export pumping is almost always lower in April and May; the modeling assumption that the HOR gates are closed 50% of the time during the fall run Chinook salmon migration period combined with differing modeling assumptions for south Delta exports to fill San Luis Reservoir results in Old River channel velocities that were slightly lower under the PA scenario than the NAA (although both had positive median velocity). Channel velocity in Old River upstream of the south Delta export facilities was less positive under the PA than NAA, reflecting less south Delta exports under the PA (i.e., the export facilities exert some hydrodynamic influence by increasing velocity toward the facilities when pumping) and the operation of the HOR gate, which blocks flow from entering 50% of the time during the January–June period.

Fall-run Chinook salmon fry/parr sized fish in the Old River channel corridor would benefit from the more positive flow velocities downstream of the CVP and SWP facilities during the December through March period. These fish could come from anywhere in the Central Valley region. The more positive velocities indicate that there is less net flow towards the facilities since the channel dimensions remain the same. This is a result of anticipated reduced exports in the south Delta under the PA scenario. More positive velocities (even though they are still predominately negative) may mean that fall-run Chinook salmon within the Old River channel downstream of the facilities are advected towards the fish salvage facilities at a lower rate under the PA compared to the NAA scenario. In the Old River channel, upstream of the project facilities, the reduced median velocity is related to the operations of the HOR gate and the reduction in exports from the facilities under the PA scenario. Under the NAA, more flow is routed into the Old River channel at the HOR and under higher export moves at an increased velocity towards the facilities. This would provide an alternative route for emigrating fall-run Chinook salmon smolts from the San Joaquin River basin towards the ocean. However, once in the vicinity of the export facilities, few fish are able to pass the intakes and proceed downstream and are typically entrained into the facilities. Under the PA, the HOR gates are operated to reduce the routing of fall-run Chinook salmon into the Old River channel when emigrating fish are detected in regional monitoring efforts (i.e., Mossdale trawls). Nevertheless, some fish will enter the Old River channel when the gates are lowered during the January through June period or pass through the boat locks or fish ladder when they are in operation. These fish will have slower transit times through the Old River migratory route between the HOR location and the project facilities. Slower transit times related to reduced flow velocity are likely to enhance the risk of predation on fall-run Chinook salmon smolts in the channels that make up the Old River migratory route.

The magnitude of negative flow velocity was modeled to compare the changes between the PA and NAA scenarios (BA Table 5.4-10 in Appendix C of this Opinion). Considering only negative velocity estimates under the PA, the median negative velocity in the San Joaquin River downstream of Old River was greater (closer to zero) than under the NAA, with the relative difference decreasing as water years became drier. The muting of the negative velocities (flow velocity becoming more positive) is a reflection of the operation of the HOR gate, which redirects more flow down the San Joaquin River main channel. The greater percentage of river flow moving down the main channel will increasingly offset the influence of the tides in this river reach, and enhance downstream movement of fish. These effects occur in all water year types from January through June and should benefit emigrating fall-run Chinook salmon juveniles from the San Joaquin River basin. There was little difference between the PA and NAA scenarios farther downstream near the confluence with the Mokelumne River (Channel node 45), reflecting greater tidal influence on flow velocities relative to river inflow. Negative velocity estimates in Old River downstream of the south Delta export facilities under the PA were either less than or similar to those under the NAA scenario (defined as <5% difference in the medians), whereas in Old River upstream of the facilities, the negative velocities were greater (again reflecting less south Delta exports and the influence of the HOR gate, both of which would increase the influence of flood tides in this channel). More negative velocities are believed to be detrimental to downstream migration of fall-run Chinook salmon smolts by increasing travel times. As stated above, increased travel times will likely increase the smolts' exposure to predators and reduce survival in those channels.

The third part of the velocity analysis was proportion of day with negative velocities. In the south Delta, the analysis showed positive effects under the PA in the San Joaquin River downstream of the HOR and Old River downstream of the south Delta export facilities (BA Table 5.4-11 in Appendix C of this Opinion) in which a lower percentage of the day had negative flows. There were a couple of water years in January, February, and March when the PA reduced proportion of day with reverse flow by 6% to 16%. Conversely, for reasons already explained, the operations of the HOR gate increased the percentage of the day in which flows were negative upstream of the South delta export facilities from January through May. Emigrating fall-run Chinook salmon smolts should benefit with the reduction in the proportion of the day in which negative flows occur in the San Joaquin River downstream of the HOR gate location and in Old River downstream of the South Delta export facilities.

Effect of NDD bypass rules on fall-run migration (Perry et al. 2016 NDD bypass flows and smolt entrainment model)

As noted in the fall-run temporal distribution tables, the Delta migration period generally occurs between January and June with low presence occasionally in December and July (Table 2-173).

Under the PA NDD bypass rules, December and April fall under identical operations rules once initial pulse protection ends; beginning with Level 1 operation, and then increasing to Level 2 or Level 3 operations when flow criteria are met. Of the three main operations levels, Level 1 provides the most protection or least change in riverine flows from the NAA scenario. Under Level 1 operations, the increase in probability of a flow reversal remains under 30% and the increase in the proportion of the day with a flow reversal remains under 5%. Under Level 2, the probability of a flow reversal can be as high as 80% with a ~4-6% increase in the proportion of the day with a flow reversal; while under Level 3, the probability of a flow reversal is up to 100%, with the increase in the proportion of the day with a flow reversal up to 15% (Figure 2-120). Fall-run Chinook salmon will complete the fry life-stage during these months and a large portion of the smolt life-stage will be in the Delta during these months as well (Table 2-173).

May has a unique set of NDD bypass rules that is less protective than the diversion rules in December through April (Appendix A2 Table 3.3-2 of this Opinion). A large proportion of fall-run Chinook salmon smolts are expected to be in the Delta during this month (Table 2-173). They may experience slightly longer travel times than smolts traveling during earlier months given the same inflow at Freeport. This would be due to lower velocities that result from less restrictive diversions under the NDD bypass rules (BA Table 5.4-11 in Appendix C of this Opinion). Under the May Levels 1-3 bypass rules, the probability of a flow reversal ranges from 40% at Level 1 up to 100% at Level 3 and the proportion of the day with reverse flow ranges from 5% under Level 1 up to 16% during Level 3 when discharge at Freeport ranges from 10,000 cfs to 30,000 cfs (Figure 2-121).

June NDD bypass rules are less protective than the diversions rules in December through April and the diversion rules unique to May (Appendix A2 Table 3.3-2). A large portion of fall-run Chinook salmon smolts are likely to still be in the Delta or out-migrating through the Delta. This means the longer travel times experienced by smolts out migrating in June will likely be the highest adverse impact under the PA for the fall run smolt population. Under the June Levels 1-3 bypass rules, the probability of a flow reversal ranges from 50% at Level 1 up to 100% at Level 3 and the proportion of the day with reverse flow ranges from 5% under Level 1 up to 18% during Level 3 when discharge at Freeport ranges from 10,000 cfs to 30,000 cfs (Figure 2-122).

Based on the adverse effects Level 2 and Level 3 diversions have on riverine conditions that influence migration routing, travel time, and overall survival, fall-run would be less impacted under low level pumping and Level 1 operations. Under the NDD bypass rules and no other constraints to diversions, fall-run Chinook salmon smolts that are in the Delta during May and particularly June may have slightly longer travel times than smolts who migrate out earlier. This could result in higher mortality rates for the later migrating fall-run Chinook salmon smolts that are an important part of the species life history diversity.

Perry Survival Model – Travel Time

The Perry Survival Model helps to quantify the actual travel time that smolts will experience under the different Delta inflows between scenarios. Travel time through the Delta will be increased under the PA during the migration period for fall-run Chinook salmon. February, March, and June show the largest increase in travel time, which corresponds with the fall-run Chinook salmon fry life-stage presence in the Delta and the later arriving smolt outmigration in June. For example, travel time under the PA will increase from 0.33 days to 1.4 days during February and March for 50% of the years (Table 2-168). During 25% of the years, travel time will increase during February and March from 1.1 to 3 days under the PA (Table 2-168). During June, travel times will increase under the PA from 0.12 to 1.3 days during 50% of years (Table 2-168). During 25% of the years in June, travel time will increase from 1.3 to 3.5 days under the PA (Table 2-168). Travel times are also increased under the PA in key migratory months of April and May when the majority of fall run Chinook salmon smolts are expected to be in the Delta. Travel time differences in April and May are less than in the other fall run migration months. Travel time for 50% of years will increase under the PA in April from 0.02 days to 0.39 days and in May from 0.05 days to 0.47 days (Table 2-168). During 25% of years, travel time will increase under the PA from 0.39 days to 1.6 days and 0.47 days to 1.7 days in April and May, respectively (Table 2-168). During the other 25% of years, travel time differences under the PA will range from a slight increase of 0.02 days to a reduction of 0.73 days and an increase of 0.05 days to a reduction of 0.54 days during April and May, respectively (Table 2-168).

Since travel time will affect fall-run Chinook salmon survival in the Delta, a more thorough look at fall-run Chinook salmon survival under the different operating levels by month and water year type is included in the Perry Survival Model. The Perry Survival Model is best suited to determine overall effects to fall-run Chinook salmon due to PA operations in the north Delta. The Perry Survival Model encompasses the key stressors that affect overall migratory success in the Delta, travel time, route selection, and survival probabilities under Freeport inflows. While we identify the individual stressors, the effects of the PA on travel time are best evaluated holistically to determine an overall migratory success (survival) or failure (mortality).

Based on the travel time analysis in Section 2.5.1.2.7.1.3 Perry Survival Model (Travel Time Component), operations under the PA would increase travel times throughout the fall-run migratory period with the biggest increases in February, March, and June, which are important migratory months for fall-run Chinook salmon juvenile diversity in the Delta. Increases in travel times for fall-run Chinook salmon fry sized fish (<70 mm) could be expected particularly in the month of February and March. April is the main migratory month of fall-run Chinook salmon smolts and travel time differences between scenarios were modest for 75% of the years ranging from 0.39 days increase to 0.73 days decrease under the PA. The 25% of years with the greatest increase under the PA ranged up to 1.6 days (Table 2-168). Likewise, in May, travel time for 75% of years increased under the PA up to 1.7 days. Although the effect of increase in travel time for these key migratory months are not substantial, it is still an adverse effect of the PA. Additionally, when fall-run Chinook smolts are mostly present in the Delta during April and May, there was not a substantial benefit in south Delta velocities and sometimes in drier years there was an increase in entrainment risk at the south Delta facilities. NMFS therefore expects that reduction in flow as a result of the PA will increase travel time for the majority of outmigrating smolts. This will result in an adverse effect to a high proportion of rearing and outmigrating fall-run Chinook juveniles.

2.5.1.2.7.1.3.6 Late Fall-run Chinook Salmon Exposure and Risk

Late fall-run Chinook salmon occur in the Delta from July through January, with peak occurrence in December (Table 2-174).

Table 2-174. Late Fall-run Sacramento and San Joaquin Basin Emigration from 1995 to 2008.

Monitoring Location	Data	Month											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Sacramento Trawl (RM 55)	Mean Size (Fork length) Size Range	NA	108 (81-125)	117 (103-132)	153 (130-201)	NA	NA	NA	NA	NA	64 (58-67)	77 (72-81)	89 (80-103)
Chipps Island Trawl (RM 18)	Mean Size (Fork length) Size Range	NA	119 (106-129)	125 (112-147)	137 (122-176)	NA	NA	NA	NA	NA	NA	NA	90 (84-100)

KEY	Degree of rearing expected	High >20%	Medium 10-20%	Low 2-10%	Rare to None <2%

Note: Midwater Trawl at Chipps Island, Midwater and Kodiak Trawls at Sherwood Harbor near Sacramento, conducted by The Delta Juvenile Fish Monitoring Program (DJFMP), Stockton, CA, USFWS.

Channel Velocity Differences in North Delta

The Delta velocity analysis was conducted for the months of December through June, which overlaps with late fall-run Chinook salmon juvenile migration through the Delta in December and January. The analysis revealed that the median velocities in the north Delta on the Sacramento River are reduced under the PA throughout December and January across all water year types, with just a few exceptions (BA Table 5.4-9 in Appendix C of this Opinion). The reduction in median velocity under the PA downstream of the North Delta Diversion (site 418) in December ranges from 7% in dry water years up to 15% in wet water years; in January, the reduction ranges from 7% in critical water years up to 18% in above normal water years. The reduced velocities in the North Delta in December and January under the PA suggest outmigrating late fall-run smolts will experience longer travel time and, therefore, greater predation risk and higher mortality, relative to under the NAA.

An analysis was done to look at changes in differences in the magnitude of negative velocities (flow reversing) between the PA and the NAA (BA Table 5.4-10 in Appendix C of this Opinion). This analysis recognizes that velocities in the tidal Delta are not always seaward and can become slack or negative during flood tides. This affects fish migration as fish may be pushed back upstream during flood tide, hold in the water column or a side bank or exert more energy to continue seaward, all affecting travel time during active outmigration. As discussed in Section 2.5.1.2.7.1.2 NDD Bypass Flows and Smolt Entrainment Analysis, there is insufficient information to analyze the PA operational constraint regarding no increase in reverse flows.

In the north Delta, the velocity analysis indicated there was no consistent change or pattern in the negative velocities under the PA relative to the NAA in December and January (see locations 418, 421, and 423 in BA Table 5.4-10 in Appendix C of this Opinion). The PA increased negative velocity in some water years at some locations, and decreased negative velocity in other water years and locations, and in many location/water year combinations there was little to no difference between the alternatives. The PA increased negative velocity in the Sacramento River just upstream from Georgiana Slough by as much as 78% in January in above normal water years. Conversely, the PA decreased negative velocity just downstream of the proposed North Delta Diversion by 35% in January of critical water years.

The third part of this hydrodynamic analysis looked for differences in modeling results between the NAA and PA in the proportion of time each day that velocity was negative in north Delta channels. In the north Delta, the modeling results for the peak late fall-run Chinook salmon migration (December) show that the proportion of day with reverse flows generally increases under the PA at some locations and water year types and is no different than under the NAA in other locations and water year types (BA Table 5.4-11 in Appendix C of this Opinion). There are no locations and water years that the PA decreases the proportion of the day with reverse flows.

Overall, the three velocity analyses indicate that juvenile late fall-run Chinook salmon moving through the north Delta during the peak of the juvenile emigration period will experience an increase in travel time, likely resulting in increased predation risk and decreased survival relative to under the NAA.

Channel Velocity Differences in Central Delta

Based on the velocity analysis within the Delta Cross Channel, travel time and predation risk for emigrating late fall-run Chinook salmon smolts in the central Delta are not expected to increase under the PA during December and January (BA Table 5.4-9 in Appendix C of this Opinion). In fact, travel time under the PA is expected to decrease by 6% in December of above normal water years and decrease by 5% in January of below normal water years relative to under the NAA.

There was little to no change in the Delta Cross Channel between the PA and NAA in December and January across all water year types in the magnitude of negative water velocities (BA Table 5.4-10 in Appendix C of this Opinion) and in the proportion of the day in which water velocities were negative (BA Table 5.4-11 in Appendix C of this Opinion). Based on the water velocity analyses, late fall-run Chinook salmon juveniles are not expected to experience adverse effects related to water velocity in the Central Delta under the PA relative to the NAA. It is important to note that negative velocities in Georgiana Slough were not examined in this analysis though it is an important migratory route that is examined in other models in this biological opinion. Specifically, the NDD bypass flows and smolt entrainment model assesses changes in proportion of smolts using Georgiana Slough, and the DPM and Perry Survival Model assess differences in survival using this migratory route.

Channel Velocity Differences in South Delta

Late fall-run Chinook salmon originate from the Sacramento River basin or the Coleman National Fish Hatchery, and as such are relatively unlikely to occur in the south Delta, particularly at the most upstream locations in the south Delta. The velocity analyses indicate that PA flow velocities in the south Delta in December and January generally are the same or higher than flow velocities under the NAA (BA Table 5.4-9 in Appendix C of this Opinion). The increases in velocity would likely improve the survival of any late fall-run Chinook salmon smolts that may have moved into the south Delta. In January, flow velocity decrease in the Old River upstream of the south Delta export facilities, but it is unlikely that late fall-run Chinook salmon would occur that far upstream.

The San Joaquin River flow velocity near the mouth of the Mokelumne River (Channel node 45) would also generally be higher under the PA compared to the NAA scenario. Flow velocities would be higher in all water year types during December and January, with most of these increases being greater than 5%. The increases in velocity under the PA relative to the NAA would likely improve the survival of any late fall-run Chinook salmon smolts that may have moved into the south Delta in the vicinity of the mouth of the Mokelumne River.

Late fall-run Chinook salmon fry/parr sized fish in the Old River channel corridor downstream of the export facilities would benefit from more positive flow velocities December and January under the PA (BA Table 5.4-9 in Appendix C of this Opinion). The more positive velocities indicate that there is less net flow towards the facilities since the channel dimensions remain the same. This is a result of anticipated reduced exports in the south Delta under the PA scenario. More positive velocities (even though they are still predominately negative) may mean that late fall-run Chinook salmon within the Old River channel downstream of the facilities are pushed towards the fish salvage facilities at a lower rate under the PA compared to the NAA scenario.

The magnitude of negative flow velocity in the south Delta was modeled to compare the changes between the PA and NAA scenarios. Channel velocity under the PA in December and January in the San Joaquin River downstream of the head of Old River and near the mouth of the Mokelumne River, and in the Old River downstream of the export facilities was similar to or less negative than velocity under the NAA across all water years (BA Table 5.4-10 in Appendix C of this Opinion). In the San Joaquin River, downstream of the head of Old River in January, velocity under the PA became less negative than under the NAA by a range of 14% in critical water years to 21% in wet water years. The muting of the negative velocities (flow velocity becoming less negative) in the San Joaquin River is a reflection of the operation of the HOR gate, which redirects more flow down the San Joaquin River main channel. The greater percentage of river flow moving down the main channel would offset the influence of the tides in this river reach, and enhance downstream movement of fish. These effects should benefit emigrating late fall-run Chinook salmon juveniles by decreasing the likelihood that juveniles would become disoriented by reverse flows and move into the San Joaquin River, as well as decreasing seaward travel time for any juveniles that do make their way from their Sacramento River origins into the south Delta. More negative velocities are assumed to be detrimental to the downstream migration of late fall-run Chinook salmon juveniles by increasing travel times. As stated above, increased travel times for juveniles will likely increase their exposure to predators and reduce their survival.

The third part of the velocity analysis was proportion of day with negative velocities. In the south Delta in January, the analysis showed positive effects for multiple water year types under the PA in the San Joaquin River downstream of the HOR and Old River downstream of the south Delta export facilities (BA Table 5.4-11 in Appendix C of this Opinion) in which a lower percentage of the day had negative flows. Conversely, for reasons already explained, the operations of the HOR gate under the PA increased the percentage of the day in which flows were negative upstream of the South delta export facilities during January, relative to the NAA. However, given that late fall-run Chinook salmon originate from the Sacramento River basin, they are unlikely to occur in the Old River upstream of the south Delta export facilities. Emigrating late fall-run Chinook salmon juveniles should be unaffected or would benefit with the reduction in the proportion of the day in which negative flows occur in the San Joaquin River downstream of the HOR gate location and in Old River downstream of the south Delta export facilities.

Effect of NDD Bypass Rules on Late Rall-run Migration (Perry et al. 2016 NDD Bypass Flows and Smolt Entrainment Model)

As noted in the fall-run temporal distribution tables, the Delta migration period generally occurs between July and January, with peak presence in December (Table 2-174). Late fall-run Chinook salmon occurring in the Delta in December and January would be smolt-sized and, therefore, the Perry et al. 2016 NDD bypass flows and smolt entrainment model is applicable for late fall-run Chinook salmon in those months.

Under the PA NDD bypass rules, December through April fall under identical operations rules once initial pulse protection ends; beginning with Level 1 operation, and then increasing to Level 2 or Level 3 operations when flow criteria are met. Of the three main operations levels, Level 1 provides the most protection or least change in riverine flows from the NAA scenario. Under Level 1 operations, the increase in probability of a flow reversal remains under 30% and the increase in the proportion of the day with a flow reversal remains under 5%. Under Level 2, the increase probability of a flow reversal can be as high as 80% with a ~4-6% increase in the proportion of the day with a flow reversal; while under Level 3, the probability of a flow reversal is up to 100%, with the increase in the proportion of the day with a flow reversal up to 15% (Figure 2-120).

Based on the adverse effects Level F2 and Level 3 diversions have on riverine conditions that influence migration routing, travel time, and overall survival, late fall-run would be less impacted under low level pumping and Level 1 operations. Under the NDD bypass rules and no other constraints to diversions, late fall-run Chinook salmon smolts that are in the Delta during December and January may have slightly longer travel times under the PA than the NAA. This could result in higher mortality rates under the PA than under the NAA for the peak migration of late fall-run Chinook salmon smolts.

Perry Survival Model – Travel Time

The Perry Survival Model helps to quantify the actual travel time that smolts will experience under the different Delta inflows between scenarios. Travel time through the Delta will be increased under the PA during the migration period for late fall-run Chinook salmon. For example, during the peak month of late fall-run Chinook salmon smolt emigration (December), the median increase in travel time over all water year types is 0.29 days under the PA as compared to the NAA (Table 2-168). Travel time for late fall-run Chinook salmon juveniles across all water year types also is expected to increase under the PA relative to the NAA during October and November (Table 2-167) and January (Table 2-166). For 75% of years under the PA, travel time increases during October and November range from 0.2 days up to 4.6 days. The increased travel time from October through January is expected to result in decreased survival for the majority of outmigrating late fall-run Chinook salmon juveniles.

2.5.1.2.7.2 Outmigration Routing

Several studies of salmonid migration through the Sacramento-San Joaquin Delta show that the survival rate for salmonids is notably lower for fish that travel through the interior Delta than for those that migrate through the Sacramento River or Sutter and Steamboat Sloughs (Perry 2010; Newman 2003). These reductions are most likely due to higher predation rates in the interior Delta, longer migration times required to navigate the circuitous path of channels under lower distributary velocities, and risk of entrainment into the CVP/SWP (Perry et al. 2010; Perry et al. 2013; Newman 2003; Newman,and Brandes 2010; NMFS 2009). Because a proportion of Sacramento River basin salmonids are exposed to interior Delta migration routes, migratory route entrainment is considered a stressor that can affect individual fish survival and overall population abundance. Assessing survival and migratory patterns for salmonids in the Delta under the operations of the PA relies on examination of flows into and hydrodynamics of the Delta. Note we do not analyze the effects on salmonid outmigration routing from the revised NDD operations (e.g., unlimited pulse protection as described in Section 2.5.1.2.7.4 Delta Survival) because we do not have modeling information to inform the analysis of outmigration routing specifically.

The methods that are used to analyze how changes in hydrology or flows can affect migratory route entrainment are summarized in Table 2-175.

Table 2-175. Methods or Models Used to Assess Changes in Migratory Route Entrainment in the Delta Under the PA Compared to NAA.

Model	Source	Method	Applicability	Analysis
Flow Routing at Delta Channel Junctions	CWF BA Section 5.4.1.3.1.2.1.2.1	DSM2 hydrodynamic modeling examining changes in proportional flow at key junctions.	Juvenile salmonids and sturgeon migratory patterns	Hydrological changes between PA and NAA at key channel junctions throughout the north, central, and south Delta
NDD Bypass Flows and Smolt Entrainment Model	Perry et al. (2016)	Re-calibrated DSM2 hydrodynamic modeling coupled with observed route entrainment of acoustically tagged smolts.	Juvenile salmonid smolts (>70 mm)	Hydrodynamic analysis of smolt entrainment into key migratory channels in Delta based on acoustic tag studies of late-fall run smolts
Perry Survival Model (Migratory routing component)	Perry 2016	Calsim hydrodynamic analysis of route selection coupled with observed route entrainment of acoustically tagged smolts.	Salmonid smolts (i.e., >70 mm)	Calsim simulations of scenarios to determine migratory routing based on relationships from acoustic tag studies.

2.5.1.2.7.2.1 Flow Routing in Delta

The BA includes analysis of changes in flow routing at important channel junctions in the Delta (BA Section 5.4.1.3.1.2.1.2.1 Flow Routing into Channel Junctions). Since hydrology affects the proportion of fish entering a channel, this analysis was undertaken to describe differences in flow between PA and NAA at the junction of key Delta migratory channels that fish may encounter. The resultant change in flow at these key junctions may make fish more or less likely to enter the channel. In general, more flow into a channel is assumed to result in more fish entering that channel (Cavallo et al. 2015).

As the BA notes, lower flow in the Sacramento River (as would occur because of exports by the NDD) increases the tidal influence at the Georgiana Slough junction (Perry et al. 2015) and results in a greater proportion of flow (and, presumably, fish) entering Georgiana Slough (Cavallo et al. 2015) and the central Delta. Entry into the central Delta is expected to result in an adverse effect to salmonids due to lower survival probabilities observed for fish that enter the central and interior Delta. Conversely, entry into the distributaries of Sutter and Steamboat Sloughs, which are upstream of the Georgiana and DCC junctions, would be beneficial to salmonids because these are relatively high survival migration pathways that allow fish to avoid potential entry into the central Delta (Perry et al. 2010, 2013).

NMFS analysis of the flow routing results shows that there is little change in the proportion of flow entering Sutter Slough for the PA versus NAA, with the exception of December of critical years, when there is five percent less flow entering Sutter Slough under the PA (BA Table 5.4-12 in Appendix C of this Opinion). At Steamboat Slough, the proportion of flow into the distributary decreased by more than 5% under the PA in some months and water year types such as during February and March of below normal and dry years (BA Table 5.4-12 in Appendix C of this Opinion and Table 2-176). The proportion of flow entering Georgiana Slough for the PA was generally similar to the proportion entering under the NAA. However, increases in flow proportion into Georgiana Slough occur under the PA in February and March of below normal and dry years (BA Table 5.4-12 in Appendix C of this Opinion and Table 2-176), and January and April of above normal years and December of wet years (BA Table 5.4-12 in Appendix C of this Opinion).

NMFS' analysis of the flow routing in (BA Table 5.4-12 in Appendix C of this Opinion) shows more flow entering the DCC for the PA in December and February through May. Because the DCC is closed during January through May, December becomes the only month of concern. The effects of increased opening of the DCC for the PA operations is analyzed further in the entrainment model Perry et al. (2016) in Section Salmonid Smolt Routing into the Interior Delta.

In the south Delta, at the head of Old River, where entry for salmonids is considered adverse, because this channel leads directly to the south Delta pumping facilities, there is a substantial decrease in the amount of flow from the mainstem San Joaquin River entering Old River in January through June in all water year types for the PA due to the HOR gate being in place during key salmonid migratory months (BA Table 5.4-12 in Appendix C of this Opinion). In December of all water year types, there is less than five percent change between the scenarios.

At Turner Cut, where entry for salmonids is considered adverse, because fish in this channel are under the hydrodynamic influence of the south Delta pumping facilities and will likely get entrained there, there is a consistent trend of more flow (greater than five percent) entering this distributary for the PA during February through May (BA Table 5.4-12 in Appendix C of this Opinion). In December, January, and June there is less than five percent change between scenarios.

At Columbia Cut, where entry for salmonids is considered adverse, because fish in this channel are under the hydrodynamic influence of the south Delta pumping facilities and will likely get entrained there, the PA increases the proportion of flow entering this distributary in above normal and below normal water year types during April and May and also in April of dry years by more than five percent (BA Table 5.4-12 in Appendix C of this Opinion). In the wet water year types in February, March, and June, the NAA has an increased proportion of flow into Columbia Cut. The changes in flow into Columbia Cut are relative changes greater than five percent, but under ten percent. In the other months and water year types, there were no changes greater than five percent between scenarios.

In Middle River and the mouth of Old River, where entry for salmonids is considered adverse, because these channels lead directly to the south Delta pumping facilities, there were a few months in the wetter water year types when flows into these distributaries were lower (between 5% - 9%) under the PA. This includes February of wet years and March of wet and above normal years for both junctions, and June of wet years for Middle River.

Overall, effects of the PA on migratory routing in the south Delta vary by channel as well as month and water year type particularly for Sacramento basin salmonid juveniles. Salmonid juveniles originating from the San Joaquin basin would have benefits of higher probability of remaining in San Joaquin River due to HOR gate under the PA.

Table 2-176. Proportion of Flow Highlighted in Red When Over 5% Difference Between Scenarios and is Considered an Adverse Effect to Salmonids.

Location			Months						
			February			March			
Steamboat Slough									
		Scenario:	NAA	PA	PA vs NAA		NAA	PA	PA vs NAA
	Water Year Type								
	W		0.291	0.284	-0.007 (-2%)	W	0.277	0.270	-0.007 (-3%)
	AN		0.279	0.272	-0.007 (-3%)	AN	0.263	0.257	-0.006 (-2%)
	BN		0.238	0.220	-0.018 (-8%)	BN	0.218	0.205	-0.013 (-6%)
	D		0.222	0.210	-0.012 (-5%)	D	0.232	0.212	-0.020 (-9%)
	C		0.203	0.199	-0.004 (-2%)	C	0.193	0.194	0.001 (1%)
Georgia Slough									
	W		0.291	0.292	0.001 (0%)		0.292	0.293	0.001 (0%)
	AN		0.292	0.293	0.001 (0%)		0.299	0.302	0.003 (1%)
	BN		0.339	0.379	0.040 (12%)		0.391	0.417	0.026 (7%)
	D		0.382	0.400	0.018 (5%)		0.366	0.406	0.040 (11%)
	C		0.418	0.416	-0.002 (0%)		0.431	0.429	-0.002 (0%)

2.5.1.2.7.2.2 Salmonid Smolt Routing into the Interior Delta

As examined in the flow routing at Delta channel junctions analysis above, the proposed operations of the North Delta Diversions may influence the migratory routes outmigrating fish use through the Delta. Fish from the Sacramento River may stay in the mainstem Sacramento River or enter Sutter or Steamboat Sloughs or enter the central Delta via Georgiana Slough or Delta Cross Channel (DCC). This analysis uses the NDD bypass evaluation and smolt entrainment model of Perry et al. (2016) (in review) to predict the probability of juvenile Chinook salmon smolts remaining in the mainstem Sacramento River or being entrained into the central Delta via Georgiana Slough or the DCC under the operations of the PA and NAA scenarios. This model allows for observed fish behavior to inform the hydrodynamic analysis providing a more realistic probability of proportion of fish using each migratory route. The NDD bypass evaluation and smolt entrainment model uses flows simulated by DSM2-HYDRO and further recalibrated to better match empirical gauge data for the months of October through June over the 82-year modeling sequence used in the CWF scenarios (Reclamation 2016).

A complete description of the model, including model equations, estimated parameters, and goodness-of-fit, can be found in Perry et al. (2015) and Perry (2010). Information on the methods and the DSM2 bias correction performed to conduct this analysis can also be found in Perry et al. (2016). Perry et al. (2015) models entrainment probabilities as a function of hydrodynamic variables such as river flow, tides, and gate operations. The model was fitted with telemetry data of late-fall run smolts to couple fish behavior with hydrodynamic variables. The Perry smolt entrainment model is the application of the Perry et al. (2015) model to the CWF scenarios.

The probabilities of entrainment into Georgiana Slough, DCC, or the mainstem Sacramento River were based on averaging daily entrainment probabilities as follows: 1) annually, 2) monthly within water year types, and 3) by run timing distributions. The entrainment model was based on data collected at a maximum Freeport discharge of 40,700 cfs, whereas the DSM2 simulations of the PA and NAA scenarios of CWF include Freeport flows up to approximately 80,000 cfs. Because the Perry et al. (2015) model appears to over-estimate entrainment at flows greater than 41,000 cfs, the analysis of simulated daily entrainment probabilities was restricted to modeled Freeport flows lower than 41,000 cfs.

Because the timing of smolt outmigration varies by year and is largely influenced by the timing of first pulse flows (del Rosario et al. 2013), the NDD bypass evaluation and smolt entrainment model predicts the probability of entrainment under three categories of run timing. The three run-timings are: 1) a uniform distribution, where an equal proportion of fish outmigrate on each day of the month during October through June; 2) an early run timing representing winter-run Chinook salmon smolts in years when flow conditions trigger an early migration into the Delta (i.e., on or before December 31); and 3) a late run timing representing winter-run Chinook salmon smolts in years when flow conditions trigger a later migration into the Delta (i.e., on or after January 1) (Figure 2-130). Estimates of annual entrainment probability for the different run timings were calculated as a weighted average of the daily entrainment probability weighted by the proportion of the run migrating on a given day. Run timing distributions were based on winter-run sized (greater than 70-millimeter fork length) juvenile sample data from Sacramento Trawl (Redler 2016).

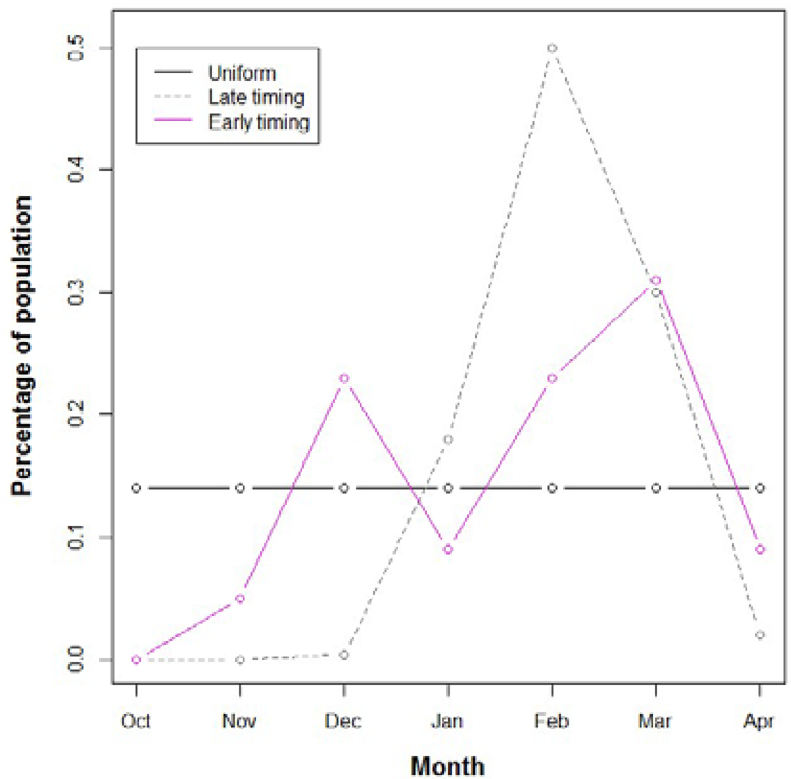


Figure 2-130. Migration timing scenarios used to estimate mean annual entrainment probabilities, with the early and late timings representing two scenarios for winter-run Chinook salmon in the Sacramento River.

Under the PA, the mean annual probability of smolts remaining in the mainstem Sacramento River is lower regardless of run-timing scenario (Table 2-75). In general, the mean annual entrainment probabilities differ little between NAA and PA; however, there is a consistent trend of greater entrainment into the interior Delta for the PA for all three run timings (Table 2-75). Specifically, entrainment in the DCC is consistently higher for uniform and early run timings (Table 2-75). Entrainment into Georgiana Slough is slightly higher under late and early run timings (Table 2-75). The differences in annual entrainment among the run timing scenarios suggests that daily entrainment probabilities vary seasonally, thereby affecting annual entrainment differentially for the alternative run timings (Figure 2-131). The probability of entrainment into DCC is notably higher for the PA (Figure 2-131).

Table 2-177. Mean (SD) Predicted Annual Entrainment Probabilities Under Different Run-Timing Scenarios for NAA and PA Simulations Conducted with DSM2 (Entrainment into the Sacramento River is Equivalent to Remaining in the Sacramento River).

	Sacramento River		Georgiana Slough		Delta Cross Channel	
Run-timing	NAA	PA	NAA	PA	NAA	PA
Uniform	0.571 (0.031)	0.556 (0.028)	0.349 (0.017)	0.346 (0.017)	0.072 (0.03)	0.089 (0.024)
Late	0.555 (0.132)	0.547 (0.129)	0.344 (0.09)	0.352 (0.094)	0 (0)	0 (0)
Early	0.558 (0.085)	0.549 (0.082)	0.346 (0.061)	0.352 (0.063)	0.018 (0.018)	0.021 (0.018)

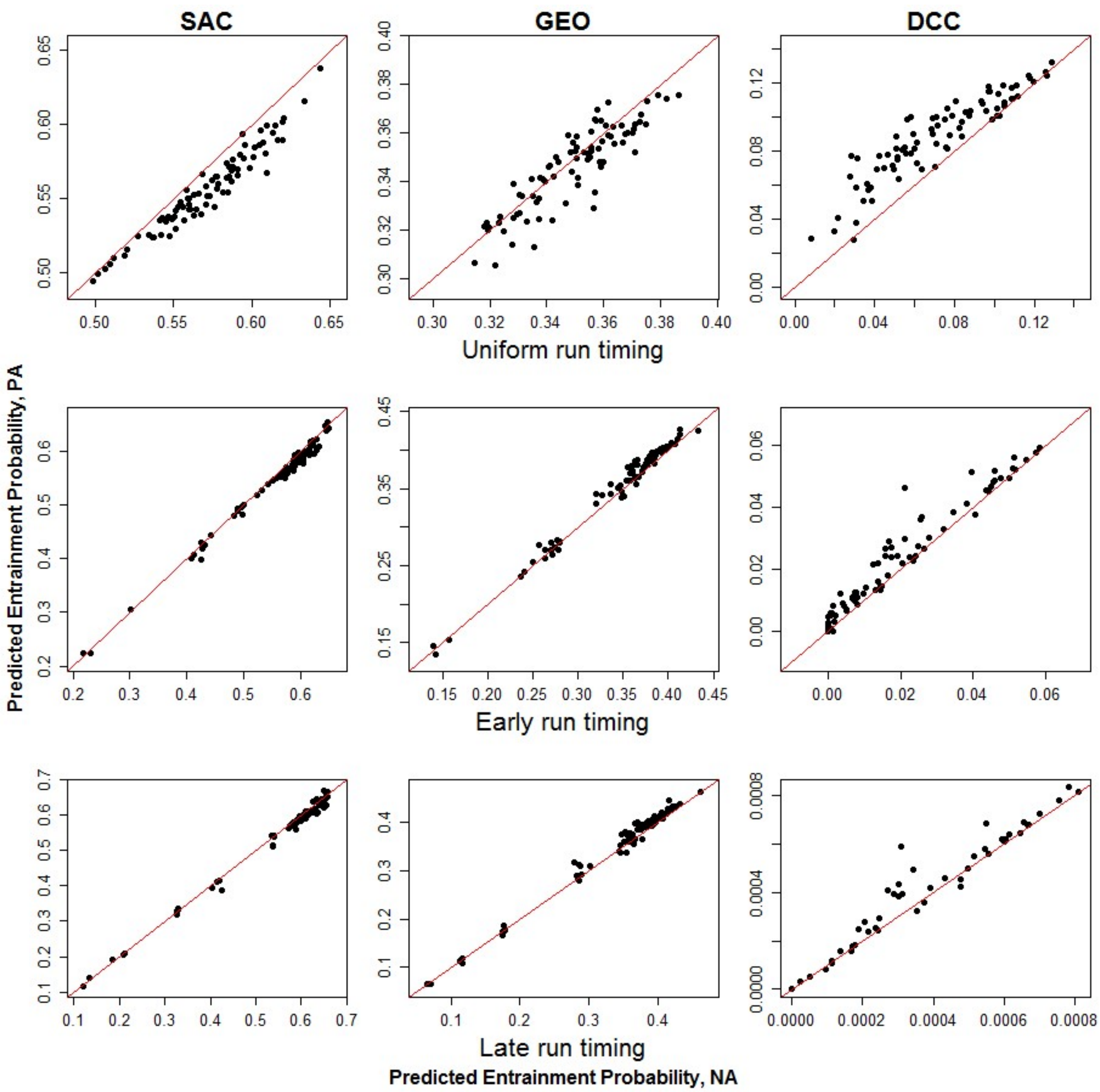


Figure 2-131. Comparison of Predicted Mean Entrainment Probability for the Sacramento River (SAC), Georgiana Slough (GEO), and Delta Cross Channel (DCC) between the Proposed Action (PA) and No Action Alternative (NAA) for Uniform Arrival, and Early and Late Run Timing.

When looking at uniform run timing scenario under the PA operations, the probabilities of smolts remaining in the mainstem Sacramento River during the salmonid migration period are consistently lower across water year types, especially in the months of October, November, December, and occasionally June (Figure 2-132). Entrainment into Delta Cross channel is also higher in October, November, and December (Figure 2-132).

The DCC gates are open more frequently during these months for PA operations, which is the reason for higher probability of entrainment into DCC at these times. DCC operations, as characterized in both scenarios, requires that the DCC gates remain closed when Sacramento River flow downstream of the NDD intake location is greater than 25,000 cfs. This is required to limit the potential for flooding and scour at the cross channel. For PA operations, water diversion at the DCC could reduce bypass flows to levels lower than 25,000 cfs, which allows the DCC gates to remain open at times when they would have otherwise been closed. In turn, opening the Delta Cross Channel gates substantially reduces the instantaneous probability of fish remaining in the Sacramento River by increasing the probability of fish entering the Delta Cross Channel (Figure 2-131). It is likely that DCC gate operations will be managed in real-time and the increased opening seen in the model will not necessarily occur during actual operations.

As Figure 2-132 shows, in wet years, the most notable changes are that fewer fish remain (median ~3-5%) in the Sacramento River for the PA during October, November, and June. Smaller changes include fewer fish (median 1%) remaining in the Sacramento River for the PA in December, February, and March.

In AN years, fewer fish remain (median 2-4%) in the Sacramento River for the PA during October, November, and June and slightly fewer remain (median ~ 1%) in December.

In BN years, fewer fish remain (median ~2-5%) in the Sacramento River for the PA during October, November and March. In December, January, February and June fewer fish (median ~1%) remain in Sacramento River for the PA as well.

In Dry years, October and November show the biggest differences with fewer fish (median~4%) remaining in the Sacramento River for the PA. December, January, February, March and June have fewer fish (median ~ 1%) remaining in the Sacramento River for the PA.

In Critical years, the median entrainment is similar in all months with a probability of fewer fish remaining in the Sacramento River for the PAA during October, November, December and February (median 1 to 2%).

April and May were very similar between the scenarios throughout all water year types with median differences remaining under 1% (Figure 2-132).

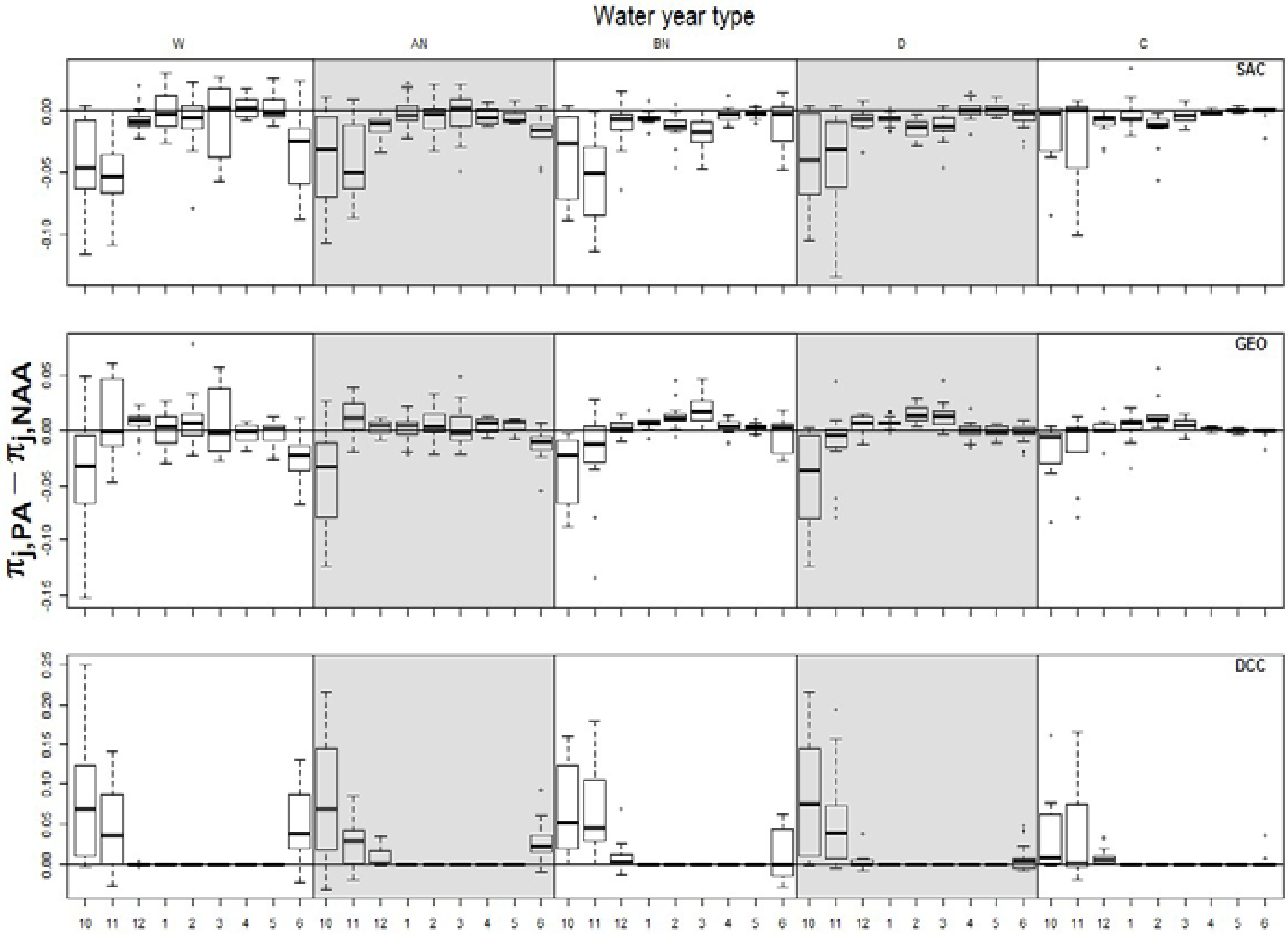


Figure 2.132. Difference in entrainment probability between Proposed Action (PA) and No Action Alternative (NAA) by water year type and month assuming a uniform run timing (W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical) for the Sacramento River (top panel), Georgiana Slough (middle panel), and DCC (bottom panel). π_j is the probability of entrainment into channel j. Y-axis refers to month (1=Jan, 2=Feb, etc.). Boxes range from the 25th to the 75th percentiles with a line indicating the median; whiskers extend 1.5 times past the length of the box, and dots represent data points that fall beyond the whiskers. Entrainment into DCC is possible only when the gate is open during the months of October, November, December, and June. Entrainment for the Sacramento River means remaining in the Sacramento River.

Further components of the analysis shows that much of the interannual variation in mean annual entrainment probabilities could be attributed to water year classification. For example, mean annual probability of remaining in the mainstem Sacramento River for the uniform run timing decreased from a median of about 0.60 to 0.52 as water year type transitioned from wet to critically dry years (Figure 2-133). Therefore, relative entrainment probabilities into the interior Delta increase in drier years.

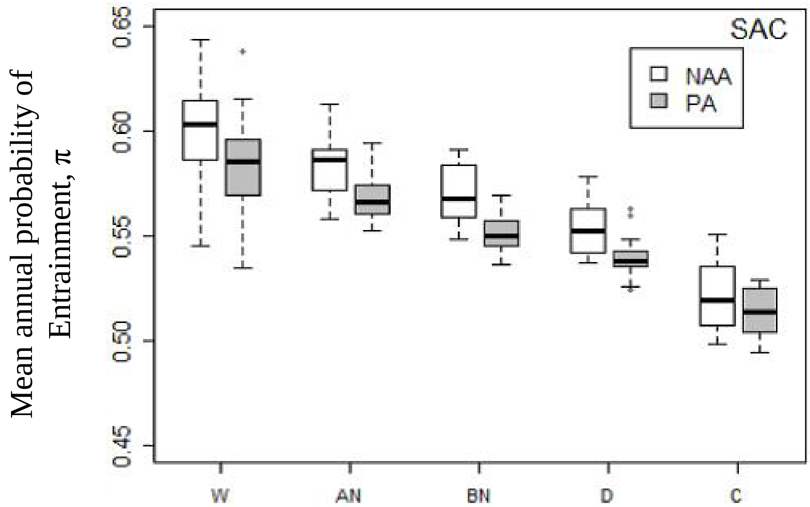


Figure 2-133. Boxplot of predicted mean annual entrainment probability for the Sacramento River (SAC) between the No Action Alternative (NAA) and Proposed Action (PA) by water year type based on a uniform run-timing distribution (W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical) (Entrainment for the Sacramento River means remaining in the Sacramento River).

In summary, under the PA, the median probability of remaining in the Sacramento River was lower under all three run timings and across all water year types (Figure 2-134, top panel). The median probability of entrainment into Georgiana Slough in wet years under the uniform run timing is higher under the NAA (Figure 2-134, middle panel). However, this is due to the DCC, which is located above the Georgiana Slough junction, entraining fish from the Sacramento River under operations of the PA (Figure 2-134, bottom panel) leaving less of a proportion of the population in the Sacramento that could then be entrained into Georgiana Slough. Overall, the probability of entrainment into the central Delta varies by month and is consistently higher under the PA under all water year types and run timings examined. The increase in entrainment into the central Delta under the PA for all 3 run timings was < 2 percentage points for all the mean annual entrainment probabilities (Table 2-177).

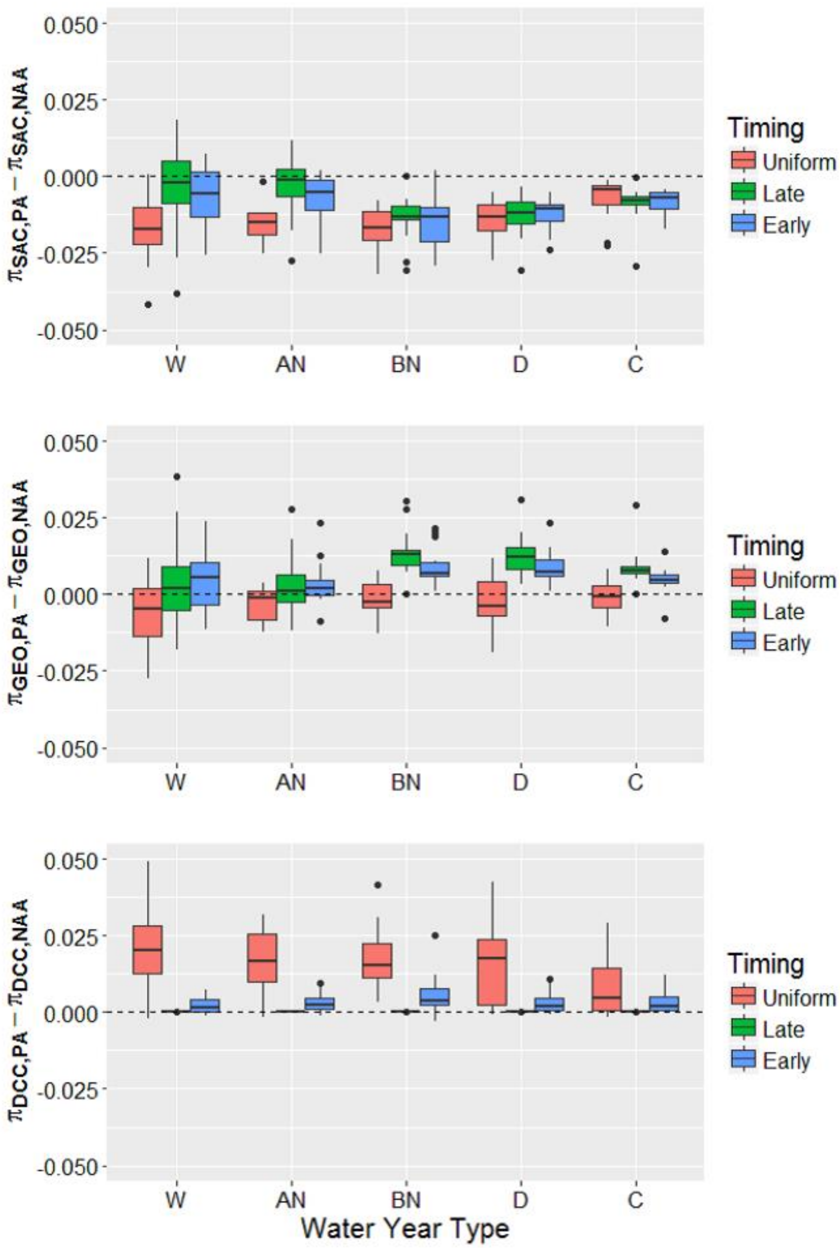


Figure 2-134. Boxplots of the difference between No Action Alternative (NAA) and Proposed Action (PA) for each route (SAC = Sacramento River, GEO = Georgiana Slough, DCC = Delta Cross Channel) by water year type (W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical) and run timing scenario. π_j is the probability of entrainment into channel j. Boxes range from the 25th to the 75th percentiles with a line indicating the median, whiskers extend 1.5 times past the length of the box, and dots represent data points that fall beyond the whiskers.

The analysis of Perry et al. (2012) included an evaluation of the sensitivity of overall survival of emigrating juvenile Chinook salmon to changes in entrainment into the interior Delta. Results show that overall survival through the Delta increases between 2-7 percentage points if entrainment into the interior Delta is completely eliminated (assuming no change in route-specific survival). Applying this information to the above analysis of the PA, the 3-5 percentage point difference between PA and NAA in the probability of being entrained to the interior Delta that occurs in certain months or the <2 percentage point difference in mean annual entrainment is expected to contribute relatively little to the change in overall survival. However, reduced inflows to the Delta caused by the operations of the NDD may simultaneously influence both route-specific survival and migration routing. Such simultaneous changes may result in larger than expected changes in survival than the effect of routing alone on overall survival.

Interpretation of these analyses must also consider that small changes in absolute survival could translate to a large effect to a population, especially in years when overall Delta survival is low. The 2-7% increase in Delta survival that would occur if entrainment into the interior Delta were eliminated (Perry et al. 2012) resulted in a 10-35% relative change in survival for five of the six release groups in that study.

Salmon Smolt Entrainment Proportion

The NDD bypass evaluation and smolt entrainment model (Perry et al. 2016) analyzed daily entrainment into each migratory route as part of the overall through Delta and route specific survival. The results were grouped by month and water year type for the proportion of population remaining in the Sacramento River, entering Sutter and Steamboat Sloughs, entering Georgiana Slough and entering Delta Cross Channel. Illustrated below is how the NDD bypass evaluation and smolt entrainment model tracks smolt migration through the Delta using 1927, a wet water year, as an example (Figure 2-135).

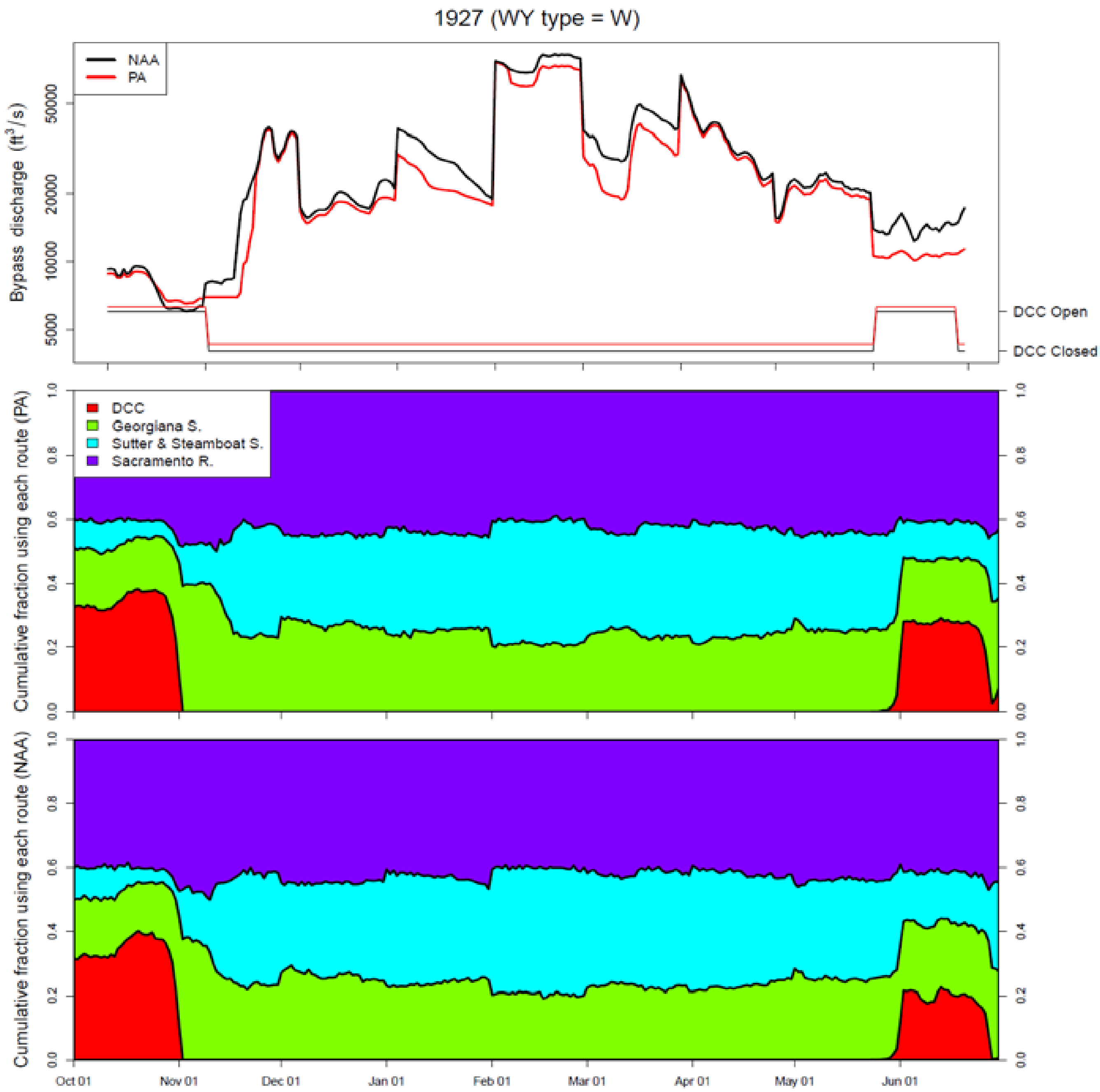


Figure 2-135. Freeport discharge under NAA (black line) and bypass flow under PA (red line) along with DCC gate open/closed between scenarios (top panel). Cumulative proportion using each of the four routes under PA (middle panel). Cumulative proportion using each of the four routes under the NAA (bottom panel).

The differences in probability of entrainment between the scenarios are presented in Figure 2-136 through Figure 2-138. Figure 2-136 shows differences in the proportion of fish migrating via the Sacramento River between scenarios, Figure 2-137 shows the difference in the proportion of fish migrating via Sutter and Steamboat Sloughs between scenarios, and Figure 2-138 shows the difference in proportion of fish migrating through the central Delta via Georgiana Slough or

Delta Cross Channel between scenarios. Besides comparison of NAA and PA, there is also a comparison of NAA and L1. L1 is part of the PA but represents a scenario where NDD bypass diversions are limited to Level 1 only. The L1 scenario is analyzed as part of the PA as it is stated that under real-time management, operations will be limited to Level 1 diversions when salmonids are migrating through the Delta as informed by fish monitoring criteria that are yet to be determined.

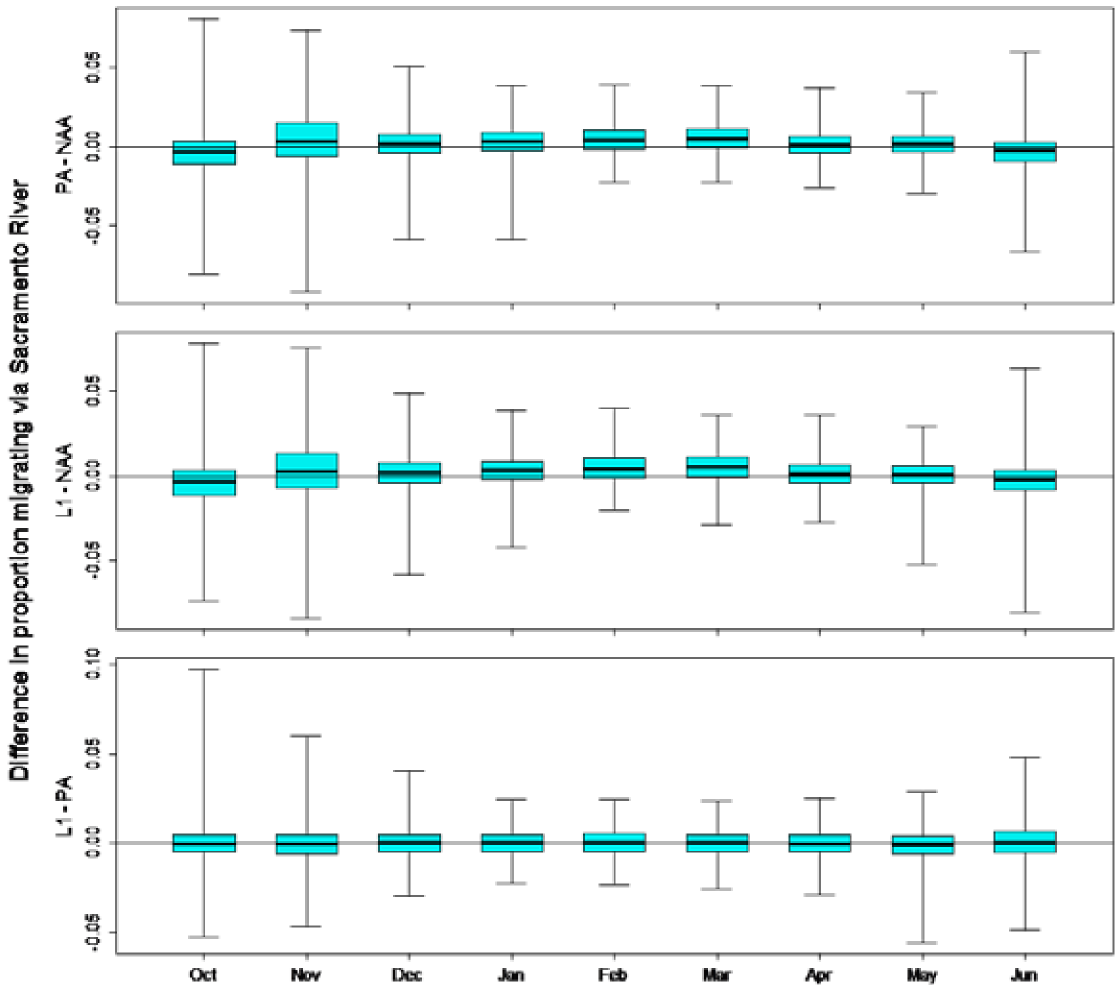


Figure 2-136. Boxplots of differences between scenarios for the proportion of fish migrating via the Sacramento River. Each box plot represents the distribution of daily differences among years of a given water-year type and month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

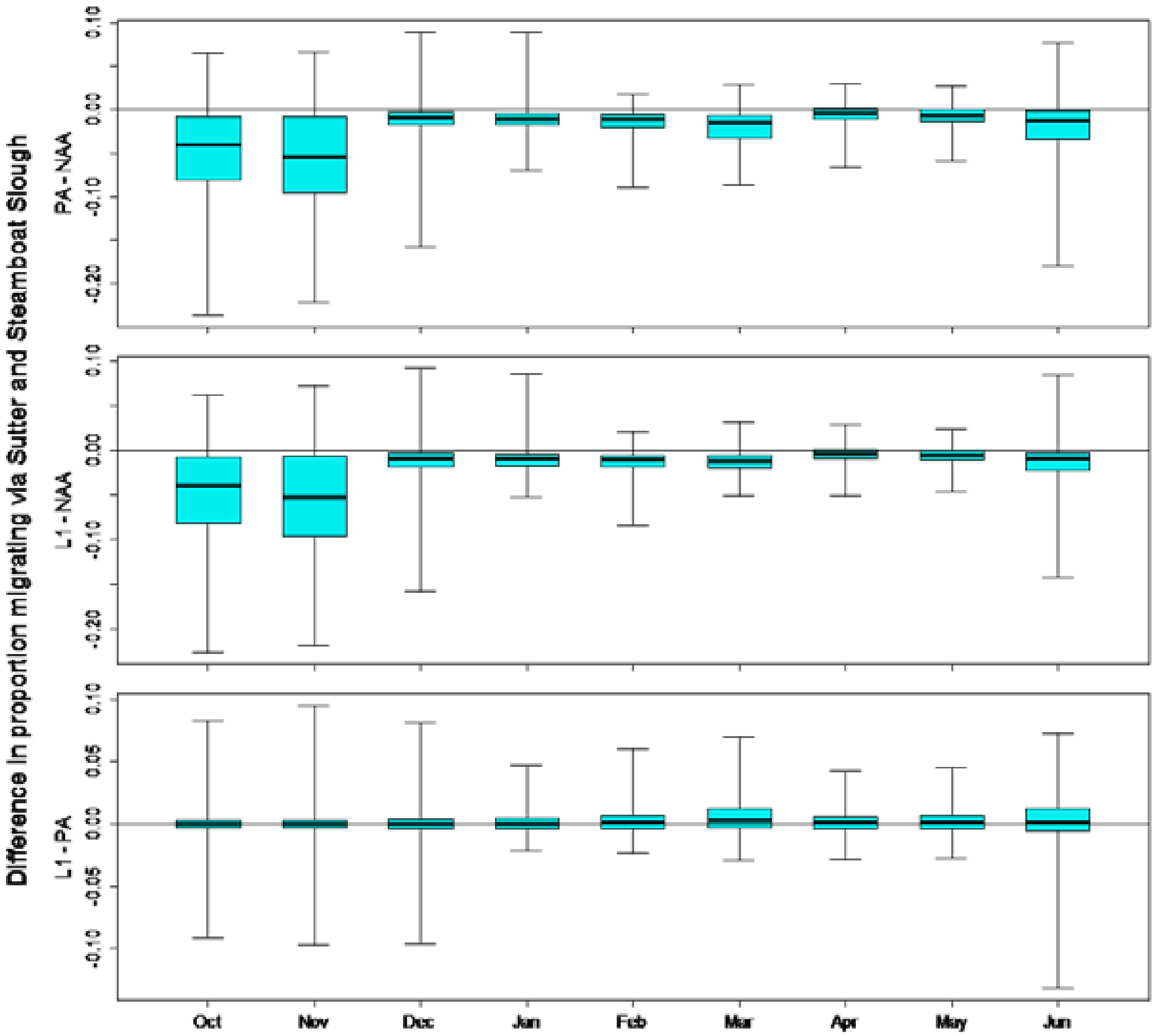


Figure 2-137. Boxplots of differences between scenarios for the proportion of fish migrating via the Sutter and Steamboat Slough. Each box plot represents the distribution of daily differences among years of a given water-year type and month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

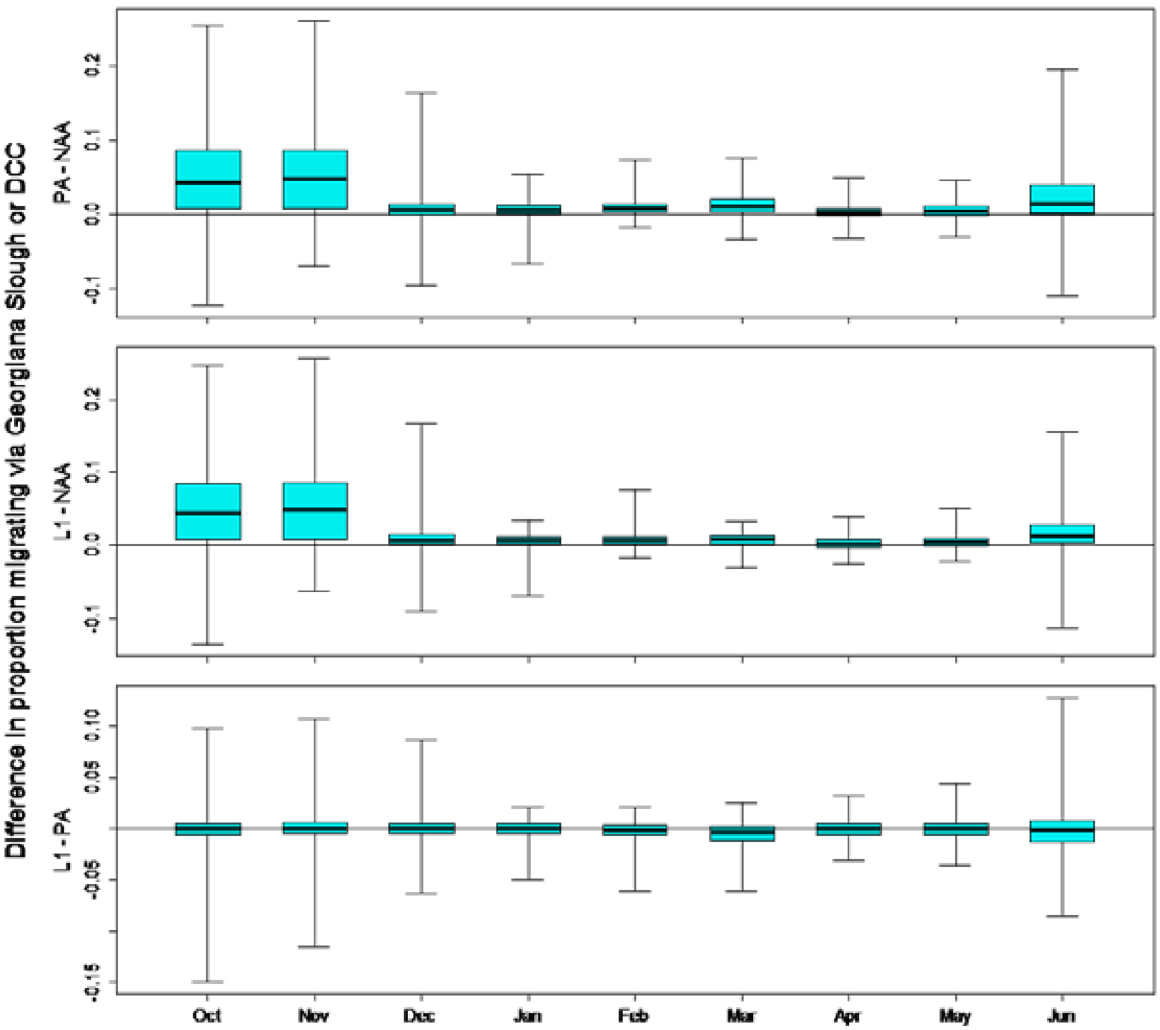


Figure 2-138. Boxplots of differences between scenarios for the proportion of fish migrating via the Georgiana Slough or the Delta Cross Channel (DCC). Each box plot represents the distribution of daily differences among years of a given water-year type and month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

Overall, differences on remaining in the Sacramento River (which is expected to result in a positive effect) between scenarios are small with the median difference between NAA and PA and NAA and L1 all under 1% (Figure 2-136). Therefore, the overall change between scenarios in proportion of smolts remaining in the Sacramento River migratory route is rather small and varies by month with more smolts remaining in the Sacramento River under both the PA and L1.

The proportion of smolts migrating through Sutter and Steamboat Sloughs (which is expected to result in a positive effect) show more significant changes between scenarios. The median difference in proportion of smolts using Sutter and Steamboat Sloughs are higher each month

(October through June) under the NAA (Figure 2-137). January, February, March, and June show a median difference of approximately 1% more smolts entering Sutter and Steamboat Slough under the NAA (Figure 2-137). The largest median difference is that 4% to 5% more smolts enter the Sutter and Steamboat Sloughs during October and November respectively under the NAA (Figure 2-137). During 75% of the years more smolts will enter Sutter and Steamboat Slough in every month but April and May under the NAA. Variation in monthly entrainment can range from approximately 5% to 23% more smolts entering Sutter and Steamboat Slough under the NAA during over 75% of years to 2% to 9% more smolts occasionally (< 25% of years) entering Sutter and Steamboat Slough under the PA (Figure 2-137).

The proportion of smolts migrating through the central Delta (which is expected to result in a negative effect) also show some significant changes between scenarios. Every month shows an increase in the number of smolts entering the central Delta under the PA, and during 75% of years, more smolts will enter the central Delta under the PA except for the months of April and May (Figure 2-138). Median difference between NAA and PA/L1 are under 1% for the months of December, January, February, April and May (Figure 2-138). March and June have a median difference just over 1% and October and November have median difference between 4% to 5% (Figure 2-138). Variation in monthly entrainment can range from approximately 3% to 26% more smolts entering the central Delta under the PA during 75% of years to up to 12% more smolts entering the Central Delta occasionally (>25% of years) under the NAA (Figure 2-138). The overall results from the flow routing and salmon smolt entrainment modeling are presented in Table 2-178.

Table 2-178. Summary of Flow and Salmonid Smolt Routing Results.

Model	Overall Trend in Results
Flow Routing at Delta Channel Junctions	Increased probability of entrainment into central Delta for Sacramento basin salmonids under the PA. Increased probability of remaining in San Joaquin River for San Joaquin basin salmonids under the PA. Varied results on migratory routing effects in several channels in the south Delta.
NDD Bypass Flows and Smolt Entrainment Model	Increased probability of entrainment into central Delta under the PA. Median increase of proportional entrainment into central Delta under the PA was usually small but consistent under all run timings and water year types.
Perry Survival Model (Migratory routing component)	Increased probability of entrainment into central Delta under the PA. The most significant changes were greater entrainment into Sutter and Steamboat Slough under the NAA and greater entrainment into central Delta under the PA.

The differences in flow routing characterized by the analysis of Section 2.5.1.2.7.2.1 Flow Routing in Delta do not necessarily translate directly into biological outcomes between scenarios; therefore, the significance of these differences in the scenarios is not easily quantified. The smolt entrainment model (Perry et al. 2016) discussed in Section 2.5.1.2.7.2.2 Salmonid Smolt Routing into the Interior Delta uses hydrologic data coupled with acoustic tag data of Chinook salmon smolts, providing the behavioral component that is lacking from the flow routing hydrologic model. Because of this better characterization of fish behavior, the analysis from the smolt entrainment model is considered with a higher weight of evidence than the flow routing hydrologic model analysis for the junctions at Sutter Slough, Steamboat Slough, Georgiana Slough, and the DCC in the Sacramento River. However, because the flow routing analysis provides flow characterizations for junctions where: (1) there is little or no associated acoustic tagging data, and (2) for junctions that are not covered in the smolt entrainment model, the flow routing analysis will be used to assess potential migratory outcomes at interior Delta junctions (such as the head of Old River, Turner Cut, Columbia Cut, Middle River, and the mouth of Old River).

2.5.1.2.7.2.2.1 Winter-Run Exposure and Risk

Flow Routing

In the north Delta, as described in Section 2.5.1.2.7.2.1 Flow Routing in Delta, there will be changes in proportion of flow entering key junctions between scenarios, which has implications for migrating juvenile winter-run Chinook salmon.

At Steamboat Slough, the proportion of flow into the distributary decreased by more than 5% for the PA in February and March of below normal and dry years and in January and April of above normal years (BA Table 5.4-12 in Appendix C of this Opinion). The reductions in proportional flow into this particular distributary are expected to result in an adverse effect for juvenile winter-run Chinook salmon; Steamboat Slough provides a route of higher survival for winter-run Chinook salmon smolts by removing exposure to both the Georgiana Slough and DCC junctions, and eliminating the risk of entrainment into the interior Delta.

At Georgiana Slough, results also show that 5-12% more flow enters Georgiana Slough under the PA during February and March of below normal and dry years (BA Table 5.4-12 in Appendix C of this Opinion). This is expected to result in an adverse effect for winter-run Chinook salmon since it indicates an increased proportion of outmigrating fish could enter into the interior Delta and be subject to a route of lower survival than that of the mainstem Sacramento River. A large proportion of winter-run Chinook salmon smolts are expected to enter the Delta in February during these drier water year types. Additionally, since over 60% of the sampled population is present in the Delta during March (Table 2-170), and in drier water years the population is mostly present during February-April (Figure 2-129), any negative changes in flow or migratory patterns during these particular months and water year types due to the operations of the PA could result in a negative effect on the majority of the population.

In the south Delta, at Turner Cut, the proportion of flow entering the distributary is consistently higher for the PA during winter-run Chinook salmon migratory months of February through April (BA Table 5.4-12 in Appendix C of this Opinion); this is expected to result in an adverse effect of the PA operations because smolts migrating through corridors in the south Delta have relatively low survival probability and high predation risk. At Columbia Cut, the PA would offer some beneficial effects in the wet water year types of February and March through proportional reduction in flow but is expected to result in more potential juvenile Chinook salmon entrainment in April. At the Middle River and the mouth of Old River, the PA offers some benefit to outmigrating smolts in the wetter water year types through a proportional reduction in flow during February and March.

The PA increases the potential for winter-run Chinook salmon migrating down the Sacramento River to enter the interior Delta through Georgiana Slough. This can result in adverse effects from the relatively low survival probability and high predation risk in that migration route. Any winter-run Chinook salmon that may be in the lower San Joaquin River in the Delta would, based on flow routing, potentially benefit from a HOR gate due to reduced entry into Old River and reduced entrainment at the south Delta export facilities. However, only a small proportion of the winter-run Chinook salmon population would potentially be in the San Joaquin River near the head of Old River. The effects of PA operations on winter-run Chinook salmon that are in the south Delta are better examined using other methods that are applied in this Opinion (i.e., Section 2.5.1.2.7.3 South Delta Operations, which offer a more thorough analysis of entrainment risk under varying export levels, etc.

Overall, the flow routing analysis indicates that the PA operations would increase the risk of juvenile winter-run Chinook salmon entering lower survival routes in the central Delta. It also indicates PA operations would reduce the probability of juvenile winter-run Chinook salmon entering or remaining in higher survival routes of Steamboat Slough and the Sacramento River. The effects are most prominent in drier water year types during migratory months that are especially important for winter-run Chinook salmon juveniles during drier water years. This is expected to result in an adverse effect of the PA for most rearing and outmigrating winter-run Chinook salmon juveniles.

Entrainment

The NDD bypass evaluation and smolt entrainment model described in Section 2.5.1.2.7.2.2 Salmonid Smolt Routing into the Interior Delta, gives a detailed look into changes in migratory patterns for winter-run Chinook salmon. Of the three migratory patterns used in the model, two are specific for winter-run Chinook salmon (i.e., early and late run timing). Because migration into the Delta is hydrology driven for winter-run Chinook salmon, monthly distribution varies year to year. Of the three migratory patterns, the late arriving temporal distribution has the least change in routing between scenarios with overall small negative effects of fewer smolts (1-2%) remaining in the Sacramento River for the PA. This is due to reduced routing differences between scenarios in January-April, the months of late arriving temporal distribution. The early arriving temporal distribution (i.e., on or before December 31) had larger changes in routing between scenarios ranging from 1-5 percent in key months and water year types. November and December become important migratory months for winter-run Chinook salmon in the early arriving temporal distribution because fall and early winter storms create the upstream pulse flows that trigger their migration (del Rosario et al. 2013). The equal distribution timing showed the largest routing changes due to the DCC being open more in October through December and June for the PA and the winter-run Chinook salmon smolt population being evenly distributed into the model from October through June. While the equal distribution run is not an accurate representation of winter-run Chinook salmon outmigration, its application in this analysis allows assessment of entrainment probability equally under all months; this is useful for assessing effect to the four salmonid species (that is, winter-run, spring-run, and fall/late-fall run Chinook salmon, and steelhead), which have varying run timings.

Overall changes in migratory routing in key migratory months for most species (December – June) are not substantial. However, there is a consistent pattern that holds up for all water year types and most months within those water year types of greater entrainment into the lower survival routes of the interior Delta (Georgiana Slough and DCC combined) under the PA. This is a negative effect of PA operations. The PA operations also result in more frequent opening of the DCC gate (especially in October and November), resulting in a greater probability of entrainment into that low survival route.

For winter-run Chinook salmon, October and November operations under the PA provide the greatest risk or probability of interior Delta entrainment during the migration period. This is because the DCC gate may be open during these months and the bypass flows could be set at a constant minimum of 7,000 cfs, which would result in reverse flows that increase central Delta entrainment probability. Although this is what is modeled, the DCC operations are dependent on real-time operations based on fish presence and are unlikely to actually be open more often under the PA. Winter-run Chinook salmon juvenile populations (fry- and smolt-sized) are expected to be rare in the Delta during October and common in the Delta during November of wetter water year types. Therefore, November is an important month for expression of life history diversity of this endangered species. When hydrological conditions vary, winter-run respond accordingly by utilizing the Delta earlier and at a smaller size when early rains trigger migration. In absence of fall or early winter migration cues, winter run Chinook rear upstream and enter the Delta later and at larger sizes. Since a wet November month does not occur every year, it becomes an important month in which winter-run Chinook express diversity in rearing strategies and habitats. Under the NDD bypass rules, October and November will operate to a constant bypass flow of 7,000 cfs unless a pulse protection action is triggered under real-time operations, which would result in DCC gate closure and more protective bypass flows under pulse protection and/or Level 1.

The results of the NDD bypass evaluation and smolt entrainment model indicate that, under PA operations, the least adverse effect for winter-run Chinook when compared to NAA would be when the bypass flows are operating at low level pumping or Level 1 and winter run migrate during the late-arriving temporal distribution. However, this does not consider flow-survival relationship differences by month between the scenarios or the effects of a later arriving temporal distribution on the population overall. It only summarizes under what PA diversion levels and distribution timing the PA has the least adverse effect on migrating smolts when compared to the NAA scenario. Likewise, a uniform run timing distribution of winter-run Chinook juveniles under Level 3 operations of the PA would likely experience the most adverse migratory conditions as compared to the NAA.

Results in migration routing between the scenarios are similar between the Perry Survival Model and the NDD bypass evaluation and smolt entrainment model. Slightly different methods and hydrological inputs were used between the models which account for some of the proportional route entrainment differences. The Perry Survival Model predicts migration routing from daily Freeport flows, whereas the smolt entrainment model uses 15-minute DSM2 flow data of the Sacramento River below Georgiana Slough. The 15-minute hydrology data is better at capturing sub-daily tidal fluctuations. Additionally, the Perry Survival Model and the NDD bypass evaluation and smolt entrainment model use different interpretations on assessing either migration route probabilities or route entrainment probabilities (Perry 2010). Migration route probabilities will be less than (or equal to) route entrainment probabilities because they are comprised of the product of route entrainment probabilities at multiple river junctions. Both models do show consistently higher entrainment into the interior Delta under the PA under each month with varying degree and therefore varying effects. The overall result is an adverse effect on migration that is evident under the PA.

To better understand how these analyses on hydro-dynamics and migration routing would affect juvenile survival between the scenarios, we have used biological models that couple the flow-survival relationships with the travel time (see Section 2.5.1.2.7.1 Travel Time) and routing studies. The analyses of the survival models are contained in Section 2.5.1.2.7.3 Delta Survival.

2.5.1.2.7.2.2.2 Spring-Run Exposure and Risk

Flow Routing

In the north Delta, as described in Section 2.5.1.2.7.2.1 Flow Routing in Delta, there will be changes in proportion of flow entering key junctions between scenarios, which has implications for migrating juvenile spring-run salmon.

At Steamboat Slough, the proportion of flow into the distributary decreased by more than 5% for the PA in February and March of below normal and dry years and in January and April of above normal years (BA Table 5.4-12 in Appendix C of this Opinion). The reductions in proportional flow into this particular distributary is expected to result in an adverse effect; Steamboat Slough provides a route of higher survival for spring-run Chinook salmon smolts by removing exposure to both the Georgiana Slough and DCC junctions, and eliminating the risk of entrainment into the interior Delta.

At Georgiana Slough, results also show that 5-12% more flow enters Georgiana Slough under the PA during February and March of below normal and dry years (BA Table 5.4-12 in Appendix C of this Opinion). This is expected to result in an effect for spring-run Chinook salmon since it indicates an increased proportion of outmigrating fish could enter into the interior Delta and be subject to a route of lower survival. March and April in particular are important migratory months for spring run Chinook salmon so this is expected to result in an adverse effect for the majority of spring run juveniles during the water year types that are affected.

In the south Delta, spring run Chinook salmon may be present as they migrate from the Sacramento basin, and spring run from the experimental population of spring-run Chinook salmon in the San Joaquin basin would also be affected under PA operations. The modeling results indicate that there is a substantial decrease in the amount of flow from the mainstem San Joaquin River entering Old River from January through June in all water year types for the PA due to the operation of the HOR gate. From January through May there is an approximately 30 to 50% reduction in the proportion of flow going into the Old River channel (BA Table 5.4-12 in Appendix C of this Opinion). Therefore, spring run Chinook salmon juveniles will be better protected from south Delta facility entrainment due to the operations of the HOR gate under the PA.

At Turner Cut, there is a consistent trend of more flow (up to 11%) entering this distributary for the PA during February through May (BA Table 5.4-12 in Appendix C of this Opinion). This increase in the proportion of flow going into Turner Cut overlaps with the emigration of spring run Chinook salmon juveniles. The greatest increases occur in April and May, which overlaps with the peak of spring run smolt emigration from the Sacramento and San Joaquin River basin and is expected to result in an adverse effect.

At Columbia Cut, the PA would offer some beneficial effects in the wet water year types of February and March through proportional reduction in flow, but is expected to result in an adverse effect of more potential entrainment in April and May of up to 5-6% in above normal to dry water year types (BA Table 5.4-12 in Appendix C of this Opinion). This would result in greater risk of entrainment into lower survival interior Delta routes and south Delta facility entrainment and is expected to result in an adverse effect of the PA.

At the Middle River and the mouth of Old River, the PA offers some benefit to outmigrating smolts in the wetter water year types through a proportional reduction in flow during February and March (BA Table 5.4-12 in Appendix C of this Opinion), which could lead to less entrainment into this low survival route that leads to the south delta pumping facilities.

Overall, the flow routing analysis indicates that the PA operations would increase the risk of juvenile spring-run Chinook salmon entering lower survival routes in the central Delta. It also indicates PA operations would reduce the probability of entering or remaining in higher survival routes of Steamboat Slough and the Sacramento River. Spring-run from the experimental population of spring-run Chinook salmon in the San Joaquin basin would experience benefits under the PA due to the HOR and reduced south Delta pumping that affects flow into Old and Middle Rivers. However, Turner Cut and Columbia Cut would often have more entrainment risk than NAA, which could lead fish into lower survival routes of the interior Delta.

Entrainment

Results from the NDD bypass evaluation and smolt entrainment model described in Section Salmonid Smolt Routing into the Interior Delta give a detailed look into changes in migratory patterns under winter-run Chinook salmon timing distributions, including an equal timing distribution with the smolt population spread out evenly between October through June. For spring run Chinook salmon, who enter the Delta as smolts primarily during March through May, we can specifically look at those months to understand potential changes in migratory routing under the PA.

Mean annual entrainment changed slightly between scenarios resulting in <2 percentage points higher entrainment into the central Delta under the PA (Table 2-177). The probability of entrainment into the central Delta varies by month and is consistently higher under the PA under all water year types. For the March through May period, the largest differences in entrainment into the central Delta occurred during the month of March when approximately 20% of spring run Chinook smolts are expected to be in the Delta. During March, in the drier water year types, there is a slight increase (~2% median) in central Delta entrainment under the PA. April and May were very similar between the scenarios throughout all water year types with median differences remaining under 1% (Figure 2-132). The majority of spring run Chinook salmon smolts will transit the Delta during April when there is very little change in central Delta entrainment between the scenarios.

Results of the Perry Survival Model analysis on routing also suggest that central Delta entrainment levels are consistently higher under the PA. The largest change that would affect spring run Chinook smolts occurs in the month of March when, during at least 75% of years, more smolts will enter the central Delta under the PA (Figure 2-138). The median change in entrainment is just over 1% under the PA. During April and May, changes in central Delta entrainment are slight with a median of less than 1% of smolts entering the central Delta under the PA. During April and May, central Delta entrainment occurs more than 50% of years but less than 75% of years under the PA (Figure 2-138).

Overall, the slight increase in central Delta entrainment during March is expected to result in an adverse effect on the early arriving spring-run Chinook smolt migrants during the drier water year types. However, the changes in entrainment during the peak migratory month of April and during the month of May, when the later arriving migrants arrive, is expected to be less than 1 percentage point and is not expected to result in a detectable adverse effect on spring-run Chinook salmon.

2.5.1.2.7.2.2.3 Steelhead Exposure and Risk

Flow Routing

In the north Delta, as described in Section 2.5.1.2.7.2.1 Flow Routing in Delta, there will be changes in proportion of flow entering key junctions between scenarios, which has implications for migrating juvenile steelhead.

For the Sacramento River, the analysis of flow routing into channel junctions showed that at Sutter Slough, the most upstream junction, there generally would be little difference in proportion of flow entering the junction between the NAA and the PA, although in one case (December of critical years) the difference in median proportion was 5% less under PA (0.01 absolute difference) (BA Table 5.4-12 in Appendix C of this Opinion). A lower proportion of Sacramento River flow entering Sutter Slough under this situation could potentially reduce the survival of emigrating steelhead smolts in December, although this only represents a small proportion of the annual population of steelhead smolts emigrating to the Delta.

Slightly farther downstream, the proportion of flows entering Steamboat Slough from the mainstem Sacramento were consistently less under the PA than under the NAA from December through April. The only months in which the reduction in the proportion of flows entering Steamboat Slough under the PA was more than 5% occurred in February and March of below normal and dry years. This would affect a substantial proportion of the annual steelhead smolt emigration during these water year types as it overlaps with the peak of the smolt outmigration from January through March.

Differences in flow routing into the Delta Cross Channel from December through May are discountable because the gates are usually closed in these months per the requirements of the 2009 NMFS biological opinion for long term operations of the SWP and CVP (NMFS 2009) and D-1641 and as described in the PA, whereas there were negligible differences in June, when the gates are opened again (see summary of gate openings in the BA, Table 5.B.5-24 in Appendix 5.B, DSM2 Methods and Results). Emigration of steelhead smolts is typically over by June and only a few individuals would likely be present when the gates are reopened.

The proportion of flow entering Georgiana Slough under the PA was generally similar to (<5% difference, considered not biologically meaningful) or somewhat greater than the proportion of flow entering under the NAA. The times during which the PA was modeled to have a larger proportion of flow entering the Georgiana Slough channel in excess of 5% difference were December of wet years (9%), January of above normal years (8%), February of below normal and dry years (12 and 5% respectively), March of below normal and dry years (7 and 11% respectively) and April of above normal years (7%). Overlap with emigrating steelhead smolts would occur primarily from December through April, with most steelhead moving through the affected area in January through March. Increases in the expected proportion of flow entering Georgiana Slough under the PA would be expected to result in adverse effects to emigrating steelhead smolts, as more fish would be expected to be entrained into the interior Delta where survival is lower.

In the south Delta, entry of salmonids into the Head of Old River is considered to be an adverse event, as this channel leads directly to the south Delta pumping facilities where fish are likely to get entrained. The modeling results indicated that there is a substantial decrease in the amount of flow from the mainstem San Joaquin River entering Old River from January through June in all water year types for the PA due to the operation of the HOR gate during key steelhead smolt migratory months. From January through May there is an approximately 30 to 50% reduction in the proportion of flow going into the Old River channel. In December of all water year types, there is less than five percent change between the scenarios due to the HOR gate being open. Therefore, a substantial proportion of the steelhead smolt population will be protected due to the operations of the HOR gate, in which gate closures will be linked to the presence of fish detected in regional monitoring efforts (i.e., Mossdale trawls).

At Turner Cut, where entry of salmonids is considered to be an adverse event, because this channel leads directly to the south Delta pumping facilities where fish are likely to get entrained, there is a consistent trend of more flow (up to 11%) entering this distributary under the PA during February through May (BA Table 5.4-12 in Appendix C of this Opinion). In December, January, and June there is less than five percent change between scenarios. This increase in the proportion of flow going into Turner Cut overlaps with the emigration of steelhead smolts from the San Joaquin River basin. The greatest increases occur in April and May, which overlaps with the peak of steelhead smolt emigration from the San Joaquin River basin. The modeled increases in April and May reflect changes in the export operations linked to the criteria for filling San Luis Reservoir under the PA scenario, which differs from the implementation of the criteria under the NAA.

At Columbia Cut, where entry for salmonids is considered adverse, because this channel leads directly to the south Delta pumping facilities where fish are likely to get entrained, the PA increases the proportion of flow entering this distributary during April and May, with increases of approximately 5 to 6% in above normal to dry water year types. In the wet water year types in February, March, and June, the NAA has an increased proportion of flow into Columbia Cut. In the other months and water year types, there were no changes greater than five percent between scenarios. Increases in the proportion of flow entering Columbia Cut during the April and May time period overlap with the peak of steelhead smolt emigration from the San Joaquin River basin and is expected to result in a negative impact to steelhead smolts through routing of fish into the interior channels of the south Delta where survival is likely to be lower.

In Middle River and the mouth of Old River, where entry for salmonids is considered adverse, because this channel leads directly to the south Delta pumping facilities where fish are likely to get entrained, there were a few months in the wetter water year types when flows into these distributaries were lower under the PA compared to the NAA scenario. This includes February of wet years and March of wet and above normal years for both junctions, and June of wet years for Middle River. These changes reflect the reduction of exports from the south Delta during diversions from the NDD. The reduction of flows into the Old and Middle river corridors is considered to be beneficial to emigrating steelhead smolts.

Even though the smolt routing model is intended to evaluate juvenile Chinook salmon migration, the results are applicable to steelhead smolts that are migrating at a similar size and timing as Chinook salmon smolts. Overall, the modeling suggests that juvenile salmonids migrating down the Sacramento River would have somewhat greater potential to enter the interior Delta through Georgiana Slough, potentially resulting in adverse effects from the relatively low survival probability in that migration route. The summary of Delta hydrodynamic conditions based on DSM2 does not account for real-time operations that would be done in order to limit potential operational effects, by assessing flow conditions in the context of fish presence. Juvenile salmonids migrating down the San Joaquin River would, based on flow routing, potentially benefit from an operable HOR gate, which would considerably reduce entry into Old River and therefore reduce entrainment at the south Delta export facilities.

Entrainment

Although the modeling described earlier in this section (Perry et al. 2016) was developed to predict juvenile Chinook salmon entrainment probabilities during outmigration (and in particular winter-run Chinook salmon), it provides results applicable to steelhead in regards to the tendency of entrainment probabilities for salmonids into the central Delta under the PA and NAA scenarios. The model is used to predict the probability of juvenile Chinook salmon: 1) remaining in the mainstem Sacramento River; 2) being entrained into Georgiana Slough; or 3) being entrained into the DCC for the operations of the PA and NAA scenarios. The Perry et al. (2015) model predicts the probability of entrainment under three categories of run timing previously described above. The modeling results indicated that, under the PA operating conditions, the mean annual probability of fish remaining in the mainstem Sacramento River is lower regardless of run-timing scenario. In general, the mean annual entrainment probabilities differ little between NAA and PA; however, there is a consistent trend of greater entrainment into the interior Delta under the PA for all three run timings modeled. Specifically, entrainment in the DCC is consistently higher for uniform and early run timings. Entrainment into Georgiana Slough is slightly higher under late and early run timings. The differences in annual entrainment among the run timing scenarios suggest that daily entrainment probabilities vary seasonally, thereby affecting annual entrainment differentially for the alternative run timings. The probability of entrainment into DCC is notably higher for the PA due to the increased percentage of time the gates are open because of operations of the diversions prior to December.

These results should apply for emigrating steelhead smolts originating in the Sacramento River basin as they have similar run timing (December through March) to winter-run, and therefore will be subject to the same operating conditions used in the modeling. Steelhead smolts that emigrate early will be exposed to the more frequent openings of the DCC gates and thus have an increased vulnerability to entrainment into the Delta interior as indicated in the modeling. Furthermore, steelhead smolts that emigrate downstream from January to March will be exposed to greater risks of entrainment into Georgiana Slough as indicated in the modeling results since they have similarity in timing to the early and late group of winter-run emigrants that have a peak in Delta presence in February and March. It is also likely that steelhead smolts will respond to water year types in a similar fashion to the winter-run Chinook salmon because the modeled routing depends on the operations of the PA and the responses of the regional hydrodynamics to those operations coupled with the behavioral responses of the fish to the flows as determined in the studies using acoustic tagged Chinook salmon. Therefore, it is likely that steelhead smolts will experience less entrainment into the Delta interior in wetter years than drier years, based on the modeling results.

As stated for winter-run Chinook salmon, overall changes in migratory routing in key migratory months for most species (December-June) are not substantial. However, there is a consistent pattern for salmonid smolts under the PA that holds up for all water year types and most months within those water year types of greater entrainment into lower survival routes of the interior Delta (Georgiana Slough and DCC combined). The PA operations also result in more frequent opening of the DCC gate (especially in October and November), resulting in a greater probability of entrainment into that low survival route for salmonids passing that junction.

The results of the Perry Survival Model indicate that, under PA operations, the migratory conditions for salmonids, as represented by winter-run Chinook salmon, will be best when the diversions are operating at low level pumping or Level 1 and under a late-arriving temporal distribution (after January 1). The modeling summarizes under what PA diversion levels and distribution timing the PA has the least adverse effect on migrating salmonid smolts when compared to the NAA scenario. Likewise, a uniform run timing distribution of salmonid juveniles under Level 3 operations of the PA would likely experience the most adverse migratory conditions as compared to NAA. However, this does not consider flow-survival relationship differences by month between the scenarios or the effects of a later arriving temporal distribution on the population overall.

Overall, these results should apply for emigrating steelhead smolts originating in the Sacramento River basin as they have similar run timing (December through March) to winter-run, and therefore will be subject to the same operating conditions used in the modeling.

2.5.1.2.7.2.3 Green Sturgeon Exposure and Risk

Based on the best currently available data, it is impossible to determine if the growth, fitness, or survival of sDPS green sturgeon is influenced either positively or negatively to any substantial degree by the route selection of juveniles migrating through the Delta, as influenced by the PA, without a clear understanding of their movement patterns. Recent advances in capturing and tracking acoustically tagged juvenile green sturgeon movements from the mainstem Sacramento River into the Delta (Gruber et al. 2017) may offer some promising new insights into what drives route selection into and through the Delta and how changes in flow caused by the PA may affect migration of juvenile and adult green sturgeon. Preliminary information indicates that the timing of the opening and closure of the Delta Cross Channel gates during high flow events may have a profound influence on route selection and the relative distribution of sDPS green sturgeon entering the waters of the central and southern Delta during their seasonal migrations (Poytress, 2017). Although the Delta Cross Channel gate operations are part of the PA, specific operations that may occur during high flow events and the effect those operations may have on green sturgeon routing have not been evaluated.

2.5.1.2.7.2.4 Fall-Run Exposure and Risk

Flow Routing

In the north Delta, as described in Section 2.5.1.2.7.2.1 Flow Routing in Delta, there will be changes in proportion of flow entering key junctions between the scenarios.

At Steamboat Slough, the proportion of flow into the distributary decreased by more than 5% for the PA in February and March of below normal and dry years and in January and April of above normal years (BA Table 5.4-12 in Appendix C of this Opinion). The reductions in proportional flow into this particular distributary are expected to result in an adverse effect; Steamboat Slough provides a route of higher survival for fall-run Chinook salmon smolts by removing exposure to both the Georgiana Slough and DCC junctions, and eliminating the risk of entrainment into the interior Delta.

At Georgiana Slough, results show that 5-12% more flow enters Georgiana Slough under the PA during February and March of below normal and dry years (BA Table 5.4-12 in Appendix C of this Opinion). This is expected to result in an adverse effect for fall-run Chinook salmon since it indicates an increased proportion of outmigrating fish could enter into the interior Delta and be subject to a route of lower survival. March and April in particular are important migratory months for fall run Chinook salmon so this is expected to result in an adverse effect to the majority of fall run Chinook salmon juveniles during the water year types that are affected.

In the south Delta, fall run Chinook salmon may be present as they migrate from the Sacramento basin and there is also the fall run populations that spawn in the San Joaquin basin that would be affected under PA operations. The modeling results indicated that there is a substantial decrease in the amount of flow from the mainstem San Joaquin River entering Old River from January through June in all water year types for the PA due to the operation of the HOR gate. From January through May there is an approximately 30 to 50% reduction in the proportion of flow going into the Old River channel (BA Table 5.4-12 in Appendix C of this Opinion). Therefore, fall run Chinook salmon juveniles will be better protected from south Delta facility entrainment due to the operations of the HOR gate under the PA.

At Turner Cut, there is a consistent trend of more flow (up to 11%) entering this distributary for the PA during February through May (BA Table 5.4-12 in Appendix C of this Opinion). This increase in the proportion of flow going into Turner Cut overlaps with the emigration of fall run Chinook salmon juveniles. The greatest increases occur in April and May, which overlaps with the peak of fall run smolt emigration from the Sacramento and San Joaquin River basin and is expected to result in an adverse effect. At Columbia Cut, the PA would offer some beneficial effects in the wet water year types of February and March through proportional reduction in flow but more potential entrainment in April and May of up to 5-6% in above normal to dry water year types (BA Table 5.4-12 in Appendix C of this Opinion). This would result in greater risk of entrainment into lower survival interior Delta routes and south Delta facility entrainment and is expected to result in an adverse effect of the PA.

At the Middle River and the mouth of Old River, the PA offers some benefit to outmigrating fry/parr lifestages of fall run Chinook salmon in the wetter water year types through a proportional reduction in flow during February and March (BA Table 5.4-12 in Appendix C of this Opinion), which would lead to less entrainment into this low survival route that leads to the south Delta pumping facilities.

Overall, the flow routing analysis indicates that the PA operations would increase the risk of juvenile fall-run Chinook salmon entering lower survival routes in the central Delta. It also indicates PA operations would reduce the probability of entering or remaining in higher survival routes of Steamboat Slough and the Sacramento River. For fall-run Chinook salmon migrating from the San Joaquin basin, there would be benefits under the PA due to the HOR and reduced south Delta pumping that affects flow into Old and Middle Rivers. However, Turner Cut and Columbia Cut would often have more entrainment risk under the PA, which could lead fall-run Chinook salmon into lower survival routes of the interior Delta.

Entrainment

The NDD bypass evaluation and smolt entrainment model described in Section Salmonid Smolt Routing into the Interior Delta gives a detailed look into changes in migratory patterns under winter-run Chinook salmon timing distributions and also provides an equal timing distribution with the smolt population spread out evenly between October through June. For fall run Chinook salmon, who enter the Delta as smolts primarily during April through June, we can specifically look at those months to understand potential changes in migratory routing under the PA.

Mean annual entrainment changed slightly between scenarios resulting in <2 percentage points higher entrainment into the central Delta under the PA (Table 2-177). The probability of entrainment into the central Delta varies by month and is consistently higher under the PA under all water year types. For the April through June period, the largest differences in entrainment into central Delta occurred during the month of June when the later arriving fall-run Chinook smolts are expected to be in the Delta. April and May were very similar between the scenarios throughout all water year types with median differences remaining under 1% (Figure 2-132). The majority of the fall run Chinook smolt population will migrate through the Delta during April and May when there is very little change in central Delta entrainment between the scenarios.

Results of the Perry survival model analysis on routing also suggests that changes in central Delta entrainment are consistently higher under the PA. The largest change that would affect fall run Chinook smolts occurs in the month of June when, during at least 75% of years, more smolts will enter the central Delta under the PA (Figure 2-138). The median change in entrainment is just over 1% under the PA. During April and May, changes in central Delta entrainment are slight with a median of less than 1% increase of smolts entering the central Delta under the PA. During April and May, a greater degree of central Delta entrainment occurs more than 50% of years but less than 75% of years under the PA (Figure 2-138).

Overall, the slight increase in central Delta entrainment during June is expected to result in an adverse effect on the later arriving fall-run Chinook smolt migrants. However, the changes in entrainment during the peak migratory months of April and May are expected to be less than 1 percentage point.

2.5.1.2.7.2.5 Late Fall-Run Exposure and Risk

Flow Routing

In the north Delta, as described in Section 2.5.1.2.7.2.1 Flow Routing in Delta, there will be changes in proportion of flow entering key junctions between the scenarios. Late fall-run Chinook salmon juveniles occur in the Delta from July through January, with larger, smolt-sized fish occurring only in November through January.

At Sutter Slough, the proportion of flow into the distributary decreased by 5% for the PA in December of critical water years (BA Table 5.4-12 in Appendix C of this Opinion). The reductions in proportional flow into this particular distributary are expected to result in an adverse effect; Sutter Slough provides a route of higher survival for late fall-run Chinook salmon smolts by removing exposure to both the Georgiana Slough and DCC junctions, and eliminating the risk of entrainment into the interior Delta.

At Steamboat Slough, the proportion of flow into the distributary decreased by 5% for the PA in December of wet water years (BA Table 5.4-12 in Appendix C of this Opinion). The reductions in proportional flow into this particular distributary are expected to result in an adverse effect; Steamboat Slough provides a route of higher survival for late fall-run Chinook salmon smolts by removing exposure to both the Georgiana Slough and DCC junctions, and eliminating the risk of entrainment into the interior Delta.

At the Delta Cross Channel in December, the proportion of flow into the distributary increased by 11% for the PA of below normal and above normal water years and increased by 17% in wet water years (BA Table 5.4-12 in Appendix C of this Opinion). This is expected to result in an adverse effect for late fall-run Chinook salmon because it indicates an increased proportion of outmigrating fish could enter into the interior Delta and be subject to a route of lower survival. December is an important migratory month for late fall-run Chinook salmon smolts given that their highest occurrence in trawl catches occurs during that month.

Results show that 9% more flow enters Georgiana Slough under the PA during December of wet years and 8% more flow enters the slough during January of above normal years (BA Table 5.4-12 in Appendix C of this Opinion). This is expected to result in an adverse effect for late fall-run Chinook salmon since it indicates an increased proportion of outmigrating fish could enter into the interior Delta and be subject to a route of lower survival. December and January are important migratory months for late fall-run Chinook salmon smolts given that their highest occurrence in trawl catches occurs during those months.

In the south Delta, late fall-run Chinook salmon may be present as they migrate from the Sacramento basin. The modeling results indicated that there is a substantial decrease in the amount of flow from the mainstem San Joaquin River entering Old River in January in all water year types for the PA due to the operation of the HOR gate. During January, the reduction in the proportion of flow going into the Old River channel ranges from 37% in critical water years to 46% in below normal water years (BA Table 5.4-12 in Appendix C of this Opinion). Therefore, late fall-run Chinook salmon juveniles will be better protected from south Delta facility entrainment due to the operations of the HOR gate under the PA.

At Turner Cut, Columbia Cut, the Middle River, and mouth of the Old River, there is little difference in flow routing between the PA and NAA (BA Table 5.4-12 in Appendix C of this Opinion).

Overall, the flow routing analysis indicates that the PA operations would slightly increase the risk of juvenile late fall-run Chinook salmon entering lower survival routes in the central Delta. It also indicates PA operations would slightly reduce the probability of entering or remaining in higher survival routes of Steamboat Slough and the Sacramento River. For late fall-run Chinook salmon occurring in the south Delta, there would be benefits under the PA due to operations of the HOR gate and reduced south Delta pumping that affects flow into Old and Middle Rivers.

Entrainment

The Perry smolt entrainment model described in Section 2.5.1.2.7.2.2 Salmonid Smolt Routing into the Interior Delta gives a detailed look into changes in migratory patterns under winter-run Chinook salmon timing distributions and also provides an equal timing distribution with the smolt population spread out evenly between October and June. For late fall-run Chinook salmon, who enter the Delta as smolts primarily during November through January, we can specifically look at those months to understand potential changes in migratory routing under the PA. The Perry smolt entrainment model covers January through June, November, and December. Thus, we analyze the three key months for late fall-run Chinook salmon smolts in the Delta.

Mean annual entrainment changed slightly between scenarios resulting in <2 percentage points higher entrainment into the central Delta under the PA (Table 2-177). The probability of entrainment into the central Delta varies by month and junction. During November, entrainment at Georgianna Slough is higher under the PA for above normal water years and lower under the PA for below normal and dry water years; during wet and critical years, little to no difference is observed. At the Delta Cross Channel in November, entrainment is primarily higher under the PA, relative to the NAA for all water year types. During December, entrainment at both

Georgianna Slough and the Delta Cross Channel under the PA is consistently slightly higher than under the NAA for all water year types. During January at Georgianna Slough, entrainment under the PA is largely the same or slightly higher than under the NAA for all water year types. Overall, results from the Perry model indicate that entrainment of late fall-run Chinook salmon into the central Delta is expected to be slightly higher under the PA than the NAA.

Results of the Perry survival model analysis on routing also suggest that changes in central Delta entrainment are consistently higher under the PA. Changes in routing that would affect late fall-run Chinook salmon smolts occur in the months of November through January, when during at least 75% of years, more smolts will enter the central Delta under the PA (Figure 2-138). Overall, the increase in central Delta entrainment during November through January is expected to result in an adverse effect on late fall-run Chinook salmon smolts.

2.5.1.2.7.3 South Delta Operations

There are two primary categories of effects in the south Delta due to water export: 1) salvage and entrainment at the south Delta export facilities; and 2) water-project-related changes to south Delta hydrodynamics that may reduce the suitability of the south Delta for supporting successful rearing or migration of salmonids and sturgeon from increased predation probability and exposure to poor water quality conditions. The effects from the PA with regard to salvage and entrainment at the south Delta export facilities are described in Section 2.5.1.2.7.3.2 South Delta Salvage and Entrainment. The effects relate to water-project-related changes to south Delta hydrodynamics that may reduce the suitability of the south Delta for supporting successful rearing or migration of salmonids and sturgeon, specifically the impacts to listed fish travel time, outmigration, and juvenile survival from south Delta hydrodynamics are evaluated elsewhere in this Opinion (see Sections 2.5.1.2.7.1 Travel Time, 2.5.1.2.7.2 Outmigration, and 2.5.1.2.7.4 Delta Survival). These analyses were conducted comparatively to demonstrate the differences between the NAA versus the PA, and these analyses capture certain aspects of improvement to south Delta conditions under the PA operating criteria based on reduced diversions through the south Delta export facilities under the PA. However, even though the PA generally results in reduced diversions through the south Delta export facilities, there will still be diversions through the south Delta export facilities under the proposed action that adversely impact listed fish. These impacts from South Delta export facilities operations are added to the impacts evaluated in comparing PA and NAA, which together are discussed in this section.

Key water-project-related drivers of south Delta hydrodynamics are Vernalis inflow, CVP and SWP exports from the south Delta export facilities, and the gate position of the Head of Old River Barrier (HOR); these drivers interact with tidal influences over much of the central and southern Delta. In day-to-day operations, these drivers are often correlated with one another (for example, exports tend to be higher at higher San Joaquin River inflows) and regulatory constraints on multiple drivers may simultaneously be in effect. The modeling of the PA and NAA scenarios reflects those realities and, while those scenarios are appropriate for project analysis, they have limited value for evaluating the isolated effects of one driver vs. another. Recently, the Salmonid Scoping Team, a technical team associated with the Collaborative Adaptive Management Team (CAMT) process, evaluated how the relative influence of these drivers on hydrodynamic conditions varied temporally and spatially throughout the south Delta, (Salmonid Scoping Team 2017a: Appendix B: Effects of Water Project Operations on Delta Hydrodynamics). In order to describe the driver-specific effects on south Delta hydrodynamics which are relevant to the types of operations anticipated in the PA, highlights of that report are provided below. While the specific combinations of drivers in the Salmonid Scoping Team (2017a) analysis are not necessarily representative of any specific PA scenario, these scenarios cross factor individual drivers in a way that allows the evaluation of *trends* that are relevant to the PA. For example, the low versus high south Delta exports represented by the green and red lines in Figures 2-139 and 2-140 can be used to infer the directional trends of flow changes that might be expected in the PA (with lower south Delta exports in many months and year types) compared to the NAA.

Key findings with examples of relevance to effects of south Delta operations under the PA include:

- The major river channel distributaries in the south Delta (San Joaquin, Old, and Middle) transition from a riverine environment to a tidally dominated environment in the Delta.

The effect of tides decreases with increasing distance upstream on the mainstem river channels, and the tidally dominated region varies with Delta inflow, exports, and tidal phase. The effect of HOR gate closure on flow routing decreases the upstream reach of the tidally dominated region in the mainstem San Joaquin channel downstream of the junction with Old River, but increases the upstream reach of tidal dynamics in interior Delta channels upstream of the export facilities. Those different effects on tidal extent are why the PA leads to less negative median daily velocities, median negative velocities, and lower median daily proportions of negative velocity in the modeling results at DSM2 channel 21 (San Joaquin River downstream of HOR). But the analysis shows more negative median velocities and median negative velocities, and higher median daily proportions of negative velocity in the modeling results at DSM2 channel 212 (Grant Line/Fabian and Bell Canal near the confluence with Old River). (See BA tables 5.4-9, 5.4-10, 5.4-11 in Appendix C of this Opinion.)

- The hydrodynamic effect of increases in Delta inflow on flow and velocity in the south Delta is greatest at the upstream reaches of the major river channels; diminishes with distance downstream through the Delta or away from the mainstem rivers (i.e., into the interior Delta); and is affected by barriers, tidal phase, and exports. HOR gate closure effect on flow routing in the PA increases the percentage of mainstem San Joaquin River flow remaining in the mainstem channel downstream of the junction with Old River. The PA results in less negative median negative velocities at both DSM2 channel 21 (San Joaquin River downstream of HOR) and DSM2 channel 45 (San Joaquin River near the confluence with the Mokelumne River), but the effects are greatest at the upstream-most location near the HOR. (See BA table 5.4-10 in Appendix C of this Opinion.)
- The hydrodynamic effect of exports on flow and velocity in the south Delta is strongest in Old River near the export facilities, in Middle River at Victoria Canal and the downstream ends of Turner Cut, and Columbia Cut; and it is affected by tidal phase, Delta inflow, distance from the exports, and barriers (see, for example, Figure 2-139). South Delta exports in the PA are expected to have the stronger effects in DSM2 channels 94 (Old River downstream of the south Delta export facilities) and DSM2 channel 21 (San Joaquin River downstream of HOR) compared to locations on the San Joaquin River. The interaction with barrier condition (and inflow, via HOR gate effects on flow routing) at these interior Delta channel locations can be seen in differences in median velocities between December (HOR open 100% of the time) and January (HOR open 50% of the time) results. (See BA table 5.4-9 in Appendix C of this Opinion.)

Figures 2-139 and 2-140 summarize how flow along the mainstem San Joaquin River (top row of panels), Old River (middle row of panels), and Middle River (bottom row of panels) channels are affected by Vernalis inflow (lowest Vernalis inflow in the left panel of each row, highest on the right; see “SJR” value at top of each panel), cross factored with south Delta export rate (2,000 cfs combined CVP/SWP exports in green, 10,000 cfs combined exports in red), with the DCC closed. Figure 2-139 summarizes conditions with the HOR in while Figure 2-140 summarizes conditions with the HOR out.

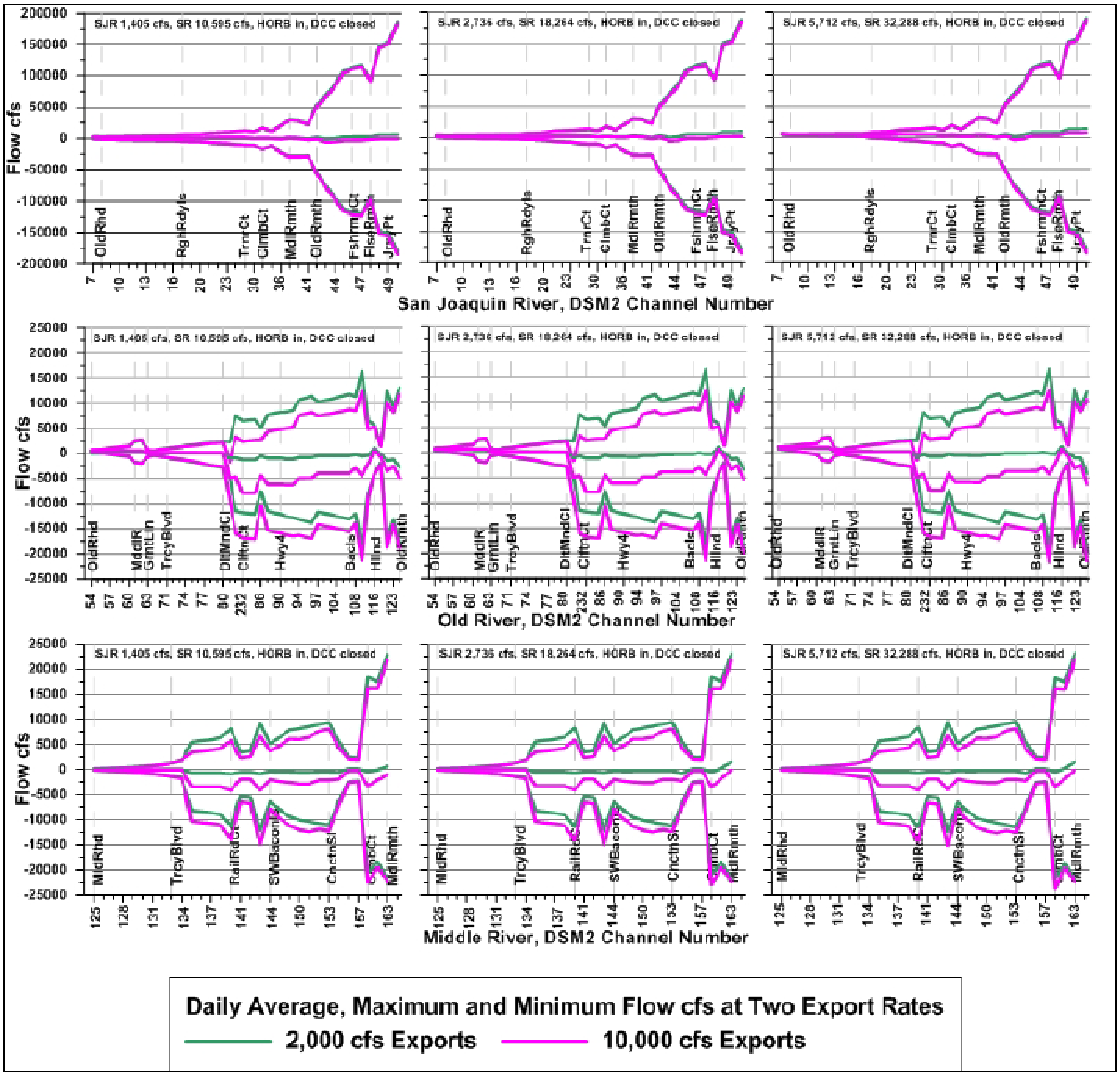


Figure 2-139. DSM2 Modeled Daily Average, Maximum, and Minimum Flow in Each DSM2 Channel Reach for Each of the Six Model Scenarios in Each of Three Routes in the South Delta with the HOR in place. (Source: Figure B.5-1 from Salmonid Scoping Team 2017). The x-axis in each figure depicts the serial DSM2 channel reach number.

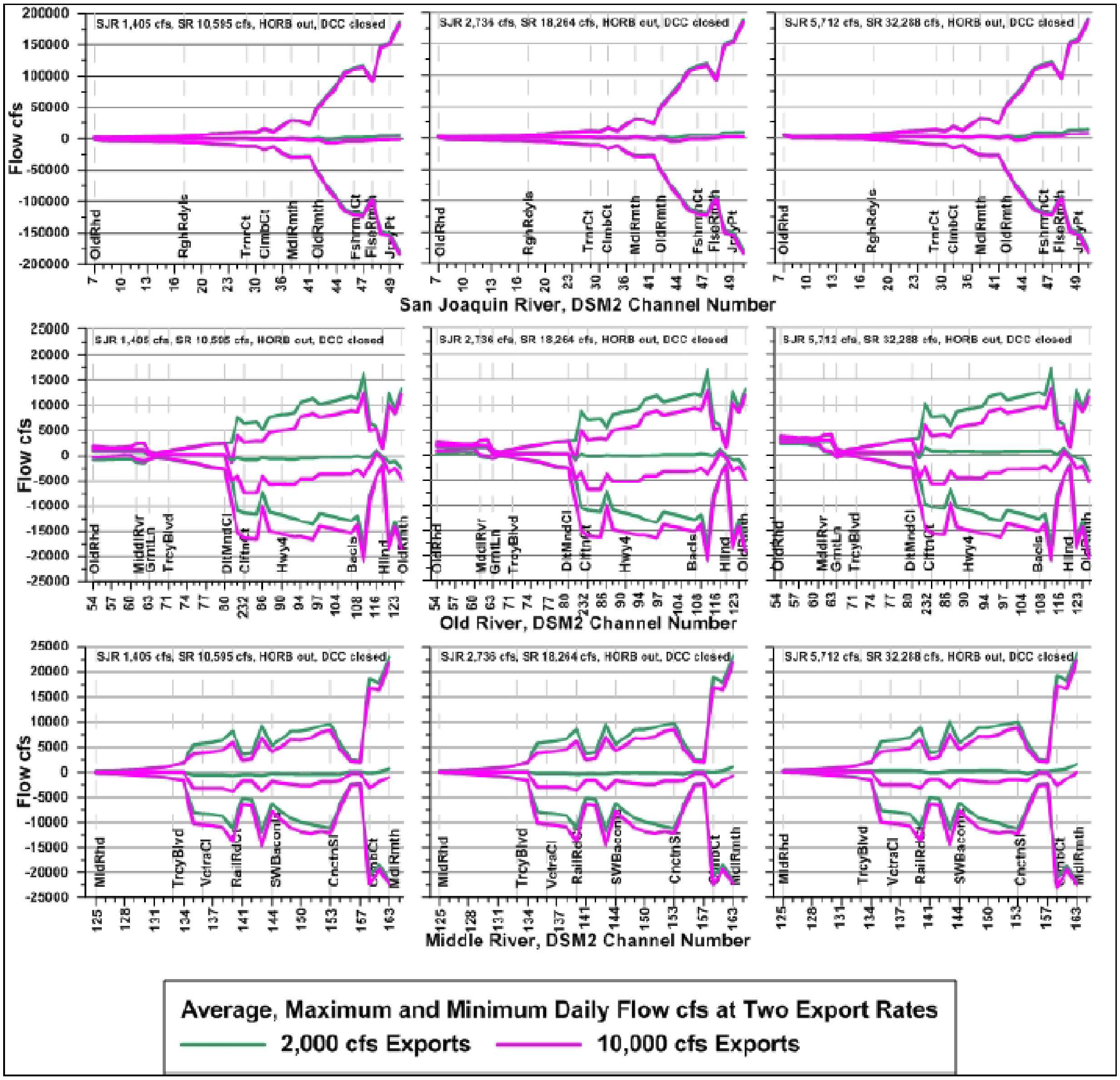


Figure 2-140. DSM2 Modeled Daily Average, Maximum, and Minimum Flow in Each DSM2 Channel Reach for Each of the Six Model Scenarios in Each of Three Routes in the South Delta without the HOR. (Source: Figure B.5-2 from Salmonid Scoping Team 2017). The x-axis in each figure depicts the serial DSM2 channel reach number.

The Delta flow regime can have effects on a wide range of factors such as productivity, food webs, or invasive species, and management actions related to CVP and SWP operations, which are just a few of many interacting drivers (Monismith et al. 2014, Delta Independent Science Board 2015, Figure B).

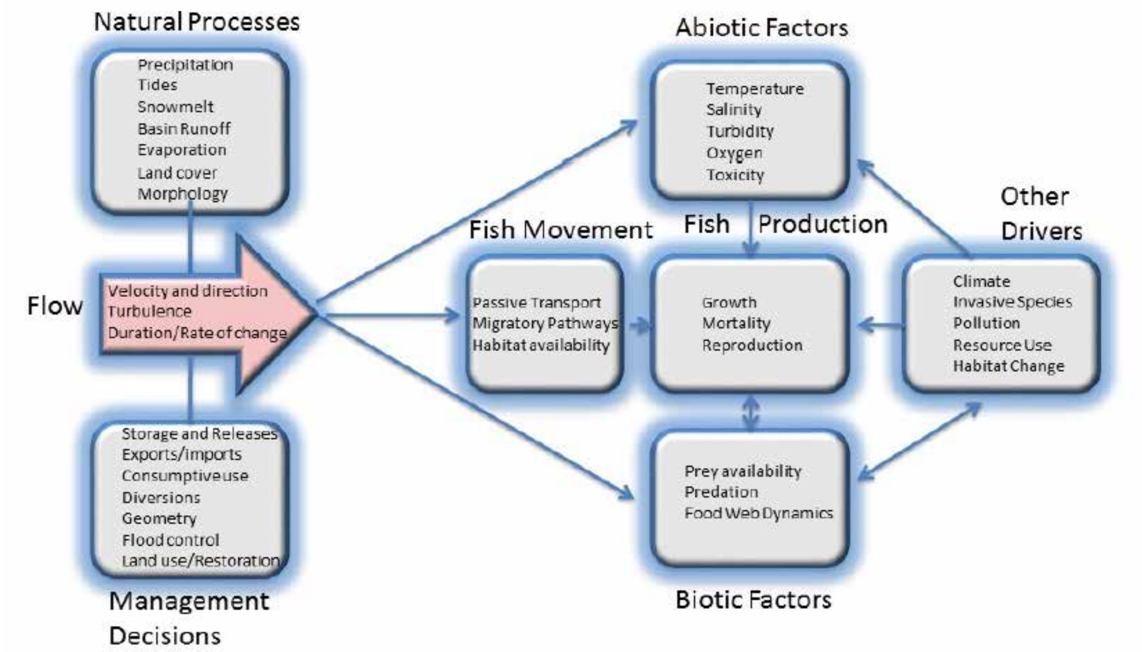


Figure 2-141. Detailed Conceptual Diagram of the Linkages Between Flows and Fishes in the Delta. (Source: Appendix B from Delta Independent Science Board 2015).

The operations criteria in the PA with effects in the south Delta include requirements for:

- Old and Middle River (OMR) flows October through June,
- Delta outflow March through May (BA Table 3.3-1 Appendix A2 of this Opinion), and
- HOR operations in the fall (October and November) and winter/spring (January-June 15).

OMR and Delta outflow requirements, if controlling, reduce south Delta exports and are intended to reduce the PA’s contribution to disruption to south Delta hydrodynamics while rearing or outmigrating juvenile salmonids are present in the Delta. HOR gate closures per the HOR operations criteria are intended to route fish at the Head of Old River junction into the mainstem San Joaquin River, and will also route more San Joaquin River flow into the mainstem San Joaquin River rather than down Old River. The HOR gate effects flow routing in the south Delta in a way that tends to improve migratory conditions in the mainstem San Joaquin River, while adversely impacting conditions in Old River and Middle River.

The effects of south Delta export operations on listed winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon are described in the 2009 NMFS BiOp (NMFS 2009: 341-382). Export effects in the south Delta are expected to reduce the probability that juvenile salmonids in the south Delta will successfully migrate out past Chipps Island, either via entrainment or mortality in the export facilities, or via changes to migration rates or routes that increase residence time of juvenile salmonids in the south Delta and thus increase exposure time to agents of mortality such as predators, contaminants, and impaired water quality parameters (such as dissolved oxygen or water temperature). Effects of exports and HOR gate operations in the PA depend on location within the south Delta. For example, HOR gate closure improves migratory conditions in the mainstem San Joaquin River but adversely impacts conditions in Old River if exports remain static with no concurrent reductions. Export effects of ongoing diversions from the south Delta export facilities adversely impact hydrodynamic conditions in the south

Delta, even though impacts are reduced in the PA compared to the NAA. If export diversions remain static with the HOR gate closed, the supply of water to maintain exports at the south Delta facilities must come from the channels to the north of the export facilities (i.e., Old River, Middle River, Columbia Cut and Turner Cut) which will increase flows towards the export facilities and thus make cumulative flows more negative. This reduces the likelihood of fish successfully migrating out of these channels should they be present, and increases the likelihood that fish from the mainstem San Joaquin River to the north that are entrained into these river channels by tides or other mechanisms will have a higher probability of moving southwards towards the export facilities under the influence of reverse flows.

Much uncertainty remains about how reach-scale hydrodynamic effects link to salmonid migration behavior in the south Delta. More data are available on both through-Delta survival and reach-scale survival for Chinook salmon and CCV steelhead. Two recent reports (Salmonid Scoping Team 2017a, b) summarize select data relevant to water-project-related effects on juvenile salmonid migration and survival in the south Delta (see in particular Appendices D and E of Volume 1 (Salmonid Scoping Team 2017a)). While those reports did not evaluate specific elements of the PA, they were designed to summarize the latest information on salmonid behavior and survival in the south Delta in the context of water project operations and so offer relevant information to understanding effects of south Delta operations in the PA. Some overarching findings, summarized in Volume 1, are:

- Spatial variability in the relative influence of Delta inflow and exports on hydrodynamic conditions means that any given set of operational conditions may differentially affect fish routing and survival in different Delta regions.
- Gates and barriers influence fish routing away from specific migration corridors.
- The relationship between San Joaquin River inflow and survival is variable, and depends on barrier status and region of the Delta.
- Juvenile salmonid migration rates tend to be higher in the riverine reaches and lower in the tidal reaches.
- The extent to which management actions such as reduced negative OMR reverse flows, ratio of San Joaquin River inflow to exports, and ratio of exports to Delta inflow affect through-Delta survival is uncertain.
- Uncertainty in the relationships between south Delta hydrodynamics and through-Delta survival may be caused by the concurrent and confounding influence of correlated variables, overall low survival, and low power to detect differences.

The first four findings highlight that effects on routing and survival differ across the Delta and are sensitive to inflow and barrier status; as discussed earlier, the HOR effects tend to be positive on the mainstem San Joaquin River but negative in Old River mediated in part by the effect of inflow on tidal extent. The final two findings relate to uncertainties and highlight the need for the adaptive management program associated with the PA.

2.5.1.2.7.3.1 Species Exposure and Risk

The temporal and spatial occurrence of each run of Chinook salmon, CCV steelhead, and green sturgeon in the Delta is intrinsic to their natural history and summarized in Section 2.2 Status of the Species. The expected exposure to the hydrodynamic-mediated effects of the proposed action in the south Delta is reiterated in the discussion of impacts to listed fish travel time, outmigration, and juvenile survival from south Delta hydrodynamics in Sections 2.5.1.2.7.1 Travel Time, 2.5.1.2.7.2 Outmigration, and 2.5.1.2.7.4 Delta Survival, and is not repeated here.

Old and Middle River Flows

In most months, OMR restrictions in the PA (summarized in BA Table 3.3-1 in Appendix A2 of this Opinion) require more positive OMR levels compared to operations under 2009 NMFS BiOp. Potential restrictions in October and November (when juvenile listed salmonids are less likely to be present in the Delta, or present only in low abundance) will be guided by real-time operations; restrictions in December are linked to flow triggers on the Sacramento River that are associated with movement of winter-run Chinook salmon into the Delta; restrictions in January through March are linked to the water year type of the Sacramento basin; and restrictions in April through June are linked to Vernalis inflows.

When export reductions are achievable, the resulting less negative OMR flows should result in less disruption to natural south Delta hydrodynamics However, whenever south Delta exports occur, flow of water towards the export facilities creates adverse hydrodynamic-mediated effects; negative impacts to listed salmonid migrations and reduced survival are still expected to occur. The expected effects of south Delta exports and basin inflows on OMR flows will expose all San Joaquin basin salmonids (CCV steelhead, fall-run Chinook salmon, and spring-run Chinook salmon) and any Sacramento basin salmonids (CCV steelhead, winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, and late-fall run Chinook salmon) that reach the south Delta to reduced survival as the result of adverse hydrodynamic conditions. Juvenile green sturgeon are very likely to be present in the south Delta during the October to June timeframe of OMR management under current and proposed operations in the PA; however, hydrodynamic-mediated effects of current operations and those proposed for the PA on juvenile green sturgeon are uncertain. Few, if any studies have focused on the movements of juvenile green sturgeon rearing in the Delta, and individual fish may be present for up to three years while rearing in the Delta and will be exposed to a variety of hydrodynamic conditions.

Spring Outflow

The March through May spring outflow requirements in the PA were derived from modeling the implementation of the San Joaquin Inflow to CVP/SWP Exports (I:E) ratio, a management action in the Reasonable and Prudent Alternative of the 2009 NMFS BiOp (NMFS 2009). Many, if not most, of the effects of “outflow” for salmonids accrue upstream of the compliance location where outflow is measured. Therefore, how Delta outflow requirements may benefit Sacramento basin vs. San Joaquin basin salmonids depends on the relative contribution of San Joaquin River and Sacramento River flow to the outflow. Since the outflow requirements were derived from modeling that assumed the I:E ratio, for the purposes of this analysis, NMFS assumes that the San Joaquin flows during the “operations phase” will be comparable to those in the no action alternative, but the realized flows under these new operating criteria should be monitored due to changes in the point of diversion between the south Delta and the north Delta. Whenever south Delta exports occur, some adverse hydrodynamic-mediated effects are still expected to reduce probability of successful juvenile migration in the central and south Delta waterways under both current operational conditions and those proposed for the PA.

Expected effects from the San Joaquin River contribution to outflow will expose all San Joaquin basin salmonids (CCV steelhead, fall-run Chinook salmon, and spring-run Chinook salmon) and any Sacramento basin salmonids (CCV steelhead, winter-run Chinook salmon, spring-run

Chinook salmon, fall-run Chinook salmon, and late-fall run Chinook salmon) that reach the mainstem San Joaquin River and south Delta to migrational delays and increased vulnerability to factors which reduce survival, including predation and exposure to poor water quality conditions. Juvenile green sturgeon could be present in the south Delta during the October to June timeframe of outflow management in the PA; however, hydrodynamic-mediated effects of the PA on juvenile green sturgeon are uncertain. As described above, few if any studies have focused on juvenile green sturgeon movements and behavior in the Delta during their multi-year rearing phase in the Delta. Rearing green sturgeon would be exposed to a variety of hydrodynamic conditions during this life history phase. Spring outflow effects on listed fish are further described in Section 2.5.1.2.8 Reduced Delta Outflow.

2.5.1.2.7.3.2 South Delta Salvage and Entrainment

As described by NMFS (2009: 341-374), entrainment of juvenile winter-run Chinook salmon, spring-run Chinook salmon, and CCV steelhead at the south Delta export facilities may result in mortality. “Loss” is a term used to refer to the estimated number of fish that experience mortality within the export facilities, and is estimated based on the number of salvaged fish (fish observed within the fish collection facilities at the export facilities) and a number of components related to facility efficiency and handling. Percentages refer to the percent of fish reaching a specific stage in the salvage process that are assumed to experience mortality during that stage. For example, the 75% loss associated with prescreen loss at the SWP means that 75% of the fish entering Clifton Court Forebay at the radial gates are assumed to die before reaching the primary louvers at the Skinner Fish Protection Facility. Of those fish that do reach the louvers, another 25% are lost, and so on. The total loss percentages represent the overall percent loss across all stages, that is, the percent of all fish entering the facility that die somewhere during the salvage process.

- SWP: (1) Prescreen loss (from Clifton Court Forebay radial gates to primary louvers at the Skinner Fish Protection Facility): 75% loss, (2) Louver efficiency: 25% loss; (3) Collection, handling, trucking, and release: 2% loss; (4) Post release: 10% loss; and (5) Total loss (combination of the above): 83.5%.
- CVP: (1) Prescreen loss (in front of trash racks and primary louvers): 15% loss; (2) Louver efficiency: 53.2% loss; (3) Collection, handling, trucking, and release: 2% loss; (4) Post release: 10% loss; and (5) Total loss (combination of the above): 35.1%.

For purposes of evaluating the effect of near-field south Delta exports on Chinook salmon, steelhead, and green sturgeon, NMFS presents juvenile loss data using: (1) historical salvage and loss data; (2) loss-density method presented in the BA; and (3) the Zeug and Cavallo method (winter-run hatchery salvage/loss only) presented in the BA.

NMFS provides a quantitative analyses of entrainment differences between NAA and PA, and a qualitative discussion of potential predation differences between NAA and PA using the loss density methodology presented in the BA. The loss multipliers used to calculate the loss metric in the loss density method are assumed not to differ between NAA and PA; the only differences are attributable to differences in export pumping under the PA (BA Section 5.4.1.3.1.1.2 South Delta Exports). While the PA tends to reduce exports and thus reduce loss, loss is still expected to occur due to entrainment into the export facilities, although at a substantially reduced rate, particularly in wetter years when south Delta exports are curtailed to a greater extent under the PA operational scenario. It is important to note that significant changes in operational criteria in the South Delta were implemented in 2009, as a result of the NMFS and FWS 2009 BiOps, and, thus, resulting loss, while highly variable, is generally expected to be lower in more recent years. The recent upgrade to the CVP facilities should also reduce the impacts to listed fish from salvage operations.

Following completion of PA construction and commencement of PA operations, studies will be undertaken as part of the Clifton Court Forebay Technical Team to estimate the extent to which the reconfigured Clifton Court Forebay and associated changes to the south Delta export facilities change the prescreen loss of juvenile salmonids (i.e., from the Clifton Court Forebay radial gates to the primary louvers at the Skinner Fish Protective Facility) relative to the assumptions currently made for estimating loss and take per the NMFS (2009) BiOp, or the prevailing assumptions at the commencement of PA operations (BA Section 3.2.5.1.3 Clifton Court Forebay Technical Team). These studies will consist of releases of tagged (acoustic or PIT) or otherwise marked juvenile salmonids, followed by recapture or detection in order to estimate survival in different parts of the salvage process, as has been done in previous studies (Gingras 1997; Clark et al. 2009). The results of these experiments will inform the need to change the loss multipliers used to estimate loss and take as a function of expanded salvage. Should the experiments indicate statistically significant differences between the PA loss multipliers and the prevailing multipliers used prior to the commencement of PA operations, and following regulatory agency approval of any changes to the loss multipliers described above, the new PA multipliers will be applied to subsequent loss estimates that are used to estimate the level of incidental take in relation to the level of incidental take that has been specified by NMFS/CDFW for the PA in each water year. South Delta export pumping will be managed in real time, as currently occurs, in order to ensure that losses of listed juvenile salmonids are minimized and remain below the amount and extent of incidental take identified in this Opinion.

2.5.1.2.7.3.2.1 Winter-run Exposure and Risk

2.5.1.2.7.3.2.1.1 Historical Salvage and Loss Data Analysis

Fish entrained at the state and federal water project facilities that reach the salvage tanks are collected and transported back to the Delta from both the state and federal water projects. A screened subsample of fish that reach the salvage tanks are sampled every two hours and the total fish salvage per each sampling period is calculated by expanding the number of fish salvaged by the fraction of time that diversions were sampled. Fish loss for that period of time is calculated based on the standard loss multipliers. Daily salvage and loss is the cumulative sum for those metrics for all of the sampling periods that occurred in that given day. Historical salvage and loss data analysis is presented here to provide context for the loss estimates for the PA and NAA based on the new loss calculation method presented in Section 2.5.1.2.7.3.2.1.2 Juvenile Loss Estimates Using the Loss-Density Method.

Using the current methodology for calculating salvage and loss, based on expansion of observed salvaged fish and using the current loss multipliers, the average annual adipose fin clipped winter-run juvenile (hatchery produced fish) salvage and loss from year 1999 to 2014 were estimated to be 1,656 and 4,607 juveniles, respectively (Table 2-179). The average proportional loss, which is the annual total loss of clipped winter-run juveniles divided by the annual number of hatchery-reared and released winter-run juveniles, was 2.78% (Table 2-179).

Table 2-179. Average Annual Fin-clipped Winter-run Chinook Juvenile Salvage and Loss from 1999 to 2014.

Brood Year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release
1999	987	2,482	153,908	1.61%
2000	965	3,295	30,840	10.68%
2001	2,259	6,734	166,206	4.05%
2002	7,751	22,748	252,684	9.00%
2003	6,094	19,319	233,613	8.27%
2004	1,103	3,964	218,617	1.81%
2005	477	1,251	168,261	0.74%
2006	1,353	2,034	173,344	1.17%
2007	2,919	5,618	196,288	2.86%
2008	179	435	71,883	0.60%
2009	1,230	2,356	146,211	1.61%
2010	463	1,449	198,582	0.73%
2011	460	1,210	123,859	0.98%
2012	187	595	194,264	0.31%
2013	6	12	181,857	0.01%
2014	62	214	193,155	0.11%
Mean	1,656	4,607	168,973	2.78%
Median	976	2,195	177,601	1.39%
SD	2,223	6,714	56,556	3.43%
95% CI	1,089	3,290	27,712	1.68%

We also estimated the annual winter-run juvenile loss using a new loss calculation tool developed by Cramer Fish Sciences (Simonis et al. 2016), which is based on the recommendations of the 2013 Independent Review Panel (Anderson et al. 2013). The average annual total loss is estimated to be 12,092 juveniles (Table 2-180, which is about 3 times the average annual total loss estimated from the currently used method as presented in Table 2-179 (above). The average proportional loss from the new tool was 8.9% (Table 2-180).

Table 2-180. Annual Adipose Fin Clipped Winter-run Juvenile Loss Based on the New Loss Calculation Tool from Brood Years 1997 to 2014.

Brood Year	Loss at CVP	Loss at SWP	Total Loss	Loss/Release
1997	1,097	4,339	5,436	NA
1998	831	3,853	4,684	NA
1999	1,641	10,603	12,244	8.0%
2000	1,022	9,556	10,578	34.3%
2001	1,940	18,745	20,686	12.4%
2002	6,058	29,475	35,533	14.1%
2003	3,687	26,944	30,631	13.1%

Brood Year	Loss at CVP	Loss at SWP	Total Loss	Loss/Release
2004	1,006	14,839	15,844	7.2%
2005	950	4,898	5,848	3.5%
2006	2,101	8,340	10,441	6.0%
2007	6,121	13,719	19,840	10.1%
2008	1,998	3,575	5,573	7.8%
2009	4,490	6,380	10,870	7.4%
2010	630	9,495	10,125	5.1%
2011	1,573	7,323	8,896	7.2%
2012	775	5,434	6,208	3.2%
2013	818	1,610	2,428	1.3%
2014	349	1,435	1,784	0.9%
Mean	2,060	10,031	12,092	8.9%
Median	1,335	7,831	10,283	7.3%
SD	1,807	8,065	9,320	7.8%
95% CI	835	3,726	4,306	3.8%

Using the current methodology for calculating salvage and loss, based on expansion of observed salvaged fish and using the current loss multipliers, the average annual unclipped winter-run sized juvenile salvage and loss from brood years 1992 to 2015 were estimated to be 1,299 and 3,450 juveniles, respectively (Table 2-181). The average proportional loss of unclipped juveniles, which is the annual total loss of unclipped juveniles divided by the annual juvenile production estimate (JPE) of juvenile winter-run, was 1.08% (Table 2-181).

Table 2-181. Unclipped (Wild) Annual Winter-run Sized Juvenile Salvage and Loss from Brood Years 1992 to 2015.

Brood Year	Total Fish Salvage	Total Fish Loss	JPE	Loss/JPE
1992	1,053	4,003	246,157	1.63%
1993	1,337	2,769	90,546	3.06%
1994	1,416	4,582	74,491	6.15%
1995	781	2,376	338,107	0.70%
1996	397	630	165,069	0.38%
1997	726	1,525	138,316	1.10%
1998	1,514	3,715	454,792	0.82%
1999	1,936	5,828	289,724	2.01%
2000	5,932	20,062	370,221	5.42%
2001	1,442	3,331	1,864,802	0.18%
2002	2,277	6,816	2,136,747	0.32%
2003	2,728	7,779	1,896,649	0.41%
2004	469	1,373	881,719	0.16%

Brood Year	Total Fish Salvage	Total Fish Loss	JPE	Loss/JPE
2005	1,008	2,601	3,831,286	0.07%
2006	2,764	3,297	3,739,069	0.09%
2007	660	1,292	589,911	0.22%
2008	582	1,515	617,783	0.25%
2009	1,064	1,656	1,179,633	0.14%
2010	1,703	4,360	332,012	1.31%
2011	841	2,079	162,051	1.28%
2012	271	732	532,809	0.14%
2013	192	322	1,196,387	0.03%
2014	53	106	124,521	0.09%
2015	36	56	101,716	0.06%
Mean	1,299	3,450	889,772	1.08%
Median	1,030	2,488	412,507	0.35%
SD	1,253	4,096	1,078,208	1.63%
95% CI	501	1,639	431,365	0.65%

We also estimated the annual unclipped (wild) winter-run juvenile loss using the new loss calculation tool developed by Cramer Fish Sciences (Simonis et al. 2016), which is based on the recommendations of the 2013 Independent Review Panel (Anderson et al. 2013). The average annual total loss for unclipped (wild) winter-run is estimated to be 9,573 juveniles (Table 2-182), which is about 3 times the average annual total loss estimated from the currently used method as presented in Table 2-181 (above). The average proportional loss of unclipped juveniles, which is the annual total loss divided by the annual JPE, was 1.9% (Table 2-182).

Table 2-182. Unclipped Annual Winter-Run Sized Juvenile Loss Based on the New Loss Calculation Tool from Brood Years 1997 to 2014.

Brood Year	Loss at CVP	Loss at SWP	Total Loss	Loss/JPE
1997	1,120	5,134	6,254	4.5%
1998	7,207	6,329	13,536	3.0%
1999	1,978	11,555	13,533	4.7%
2000	3,327	12,118	15,445	4.2%
2001	1,854	9,292	11,146	0.6%
2002	2,248	14,614	16,862	0.8%
2003	1,950	10,195	12,145	0.6%
2004	765	8,355	9,120	1.0%
2005	1,280	7,638	8,918	0.2%
2006	3,127	7,638	10,765	0.3%

Brood Year	Loss at CVP	Loss at SWP	Total Loss	Loss/JPE
2007	1,720	4,298	6,018	1.0%
2008	2,065	6,150	8,215	1.3%
2009	1,994	5,912	7,905	0.7%
2010	1,942	10,102	12,044	3.6%
2011	1,629	6,699	8,328	5.1%
2012	348	6,054	6,402	1.2%
2013	1,197	3,346	4,543	0.4%
2014	366	775	1,141	0.9%
Mean	2,006	7,567	9,573	1.9%
Median	1,898	7,169	9,019	1.0%
SD	1,521	3,370	4,004	1.7%
95% CI	703	1,557	1,850	0.8%

2.5.1.2.7.3.2.1.2 Juvenile Loss Estimates Using the Loss-Density Method

The results of the salvage-density method showed that, based on modeled south Delta exports, mean entrainment loss at the south Delta export facilities would be lower under the PA than the NAA in all water year types for winter-run Chinook salmon. The differences between the PA and the NAA were greater in wetter water years, as a result of less south Delta export pumping facilitated by operation of the NDD. For winter-run Chinook salmon, the differences ranged from 16% less under the PA at the SWP in critical years to 82% less under the PA at the CVP in wet years (Table 2-183).

Reduced entrainment into the south Delta facilities would increase migratory success for winter-run Chinook salmon that are exposed to the pumping plants in the waterways immediately adjacent to the facility intakes. A reduced negative flow in the region immediately adjacent to the intakes to the CCF and the CVP would increase the probability of fish being able to reverse course and successfully exit the Delta, although the magnitude of this benefit is currently unknown due to a lack of data regarding fish movement behavior and survival in those reaches under reduced export conditions. Reduced pumping has far-field migratory benefits as well, particularly in the Old and Middle River corridors which would positively affect winter-run Chinook salmon in those corridors. Fish that are present in the Old River or Middle River corridors and their distributaries downstream of the south Delta export facilities would experience reduced net flows towards the facilities. This is particularly important in those reaches adjacent to the mainstem San Joaquin River where tidal flows are strong and could advect juvenile winter-run Chinook salmon into those river channel reaches on the flood tide. Reduced exports would allow more of the ebbing tide signal to cue fish to move out of those corridors and back into the main migratory corridor of the San Joaquin River before moving southwards into waters that are more heavily influenced by the effects of reverse flows due to exports.

The addition of the HOR gate will also be beneficial in keeping more flow in the San Joaquin River corridor helping to increase survival for winter-run Chinook salmon entering the interior and south Delta. More downstream flow in the San Joaquin River channel downstream of the confluence with the Head of Old River in conjunction with reduced exports was modeled to very modestly improve the flow conditions in portions of the lower San Joaquin River near the confluence with the Mokelumne River. This would provide some benefit to winter-run Chinook salmon juveniles in that reach of the river that had entered the central Delta via Georgiana Slough by providing a small, but measurable, increase in net outflow towards the west and reduce the magnitude of negative flows moving upstream.

It is important to note that the biggest improvements seen under the PA, as compared to NAA, are for wet water year types. This is a trend that holds for all the species, including winter-run Chinook salmon, due to the PA having more similar export rates as the NAA in drier water years. When there is less flow coming into the Delta, particularly from the San Joaquin River, the south Delta facility pumps exert a strong hydrodynamic influence in the interior and south Delta. The PA does not reduce entrainment loss as much in the south Delta during the driest water year types especially for species that are present during April and May when OMR flows may actually be worse (more negative) under the PA.

Another important concept to note is that even though the numbers of fish salvaged in the drier water year types are lower than during wetter water year types, this is a function of overall watershed survival differences between water year types. During wet water years, more juvenile salmonids enter the south Delta from either basin and greater numbers are therefore exposed to the pumping facilities (Kjelson et al. 1981; Brandes 2009; Brandes and McLain, 2001). Lower numbers of fish salvaged in drier years, therefore, does not necessarily indicate that restrictions on pumping are impacting a smaller proportion of fish. Often the OMR flows are more negative in dry years even if exports are reduced. In dry years less water is flowing into the Delta from tributaries, and in particular the San Joaquin River basin. Less flow into the head of Old River will exacerbate the effects of exports since there is less flow moving downstream from the head of Old River towards the CVP and SWP intakes to offset the volume of water being diverted, and more water will have to come from alternative sources, such as the waters of the central Delta to supply the volume of water being exported. Conversely, it is possible to be exporting to full capacity in the wet years and OMR flows are still positive due to very high San Joaquin River and tributary flows, which can completely offset the volume of water being diverted by the Projects.

Furthermore, NMFS does have concerns that in drier years, under lower flows in the Sacramento River, more fish will enter the central Delta due to the greater effect of reverse flows created from tidal influence. This greater proportion of fish that enter the Delta interior are expected to have a lower survival rate and also have exposure to the effects of the south Delta exports. Since export rates are more similar between the scenarios in drier years, the PA does not appear to substantially improve migratory conditions during critical years or during certain key migratory months as shown by modeling of the hydrodynamics in delta waterways. Regional flows in south Delta waterways are expected to remain strongly affected by any export actions in drier water year types, which in turn increases the likelihood that out-migrating juvenile winter-run will be adversely affected by exports. This is somewhat offset by changes in operations under the PA. In the San Joaquin River, the HOR gate will improve migratory condition for out migrating smolts in drier years by increasing the probability of remaining in the mainstem San Joaquin River due to a closed gate configuration and increasing the proportion of flows remaining in the mainstem and entering the lower portion of the river downstream of the Port of Stockton. Although there would typically be an increase in negative OMR flows due to the presence of the closed HOR gate, it is expected that the criteria for OMR flows under the PA will provide some relief. In drier years, OMR flows will be no more negative than required under the current operating criteria. OMR flows will actually be slightly more positive during below normal years than currently seen (-4,000 cfs versus -5,000 cfs, 3-day average) in January and February. In January of dry and critical water year types, OMR will be no more negative than -5,000 cfs, which is the same as current operations for this month. This may actually represent a slightly lower export rate during this time period since the HOR gate is anticipated to be closed 50 percent of the time during January and would tend to exacerbate the negative flows in the Old and Middle River corridors leading to a more negative OMR than -5,000 cfs if exports remained unchanged. In March the OMR criteria under the PA operations would keep OMR flows no more negative than -3,500 cfs in below normal and dry years, and -3,000 cfs in critical years. March is the peak month of winter-run outmigration from the Delta and it would be expected that a proportion of these fish would be in range of the footprint of export effects from the CVP and SWP in the south Delta.

Below are results on differences in winter-run Chinook salvage expected between the scenarios for each water year type. There is expected to be a large reduction in salvage during wet water years due to most of the exports being diverted at the NDD facilities. The reduction in salvaged winter-run Chinook salmon continue until the critical years though the absolute difference between scenarios is not substantial.

Table 2-183. Estimated Mean Entrainment Index (Number of Fish Lost, Based on Normalized Salvage Data) of Juvenile Winter-run Chinook Salmon for NAA and PA Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type.

Water Year Type	State Water Project			Central Valley Project		
	NAA	PA	PA vs. NAA[1]	NAA	PA	PA vs. NAA[1]
Wet	10,629	3,531	-7,097 (-67%)	1,404	248	-1,156 (-82%)
Above Normal	5,995	3,073	-2,922 (-49%)	613	134	-479 (-78%)
Below Normal	5,655	3,434	-2,221 (-39%)	790	529	-261 (-33%)
Dry	3,327	2,775	-552 (-17%)	731	481	-250 (-34%)
Critical	917	772	-145 (-16%)	305	244	-62 (-20%)

Note:
[1]Negative values indicate lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

Overall, the results of the loss-density method showed that, based on modeled south Delta exports, average loss at the south Delta water export facilities would be lower under the PA than the NAA in all water year types for winter-run Chinook salmon. Juvenile fish loss under the PA would be reduced by 48% at the SWP and 57% at the CVP (Table 2-184). Note that winter-run loss estimates were normalized by the juvenile production estimate (JPE) entering the Delta.

Table 2-184. Estimated Average Number of Juvenile Winter-run Losses at the CVP and SWP Water Export Facilities under the PA and NAA.

Species	SWP			CVP		
	NAA	PA	% Reduction	NAA	PA	% Reduction
Winter-run	5,305	2,717	48.8%	769	327	57.4%

Projected loss under the PA would still result in the loss of winter-run Chinook salmon due to continued exports from the CVP and SWP facilities. As described in the tables illustrating the differences between the PA and NAA scenarios, the loss of winter-run Chinook salmon will be higher in drier years when exports are preferentially shifted to the south Delta facilities due to reduced Sacramento River flows limiting diversions from the north Delta facilities. In wetter years when more exports are drawn from the north Delta, projected salvage and loss will be lower due to less exports occurring. Using the percentages of change as modeled for the PA and NAA scenarios and applying them to the historic unclipped (wild) winter-run salvage and loss data results, the following table presents the adjusted values for the historical record of salvage and loss for unclipped winter-run juveniles from the PA (Table 2-185).

Table 2-185. Adjusted Historical Clipped Winter-run Chinook Salmon Salvage and Loss Using Fish Density Loss Reduction Parameters by Water Year Type.

Brood Year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release	Water year type[1]	% Difference
1999	306	769	153,908	0.50%	w	69%
2000	473	1,615	30,840	5.24%	an	51%
2001	1,807	5,387	166,206	3.24%	d	20%
2002	6,201	18,198	252,684	7.20%	d	20%
2003	2,986	9,466	233,613	4.05%	an	51%
2004	673	2,418	218,617	1.11%	bn	39%
2005	234	613	168,261	0.36%	an	51%
2006	419	631	173,344	0.36%	w	69%
2007	2,335	4,494	196,288	2.29%	d	20%
2008	149	361	71,883	0.50%	c	17%
2009	984	1,885	146,211	1.29%	d	20%
2010	282	884	198,582	0.45%	bn	39%
2011	143	375	123,859	0.30%	w	69%
2012	114	363	194,264	0.19%	bn	39%
2013	5	10	181,857	0.01%	d	20%
2014	51	178	193,155	0.09%	c	17%
Mean	1,073	2,978	168,973	1.70%		
Median	363	827	177,601	0.50%		
SD	1,629	4,780	56,556	2.15%		
95% CI	868	2,547	30,136	1.15%		

Note:
Water year types: Wet = W, Above Normal = AN, Below Normal = BN, Dry = D, and Critical = C

Table 2-186. Adjusted Historical Unclipped Winter-run Chinook Salmon Salvage and Loss using Fish Density Loss Reduction Parameters by Water Year Type.

Brood Year	Total Fish Salvage	Total Fish Loss	JPE	Loss/JPE	WY	% Change
1992	874	3,322	246,157	1.35%	c	17%
1993	655	1,357	90,546	1.50%	an	51%
1994	1,175	3,803	74,491	5.11%	c	17%
1995	242	737	338,107	0.22%	w	69%
1996	123	195	165,069	0.12%	w	69%
1997	225	473	138,316	0.34%	w	69%
1998	469	1,152	454,792	0.25%	w	69%
1999	600	1,807	289,724	0.62%	w	69%
2000	2,907	9,830	370,221	2.66%	an	51%
2001	1,154	2,665	1,864,802	0.14%	d	20%
2002	1,822	5,453	2,136,747	0.26%	d	20%
2003	1,337	3,812	1,896,649	0.20%	an	51%
2004	286	838	881,719	0.09%	bn	39%
2005	494	1,274	3,831,286	0.03%	an	51%
2006	857	1,022	3,739,069	0.03%	w	69%
2007	528	1,034	589,911	0.18%	d	20%
2008	483	1,257	617,783	0.20%	c	17%
2009	851	1,325	1,179,633	0.11%	d	20%
2010	1,039	2,660	332,012	0.80%	bn	39%
2011	261	644	162,051	0.40%	w	69%
2012	165	447	532,809	0.08%	bn	39%
2013	154	258	1,196,387	0.02%	d	20%
2014	44	88	124,521	0.07%	c	17%
2014	30	46	124,521	0.04%	c	17%
Mean	699	1,896	890,722	0.62%		
Median	511	1,205	412,507	0.20%		
SD	657	2,187	1,077,493	1.14%		
95% CI	278	924	454,986	0.48%		

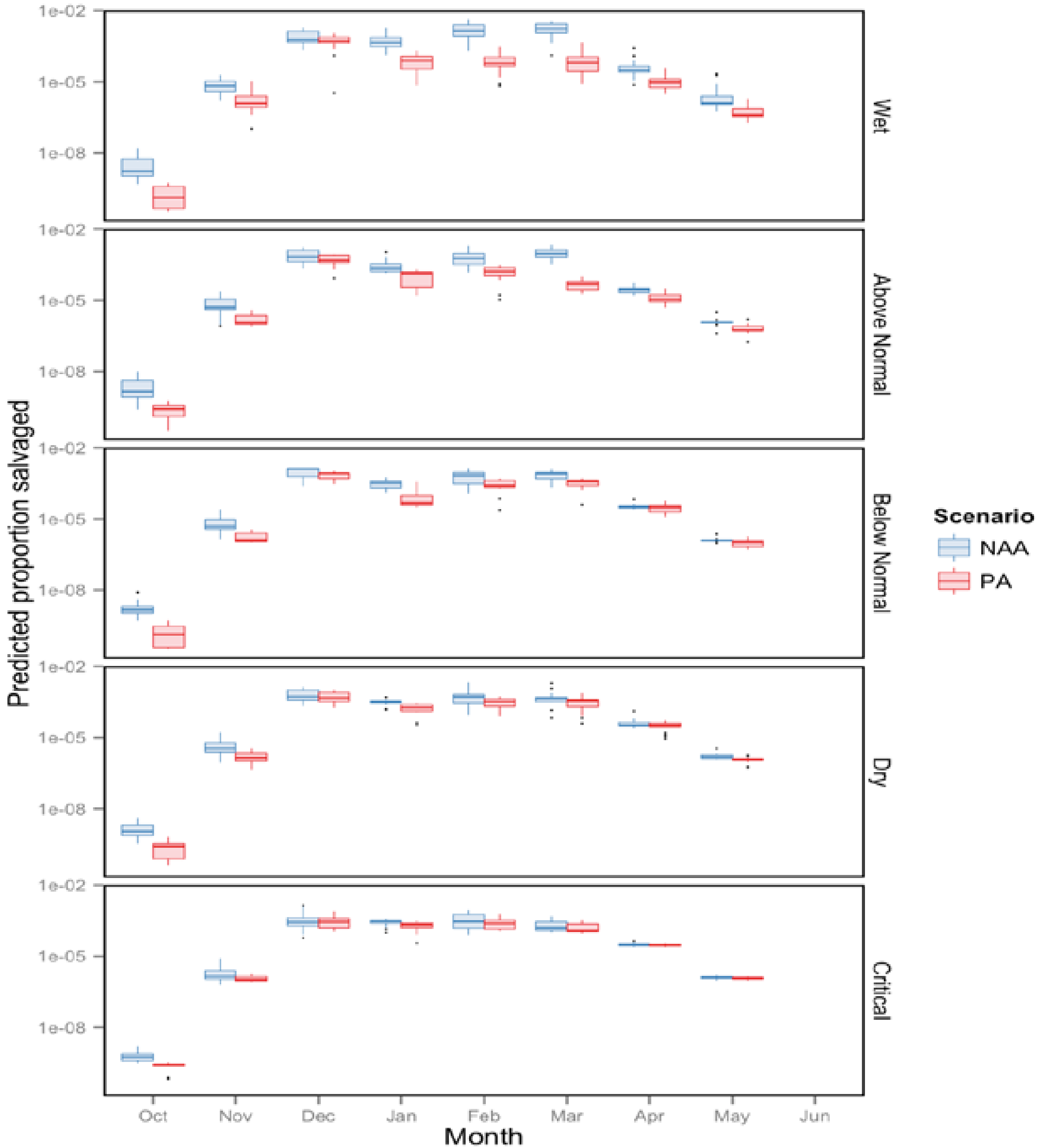
These changes in salvage and loss reflect only changes in the modeled volume of water exported and do not reflect changes in predation rates or other sources of mortality that may change under the PA in comparison to the current operations. Any near-field changes in predation rates or other mortality related to south Delta exports are uncertain.

2.5.1.2.7.3.2.1.3 Juvenile Salvage Estimates Using the Zeug and Cavallo (2014) Method for Hatchery Produced Winter-run Chinook salmon

Zeug and Cavallo (2014) developed a method specific for estimating salvage of hatchery produced winter-run Chinook salmon. Two operational factors influencing survival were included in the analysis as follows: 1) South Delta exports have a positive relationship with the probability of salvage and a positive relationship with count of fish salvaged, i.e., greater south Delta exports give a greater probability of salvage occurring, and more fish are salvaged when salvage occurs; and 2) Sacramento River flow downstream of the NDD has a positive relationship with the probability of zero salvage (possibly reflecting hydrodynamic influences in terms of lower probability of entering the interior Delta and therefore being salvaged) and a weak positive relationship with the count of fish that are salvaged (possibly reflecting the hydrodynamic influence of more flow giving better survival of the fish that do enter the interior Delta and are entrained by the export facilities, or more fish being cued to emigrate from the Delta).

The analysis showed that in wet years, salvage of juvenile winter-run Chinook salmon was predicted to be substantially higher under NAA relative to PA due to the differences in exports. These differences were particularly apparent in October and November (medians were 82-92% less under the PA), although the proportion was very small in October, reflecting very low occurrence in this month (see BA Figure 5.D.42 in Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale). These differences were also particularly apparent from January through March (medians were 81–95% less under the PA). In wet years, median salvage under the PA ranged from 15% less than the NAA in December to 92% less in October. In wetter years, more water is diverted from the NDD rather than the south Delta export facilities, reducing the chance that fish will be salvaged. A similar pattern of salvage was observed in above normal years, with median salvage under the PA ranging from 31% less than the NAA in December to 95% less than the NAA in March. In below normal and dry years, considerably lower salvage under the PA was also evident in October, November, and January (80–94% lower median salvage under the PA), but the differences were less in February through April (4–50% lower median salvage under the PA) relative to wetter years (60–96% lower median salvage under the PA). This may occur as exports shift from the north to the south Delta and less water is exported. In critical years, differences in median salvage ranged from 1% higher under the PA in December to 63% lower under the PA in October (Figure 2-142). Differences between scenarios were least during the month of December which may be a result of operating criteria specific to that month.

Historically, winter-run are rarely salvaged in October except under the very wettest of years and salvage in November is also uncommon. It is important to note that, in the drier years, median changes in salvage between the scenarios lessens though the PA still has lower salvage compared to NAA (Figure 2-143). Salvage under both scenarios begins to increase in all water year types starting in December and continues through March before declining in April and May. The predicted proportion of salvage for the number of hatchery winter-run released was always estimated to have a median value of less than 1 %, based on this model.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-142. Predicted Proportion of Annual Salvage of Juvenile Winter-run Chinook Salmon in October–June, from the Analysis Based on Zeug and Cavallo (2014).

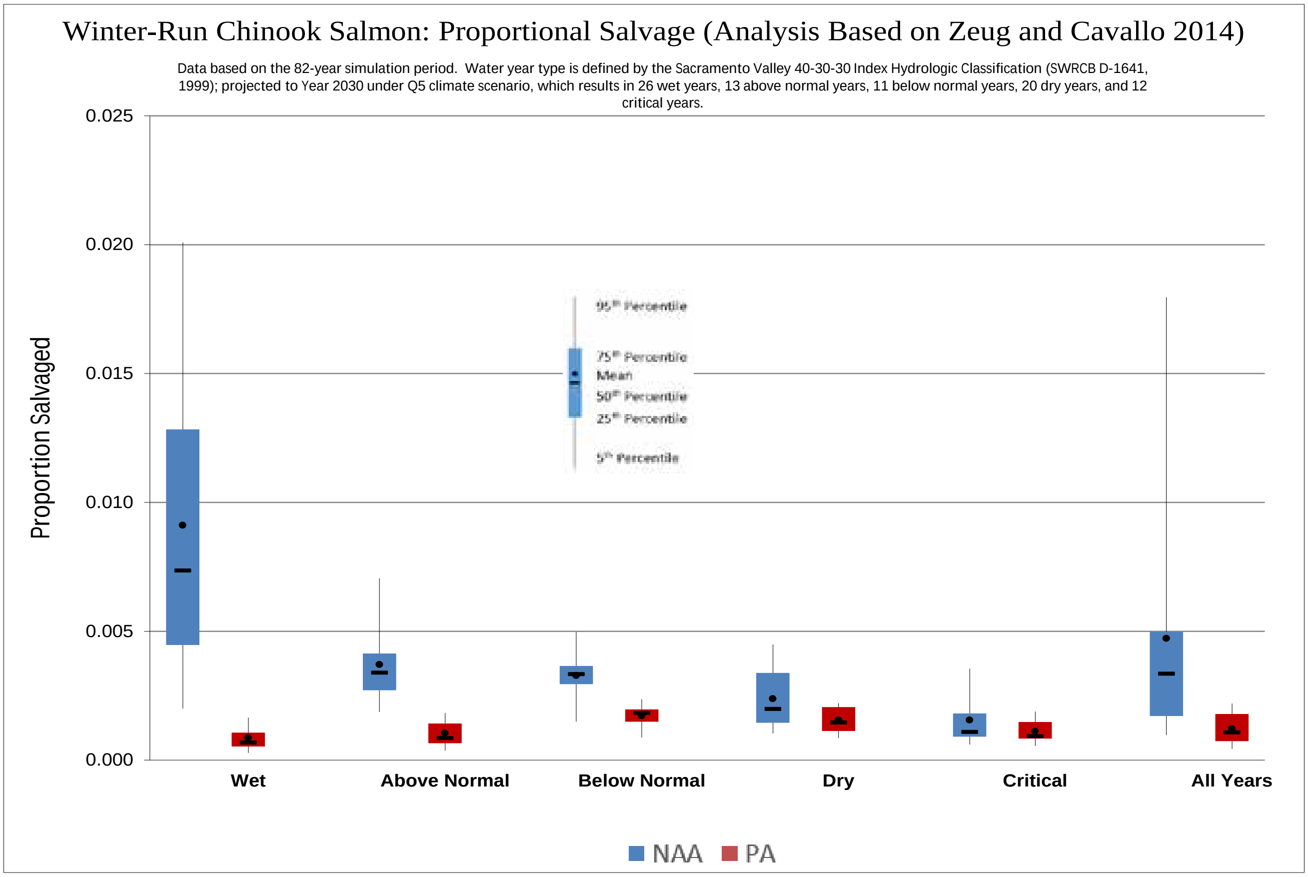


Figure 2-143. Box Plots of Annual Proportion of Juvenile Winter-run Chinook Salmon Salvaged, Grouped by Water-Year Type, from the Analysis Based on Zeug and Cavallo (2014).

Average estimates of proportional salvage for hatchery winter-run Chinook salmon for all 82 water years were less under the PA than the NAA (Table 2-187). The magnitude of the difference varied between water year types. The proportional salvage in wetter years were substantially lower under the PA than under the NAA scenario when the magnitude of south Delta water exports were estimated to be lower than occurred in drier years under the PA. Under the proposed PA operations, the estimated proportional salvage of hatchery winter-run Chinook salmon did not exceed 0.2%. Thus, although salvage (and hence loss) has been considerably reduced under the new operations, it is expected based on this modeling effort that, out of the approximately 170,000 hatchery winter-run Chinook salmon released, no more than 340 fish will be salvaged at the facilities.

Table 2-187. Average Annual Proportional Salvage of Hatchery-reared Winter-run Juveniles by Water Year-type From the Analysis Based on Zeug and Cavallo (2014).

WYT	Proportional Salvage Under NAA	Proportional Salvage Under the PA	Salvage Reduction	% Salvage Reduction
W	0.0091	0.0009	0.0082	90.1%
AN	0.0037	0.0010	0.0027	73.0%
BN	0.0033	0.0017	0.0016	48.5%

WYT	Proportional Salvage Under NAA	Proportional Salvage Under the PA	Salvage Reduction	% Salvage Reduction
D	0.0024	0.0016	0.0008	33.3%
C	0.0016	0.0011	0.0005	31.3%
Ave	0.0040	0.0013	0.0028	55.2%

2.5.1.2.7.3.2.2 Spring-run Exposure and Risk

2.5.1.2.7.3.2.2.1 Spring-run Historical Salvage and Loss Data Analysis

Using the current methodology for calculating salvage and loss, based on expansion of observed salvaged fish and using the current loss multipliers, the estimate of average annual adipose fin clipped spring-run juvenile salvage and loss from brood year 1999 to 2014 were 628 and 1,414 juveniles (Table 2-188), respectively, for the SWP and CVP combined. The estimated average proportional loss, which is the estimated annual total loss divided by the annual number of hatchery-reared and released spring-run juveniles, was 0.75% (Table 2-188).

Table 2-188. Adipose fin clipped annual spring-run juvenile salvage and loss from brood year 1999 to 2014.

Brood Year	Total Fish Salvaged	Total Fish Loss	# Juvenile Released	Loss/Release
1999	2,226	8,657	171,340	5.05%
2000	270	726	No Data	No Data
2001	2,754	4,373	254,591	1.72%
2002	864	2,520	128,200	1.97%
2003	205	586	No Data	No Data
2004	2,488	3,633	561,920	0.6465%
2005	601	632	No Data	No Data
2006	31	44	5,219,080	0.0009%
2007	107	251	214,159	0.1173%
2008	15	11	108,085	0.0106%
2009	42	73	51,762	0.1414%
2010	276	793	3,258,949	0.0243%
2011	142	289	2,314,266	0.0125%
2012	7	15	92,396	0.0163%
2013	12	8	2,997,011	0.0003%
2014	8	7	2,090,391	0.0003%
Mean	628	1,414	1,343,242	0.75%
Median	174	438	254,591	0.02%
SD	958	2,362	1,673,480	1.46%
95% CI	469	1,157	909,697	0.79%

The estimated cumulative SWP and CVP average annual unclipped spring-run sized juvenile salvage and loss from brood year 1992 to 2015 using the current methodology for calculating salvage and loss, based on expansion of observed salvaged fish and using the current loss multipliers, were 13,725 and 24,664 juveniles (Table 2-189), respectively.

Table 2-189. Annual Unclipped Spring-run Sized Juvenile Salvage and Loss from Brood Year 1992 to 2015.

Brood Year	Total Fish Salvage	Total Fish Loss
1992	7,721	13,265
1993	3,555	3,785
1994	24,200	29,905
1995	26,785	36,851
1996	42,908	54,855
1997	30,597	24,943
1998	46,655	105,615
1999	42,513	90,118
2000	17,940	40,696
2001	8,177	10,206
2002	15,706	40,383
2003	4,534	10,985
2004	14,694	27,319
2005	5,822	13,002
2006	3,378	5,213
2007	5,100	11,771
2008	4,730	8,840
2009	4,068	6,082
2010	17,654	52,505
2011	1,063	2,394
2012	909	2,496
2013	484	349
2014	50	70
2015	158	298
Mean	13,725	24,664
Median	6,772	12,386
SD	14,613	28,151
95% CI	5,846	11,262

As discussed previously for winter-run Chinook salmon juveniles, there are many issues that influence the movement and vulnerability of juvenile spring-run to entrainment, salvage, and loss at the fish collection facilities for the CVP and SWP. Like winter-run Chinook salmon, the majority of Central Valley spring-run Chinook salmon originate in the Sacramento River basin and thus follow a common emigration pathway to the Delta through the mainstem of the

Sacramento River. Factors which influence the routing and survival of winter-run juveniles will also influence the routing and survival of juvenile spring-run. A further issue, that does not apply to winter-run juveniles is the emigration of juvenile spring-run out of the San Joaquin River basin (originating from the experimental population) and the necessity of surmounting obstacles unique to the San Joaquin River basin, including the actions of the HOR gate, and migrating through the waterways of the south Delta as the primary route to the ocean and not as a secondary route as seen for the Sacramento River basin fish.

Reduced entrainment into the south Delta facilities is expected to increase migratory success for spring-run Chinook salmon that are exposed to the pumping plants in the waterways immediately adjacent to the facility intakes. A reduced negative flow environment in the region immediately adjacent to the intakes of the CCF and the CVP would increase the probability of fish being able to alter course and successfully exit the Delta, although the magnitude of this benefit is currently unknown due to a lack of data regarding fish movement behavior and survival in those reaches under export conditions. This is particularly important for spring-run that originate in the San Joaquin River basin and enter the Old River channel when the HOR gate is open. These fish would migrate downstream in either the Old River, Middle River, or Grant Line/ Fabian –Bell channels. All three channels have considerable exposure to the effects of exports. The Old River and Grant Line/ Fabian –Bell channels pass directly in front of or in very close proximity to the intakes for the CVP and SWP, and a large proportion of fish moving through these channels are expected to be entrained into the fish collection facilities of the Projects where high levels of mortality are expected. The Middle River channel joins with the manufactured Victoria Canal/ North Canal, a large dredged channel directly leading to the Projects, and net flows move towards the Project intakes under most conditions.

Reduced pumping has far-field migratory benefits as well, particularly in the Old and Middle River corridors which would positively affect spring-run Chinook salmon in those corridors. Fish that are present in the Old River or Middle River corridors and their distributaries downstream of the south Delta export facilities would experience reduced net flows towards the facilities. This is particularly important in those reaches adjacent to the mainstem San Joaquin River where tidal flows are strong and could advect juvenile spring-run Chinook salmon into those river channel reaches on the flood tide. Reduced exports would allow more of the ebbing tide signal to cue fish to move out of those corridors and back into the main migratory corridor of the San Joaquin River rather than moving farther southwards into waters that are more heavily influenced by the effects of reverse flows due to exports. This would be a benefit to both spring-run juveniles originating in the Sacramento River basin as well as those spring-run originating in the San Joaquin River basin and migrating downstream within the mainstem channel of the San Joaquin River from upstream locations.

The addition of the HOR gate will also be beneficial in keeping more flow in the San Joaquin River corridor helping to increase survival for spring-run Chinook entering the interior and South Delta. There are two main reasons for these benefits. More downstream flow in the San Joaquin River channel downstream of the confluence with the Head of Old River in conjunction with reduced exports was modeled to very modestly improve the flow conditions in portions of the lower San Joaquin River near the confluence with the Mokelumne River. This would provide some benefit to Sacramento River basin spring-run Chinook salmon juveniles in that reach of the river that had entered the central Delta via Georgiana Slough by providing a small, but measurable increase, in net outflow towards the west and reduce the magnitude of negative flows moving upstream. Fish originating from the San Joaquin River basin would benefit from this additional flow along the entire length of the channel from the Head of Old River junction to the Mokelumne River. Benefits would be greatest in the most upstream reaches that were still dominated by riverine processes (HOR junction to Channel Point/ Port of Stockton) and would diminish with increasing distance downstream as the waterway becomes more tidal. Closing the HOR gate is intended to redirect emigrating spring-run Chinook salmon juveniles away from the Old River migratory route and retain them in the mainstem San Joaquin River. With the higher percentage of flows retained in this channel with the gates closed, migrating fish will have reduced travel times downstream to the Port of Stockton area in the San Joaquin River channel, which will reduce the time for interactions with predators along this portion of the migratory route.

As discussed in the winter-run section above, it is an important concept to note that even though the absolute numbers of fish salvaged in the drier water year types under current conditions are lower than during wetter water year types, this is also a function of overall watershed survival differences between water year types as well as the magnitude of exports. During wet water years, more juvenile salmonids enter the south Delta from either basin and greater numbers are therefore exposed to the pumping facilities (Kjelson et al. 1981, Brandes 2009, Brandes and McLain, 2001). Lower numbers of fish salvaged in drier years, therefore, does not necessarily indicate that restrictions on pumping are impacting a smaller proportion of fish, but that there is potentially a smaller pool of fish present to be entrained.

The same issues with OMR flows that were described in the winter-run section apply to spring-run, too, and will not be repeated in this section for spring-run Chinook salmon. In drier water year types, the PA is expected to have more diversions of water occurring from the south Delta export facilities than from the NDD intakes. Exports would be of a similar magnitude as current operations. During the January through June time frame, the HOR gate will be operated to protect emigrating listed salmonids in the San Joaquin River basin, which will include the progeny of the spring-run experimental population reintroduced to the basin. Closure will be based on the detection of emigrating fish in the regional monitoring actions on the San Joaquin River near the HOR gate location. Although there would typically be an increase in negative OMR flows due to the presence of the closed HOR gate, it is expected that the criteria for OMR flows under the PA will provide some relief. In drier years, OMR flows will be no more negative than required under the current operating criteria. OMR flows will actually be slightly more positive during below normal years than currently seen (-4,000 cfs versus -5,000 cfs, 3-day average) in January and February. In January of dry and critical water year types, OMR will be no more negative than -5,000 cfs, which is the same as current operations for this month. This may actually represent a slightly lower export rate during this time period since the HOR gate is anticipated to be closed 50 percent of the time during January and closures would tend to exacerbate the negative flows in the Old and Middle River corridors leading to a more negative OMR than -5,000 cfs if exports remained unchanged. More positive OMR flows during this time frame would potentially benefit any yearling spring-run exiting the San Joaquin River basin, as well as any fry swept into the Delta by high flows associated with winter storms in the San Joaquin River basin. The greatest benefit would be to fish that pass the closed HOR gate and then pass downstream into the central Delta via the mainstem San Joaquin River. Those that enter the Old River channel when the gates are open would have less benefit from more positive OMR flows since they would still have to pass the south Delta export facilities to gain benefits from the more positive OMR flow conditions downstream of the facilities. Most fish taking this route would be expected to be entrained into the south Delta facilities and be exposed to the high mortality conditions associated with those operations, particularly predation in the CCF. In March, the OMR criteria under the PA operations would keep OMR flows no more negative than -3,500 cfs in below normal and dry years, and -3,000 cfs in critical years when exports are expected to be shifting to the south Delta facilities.

Starting in March, the spring-run outmigration through the Delta begins to increase. It is expected that a proportion of those fish leaving the Sacramento River basin would be in range of the footprint of export effects from the CVP and SWP in the south Delta after moving through the Georgiana Slough migratory route (i.e., the San Joaquin River reach adjacent to the confluences of the mouths of the Mokelumne River, Old River, and Middle River). The more positive OMR flows during this month would be a benefit to spring-run in this area as there would be less vulnerability to fish advected into the Old and Middle river channels by tidal flows to continue southwards under a more negative net flow to the south Delta export facilities. Spring-run from the San Joaquin River basin would also benefit for the same reasons already described for the months of January and February, with fish passing a closed HOR gate benefiting more than fish which migrating through the Old River route.

During April and May, the operations of the south Delta exports under the PA require that OMR be based on flows in the San Joaquin River, as measured at Vernalis on the San Joaquin River. Vernalis is located upstream of the HOR gate location. OMR flows will remain no more negative than -2,000 cfs if flows at Vernalis are below 5,000 cfs and will become more positive as flows at Vernalis increase as follows: if Vernalis flows ≥ 5,000 cfs: OMR is not <1,000 cfs; if Vernalis flows are ≥ 10,000 cfs: OMR is not <2,000 cfs; if Vernalis flows are ≥15,000 cfs: OMR is not <3,000 cfs; if Vernalis flows are ≥ 30,000 cfs: OMR is not < 6,000 cfs. April and May are the peak months of spring-run migration through the Delta from both the Sacramento and San Joaquin River basins. More positive OMR values, which would generally reflect lessened exports or increased flows out of the San Joaquin River basin, will benefit spring-run from both basins during their migrations through the Delta. Fish from the San Joaquin River basin will also benefit from a closed HOR gate during their out migrations from the basin during these two months, and will experience positive OMR conditions when San Joaquin River flows are greater than about 5,600 cfs at Vernalis.

By June, the majority of juvenile spring-run have migrated through the Delta to the nearshore marine system, with the exception of those individual juveniles which are expressing the yearling life history strategy and remaining in the upper watersheds of their natal tributaries. Water operations in June will export more water from the south Delta facilities in response to increasing demands, which translates to OMR flows that are more negative than the criteria for the months of April and May. After June 15th, the HOR gates will not be operated and will be left in the open position, allowing San Joaquin River flows into the Old River channel. Any spring-run that migrate through the Delta in June will see more negative OMR flows, and increased vulnerability to being entrained into the south Delta export facilities with their associated low survival rates. This is particularly true for any fish leaving the San Joaquin River basin during this time. For the month of June, OMR flows are expected to follow these criteria: if Vernalis flows are less than 3,500 cfs, OMR is not < -3,500 cfs; if Vernalis flows are between 3,500 cfs and 10,000 cfs: OMR is not < 0cfs; if Vernalis flows are between 10,000 cfs and 15,000 cfs: OMR is not < 1,000 cfs; if Vernalis flows are greater than 15,000 cfs: OMR is not < 2,000 cfs. There are no OMR restrictions between July and September and HOR gates will be open from

June 16 to September 30, allowing a sizeable fraction of San Joaquin Flow to enter the Old River channel.

2.5.1.2.7.3.2.2.2 Spring-run Juvenile Loss Estimates Using the Loss-Density Method

Below are results on differences in spring-run Chinook salmon salvage expected between the PA and NAA scenarios for each water year type (Table 2-190). There is expected to be a large reduction in salvage during wet and above normal water years due to most of the exports being diverted at the NDD facilities. There is also expected to be a reduction in salvaged spring-run Chinook salmon in below normal, dry, and critical years, though the absolute difference between scenarios is not as substantial. The estimated reductions in the number of fish salvaged and lost through the salvage facilities will help to inform the magnitude of take expected under the PA operational scenario.

Table 2-190. Estimated Mean Entrainment Index (Number of Fish Lost, Based on Non-normalized Salvage Data) of Juvenile Spring-run Chinook Salmon for NAA and PA Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type.

Water Year Type	State Water Project			Central Valley Project		
	NAA	PA	PA vs. NAA[1]	NAA	PA	PA vs. NAA[1]
Wet	27,193	5,743	-21,449 (-79%)	13,600	1,125	-12,474 (-92%)
Above Normal	16,923	2,873	-14,049 (-83%)	5,176	1,035	-4,140 (-80%)
Below Normal	4,892	3,061	-1,831 (-37%)	853	642	-211 (-25%)
Dry	10,936	7,378	-3,557 (-33%)	2,271	1,655	-616 (-27%)
Critical	5,859	4,804	-1,055 (-18%)	1,991	1,777	-214 (-11%)

Note:

[1]Negative values indicate lower entrainment loss under the proposed action (PA) than under the no action alternative(NAA).

The results of the loss-density method showed that, based on modeled south Delta exports, the average loss at the south Delta water export facilities would be lower under the PA than the NAA in all water year types for spring-run. Juvenile fish loss under the PA would be reduced, on average, by 69% for spring-run (Table 2-191).

Table 2-191. Estimated Average Number of Juvenile Spring-run Losses at the CVP and SWP Water Export Facilities Under the PA and NAA.

Species	SWP			CVP		
	NAA	PA	% Reduction	NAA	PA	% Reduction
Spring-run	13,161	4,772	63.7%	4,778	1,247	73.9%

Projected loss under the PA would still result in the loss of spring-run Chinook salmon due to continued exports from the CVP and SWP facilities. As described in the tables illustrating the differences between the PA and NAA scenarios, the loss of spring-run Chinook salmon will be higher in drier years when exports are preferentially shifted to the south Delta facilities due to reduced Sacramento River flows limiting diversions from the north Delta facilities. In wetter years when more exports are drawn from the north Delta, projected salvage and loss will be lower due to less exports occurring. Using the percentages of change as modeled for the PA and NAA scenarios utilizing the loss-density method, and applying them to the historic unclipped (wild) spring-run salvage and loss data results, the following table presents the adjusted values for the historical record of salvage and loss for unclipped spring-run juveniles from the Projects (Table 2-192).

Table 2-192. Adjusted Historical Unclipped Spring-run Chinook Salmon Salvage and Loss Using Fish Density Loss Reduction Parameters by Water Year Type.

Brood Year	Total Fish Salvage	Total Fish Loss	WY Type	% Change due to WY type
1992	6,486	11,143	c	0.16
1993	640	681	an	0.82
1994	20,328	25,120	c	0.16
1995	4,553	6,265	w	0.83
1996	7,294	9,325	w	0.83
1997	5,201	4,240	w	0.83
1998	7,931	17,955	w	0.83
1999	7,227	15,320	w	0.83
2000	3,229	7,325	an	0.82
2001	5,560	6,940	d	0.32
2002	10,680	27,460	d	0.32
2003	816	1,977	an	0.82
2004	9,404	17,484	bn	0.36
2005	1,048	2,340	an	0.82
2006	574	886	w	0.83
2007	3,468	8,004	d	0.32
2008	3,973	7,426	c	0.16
2009	2,766	4,136	d	0.32
2010	11,299	33,603	bn	0.36
2011	181	407	w	0.83
2012	582	1,597	bn	0.36
2013	329	237	d	0.32
2014	42	59	c	0.16
2015	133	250	c	0.16
Mean	4,739	8,758		
Median	3,721	6,602		
SD	4,856	9,455		
95% CI	2,050	3,993		

In a similar fashion, the adjusted numbers of clipped hatchery spring-run Chinook salmon was determined. The following table presents those estimates of salvage and loss of clipped hatchery spring-run, and the adjusted percentage of the cumulative hatchery releases lost at the CVP and SWP south Delta facilities.

Table 2-193. Adjusted Historical Clipped Spring-run Chinook Salmon Salvage and Loss Using Fish Density Loss Reduction Parameters by Water Year Type.

Brood Year	Total Fish Salvaged	Total Fish Loss	# Juvenile Released	Loss/Release	WY Type	% Change
1999	378	1,472	171,340	0.86%	w	0.83
2000	49	131	No Data	No Data	an	0.82
2001	1,873	2,974	254,591	1.17%	d	0.32
2002	588	1,714	128,200	1.34%	d	0.32
2003	37	105	No Data	No Data	an	0.82
2004	1,592	2,325	561,920	0.41%	bn	0.36
2005	108	114	No Data	No Data	an	0.82
2006	5	7	5,219,080	0.00%	w	0.83
2007	73	171	214,159	0.08%	d	0.32
2008	13	9	108,085	0.01%	c	0.16
2009	29	50	51,762	0.10%	d	0.32
2010	177	508	3,258,949	0.02%	bn	0.36
2011	24	49	2,314,266	0.00%	w	0.83
2012	4	10	92,396	0.01%	bn	0.36
2013	8	5	2,997,011	0.00%	d	0.32
2014	7	6	2,090,391	0.00%	c	0.16
Mean	310	603	1,343,242	0.31%		
Median	43	110	254,591	0.02%		
SD	580	961	1,673,480	0.49%		
95% CI	309	512	891,734	0.26%		

These changes in salvage and loss reflect only changes in the modeled volume of water exported and do not reflect changes in predation rates or other sources of mortality that may change under the PA in comparison to the current operations. Near-field changes in predation or other sources of mortality from south Delta exports is uncertain.

2.5.1.2.7.3.2.3 Steelhead Exposure and Risk

2.5.1.2.7.3.2.3.1 Steelhead Historical Salvage and Loss Data Analysis

Using the current methodology for calculating salvage and loss, based on expansion of observed salvaged fish and using the current loss multipliers, the estimated average annual cumulative clipped steelhead juvenile salvage and loss from brood year 1999 to 2014 for the SWP and CVP were 3,173 and 7,849 juveniles, respectively (Table 2-194), using the current conversion factors for estimating loss from salvage at the CVP and SWP facilities. The average proportional loss, which is the annual cumulative total loss divided by the annual number of hatchery-reared and released steelhead juveniles, was 0.50% (Table 2-194). Since 1998, all hatchery produced steelhead that are released into the waters of the Central Valley are adipose fin clipped to allow them to be distinguished from wild fish.

Table 2-194. Annual Clipped Steelhead Juvenile Salvage and Loss From Brood Year 1999 to 2014.*

Brood Year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release
1999	181	367	1,476,342	0.02%
2000	5,432	7,950	1,398,412	0.57%
2001	8,191	15,723	1,633,825	0.96%
2002	1,885	3,345	1,496,220	0.22%
2003	10,388	28,222	1,523,646	1.85%
2004	7,976	20,917	1,434,217	1.46%
2005	2,046	4,148	1,963,911	0.21%
2006	2,169	8,110	1,644,777	0.49%
2007	2,853	10,052	1,915,192	0.52%
2008	2,836	7,548	2,085,566	0.36%
2009	994	2,489	1,391,770	0.18%
2010	3,576	11,272	1,470,438	0.77%
2011	721	1,214	1,234,235	0.10%
2012	593	1,829	1,556,276	0.12%
2013	701	1,588	1,583,302	0.10%
2014	226	816	1,869,101	0.04%
Mean	3,173	7,849	1,604,827	0.50%
Median	2,108	5,848	1,539,961	0.29%
SD	3,172	7,967	236,485	0.53%
95% CI	1,554	3,904	115,876	0.26%

Note:

*Annual clipped steelhead salvage data were provided by ICF (Hassrick 2016). Loss was calculated using the current salvage-loss conversion factors: 0.57 for the CVP and 4.33 for the SWP.

The average annual cumulative unclipped steelhead juvenile salvage and loss from brood year 1999 to 2014 for the SWP and CVP were 1,571 and 3,669 juveniles, respectively (Table 2-195).

Table 2-195. Annual Unclipped Steelhead Juvenile Salvage and Loss From Brood Year 1999 to 2014.*

Brood Year	Total Fish Salvage	Total Fish Loss
1999	2,211	6,353
2000	3,728	8,299
2001	4,458	8,655
2002	1,576	4,414
2003	2,146	4,716

Brood Year	Total Fish Salvage	Total Fish Loss
2004	1,761	4,087
2005	1,215	2,460
2006	1,201	2,313
2007	2,756	8,395
2008	970	1,716
2009	360	932
2010	941	2,783
2011	557	800
2012	324	517
2013	744	1,600
2014	185	660
Mean	1,571	3,669
Median	1,208	2,621
SD	1,234	2,882
95% CI	605	1,412

Note:

*Annual unclipped steelhead salvage data were provided by ICF (Hassrick 2016). Loss was calculated using the salvage-loss conversion factors: 0.57 for the CVP and 4.33 for the SWP.

As discussed previously for winter-run and spring-run Chinook salmon juveniles, there are many issues that influence the movement and vulnerability of juvenile steelhead to entrainment, salvage, and loss at the fish collection facilities for the CVP and SWP. Comparable to the winter-run and spring-run Chinook salmon populations, the majority of CCV steelhead originate in the Sacramento River basin and thus follow a common emigration pathway to the Delta through the mainstem of the Sacramento River. Factors which influence the routing and survival of Chinook salmon juveniles will also influence the routing and survival of juvenile steelhead. Like juvenile spring-run originating from the experimental population in the San Joaquin River basin, juvenile steelhead emigrating out of the San Joaquin River basin (Southern Sierra diversity group) face the necessity of surmounting obstacles unique to the San Joaquin River basin, including the actions of the HOR gate, and migrating through the waterways of the south Delta as the primary route to the ocean and not as a secondary route as seen for the Sacramento River basin fish.

The discussion of the effects of south Delta export facilities operations that has already been described for winter-run and spring-run Chinook salmon would be applicable to CCV steelhead. Juvenile CCV steelhead migration through the Delta overlaps with both the migration timing of winter-run and spring-run, and therefore the discussion from both Chinook salmon races would be expected to apply to steelhead, too. In the San Joaquin River basin, comparisons to spring-run are especially appropriate, as it is expected that juveniles from both salmonid groups will be migrating out of the San Joaquin River basin at the same time and will experience the same hydrologic and operational effects during their movements.

2.5.1.2.7.3.2.3.2 Steelhead Juvenile Loss Estimates Using the Loss-Density Method

Below are results on differences in steelhead salvage expected between the scenarios for each water year type (Table 2-196). There is expected to be a large reduction in salvage during wet and above normal water years due to most of the exports being diverted at the NDD facilities. There is also expected to be a reduction in salvaged steelhead in below normal, dry, and critical water years, though the absolute difference between scenarios is not as substantial. The estimated reductions in the number of fish salvaged and lost through the salvage facilities will help to inform the magnitude of take expected under the PA operational scenario.

Table 2-196. Estimated Mean Entrainment Index (Number of Fish Lost, Based on Non-normalized Salvage Data) of Juvenile Steelhead for NAA and PA Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type.

Water Year Type	State Water Project			Central Valley Project		
	NAA	PA	PA vs. NAA[1]	NAA	PA	PA vs. NAA[1]
Wet	5,464	1,671	-3,792 (-69%)	1,045	212	-833 (-80%)
Above Normal	11,221	6,493	-4,729 (-42%)	1,834	585	-1,249 (-68%)
Below Normal	8,413	5,409	-3,004 (-36%)	2,337	1,595	-742 (-32%)
Dry	8,147	6,633	-1,513 (-19%)	1,625	1,057	-568 (-35%)
Critical	4,819	4,771	-48 (-1%)	838	597	-242 (-29%)

Note:

[1]Negative values indicate lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

The results of the loss-density method showed that, based on modeled south Delta exports, average loss at the south Delta water export facilities would be lower under the PA than the NAA in all water year types for steelhead. Juvenile steelhead loss under the PA would be reduced by 34% at the SWP and 47% at the CVP (Table 2-197).

Table 2-197. Estimated Average Number of Juvenile Steelhead Losses at the CVP and SWP Water Export Facilities Under the PA and NAA.

Species	SWP			CVP		
	NAA	PA	% Reduction	NAA	PA	% Reduction
Steelhead	7,613	4,995	34.4%	1,536	809	47.3%

Projected loss under the PA would still result in the loss of CCV steelhead due to continued exports from the CVP and SWP facilities. As described in the tables illustrating the differences between the PA and NAA scenarios, the loss of CCV steelhead will be higher in drier years when exports are preferentially shifted to the south Delta facilities due to reduced Sacramento River flows limiting diversions from the north Delta facilities. In wetter years when more exports are drawn from the north Delta, projected salvage and loss will be lower due to less exports occurring. Using the percentages of change as modeled for the PA and NAA scenarios utilizing the loss-density method, and applying them to the historic unclipped (wild) steelhead salvage and loss data results, the following table presents the adjusted values for the historical record of salvage and loss for unclipped spring-run juveniles from the Projects (Table 2-198).

Table 2-198. Adjusted Historical Unclipped CCV Steelhead Salvage and Loss Using Fish Density Loss Reduction Parameters by Water Year Type.

Brood Year	Total Fish Salvage	Total Fish Loss	WY type	% Change due to WY type
1999	641	1,842	w	71%
2000	2,013	4,481	an	46%
2001	3,522	6,837	d	21%
2002	1,245	3,487	d	21%
2003	1,159	2,547	an	46%
2004	1,145	2,657	bn	35%
2005	656	1,328	an	46%
2006	348	671	w	71%
2007	2,177	6,632	d	21%
2008	922	1,630	c	5%
2009	284	736	d	21%
2010	612	1,809	bn	35%
2011	162	232	w	71%
2012	211	336	bn	35%
2013	588	1,264	d	21%
2014	176	627	c	5%
Mean	991	2,320		
Median	649	1,720		
SD	908.96	2,076.11		
95% CI	484.35	1,106.28		

In a similar fashion, the adjusted numbers of clipped hatchery CCV steelhead was determined. The following table presents those estimates of salvage and loss of clipped hatchery steelhead, and the adjusted percentage of the cumulative hatchery releases lost at the CVP and SWP south Delta facilities (Table 2-199).

Table 2-199. Adjusted Historical Clipped CCV Steelhead Salvage and Loss Using Fish Density Loss Reduction Parameters by Water Year Type.

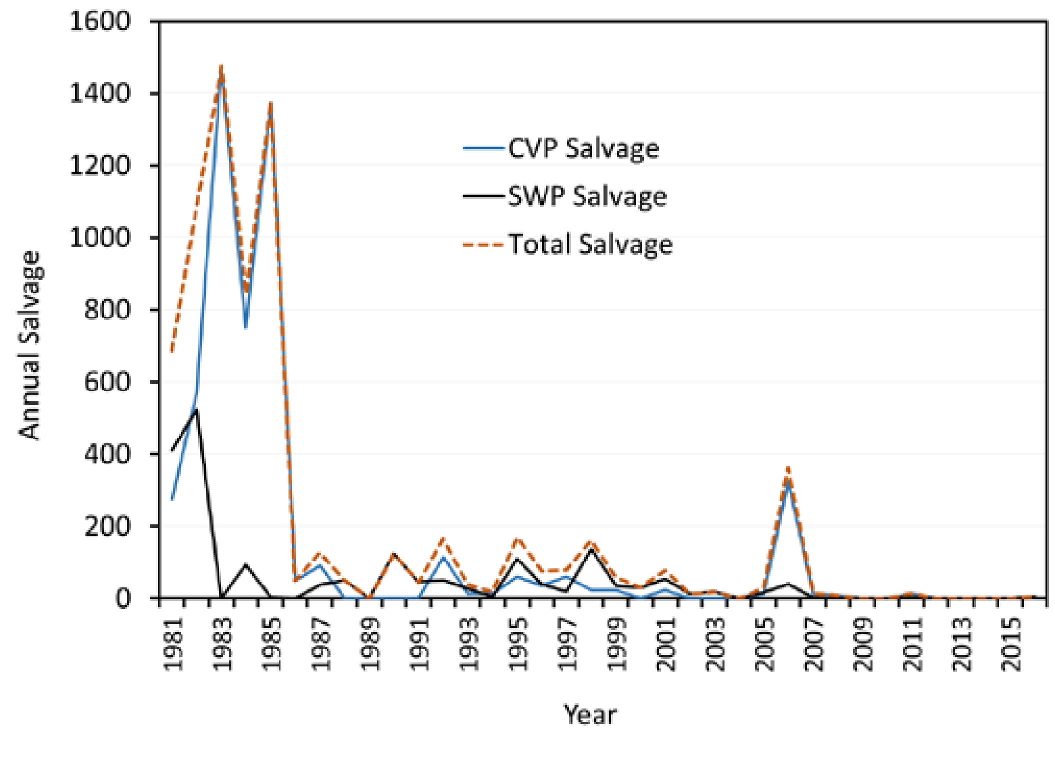
Brood year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release	WY type	% Change
1999	52	106	1,476,342	0.01%	w	71%
2000	2,933	4,293	1,398,412	0.31%	an	46%
2001	6,471	12,421	1,633,825	0.76%	d	21%
2002	1,489	2,643	1,496,220	0.18%	d	21%
2003	5,610	15,240	1,523,646	1.00%	an	46%
2004	5,184	13,596	1,434,217	0.95%	bn	35%
2005	1,105	2,240	1,963,911	0.11%	an	46%
2006	629	2,352	1,644,777	0.14%	w	71%

Brood year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release	WY type	% Change
2007	2,254	7,941	1,915,192	0.41%	d	21%
2008	2,694	7,171	2,085,566	0.34%	c	5%
2009	785	1,966	1,391,770	0.14%	d	21%
2010	2,324	7,327	1,470,438	0.50%	bn	35%
2011	209	352	1,234,235	0.03%	w	71%
2012	385	1,189	1,556,276	0.08%	bn	35%
2013	554	1,255	1,583,302	0.08%	d	21%
2014	215	775	1,869,101	0.04%	c	5%
Mean	2,056	5,054	1,604,827	0.32%		
Median	1,297	2,497	1,539,961	0.16%		
SD	2,064.521682	4,995.954981	236,484.9778	0.33%		
95% CI	1,100.10595	2,662.156493	126,013.9496	0.17%		

These changes in salvage and loss reflect only changes in the modeled volume of water exported and do not reflect changes in predation rates or other sources of mortality that may change under the PA in comparison to the current operations. Near-field predation and other sources of mortality caused by south Delta exports are uncertain.

2.5.1.2.7.3.2.4 Green Sturgeon Exposure and Risk

The estimated annual green sturgeon salvage from the CVP and SWP facilities from 1981 to 2016 is presented in Figure 2-144 using current methods for expanding salvage counts. The average annual green sturgeon salvage was 200 (Table 2-200). Very few green sturgeon have been salvaged since 2007.



Note:

*Green sturgeon salvage data are from CDFW 1981-2012 daily salvage data (ftp://ftp.dfg.ca.gov/salvage) and Sturgeon_Salvage_Table_wateryear2011_to_2016.xls (ftp://ftp.dfg.ca.gov/salvage/DOSS_Salvage_Tables).

Figure 2-144. Annual Green Sturgeon Salvage at the CVP and SWP Water Export Facilities From 1981 to 2016.

Table 2-200. Statistics of Green Sturgeon Annual Salvage Data From 1981 to 2016.*

Statistic	CVP Salvage	SWP Salvage	Total Salvage
Min	0	0	0
Max	1,475	523	1,476
Mean	148	52	200
Median	12	17	42
SD	354	109	389
95% CI	116	36	127

Note:

*Green sturgeon salvage data are from CDFW 1981-2012 daily salvage data (ftp://ftp.dfg.ca.gov/salvage) and Sturgeon_Salvage_Table_wateryear2011_to_2016.xls (ftp://ftp.dfg.ca.gov/salvage/DOSS_Salvage_Tables).

2.5.1.2.7.3.2.4.1 Green Sturgeon Salvage Estimates Using the Loss-Density Method

The results of the loss-density method showed that, based on modeled south Delta exports, average green sturgeon salvage at the south Delta water export facilities would be lower under the PA than the NAA. Green sturgeon salvage under the PA would be reduced by 55% (Table 2-

201). However, projected loss under the PA would still result in the loss of green sturgeon due to continued exports from the CVP and SWP facilities.

Table 2-201. Estimated Average Number of Green Sturgeon Salvage at the CVP and SWP Water Export Facilities Under the PA and NAA.

Species	SWP			CVP		
	NAA	PA	% Reduction	NAA	PA	% Reduction
Green Sturgeon	28.6	12.8	55.2%	25.4	11.4	55.1%

2.5.1.2.7.3.2.5 Fall-Run Exposure and Risk

2.5.1.2.7.3.2.5.1 Fall-run Historical Salvage and Loss Data Analysis

The estimated average annual cumulative adipose fin clipped fall-run juvenile salvage and loss from brood years 1992 to 2015 for the SWP and CVP using current methods for expansion of salvage and calculations of loss were 2,396 and 4,152 juveniles (Table 2-202), respectively. The average proportional loss, which is the annual total loss divided by the annual number of hatchery-reared and released fall-run juveniles with fin clips, was 0.10% (Table 2-202). Hatchery fall-run juvenile release data included only those juveniles released upstream of the Delta from 5 hatcheries: Coleman, Feather River, Nimbus, Mokelumne River, and Merced River (http://escholarship.org/uc/item/7237t9xn) (Huber and Carlson 2015). It is assumed that 25% of the total released juveniles had adipose fin-clips and were coded wire tagged (25% fractional marking).

Table 2-202. Adipose Fin Clipped Annual Fall-run Juvenile Salvage and Loss From Brood Years 1992 to 2015.

Brood year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release
1992	6,409	6,850	4,702,907	0.146%
1993	1,437	1,905	6,430,459	0.030%
1994	12,031	14,878	6,514,257	0.228%
1995	2,699	2,856	6,417,921	0.045%
1996	2,697	4,313	5,964,480	0.072%
1997	2,959	2,688	6,426,087	0.042%
1998	9,289	22,553	4,561,757	0.494%
1999	3,878	11,803	4,165,508	0.283%
2000	1,317	3,374	5,004,217	0.067%
2001	1,139	3,270	4,061,981	0.081%
2002	408	478	5,266,210	0.009%
2003	386	686	4,547,547	0.015%
2004	4,428	7,563	4,324,137	0.175%
2005	1,423	1,413	4,697,018	0.030%
2006	28	37	4,238,424	0.001%
2007	4	3	3,370,369	0.000%

Brood year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release
2008	No Data	No Data	3,407,266	No Data
2009	20	15	3,399,927	0.000%
2010	1,648	4,826	3,723,942	0.130%
2011	60	117	4,144,964	0.003%
2012	415	1,522	No Data	No Data
2013	No Data	No Data	No Data	No Data
2014	41	180	No Data	No Data
2015	5	7	No Data	No Data
Mean	2,396	4,152	4,768,469	0.10%
Median	1,370	2,296	4,554,652	0.04%
SD	3,193	5,700	1,066,584	0.13%
95% CI	1,334	2,382	467,442	0.06%

Using the same methods for expanding salvage and estimating loss, the average annual cumulative unclipped fall-run sized juvenile salvage and loss from brood years 1992 to 2015 from the SWP and CVP were 22,804 and 32,660 juveniles (Table 2-203), respectively.

Table 2-203. Annual Unclipped Fall-run Sized Juvenile Salvage and Loss From Brood Years 1992 to 2015.

Brood year	Total Fish Salvage	Total Fish Loss
1992	8,801	15,337
1993	2,508	8,489
1994	33,406	58,334
1995	18,818	36,052
1996	17,478	22,012
1997	133,112	99,591
1998	116,880	157,634
1999	70,326	120,679
2000	31,767	76,392
2001	4,971	8,992
2002	6,316	11,505
2003	21,893	27,921
2004	14,915	31,780
2005	33,553	42,331
2006	2,804	3,809
2007	4,841	9,580
2008	1,619	3,501
2009	2,847	3,882
2010	14,164	34,251
2011	1,044	2,412

Brood year	Total Fish Salvage	Total Fish Loss
2012	4,561	8,706
2013	544	401
2014	16	26
2015	119	224
Mean	22,804	32,660
Median	7,559	13,421
SD	35,429	41,830
95% CI	14,174	16,735

As discussed previously for winter-run and spring-run Chinook salmon juveniles, there are many issues that influence the movement and vulnerability of juvenile fall-run Chinook salmon to entrainment, salvage, and loss at the fish collection facilities for the CVP and SWP. Comparable to the winter-run and spring-run Chinook salmon populations, the majority of CV fall-run Chinook salmon originate in the Sacramento River basin and thus follow a common emigration pathway to the Delta through the mainstem of the Sacramento River. Factors which influence the routing and survival of winter-run and spring-run Chinook salmon juveniles will also influence the routing and survival of juvenile fall-run Chinook salmon. Like juvenile spring-run originating from the experimental population in the San Joaquin River basin, juvenile fall-run Chinook salmon emigrating out of the San Joaquin River basin face the necessity of surmounting obstacles unique to the San Joaquin River basin, including the actions of the HOR gate, and migrating through the waterways of the South Delta as the primary route to the ocean and not as a secondary route as seen for the Sacramento River basin fish.

The discussion of the effects of south Delta export facilities operations that has already been described for winter-run and spring-run Chinook salmon would be applicable to fall-run Chinook salmon. Juvenile fall-run migration through the Delta overlaps with both the migration timing of winter-run and spring-run, and therefore the discussion from both Chinook salmon races would be expected to apply to steelhead, too. In the San Joaquin River basin, comparisons to spring-run are especially appropriate, as it is expected that juveniles from both salmonid groups will be migrating out of the San Joaquin River basin at the same time and will experience the same hydrologic and operational effects during their movements.

2.5.1.2.7.3.2.6 Fall-run Juvenile Loss Estimates Using the Loss-Density Method

The results of the salvage-density method showed that, based on modeled south Delta exports, mean entrainment loss at the south Delta export facilities would be lower under the PA than the NAA in all water year types for fall-run Chinook salmon (Table 2-204). The differences between the PA and the NAA generally were greater in wetter water years, as a result of less south Delta export pumping facilitated by operation of the NDD. For fall-run Chinook salmon, the differences ranged from 8% less under the PA at the CVP in critical years to 75% less under the PA at the CVP in wet years (Table 2-204). For late fall-run Chinook salmon, the differences ranged from 8% less under the PA at the CVP in critical years to 68% less under the PA at the CVP in below normal years (Table 2-204). The estimated reductions in the number of fish salvaged and lost through the salvage facilities will help to inform the magnitude of take expected under the PA operational scenario.

Table 2-204. Estimated Mean Entrainment Index (Number of Fish Lost, Based on Non-normalized Salvage Data) of Juvenile Fall-run Chinook Salmon for NAA and PA Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type.

Water Year Type	State Water Project			Central Valley Project		
	NAA	PA	PA vs. NAA[1]	NAA	PA	PA vs. NAA[1]
Wet	49,787	14,556	-35,231 (-71%)	36,402	9,251	-27,150 (-75%)
Above Normal	22,854	8,522	-14,332 (-63%)	9,619	2,521	-7,098 (-74%)
Below Normal	9,875	5,898	-3,977 (-40%)	7,218	5,168	-2,050 (-28%)
Dry	26,548	16,601	-9,947 (-37%)	3,390	2,479	-911 (-27%)
Critical	5,093	3,808	-1,285 (-25%)	2,333	2,146	-187 (-8%)

Note:
[1] Negative values indicate lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

The results of the loss-density method showed that, based on modeled south Delta exports, the average loss at the south Delta water export facilities would be lower under the PA than the NAA in all water year types for fall-run. Juvenile fish loss under the PA would be reduced, on average, by 59% for fall-run (Table 2-205).

Table 2-205. Estimated Average Number of Juvenile Fall-run Losses at the CVP and SWP Water Export Facilities Under the PA and NAA.

Species	SWP			CVP		
	NAA	PA	% Reduction	NAA	PA	% Reduction
Fall-run	22,831	9,877	56.7%	11,792	4,313	63.4%

Projected loss under the PA would still result in the loss of fall-run Chinook salmon due to continued exports from the CVP and SWP facilities. As described in the tables illustrating the differences between the PA and NAA scenarios, the loss of fall-run Chinook salmon will be higher in drier years when exports are preferentially shifted to the south Delta facilities due to reduced Sacramento River flows limiting diversions from the north Delta facilities. In wetter years when more exports are drawn from the north Delta, projected salvage and loss will be lower due to less exports occurring. Using the percentages of change as modeled for the PA and NAA scenarios utilizing the loss-density method, and applying them to the historic unclipped (wild) fall-run salvage and loss data results, the following table presents the adjusted values for the historical record of salvage and loss for unclipped fall-run juveniles from the Projects (Table 2-206).

Table 2-206. Adjusted Historical Unclipped Fall-run Chinook Salmon Salvage and Loss Using Fish Density Loss Reduction Parameters by Water Year Type.

Brood year	Total Fish Salvage	Total Fish Loss	WY	% Diff
1992	7,041	12,270	c	20%
1993	853	2,886	an	66%

Brood year	Total Fish Salvage	Total Fish Loss	WY	% Diff
1994	26,725	46,667	c	20%
1995	5,269	10,095	w	72%
1996	4,894	6,163	w	72%
1997	37,271	27,885	w	72%
1998	32,726	44,138	w	72%
1999	19,691	33,790	w	72%
2000	10,801	25,973	an	66%
2001	3,181	5,755	d	36%
2002	4,042	7,363	d	36%
2003	7,444	9,493	an	66%
2004	9,695	20,657	bn	35%
2005	11,408	14,393	an	66%
2006	785	1,067	w	72%
2007	3,098	6,131	d	36%
2008	1,295	2,801	c	20%
2009	1,822	2,484	d	36%
2010	9,207	22,263	bn	35%
2011	292	675	w	72%
2012	2,965	5,659	bn	35%
2013	348	257	d	36%
2014	13	21	c	20%
2015	95	179	c	20%
Mean	8,373	12,878		
Median	4,468	6,763		
SD	10,453	13,880		
95% CI	4,414	5,861		

In a similar fashion, the adjusted numbers of clipped hatchery fall-run Chinook salmon were determined. The following table presents those estimates of salvage and loss of clipped hatchery fall-run (25% marked), and the adjusted percentage of the cumulative hatchery releases lost at the CVP and SWP south Delta facilities (Table 2-207).

Table 2-207. Adjusted Historical Clipped Hatchery Fall-run Chinook Salmon Salvage and Loss Using Fish Density Loss Reduction Parameters by Water Year Type.

Brood year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release	WY	% Diff
1992	5,127.2	5,480	4,702,907	0.12%	c	20%
1993	488.58	647.7	6,430,459	0.01%	an	66%
1994	9,624.8	11,902.4	6,514,257	0.18%	c	20%
1995	755.72	799.68	6,417,921	0.01%	w	72%
1996	755.16	1,207.64	5,964,480	0.02%	w	72%

Brood year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release	WY	% Diff
1997	828.52	752.64	6,426,087	0.01%	w	72%
1998	2,600.92	6,314.84	4,561,757	0.14%	w	72%
1999	1,085.84	3,304.84	4,165,508	0.08%	w	72%
2000	447.78	1,147.16	5,004,217	0.02%	an	66%
2001	728.96	2,092.8	4,061,981	0.05%	d	36%
2002	261.12	305.92	5,266,210	0.01%	d	36%
2003	131.24	233.24	4,547,547	0.01%	an	66%
2004	2,878.2	4,915.95	4,324,137	0.11%	bn	35%
2005	483.82	480.42	4,697,018	0.01%	an	66%
2006	7.84	10.36	4,238,424	0.00%	w	72%
2007	2.56	1.92	3,370,369	0.00%	d	36%
2008	No Data	No Data	3,407,266	No Data	c	20%
2009	12.8	9.6	3,399,927	0.00%	d	36%
2010	1,071.2	3,136.9	3,723,942	0.08%	bn	35%
2011	16.8	32.76	4,144,964	0.00%	w	72%
2012	269.75	989.3	No Data	No Data	bn	35%
2013	No Data	No Data	No Data	No Data	d	36%
2014	32.8	144	No Data	No Data	c	20%
2015	4	5.6	No Data	No Data	c	20%
Mean	1,255	1,996	4,768,469	0.05%		
Median	486	776	4,554,652	0.01%		
SD	2,234	2,920	1,066,583	0.06%		
95% CI	943	1,233	450,379	0.02%		

These changes in salvage and loss reflect only changes in the modeled volume of water exported and do not reflect changes in predation rates or other sources of mortality that may change under the PA in comparison to the current operations. Near-field predation or other sources of mortality that may occur due to south Delta operations are uncertain.

2.5.1.2.7.3.2.7 Late Fall-Run Exposure and Risk

2.5.1.2.7.3.2.7.1 Late Fall-run Historical Salvage and Loss Data Analysis

The estimated average annual cumulative adipose fin clipped late fall-run juvenile salvage and loss from brood years 1992 to 2015 using current methods for expansion of salvage and calculations of loss from the SWP and CVP were 466 and 1,096 juveniles (Table 2-208), respectively. The average proportional loss, which is the annual total loss divided by the annual number of hatchery-reared and released late fall-run juveniles, with fin clips was 0.08% (Table 2-208).

Table 2-208. Adipose Fin Clipped Annual Late Fall-run Juvenile Salvage and Loss From Brood Years 1992 to 2015.

Brood year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release
1992	76	149	No Data	No Data
1993	726	1,326	No Data	No Data
1994	4,217	7,410	No Data	No Data
1995	544	1,920	No Data	No Data
1996	6	28	No Data	No Data
1997	131	439	No Data	No Data
1998	20	45	1,050,464	0.004%
1999	73	100	1,092,159	0.009%
2000	24	107	810,730	0.013%
2001	172	480	1,061,164	0.045%
2002	1,199	3,262	985,112	0.331%
2003	794	1,663	1,019,304	0.163%
2004	234	674	969,327	0.069%
2005	114	455	968,120	0.047%
2006	27	29	1,118,425	0.003%
2007	104	167	1,035,074	0.016%
2008	No Data	No Data	1,076,078	No Data
2009	54	136	1,136,020	0.012%
2010	693	2,163	996,742	0.217%
2011	25	20	1,040,932	0.002%
2012	781	2,899	1,074,461	0.270%
2013	No Data	No Data	975,683	No Data
2014	136	340	1,084,858	0.031%
2015	93	298	No Data	No Data
Mean	466	1,096	1,029,097	0.08%
Median	123	389	1,040,932	0.03%
SD	904	1,716	76,375	0.11%
95% CI	378	717	36,305	0.06%

The estimated average annual unclipped late fall-run sized juvenile salvage and loss from brood years 1992 to 2015 using current methods for expansion of salvage and calculations of loss were 123 and 287 juveniles (Table 2-209), respectively.

Table 2-209. Annual Unclipped Late Fall-run Sized Juvenile Salvage and Loss From Brood Years 1992 to 2015.

Brood year	Total Fish Salvage	Total Fish Loss
1992	97	325
1993	448	1,001

Brood year	Total Fish Salvage	Total Fish Loss
1994	461	1,373
1995	88	71
1996	59	129
1997	180	345
1998	93	139
1999	364	979
2000	269	598
2001	22	98
2002	69	210
2003	37	69
2004	84	102
2005	34	59
2006	13	12
2007	26	57
2008	No Data	No Data
2009	8	8
2010	196	257
2011	20	14
2012	85	277
2013	No Data	No Data
2014	6	26
2015	44	166
Mean	123	287
Median	77	134
SD	140	372
95% CI	58	155

As discussed previously for winter-run and spring-run Chinook salmon juveniles, there are many issues that influence the movement and vulnerability of juvenile late fall-run Chinook salmon to entrainment, salvage, and loss at the fish collection facilities for the CVP and SWP. Comparable to the winter-run and spring-run Chinook salmon populations, the vast majority of CV fall-run Chinook salmon originate in the Sacramento River basin and thus follow a common emigration pathway to the Delta through the mainstem of the Sacramento River. Few, if any, late fall-run Chinook salmon are found in the San Joaquin River basin, although they did occur there historically (Moyle 2002). Factors which influence the routing and survival of winter-run and spring-run Chinook salmon juveniles will also influence the routing and survival of juvenile late fall-run Chinook salmon, which are described in their respective sections above.

The discussion of the effects of south Delta export facilities operations that has already been described for winter-run and spring-run Chinook salmon would be applicable to late fall-run Chinook salmon. Juvenile late fall-run migration through the Delta overlaps with both the migration timing of winter-run and yearling spring-run in late fall and early winter, and therefore the discussion from both Chinook salmon races would be expected to apply to late fall-run, too.

2.5.1.2.7.3.2.7.2 Late Fall-run Juvenile Loss Estimates Using the Loss-Density Method

The results of the salvage-density method showed that, based on modeled south Delta exports, mean entrainment loss at the south Delta export facilities would be lower under the PA than the NAA in all water year types for late fall-run Chinook salmon (Table 2-210). The differences between the PA and NAA generally were greater in wetter water years, as a result of less south Delta export pumping facilitated by operation of the NDD. For late fall-run Chinook salmon, the differences ranged from 8% less under the PA at the CVP in critical years to 68% less under the PA at the CVP in below normal years (Table 2-210).

Table 2-210. Estimated Mean Entrainment Index (Number of Fish Lost, Based on Non-normalized Salvage Data) of Juvenile Late Fall-run Chinook Salmon for NAA and PA Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type.

Water Year Type	State Water Project			Central Valley Project		
	NAA	PA	PA vs. NAA[1]	NAA	PA	PA vs. NAA[1]
Wet	306	228	-78 (-25%)	54	29	-25 (-47%)
Above Normal	280	195	-85 (-30%)	54	34	-20 (-37%)
Below Normal	23	11	-13 (-54%)	12	4	-8 (-68%)
Dry	150	121	-29 (-20%)	32	26	-5 (-17%)
Critical	41	37	-4 (-9%)	9	8	-1 (-8%)

Note:
1 Negative values indicate lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

The results of the loss-density method showed that, based on modeled south Delta exports, the average loss at the south Delta water export facilities would be lower under the PA than the NAA in all water year types for late fall-run. Juvenile fish loss under the PA would be reduced, on average, by 28% for late fall-run Chinook salmon (Table 2-211).

Table 2-211. Estimated Average Number of Juvenile Late Fall-run Losses at the CVP and SWP Water Export Facilities Under the PA and NAA.

Species	SWP			CVP		
	NAA	PA	% Reduction	NAA	PA	% Reduction
fall-run	160	118	26	32	20	37

Projected loss under the PA would still result in the loss of late fall-run Chinook salmon due to continued exports from the CVP and SWP facilities. As described in the tables illustrating the differences between the PA and NAA scenarios, the loss of late fall-run Chinook salmon will be higher in below normal years when exports are preferentially shifted to the south Delta facilities due to reduced Sacramento River flows limiting diversions from the north Delta facilities, although to a smaller degree than other runs. Reductions in wetter years and drier years are more similar than for other runs. This is due to the timing of late fall-run Chinook salmon emigration.

In wetter years, when more exports are drawn from the north Delta, projected salvage and loss will be lower due to less exports occurring. In drier years, less exports occur early in the year when late fall-run are present in the system. Using the percentages of change as modeled for the PA and NAA scenarios utilizing the loss-density method, and applying them to the historic unclipped (wild) late fall-run salvage and loss data results, the following table presents the adjusted values for the historical record of salvage and loss for unclipped late fall-run juveniles from the Projects (Table 2-212).

Table 2-212. Adjusted Historical Unclipped Late Fall-run Chinook Salmon Salvage and Loss Using Fish Density Loss Reduction Parameters by Water Year Type.

Brood year	Total Fish Salvage	Total Fish Loss	WY Type	% Diff
1992	87.3	292.5	c	0.1
1993	309.12	690.69	an	0.31
1994	414.9	1235.7	c	0.1
1995	62.48	50.41	w	0.29
1996	41.89	91.59	w	0.29
1997	127.8	244.95	w	0.29
1998	66.03	98.69	w	0.29
1999	258.44	695.09	w	0.29
2000	185.61	412.62	an	0.31
2001	17.82	79.38	d	0.19
2002	55.89	170.1	d	0.19
2003	25.53	47.61	an	0.31
2004	36.12	43.86	bn	0.57
2005	23.46	40.71	an	0.31
2006	9.23	8.52	w	0.29
2007	21.06	46.17	d	0.19
2008	No Data	No Data	c	0.1
2009	6.48	6.48	d	0.19
2010	84.28	110.51	bn	0.57
2011	14.2	9.94	w	0.29
2012	58.65	191.13	bn	0.31
2013	No Data	No Data	d	0.19
2014	5.4	23.4	c	0.1
2015	39.6	149.4	c	0.1
Mean	89	215		
Median	49	95		
SD	109	302		
95% CI	46	128		

In a similar fashion, the adjusted numbers of clipped hatchery late fall-run Chinook salmon was determined. The following table presents those estimates of salvage and loss of clipped hatchery late fall-run, and the adjusted percentage of the cumulative hatchery releases lost at the CVP and SWP south Delta facilities (Table 2-213).

Table 2-213. Adjusted Historical Clipped Hatchery Late Fall-run Chinook Salmon Salvage and Loss Using Fish Density Loss Reduction Parameters by Water Year Type.

Brood year	Total Fish Salvage	Total Fish Loss	# Juvenile Released	Loss/Release	WY Type	% Diff
1992	68.4	134.1	No Data	No Data	c	0.1
1993	500.94	914.94	No Data	No Data	an	0.31
1994	3,795.3	6,669	No Data	No Data	c	0.1
1995	386.24	1,363.2	No Data	No Data	w	0.29
1996	4.26	19.88	No Data	No Data	w	0.29
1997	93.01	311.69	No Data	No Data	w	0.29
1998	14.2	31.95	1,050,464	0.00%	w	0.29
1999	51.83	71	1,092,159	0.01%	w	0.29
2000	16.56	73.83	810,730	0.01%	an	0.31
2001	139.32	388.8	1,061,164	0.04%	d	0.19
2002	971.19	2,642.22	985,112	0.27%	d	0.19
2003	547.86	1,147.47	1,019,304	0.11%	an	0.31
2004	100.62	289.82	969,327	0.03%	bn	0.57
2005	78.66	313.95	968,120	0.03%	an	0.31
2006	19.17	20.59	1,118,425	0.00%	w	0.29
2007	84.24	135.27	1,035,074	0.01%	d	0.19
2008	No Data	No Data	1,076,078	No Data	c	0.1
2009	43.74	110.16	1,136,020	0.01%	d	0.19
2010	297.99	930.09	996,742	0.09%	bn	0.57
2011	17.75	14.2	1,040,932	0.00%	w	0.29
2012	538.89	2,000.31	1,074,461	0.19%	bn	0.31
2013	No Data	No Data	975,683	No Data	d	0.19
2014	122.4	306	1,084,858	0.03%	c	0.1
2015	83.7	268.2	No Data	No Data	c	0.1
Mean	363	825	1,029,097	0.06%		
Median	89	298	1,040,932	0.03%		
SD	805	1,480	76,375	0.08%		
95% CI	340	625	32,250	0.03%		

Summary of South Delta Salvage and Entrainment

Based on the results of the different modeling exercises presented in the BA, the PA will reduce the number of fish salvaged, and, by inference due to the methods of calculating loss, the number of fish lost to the south Delta export facilities compared to the NAA scenario. This is by virtue of the anticipated reduction in exports at the south Delta facilities during periods of NDD operations, shifting exports from the south Delta to the north Delta. However, projected loss under the PA would still result in the loss of listed fish due to continued exports from the CVP and SWP facilities. The modeling assumes that all parameters other than exports remain static as previously mentioned, although this is not likely to be the case. As mentioned in the section regarding winter-run Chinook salmon salvage and entrainment, altered flows in the north Delta due to increased diversions at the NDD intake sites may increase the number of salmonids from the Sacramento River basin diverted into the central and south Delta waterways due to reduced flows and increased flow reversals redirecting them into alternate routes through river junctions such as Georgiana Slough (Section 2.5.1.2.7.2 Outmigration Routing, Section 2.5.1.2.7 Reduced in-Delta flows, Section 2.5.1.2.7.4 Delta Survival, Section 2.5.1.2.7.1 Travel Time). While fewer fish may eventually be salvaged due to lower exports, there are potentially more fish moving into routes with lower survival rates. In the south Delta, fish moving downstream in the San Joaquin River will likely benefit from the operation of the HOR gate, reducing their exposure to the south Delta export facilities. This benefit is likely to be greatest in wet and above normal years when more exports will be derived from the north Delta than the south Delta. However, the benefit diminishes in drier years when more water is exported from the south Delta and the PA is more like the NAA scenario. Furthermore, it is uncertain how predation in Clifton Court Forebay and in front of the CVP export fish salvage facilities will change under the PA, as reduced exports from the south Delta may alter the behavior of predators in those locations, and increase the travel time through the fish collection process.

2.5.1.2.7.4 Delta Survival

Several studies conducted on salmonid migration through the Sacramento-San Joaquin Delta provide an understanding of how Delta inflow affects juvenile salmonid survival (Perry et al. 2010, Perry et al. 2013, Newman et al. 2003). These studies help to define the relationship of Sacramento River flow (at Freeport) and survival of juvenile salmon through the Delta, as well as the importance that fish migration routing has on migratory success. The acoustic tag studies (Perry et al. 2010, Perry et al. 2015, Perry et al. 2016, Perry 2016) indicate that survival probability increases with increasing flows, and changes in survival are steepest when flows are below 30,000 cfs at Freeport (Figure 2-145). The flow-survival relationship is strongest at lower flows, and in the reaches that transition from riverine to strong tidal influence. The relationship between flow and survival is in agreement with the assumptions and results of the velocity and entrainment analyses that indicated low, slack, and reverse velocities increase entrainment risk and increase travel time, which reduce survival probabilities. For example, entrainment into the interior Delta via Georgiana Slough or Delta Cross Channel (DCC) is increased when flows in the mainstem Sacramento River are low, reversing, or stagnant, and the proportion of fish remaining in the Sacramento River or entering Sutter or Steamboat Slough are increased under high inflows (Perry et al. 2010; Perry et al. 2015; Perry et al. 2016). While the mechanisms causing reduced survival probabilities are likely combinations of reduced velocities, route selection, and increased entrainment into the interior Delta, the flow-survival relationship can be used to collectively evaluate effects of flow changes on through-Delta survival. This Opinion analyzes the effects of the PA on travel time, route selection, entrainment, and the relationships between flows and juvenile salmon survival probabilities.

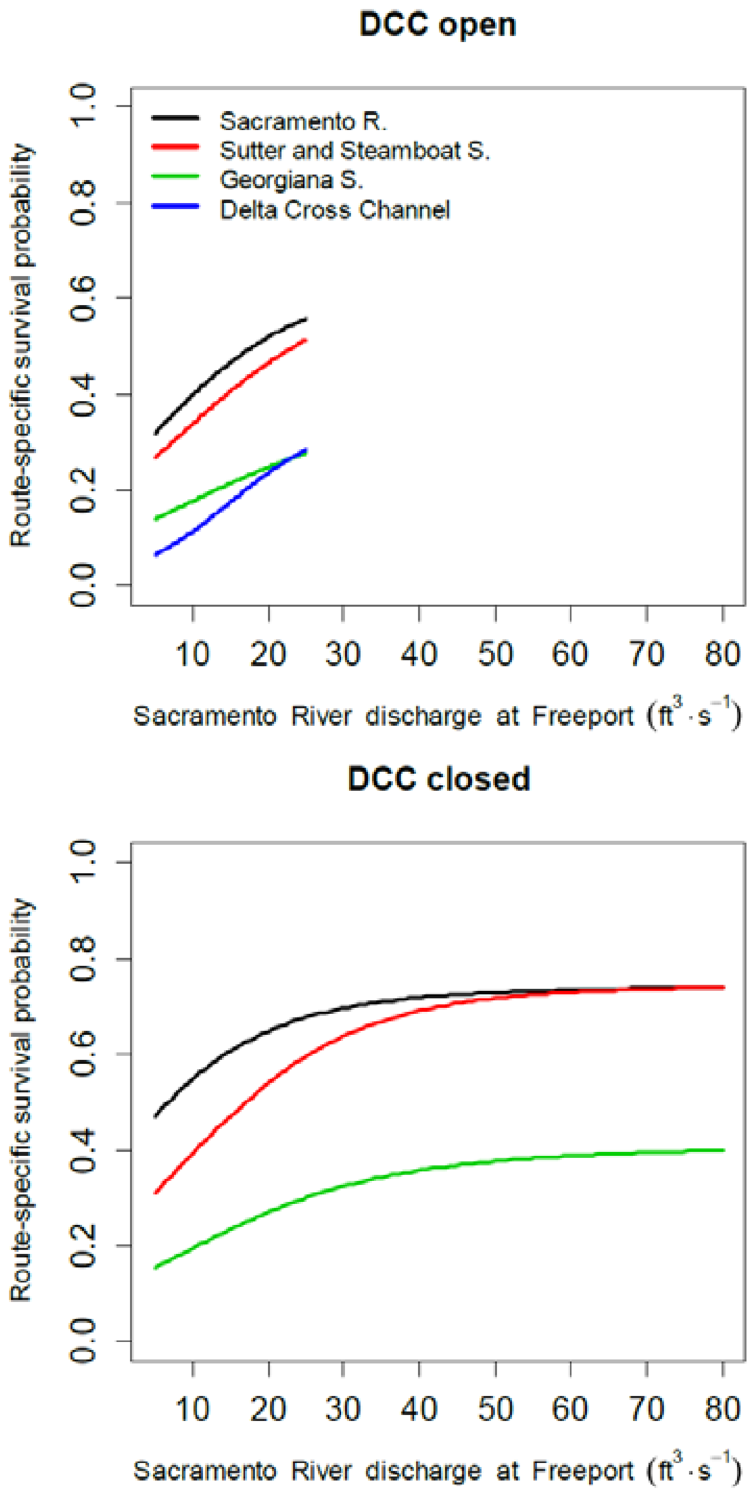


Figure 2-145. Route-specific survival between Freeport and Chipps Island as a function of Sacramento River discharge at Freeport. Top panel is with DCC open and bottom panel with DCC closed (DCC is closed once flows exceed ~25,000 cfs at Freeport).

Four models are used to assess differences in route-specific survival and/or overall through Delta survival under the PA: The Delta Passage Model (DPM), Newman (2003) and Salsim, which were presented in the BA Section 5.4.1.3.1.2.1.3, and the Perry Survival Model, which is presented in this Opinion. The Perry Survival Model supersedes the analysis that was based on Perry (2010; see BA Section 5.4.1.3.1.2.1.3.3). A summary of each model and how each were applied to this analysis is summarized in Table 2-214.

Table 2-214. Summary of Models/Methods Used to Analyze Delta Survival Differences Between the CWF Scenarios.

Model	Source	Method	Applicability	Analysis
Delta Passage Model	CWF BA Appendix 5.D.1.2.4	Simulation model using DSM2 hydrology of CWF scenarios based from acoustic tag data (Perry et al. 2010) and statistical equations (Newman & Brandes 2010)	Sacramento basin Chinook smolts and Mokelumne fall run Chinook smolts	Survival differences between scenarios by migratory route and for overall through Delta survival.
Newman 2003	CWF BA Appendix 5.D.1.2.3	Bayesian hierarchical statistical model based on CWT releases and covariates of flow, temperature and south Delta exports	Chinook smolts; particularly spring and fall-run due to studies timing	Overall through Delta survival differences between scenarios.
Salsim	CWF BA	Statistical model based on CWT of San Joaquin Basin smolts	San Joaquin basin Chinook smolts	Survival differences between scenarios for San Joaquin Basin fish
Perry Survival Model	CWF BO Appendix G	Survival probability model derived from five years of telemetry studies in Sacramento Delta (Perry 2016)	Sacramento basin Chinook smolts; particularly winter run and late-fall run due to studies' timing	Survival differences between scenarios by migratory route and for overall through Delta survival of Sacramento basin smolts.

A synopsis of the four models and the relative weight or ranking we place on each model is briefly described:

NMFS uses three models that predict survival probabilities for smolts that enter the Delta through the Sacramento River Basin: DPM, Newman (2003) and Perry 2016. The Salsim looks at survival for fish that enter from the San Joaquin River basin. Because Salsim is the only south Delta model, it is our primary model to assess changes in south Delta survival under the scenarios. There are also models from the BA analysis that NMFS incorporates into the Opinion: Salvage Density, Zeug and Cavallo (BA Entrainment Section 5.4.1.3.1.1.2.1.). These models analyze how entrainment loss to the south Delta facilities changes under the scenarios, and we also use those analyses to help assess effects on overall south Delta effects.

Perry 2016 and DPM are based on telemetry data which allowed for collection of environmental and hydrological data synchronous with the fate of individual fish as they migrate through the north and central Delta. Newman (2003) and Salsim are based on coded-wire tag studies over multiple years and both rely heavily on statistical correlation between fish recapture and more broad or generalized environmental/hydrological data.

Though the three Sacramento basin flow models may use different methods and therefore at times differ in results regarding through Delta survival, they all corroborate this finding: Discharge at Freeport influences through Delta survival. Additionally, DPM, Newman (2003), and Salsim corroborate that reduction in exports (or inherent increase in San Joaquin River flow) in the south Delta reduces salvage (see Section 2.5.1.2.7.3.1 South Delta Salvage) at south Delta facilities and/or improves overall survival in the South Delta.

- Delta Passage Model—This model is based on Perry et al. (2010) studies incorporating 2006 to 2009 data of acoustically tagged hatchery smolts. It also includes an export-dependent survival for smolts that enter the interior Delta which incorporates influence of changes in south Delta exports between scenarios (Newman and Brandes 2010). The DPM does not model a flow survival relationship in the reaches of Georgiana Slough and the DCC, but it does attempt to assess benefits that smolts in the interior Delta may experience once they exit Georgiana Slough or DCC. Therefore, under the results of this model, the PA has higher survival for smolts that enter the interior Delta because survival between scenarios relies primarily on changes in south Delta exports and not Freeport flows. In contrast, Perry (2017b) found that a flow-survival relationship exists in these reaches and smolts experience greater mortality at lower Freeport flows. DPM also models survival for fish that enter the Yolo Bypass; however, differences in survival are primarily based on proportion of fish entering that route, and this is very similar between scenarios.
- Newman 2003—This model uses CWT data to correlate survival with covariates such as temperature, flow, and south Delta exports. This model applies the covariates equally to all smolts as it does not distinguish among migratory routes of smolts traveling through the north Delta. As evidenced over several CWT and acoustic tag studies, the migratory route taken affects survival probability and environmental conditions experienced. This model is limited in that a south Delta export covariate is also applied to the majority of smolts that do not enter the interior and/or south Delta. Therefore, when interpreting results on through-Delta survival it is important to acknowledge that reduction in south Delta exports under the PA is often influencing survival for the majority of Sacramento basin smolts even though they do not enter the interior Delta. The applicability of this model is best used in corroboration of the flow survival relationships in the spring months and for smaller fish (61 mm to 96 mm) in the north Delta that were evident under the CWT study. This helps fill in data gaps on how survival of smaller fish is also affected by flow. Newman 2003 also corroborates the effect of south delta exports on south Delta facility entrainment and/or the inherent benefit increased flow (through reduced exports) has on out-migrating smolts that is also evident in the Salsim model for San Joaquin basin fish.
- SalSim—This is a statistical model based on CWT San Joaquin Basin Chinook salmon smolts, which is the best available model representation of San Joaquin origin Chinook salmon for purposes of this analysis. SalSim is a standalone life cycle modeling tool, and the coefficients of the survival function from its Delta Module were used in a spreadsheet to compare potential survival differences between NAA and PA. Note that in contrast to the DPM, the through-Delta survival function in SalSim does not account for different survival probability in San Joaquin River versus Old River, nor does it account for routing of fish into these channels. The function only considers flow into the Stockton Deepwater Ship Channel (in addition to striped bass abundance and water temperature), so that the effects of the HOR

gate are only expressed in terms of keeping more flow in the San Joaquin River. Per the SalSim documentation (see BA Appendix 5.E EFH Assessment), juvenile survival through the Delta is a function of flow entering the Stockton Deepwater Ship Channel, abundance of striped bass in the Delta, and water temperature at Mossdale, in addition to various multipliers (AD Consultants 2014).

- Perry Survival Model—This model uses the most up-to-date flow survival relationships (as measured at Freeport) using acoustically tagged hatchery smolts from the years 2006 through 2011. It allows for individual tracking of smolts to understand the proportion that use specific migratory routes as well as specific route-survival and overall through-Delta survival. We consider this model to contain the most complete and most recent scientific and commercial data available to assess survival changes in the north and central Delta between the NAA and PA.

2.5.1.2.7.4.1 The Revised PA Unlimited Pulse Protection Scenario

After release of preliminary draft sections of the CWF project analyses in December 2016 and January 2017 (as described at the beginning of Section 2.5.1 Effects to Species), Reclamation and DWR revised the PA to include revisions to the real-time operations of the north Delta diversions. The objective of these revisions are to lessen the adverse impacts of both PA and L1 operational scenarios identified in the January 21, 2017, Initial Draft Biological Opinion effects analysis. NMFS has supplemented the analyses on juvenile Delta survival to reflect the revised PA.

The Revised PA Unlimited Pulse Protection (UPP) includes revisions such that the real-time operations of the north Delta diversions are as described in BA Section 3.3.3.1 North Delta Diversion and Appendix E. Specifically,

> *"…Under RTOs, the NDD would be operated within the range of pulse protection, and Levels 1, 2, and 3, depending on risk to fish and with consideration for other factors such as water supply and other Delta conditions, and by implementing pulse protection periods when primary juvenile winter-run and spring-run Chinook salmon migration is occurring. Post-pulse bypass flow operations may remain at Level 1 pumping depending on fish presence, abundance, and movement in the north Delta; however, the exact levels will be determined through initial operating studies evaluating the level of protection provided at various levels of pumping. The specific criteria for transitioning between and among pulse protection and post-pulse bypass flow operations will be based on real-time fish monitoring and hydrologic/ behavioral cues upstream of and in the Delta that will be studied as part of the PA's Collaborative Science and Adaptive Management Plan (Section 3.4.6)…."*
>
> *"The following operational framework serves as an example that is based on the recommended NDD RTO process (Marcinkevage and Kundargi 2016)…."*
>
> - *A fish pulse is defined as combined catch of X_p[1] winter-run and spring-run sized Chinook salmon in a single day at specified locations.*

[1] Preliminary evaluation of the effects of the proposed operations will use triggers developed from data provided by existing monitoring stations. The values and monitoring location would depend upon operation of a new/additional station(s), the method used to identify winter- and spring-run Chinook salmon, collection of sufficient data, and the time of year. DFW's draft 2081

- *Upon initiation of fish pulse, operations must reduce to low-level pumping.*
- *Pumping may not exceed low-level pumping for the duration of fish pulse. However, additional pumping above low-level may be allowed as long as a minimum of 35,000 cfs[2] bypass flow is maintained during the period of pulse protection. A fish pulse is considered over after X[3] consecutive days with daily combined catch of winter- and spring run-sized Chinook salmon less than X_p at or just downstream of the new intakes.*
- *Post-pulse bypass flow operations will be determined through initial operating studies evaluating the level of protection provided at various levels of pumping.*
- *All subsequent pulses of winter- and spring-run Chinook salmon will be afforded the same level of protection as the first pulse.*
- *Unlimited fish pulses are protected in any given year.*

Under the UPP scenario, flow operations are adjusted based on capture of winter-run and spring-run Chinook salmon in the Delta. Due to the high likelihood of non-discretionary conditions the pending CDFW California Fish and Game Code Section 2081 permit, NMFS has used the permit conditions as initial catch and index values that would trigger operational adjustments for purposes of the analysis in this Opinion. NMFS expects these specific catch and index values to be further refined through the adaptive management program (see Appendix A2 Project Description of this Opinion). Any changes to these initial values would necessitate additional analysis, and could trigger reinitiation of consultation for this Opinion.

Catch or index values that would trigger the operational adjustments are not specifically defined in the revised PA; however, as described in footnote 1 quoted above from the revised PA, CDFW's draft permit for the PA under California Fish and Game Code Section 2081 includes a condition that triggers pulse protection based on a Knights Landing catch index (X_p) greater than or equal to 5 winter-run-sized and spring-run-sized fish. The number of days pulse protection would be implemented once triggered are to be based on empirical Chinook smolt migration rates and are not specifically defined under the revised PA; however, as described in footnote 3 quoted above from the revised PA, CDFW's draft permit for the PA under California Fish and Game Code Section 2081 includes a condition related to pulse protection that considers a pulse to be over when Knights Landing catch index (X_p) is less than 5 for a duration (X) of 5 days. The effectiveness of this operation relies on a robust monitoring program coupled with efficient and expedient real-time operations adjustments.

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permit includes a condition related to pulse protection which triggers a pulse based on a Knights Landing catch index (X_p) greater than or equal to 5 winter-run-sized and spring-run-sized fish.

[2] Preliminary evaluation of the effects of the proposed operations will use a minimum off-ramp bypass flow developed from existing data. The off-ramp bypass flow required will be determined based on pre-construction studies identified in BA Section 3.4.7.3 (provide citation).

[3] Preliminary evaluation of the effects of the proposed operations will use triggers developed from data provided by existing monitoring stations. The values and monitoring location would depend upon operation of a new/additional station, the method used to identify winter- and spring-run Chinook salmon, collection of sufficient data, and the time of year. DFW's draft 2081 permit includes a condition related to pulse protection which considers a pulse to be over when Knights Landing catch index (X_p) is less than 5 for a duration (X) of 5 days.

2.5.1.2.7.4.2 Delta Passage Model

The BA includes analysis of through-Delta survival using the Delta Passage Model (DPM) (BA Section 5.4.1.3.1.2.1.3.1 Delta Passage Model: Winter-Run and Sacramento River Basin Spring-Run Chinook Salmon). The DPM integrates operational effects of the NAA and PA that could influence survival of migrating juvenile winter-run Chinook salmon through the Delta; this includes differences in channel flows (flow-survival relationships), differences in routing based on flow proportions (e.g., entry into the interior Delta, where survival is lower), and differences in south Delta exports (export-survival relationships). The DPM provides estimates of the mean annual probability of survival from Freeport to Chipps Island through four (collective) migratory routes over the five water year types (mainstem Sacramento River, Yolo Bypass, Sutter and Steamboat sloughs, and interior Delta). It also provides total through-Delta survival over the five water year types and the proportion of population migrating through each migratory route under both scenarios.

2.5.1.2.7.4.2.1 Winter-run Exposure and Risk

DPM results for estimated through-Delta survival for winter-run Chinook are shown in Table 2-215. This table also includes mean survival probability by migratory route and water year types. For both the NAA and PA, the probability of survival in the Yolo Bypass, Sutter, and Steamboat Sloughs, and mainstem Sacramento River migratory routes are relatively higher than the probability of survival in the interior Delta, which is at most 23% (Table 2-215).

Under the NAA, mean through-Delta survival ranges from a low of 25% in critical years to a high of 43% survival in wet years. For the PA, smolt survival is reduced in all migratory routes as compared to NAA, with the exception of the Yolo Bypass where survival between scenarios does not change and the interior Delta where survival is higher under the PA (Table 2-215). For example, survival in the mainstem Sacramento River is reduced across all water year types for the PA, particularly for below normal and dry years when there is a 3% absolute (8% relative) mean reduction in survival. This pattern of reduced survival, regardless of water year type, is also expected for overall through-Delta survival, as well as for smolts migrating through Sutter and Steamboat Sloughs (Table 2-215). The probability of survival for smolts migrating through the Yolo Bypass is not expected to change (Table 2-215). The only region where survival is improved for the PA is the interior Delta, with the exception in critical water years (Table 2-215). However, survival is still poor in the interior Delta due to the altered hydrodynamics created by south Delta operations (see Section 2.5.1.2.7.3 South Delta Operations). The lowest probability of survival is the interior Delta, where smolts have a 12-23% probability of survival under either scenario. The probability of entry into the interior Delta is slightly higher for the PA and there is also a slight decrease in the probability of entry into the Sutter and Steamboat routes for the PA. Because of the different survival probabilities for the different routes, the routing results can affect total through-Delta survival when assessing the overall effect of operations.

Table 2-215. Delta Passage Model: Winter-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes.

WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.43	0.43	-0.01 (-2%)	0.48	0.46	-0.02 (-5%)	0.22	0.22	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.40	0.39	-0.01 (-2%)	0.44	0.42	-0.02 (-6%)	0.16	0.17	0.00 (1%)	0.47	0.47	0.00 (0%)
BN	0.31	0.29	-0.02 (-6%)	0.34	0.31	-0.03 (-8%)	0.06	0.06	0.00 (2%)	0.47	0.47	0.00 (0%)
D	0.30	0.28	-0.02 (-7%)	0.33	0.30	-0.03 (-8%)	0.06	0.06	0.00 (2%)	0.47	0.47	0.00 (0%)
C	0.25	0.24	-0.01 (-4%)	0.27	0.26	-0.01 (-4%)	0.03	0.03	0.00 (0%)	0.47	0.47	0.00 (0%)

WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.28	-0.01 (-2%)	0.52	0.50	-0.02 (-4%)	0.26	0.26	0.00 (2%)	0.18	0.23	0.05 (28%)
AN	0.30	0.29	-0.01 (-2%)	0.49	0.46	-0.02 (-5%)	0.26	0.27	0.01 (2%)	0.17	0.20	0.03 (19%)
BN	0.31	0.30	-0.01 (-2%)	0.38	0.35	-0.03 (-7%)	0.27	0.28	0.01 (2%)	0.14	0.15	0.01 (5%)
D	0.30	0.30	-0.01 (-2%)	0.37	0.34	-0.03 (-8%)	0.27	0.28	0.01 (2%)	0.14	0.14	0.00 (0%)
C	0.29	0.29	0.00 (-1%)	0.31	0.30	-0.01 (-4%)	0.29	0.29	0.00 (1%)	0.13	0.12	0.00 (-1%)

Notes:

Values in parenthesis represent percent change in mean survival under the PA.

Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions, i.e., survival is cumulative.

The results of the DPM show a logical manifestation of application of a flow-survival relationship that Sacramento River survival probabilities under the PA, which has lower flows due to the operations of the NDD, are lower. The DPM results show an increase in survival in the interior Delta due to reduced south Delta exports which is expected to influence survival in the interior Delta. The full survival effects from south Delta exports are described in Section 2.5.1.2.7.3. South Delta Operations. However, the increase in survival for the interior Delta does not necessarily mitigate for the reduction in survival in the primary north Delta migratory routes. Based on the steeper flow-survival relationship that would occur when Sacramento River flows are under 30,000 cfs (Figure 2-145), the difference in survival probability between the scenarios is likely to be more pronounced in drier years than in wetter years. In other words, the PA operations would likely reduce through-Delta survival more during drier years because flows into the Delta and/or resultant bypass flows under the PA are more likely to be under 30,000 cfs (Figure 2-146).

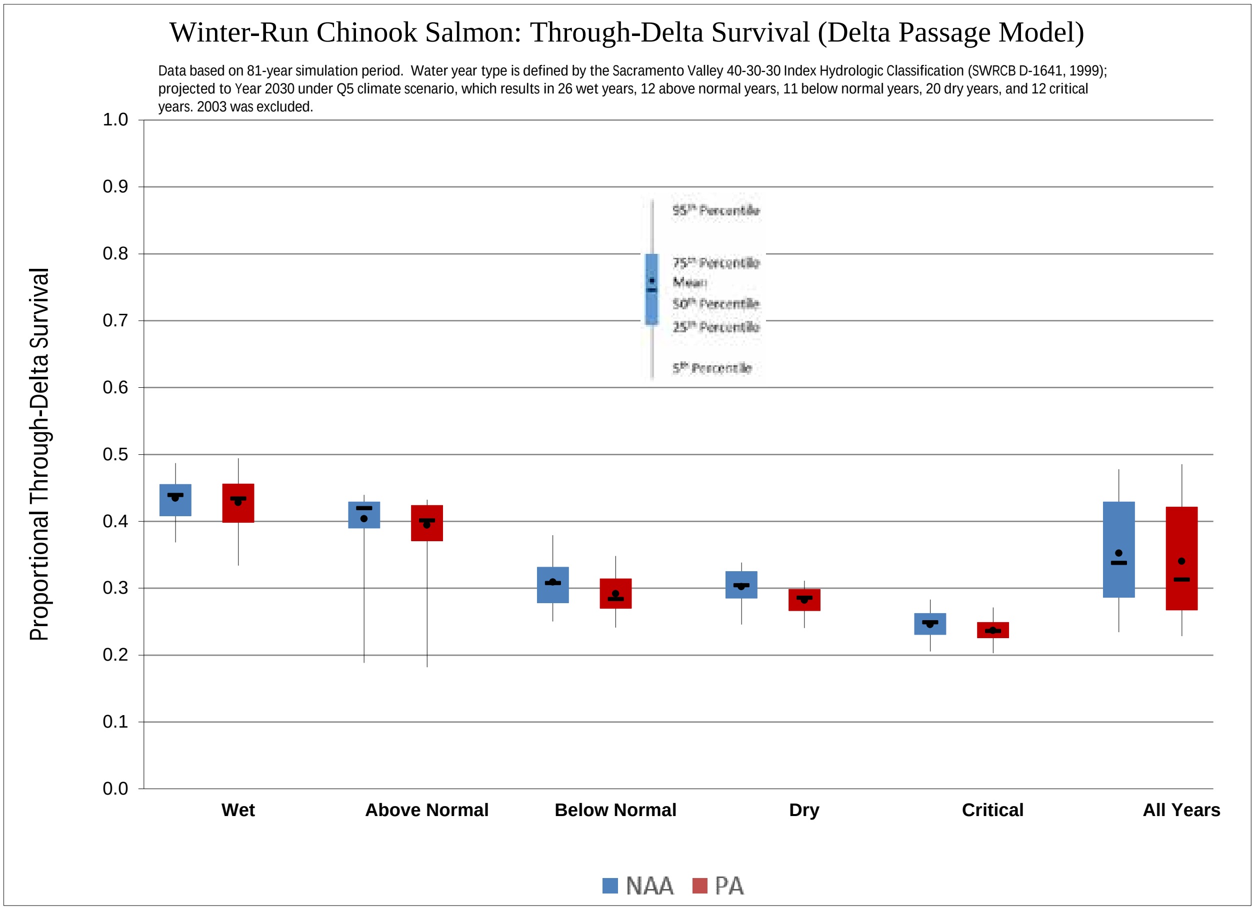


Figure 2-146. Box Plots of Winter-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Types.

Because winter-run Chinook only spawn in the upper Sacramento River, exposure to the NDD intakes and operations of the PA will affect all of the population with the exception of the proportion that may enter the Yolo Bypass. This model estimated a range from 3% in critical years to 22% in wet years would enter the Yolo Bypass (BA Table 5.4-13 in Appendix C of this Opinion). This estimation includes an assumption that there would be more access to Yolo Bypass in drier year types due to a notched weir that is currently in the planning stages.

Overall, the absolute mean reduction in smolt survival is 1% to 2% for the PA, resulting in a relative survival reduction of 2-7% depending on water year type when compared to NAA. In drier years and/or lower Delta inflows, survival is generally lower as evidenced in the flow-survival relationship curves (Figure 2-145); this results in an absolute change in survival being more impactful to a population when survival is already generally low. The 1% to 2% mean reduction in survival is a notable reduction for an endangered species, especially if it occurs on a consistent (e.g., annual) basis. Considering this, the DPM results indicate that the PA has a range of low to high adverse effects on outmigrating winter-run Chinook salmon smolts depending on water year type. This is due to an increase in routing to lower survival routes and a reduction in flow that impacts survival particularly in below normal and dry water year types. Survival during the drier water year types are about 25% lower on average than the above normal and wet water year types. Therefore, even a small change in survival impacts the population to a greater degree, resulting in 8% relative change in survival under the PA as compared to the NAA during those years.

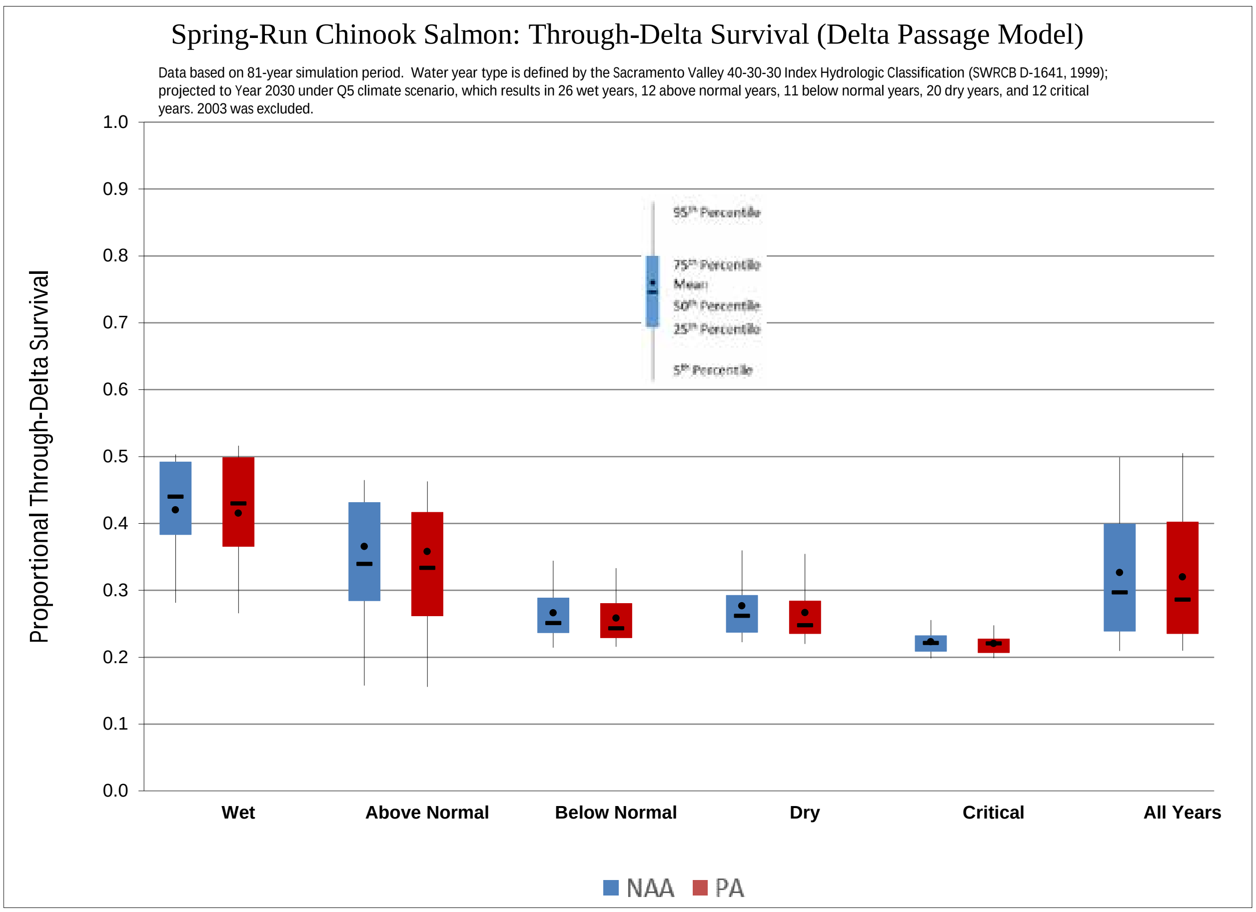
2.5.1.2.7.4.2.2 Spring run Exposure and Risk

Spring-run juveniles enter the Delta as early as December and as late as May based on Sacramento Trawl monitoring over the last 20 years. Peak entrance into the Delta is in April when 63% of the population enter the Delta based on sampling between 1995 and 2015. Monitoring at Chipps Island indicates that exit from the Delta occurs during a smaller window from March through June. Peak exit from the Delta occurs in April as well, and it is assumed the majority of the population (over 60%) migrates quickly through the Delta during the month of April changing little in size (forklength; averaging 86 mm on entrance to Delta and 91 mm upon exit from Delta). Spring-run, like all the Chinook species, are identified using length at date criteria (Fisher 1992) and only in recent years has genetic sampling been introduced into the long-term monitoring sites to improve species identification. There is a segment of the population (~16%) that enters earlier from December through March under 70 mm in size, which would likely spend weeks to months rearing in the Delta until exiting during or after the month of March.

DPM results for estimated total through-Delta survival for spring-run Chinook are shown in BA Table 5-4-14 in Appendix C of this Opinion. This table also includes mean survival probability by migratory route and water year types. For both the NAA and PA, the probability of survival in the Yolo Bypass, Sutter, and Steamboat Sloughs, and mainstem Sacramento River migratory routes are relatively higher than the probability of survival in the Interior Delta, which is at most 25% (See BA Table 5-4-14 in Appendix C of this Opinion).

Spring-run Chinook total through-Delta survival ranges from a low of 22% in critical years to a high of 42% survival in wet years (See BA Table 5-4-14 in Appendix C of this Opinion). Under the PA, smolt survival is reduced in all migratory routes, with the exception of the Interior Delta where survival is higher under the PA and Yolo Bypass where survival between scenarios does not change. Through-Delta survival is slightly reduced across all water year types for the PA, with the largest change a 3% to 4% relative reduction in survival for below normal and dry years. This pattern of reduced survival, regardless of water year type, is also expected for smolts in the Sacramento mainstem and for smolts migrating through Sutter and Steamboat Sloughs with the exception of critical years when there is no change between scenarios. The probability of survival for smolts migrating through the Yolo Bypass is not expected to change. The only region where survival is improved for the PA is the interior Delta. The lowest probability of survival is the Interior Delta, where smolts have a 13%-25% probability of survival under either scenario. The probability of entry into the interior Delta is slightly higher for the PA, and there is also a slight decrease in the probability of entry into the Sutter and Steamboat routes for the PA. Because of the different survival probabilities for the different routes, the routing results can affect total through-Delta survival when assessing the overall effect of operations.

The results of the DPM show a logical manifestation of application of a flow-survival relationship that survival probabilities under the PA, which has lower flows due to the operations of the NDD, are lower. The DPM results show an increase in survival in the interior Delta due to reduced south Delta exports which is expected to influence survival in the interior Delta. However, the increase in survival for the interior Delta does not necessarily mitigate for the reduction in survival in the primary north Delta migratory routes (see BA Table 5.4-11 in Appendix C of this Opinion). In drier years and/or during lower Delta inflows, survival is generally lower as evidenced in the flow-survival relationship curves and DPM results (Figure 2-147). This results in an absolute change in survival being more impactful to a population when survival is already generally low. The relative difference in survival probability between the scenarios is likely to be more pronounced in drier years than for wetter years with a similar level of absolute reduction in survival. In other words, the PA operations would likely reduce through-Delta survival more during drier years because flows into the Delta and/or resultant bypass flows under the PA are more likely to be under 30,000 cfs (Figure 2-146).



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-147. Box Plots of Spring-run Chinook Salmon Annual Through-Delta Survival Estimate from the Delta Passage Model, Grouped by Water Year Type.

Because spring-run Chinook primarily spawn in the Sacramento basin, exposure to the NDD intakes and operations of the PA will affect the entire population with the exception of the proportion that may enter the Yolo Bypass or the small experimental population being reintroduced into the San Joaquin basin. This model estimated a range from 3% in critical years to 19% in wet years would enter the Yolo Bypass (BA Table 5.4-14 in Appendix C of this Opinion). This estimation includes an assumption that there would be more access to Yolo Bypass in drier year types due to a notched weir that is currently in the planning stages.

Overall, the absolute mean reduction in smolt survival is 0% to 1% for the PA, resulting in a relative survival reduction of 1-4% depending on water year type when compared to NAA. In drier years and/or lower Delta inflows survival is generally lower as evidenced in the flow-survival relationship curves; this results in an absolute change in survival being more impactful to a population when survival is already generally low. The 1% mean reduction in survival is a small reduction but can impact a listed species, especially if it occurs on a consistent (e.g., annual) basis. Considering this, the DPM results indicate that the PA has a range of low to medium adverse effects on outmigrating spring-run Chinook salmon smolts depending on water year type. This is due to an increase in routing to lower survival routes and a reduction in flow that impacts survival particularly in below normal and dry water year types. Survival during the drier water year types are about 25% lower on average than the above normal and wet water year types. Therefore, even a small change in survival impacts the population to a greater degree resulting in 4% relative change in survival under the PA as compared to the NAA during those years.

2.5.1.2.7.4.2.3 Steelhead Exposure and Risk

Several models have been developed for Chinook salmon that have linked salmonid migration through the Sacramento-San Joaquin Delta with survival rates within different routes through the Delta (Perry et al. 2010, Perry et al. 2013, Newman et al. 2003). Due to the size of acoustic tags, the preferred test subjects have been late fall-run Chinook salmon (late fall-run Chinook salmon smolts are similar in size to smaller steelhead smolts). These studies helped to define the relationship of Sacramento River (Freeport) flow and juvenile salmon survival through the Delta and the importance routing has on migratory success. The acoustic tag studies in particular (Perry et al. 2010, Perry 2016) indicate that survival probability increases with increasing flows and changes in survival are steepest when flows are below 30,000 cfs at Freeport. The flow-survival relationship is strongest at lower flows, and in the reaches that transition from riverine to strong tidal influence. Since the studies and associated survival models are based on Chinook salmon, only a generalized association can be made with steelhead smolts which are typically larger and have somewhat different behaviors associated with their downstream migration as smolts (Chapman et al. 2013).

Details of the DPM results are provided in the winter-run risk and exposure section (See Section 2.5.1.2.7.3.1.1 Winter-run Exposure and Risk). Given that the DPM results show a decreased survival for winter-run smolts under the PA, it would be reasonable to conclude that steelhead smolts emigrating through the Delta at the same time and under the same conditions assumed for the PA would also have reduced survival under the PA scenario compared to the NAA scenario, although the magnitude of the decreased survival is uncertain due to the differences between Chinook salmon and steelhead.

2.5.1.2.7.4.2.4 Green Sturgeon Exposure and Risk

This modeling does not apply to green sturgeon and is not used to assess impacts to survival under the PA to any life stage of green sturgeon. The effects that reduced in-Delta flows have on migratory patterns and timing of adult, sub-adult and juvenile green sturgeon are analyzed in Sections 2.5.1.2.7.1 Travel Time and 2.5.1.2.7.2 Outmigration of this Opinion.

2.5.1.2.7.4.2.5 Fall run Exposure and Risk

Based on Sacramento trawl data (RM 55), fall-run Chinook salmon juveniles from the Sacramento River move through the Delta from December through August, with a peak of February through May; smolts (i.e., > 70 mm) occur in the Delta from April through August, with the peak from April through June. Based on Mossdale trawl data (RM 54), fall-run Chinook salmon juveniles from the San Joaquin River basin occur in the Delta from January through June; smolts occur from April through June.

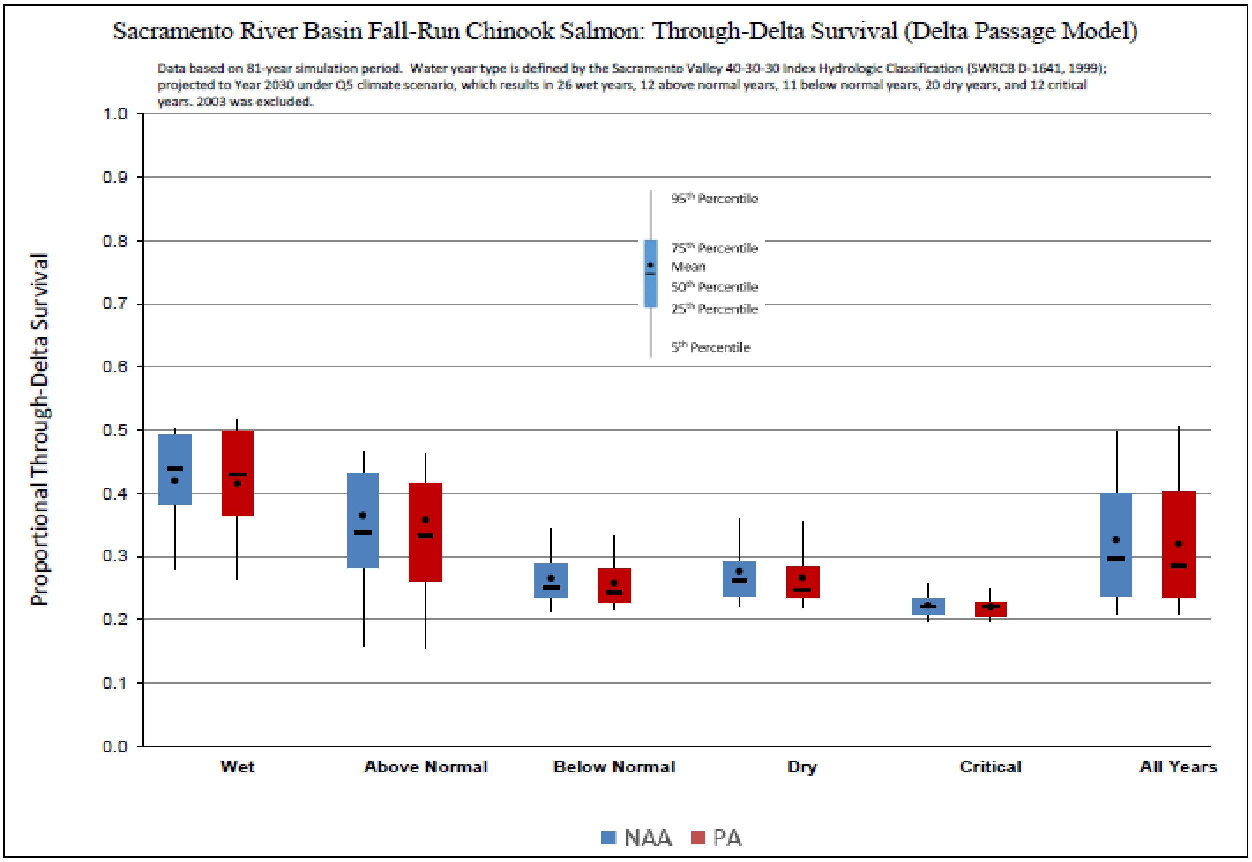
DPM results for estimated total through-Delta survival for fall-run Chinook salmon are shown in BA Table 5.E-10 in Appendix C of this Opinion. This table also includes mean survival probability by migratory route and water year types. For both the NAA and PA, the probability of survival in the Yolo Bypass, Sutter and Steamboat Sloughs, and mainstem Sacramento River migratory routes are relatively higher than the probability of survival in the interior Delta, which is at most 23% (BA Table 5.E-10 in Appendix C of this Opinion).

Fall-run Chinook salmon total through-Delta survival ranges from a low of 20% in critical years to a high of 39% survival in wet years (BA Table 5-E-10 in Appendix C of this Opinion). Under the PA, smolt survival is reduced in all migratory routes, with the exception of the Yolo Bypass where it is unchanged between scenarios and in the interior Delta where survival is higher under the PA. Through-Delta survival is slightly reduced across all water year types for the PA, with the largest change a 2% to 3% relative reduction in survival for wet and above normal years. This pattern of reduced survival under the PA, regardless of water year type, is also expected for smolts in the Sacramento mainstem and for smolts migrating through Sutter and Steamboat Sloughs. The probability of survival for smolts migrating through the Yolo Bypass is not expected to change. The only region where survival is improved for the PA is the interior Delta. The lowest probability of survival is the interior Delta, where smolts have a 12%-23% probability of survival under either scenario. The probability of entry into the interior Delta is slightly higher for the PA and there is also a slight decrease in the probability of entry into the Sutter and Steamboat routes for the PA. Because of the different survival probabilities for the different routes, the routing results can affect total through-Delta survival when assessing the overall effect of operations.

The results of the DPM show that survival for the PA, which has lower flows due to the operations of the NDD, has lower survival probabilities. The DPM results show an increase in survival in the interior Delta due to reduced south Delta exports which is expected to influence survival in the interior Delta. However, the increase in survival for the interior Delta does not necessarily mitigate for the reduction in survival in the primary north Delta migratory routes (BA Table 5-E-10 in Appendix C of this Opinion).

Because fall-run Chinook salmon primarily spawn in the Sacramento basin, exposure to the NDD intakes and operations of the PA will affect most of the population with the exception of the proportion that may enter the Yolo Bypass or the smaller proportion of the population originating from the San Joaquin basin. This model estimated a range from 3% in critical years to 8% in wet years would enter the Yolo Bypass (BA Table 5-E-10 in Appendix C of this Opinion). This estimation includes an assumption that there would be more access to Yolo Bypass in drier year types due to a notched weir that is currently in the planning stages.

Overall, the absolute mean reduction in smolt survival is 0% to 1% for the PA, resulting in a relative survival reduction of 1-3% depending on water year type when compared to NAA. Considering this, the DPM results indicate that the PA has a low adverse effects on outmigrating fall-run Chinook salmon smolts depending on water year type (Figure 2-148). This is due to an increase in routing to lower survival routes and a reduction in flow that impacts survival particularly in wet and above normal water year types.

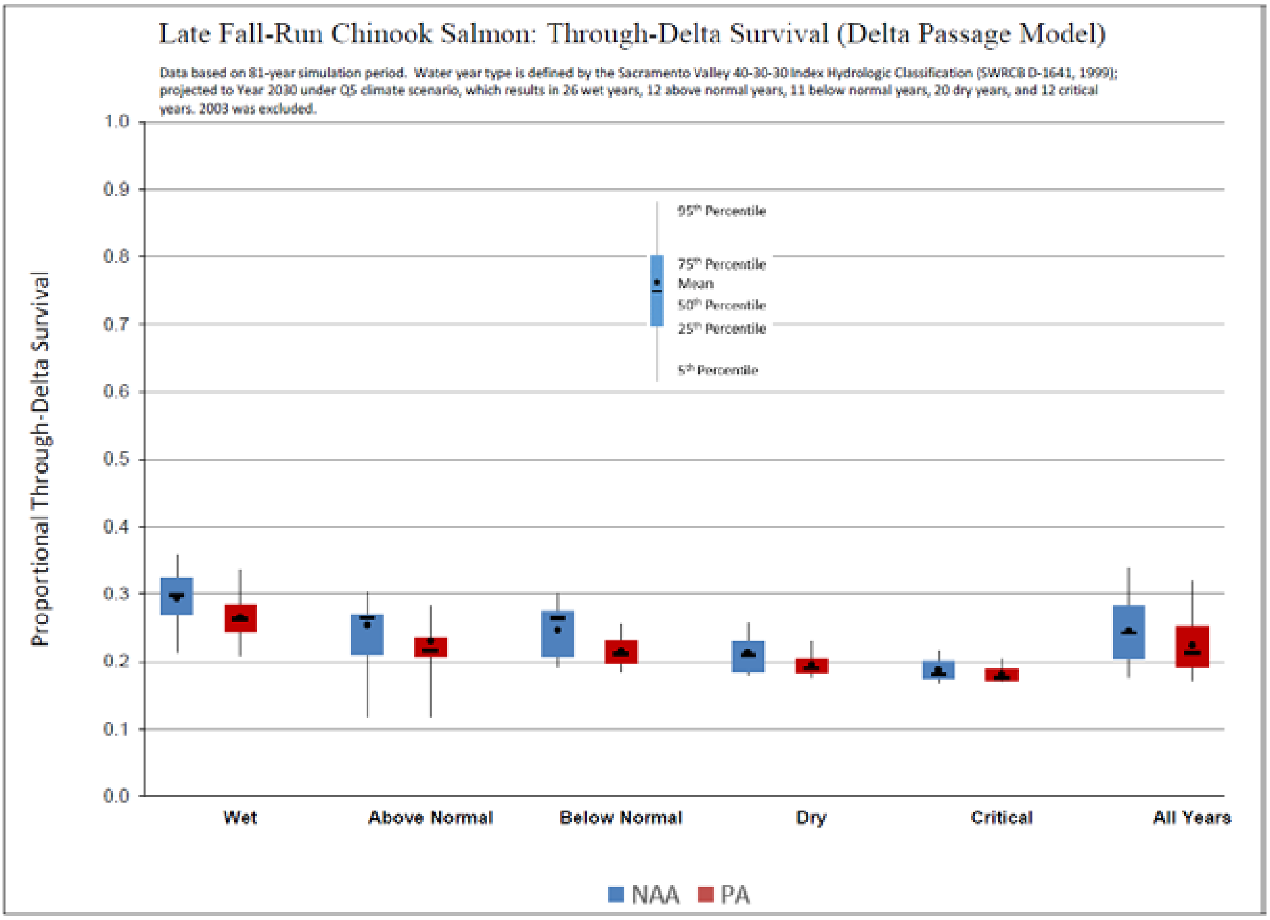


Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-148. Box Plots of Sacramento River Basin Fall-run Chinook Salmon Annual Through Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Type.

2.5.1.2.7.4.2.6 Late fall-run Exposure and Risk

The DPM results for late fall-run Chinook salmon stood in contrast to those of the other Chinook salmon runs in suggesting that total through-Delta smolt survival generally would be appreciably lower under the PA than the NAA (Figure 2-149 and BA Figure 5.E-20; BA Table 5.E-13 in Appendix C of this Opinion). The 95% confidence intervals for through-Delta survival did not overlap in 32 of 81 modeled years, and in all 32 of these years the estimate was lower under PA than NAA (BA Figure 5.E-21). The results for late fall-run Chinook salmon were driven by the entry distribution assumed in the DPM, which is broad, beginning in August and ending in February/March (see BA Figure 5.D-42 in Chapter 5). Overlap with the August-November period results in greater proportional diversion at the NDD being possible, because bypass flows are required to be 5,000 cfs (July–September) or 7,000 cfs (October–November), whereas at other times bypass flow constraints are greater (see BA Section 3.3.2.1). As a result, the mean long-term (1922–2002) ratio of flow entering the Sacramento River below Georgiana Slough weighted by the proportional presence of late fall-run Chinook salmon under the PA is 0.78, compared to 0.87-0.95 for the other Chinook salmon runs. This, combined with the flow-survival relationship being steeper at lower flows (see BA Figure 5.D- 45 in Appendix 5.D), gives appreciably lower survival under the NAA. In addition, overlap with September-November gave somewhat less closure of the DCC gates under the PA than NAA (see BA Table 5.A.6-31 in Appendix 5.A), as a result of several operational criteria described in BA Section 5.A.5.1.4.2 of Appendix 5.A. First, in September of ~20% of years, sufficient water was exported by the NDD that the 25,000-cfs threshold for closure of the DCC is not exceeded, whereas it is exceeded under the NAA in the same years and results in closure of the DCC more than under the PA. Second, in October-November, reservoir releases later in the year under the NAA triggered the 7,500-cfs Sacramento River at Wilkins Slough threshold assumed to coincide with juvenile salmon migration into the Delta, which resulted in a greater number of days with DCC closed under NAA; such differences between NAA and PA would be lessened in November if real-time reservoir operational adjustments to minimize potential upstream effects were undertaken. Last, the DCC may also have been open more under the PA to maintain water quality conditions per D-1641 (Rock Slough salinity standard), which could be managed by real- time operations in order to achieve DCC opening frequency under the PA that is more similar to NAA. The DPM results indicate that the PA will have an adverse effect on late fall-run Chinook salmon smolts migrating through the Delta, relative to the NAA.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-149. Box Plots of Late Fall-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Type.

2.5.1.2.7.4.3 Perry 2017 Flow-Survival Model (Perry Survival Model)

The Perry Survival Model combines equations from statistical models that estimate the relationship of Sacramento River inflows (measured at Freeport) on reach-specific travel time, survival, and routing of acoustic-tagged juvenile late-fall Chinook salmon. Given these equations, daily cohorts of juvenile Chinook salmon migrating through the Delta under the CalSim simulations of the Proposed Action (PA) and No Action Alternative (NAA) were simulated. Daily Delta Cross Channel gate operations from the DSM2 simulations of the PA and NAA were also included. Statistical analysis of travel time and survival in eight discrete reaches of the Delta was used for assessing travel time and survival under the PA and NAA scenarios. The data for the analysis consisted of 2,170 acoustic-tagged late-fall Chinook salmon released during a five-year period (2007-2011) over a wide range of Sacramento River inflows (6,800 – 77,000 ft3/s at Freeport). This analysis was based on acoustic telemetry data from several published studies where details of each study can be found (Perry et al. 2010, 2013; Michel et al. 2015).

The simulation output for each day was summarized to provide a number of useful statistics for each daily cohort:

- The proportion of fish using each unique migration route.

- The mean survival for each unique migration route.
- Overall survival through the Delta, calculated as the mean survival over all individuals.
- Median travel time by route and over all routes.
- Daily difference in survival and median travel time between PA and NAA scenarios.

The difference in daily through-Delta survival between the PA and NAA was summarized with boxplots that display the distribution of survival differences among years for a given date or for given months. This analysis is unique in that it summarizes daily through-Delta survival of the paired scenarios so it is more realistic of differences in survival that fish would experience under the scenarios on any given day. This is a more realistic representation of effects experienced by outmigrating smolts than the summary statistics used in some of the methods in the BA. Results of the DPM and Newman 2003, for example, provide boxplots of the highest to lowest survival for each scenario over the 82 years and then summarize those differences collectively. This grouping of results can dampen the level of effect an individual fish may experience at a smaller time scale which may underestimate the actual impact to survival.

To understand how survival differences arise, it is useful to examine how the individual components of migration routing, survival, and travel time contribute to overall survival in a particular year. In this section, we focus on differences in overall through-Delta survival and survival differences by migratory route. Figure 2-150 and Figure 2-151 illustrate detailed model output for 1943, a wet water year that exhibited bypass flows (flow remaining in the Sacramento River below the North Delta Diversion) ranging from <5,000 ft^3/s to > 50,000 ft^3/s.

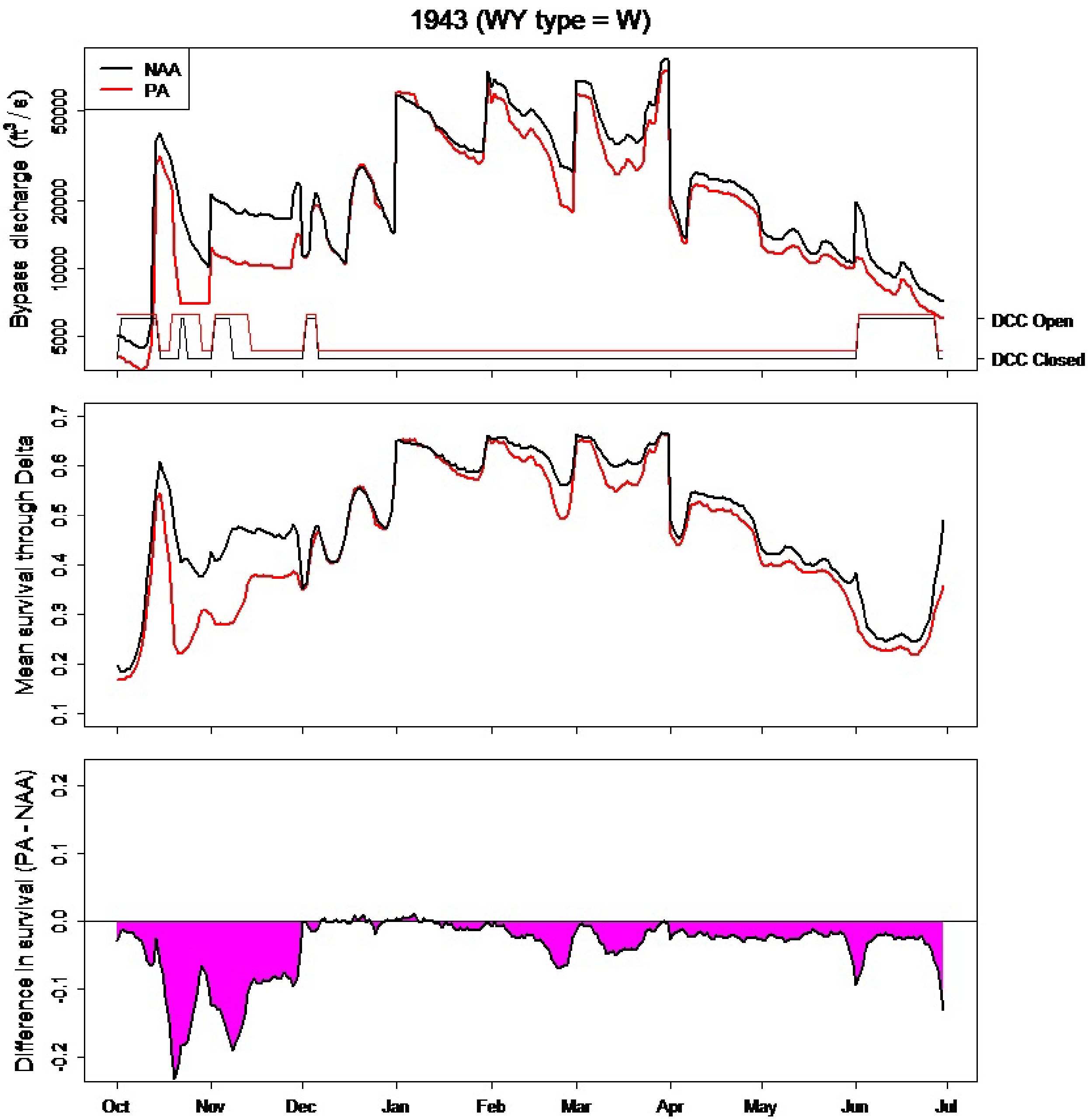


Figure 2-150. Mean Daily Survival through the Delta Simulated for the Proposed Action (PA) and No Action Alternative (NAA, Middle Panel).

Heavy lines in the top panel show bypass discharge and thin lines show DCC operation of open or closed on the second y-axis. The bottom panel shows the difference in daily survival between scenarios. Discharge in the top panel is shown on a logarithmic scale to highlight variation in discharge when discharge is low.

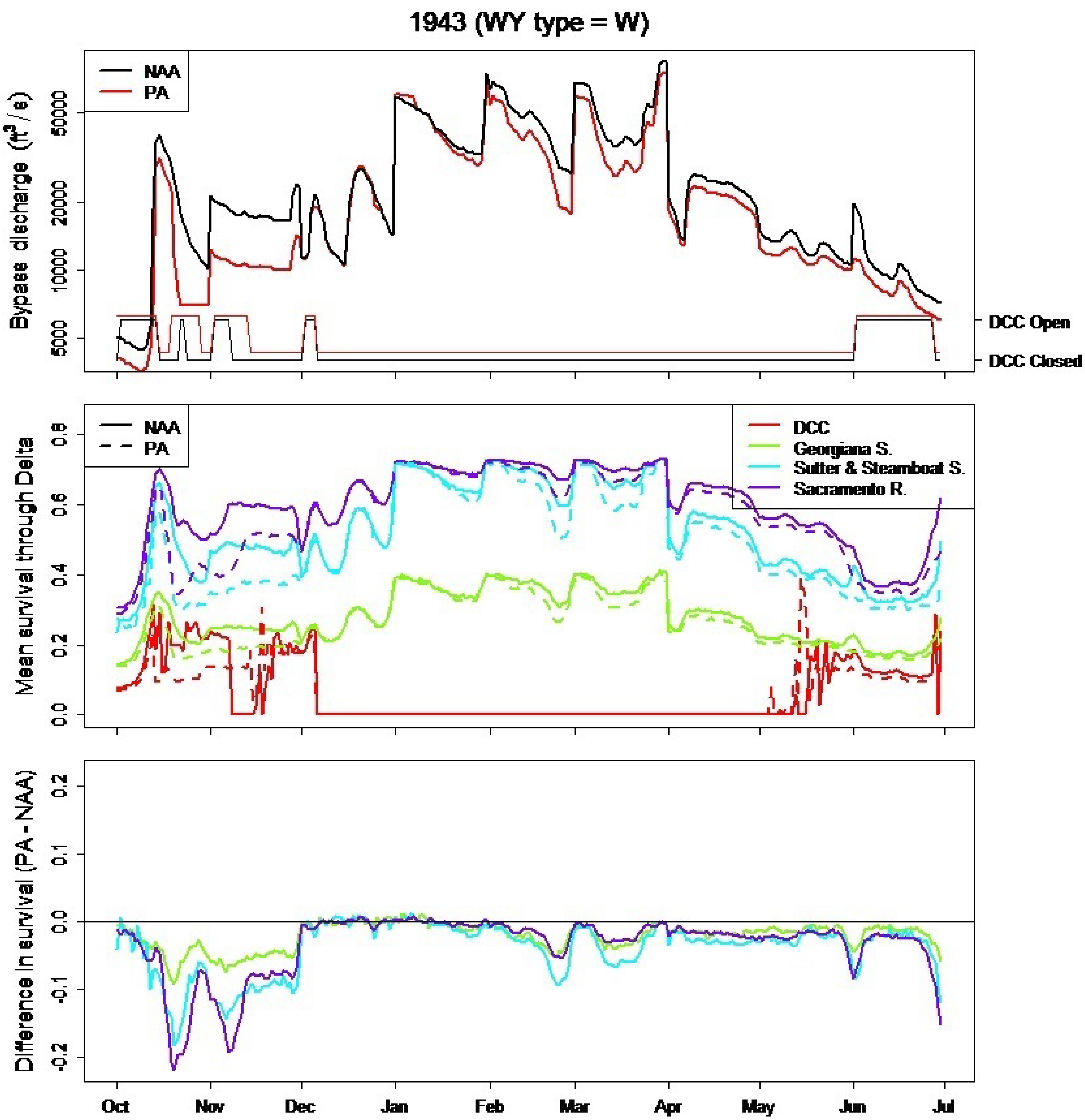


Figure 2-151. Mean Daily Route-specific Survival through the Delta Simulated for the Proposed Action (PA) and No Action Alternative (NAA, Middle Panel).

Heavy lines in the top panel show bypass discharge and thin lines show DCC operation of open or closed on the second y-axis. The bottom panel shows the difference in daily route-specific survival between scenarios. Differences in Delta Cross Channel survival is not shown owing to difference in daily operations of the DCC between scenarios.

As was discussed above in the travel time and outmigration routing sections of this Opinion (Section 2.5.1.2.7.1 Travel Time and Section 2.5.1.2.7.2 Outmigration), Delta inflow, specifically Freeport flow, is used as a predictor of survival, travel time, and route entrainment into Sutter and Steamboat Sloughs, Georgiana Slough and the DCC gate when open. We discussed in section 2.5.1.2.7.1 Travel Time how the different levels in the bypass rules (Levels

1, 2 and 3) during the months of December through June affect velocities below the intakes. Level 1 north Delta diversion operations offered the most protection of the three levels due to higher Freeport inflows before diversions can occur. Here we examine through-Delta survival under the PA using the CalSim modeling of the scenario that contained diversions at all three levels (PA) and additionally with a scenario that restricts diversions to no greater then Level 1 during December to June (L1).

Under real-time operations, the NDD would be operated within the range of low level pumping (pulse protection) and Level 1, 2, and 3, depending on risk to fish and adherence to screening and reverse flow velocity criteria as well as consideration for other factors such as water supply and other Delta conditions (BA Section 3.3.3.1). Additionally, real-time operations will implement pulse protection periods (low level pumping) when primary juvenile winter-run and spring-run Chinook salmon migration is occurring. Post-pulse bypass flow operations will remain at Level 1 pumping while juvenile salmonids are migrating through and rearing in the north Delta, unless it is determined through initial operating studies that an equivalent level of protection can still be provided at Level 2 or 3. The specific criteria for transitioning between and among pulse protection, Level 1, Level 2, and/or Level 3 operations will be based on real-time fish monitoring and hydrologic/behavioral cues upstream of and in the Delta that will be studied as part of the PA's Collaborative Science and Adaptive Management Plan (BA Section 3.4.6). Analyses in the BA characterize PA operations with the full range of pumping; that is, operations allow the NDD to operate at Level 3 if all required flow criteria are met. The Perry Survival Model analysis was applied to an additional operational scenario that provides a lower bookend of pumping. This scenario limits diversions at the NDD to amounts prescribed by Level 1 (hereafter known as "Level 1" or L1). In other words, the L1 scenario caps NDD operations to Level 1 pumping at all times from December through June. NMFS has evaluated this scenario to provide context for the range of effects that may be experienced by migrating salmonids given that the PA states that post-pulse bypass flow operations will remain at Level 1 pumping while juvenile salmonids are migrating through and rearing in the north Delta. All other operational components remained unchanged.

Below are a few figures depicting how survival changes under the PA during low level pumping (the most protective diversion operation), Oct-Nov Bypass rules, and pumping Levels 1, 2, and 3 during December to April operations (Figure 2-152, Figure 2-153 and Figure 2-154). As diversions transition from Level 1 up to Level 3, the peak difference in survival increases and shifts to the left on the X axis as a result of being able to divert more at lower flows under each successive operating level (Figure 2-154). Figure 2-153 and Figure 2-154 were produced under the assumption of constant Freeport flows during a cohort's (group of juvenile Chinook salmon) migration through the Delta, whereas the simulations performed using the CalSim results account for daily variation in Freeport flows.

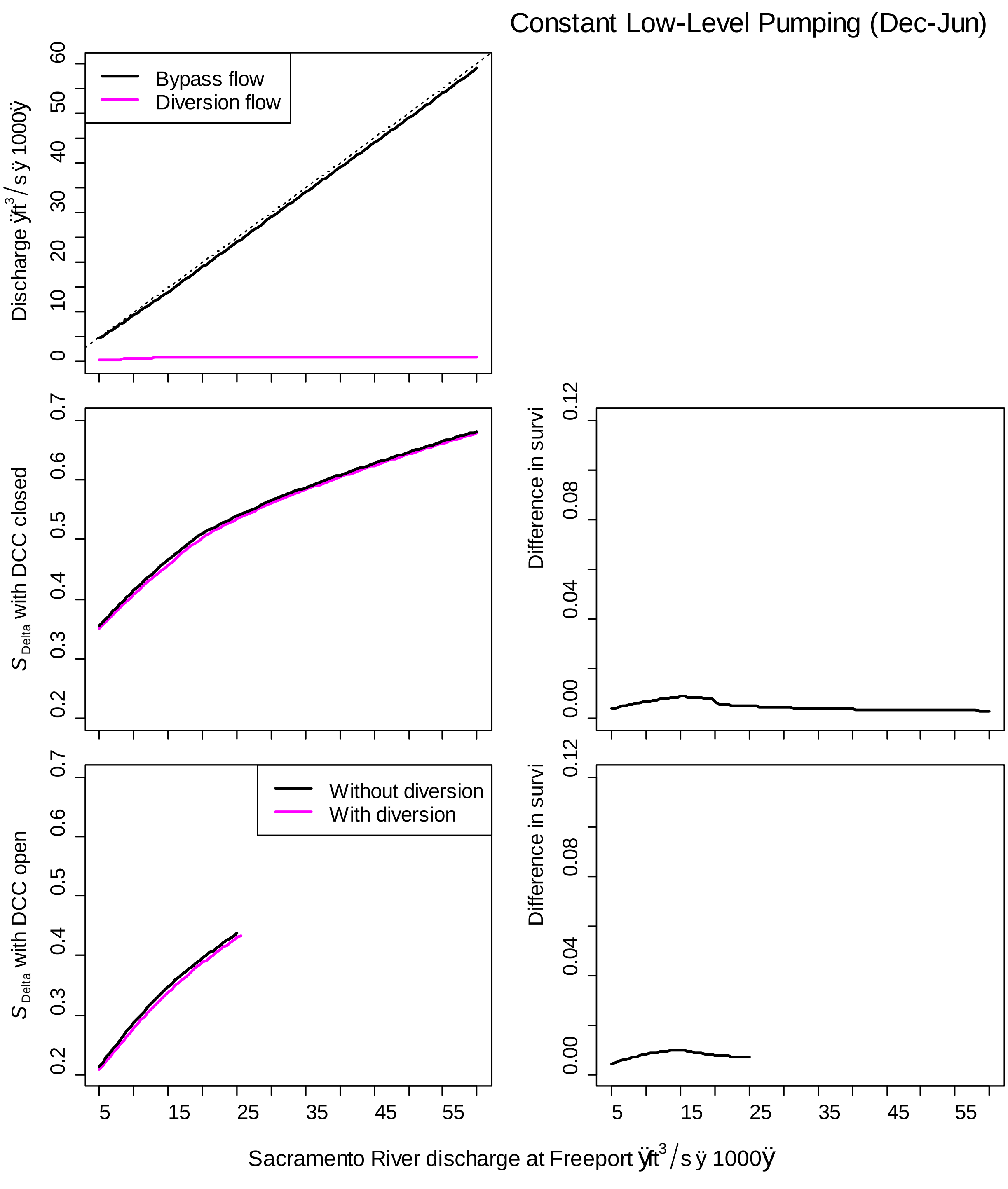


Figure 152. Effect of North Delta Diversion (NDD) on Bypass Discharge (top row), Delta Survival Probability with Delta Cross Channel (DCC) Closed (middle row), and Delta Survival with the DCC Open for Constant Low-level Pumping. (In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.)

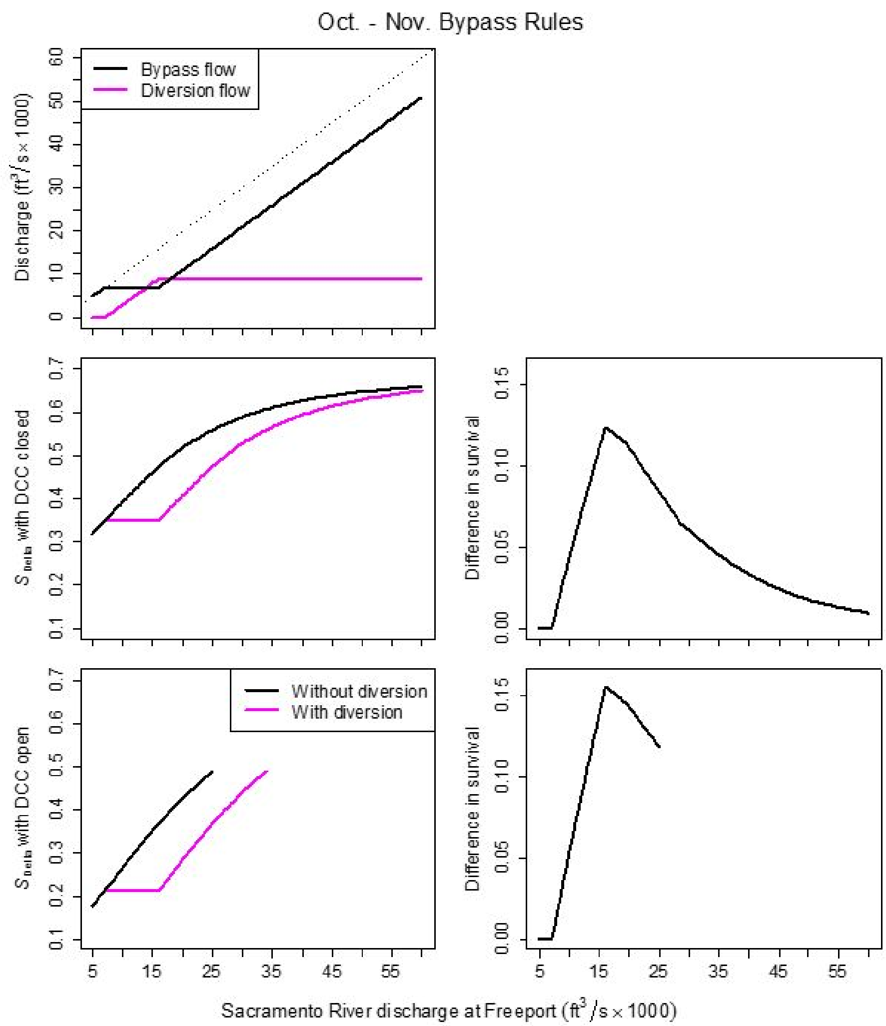


Figure 2-153. Effect of North Delta Diversion (NDD) on Bypass Discharge (top row) when Compared to the NAA, Delta Survival Probability with Delta Cross Channel (DCC) closed (middle row), and Delta Survival with the DCC open for October–November Bypass Rules. (In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.)

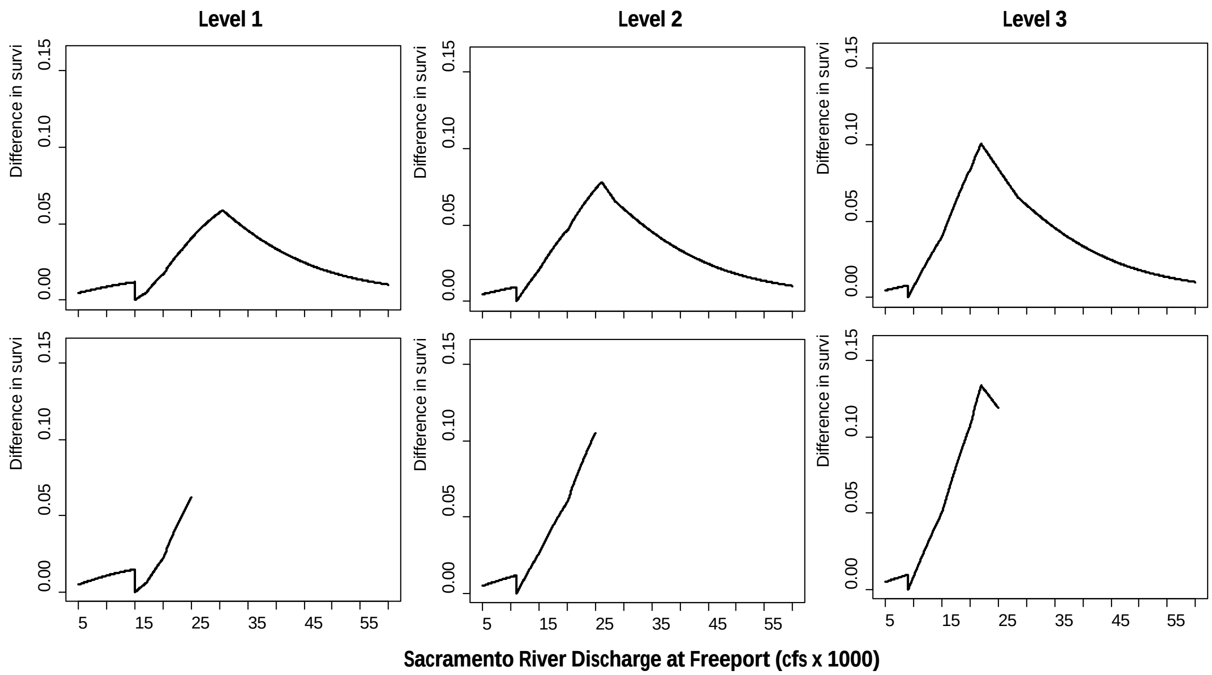


Figure 2-154. December–April effect of North Delta Diversion (NDD) on Delta Survival Probability when Compared to NAA with Delta Cross Channel (DCC) Closed (top row) and Delta Survival with the DCC Open (bottom row) for Levels 1–3 Post-pulse Operations for December through April.

The Perry Survival Model shows a pattern of reduced daily survival probabilities for smolts migrating through the Delta for each month of the salmonid migration period and across each water year type for PA operations (Figure 2-155). Furthermore, the boxplots in Figure 2-155 show that during at least 75 percent of the years (e.g., 75th percentile) survival is estimated to be reduced for PA operations for each month, from October through June, with the exception of April. Under the more protective L1 scenario, the survival probabilities remain reduced each month of the migration period with at least 75% of years estimated to have survival reductions, with the exception of April (Figure 2-155, middle panel). During April of both PA and L1 operations, survival is estimated to be the same or reduced for 75% of the years (Figure 2-155).

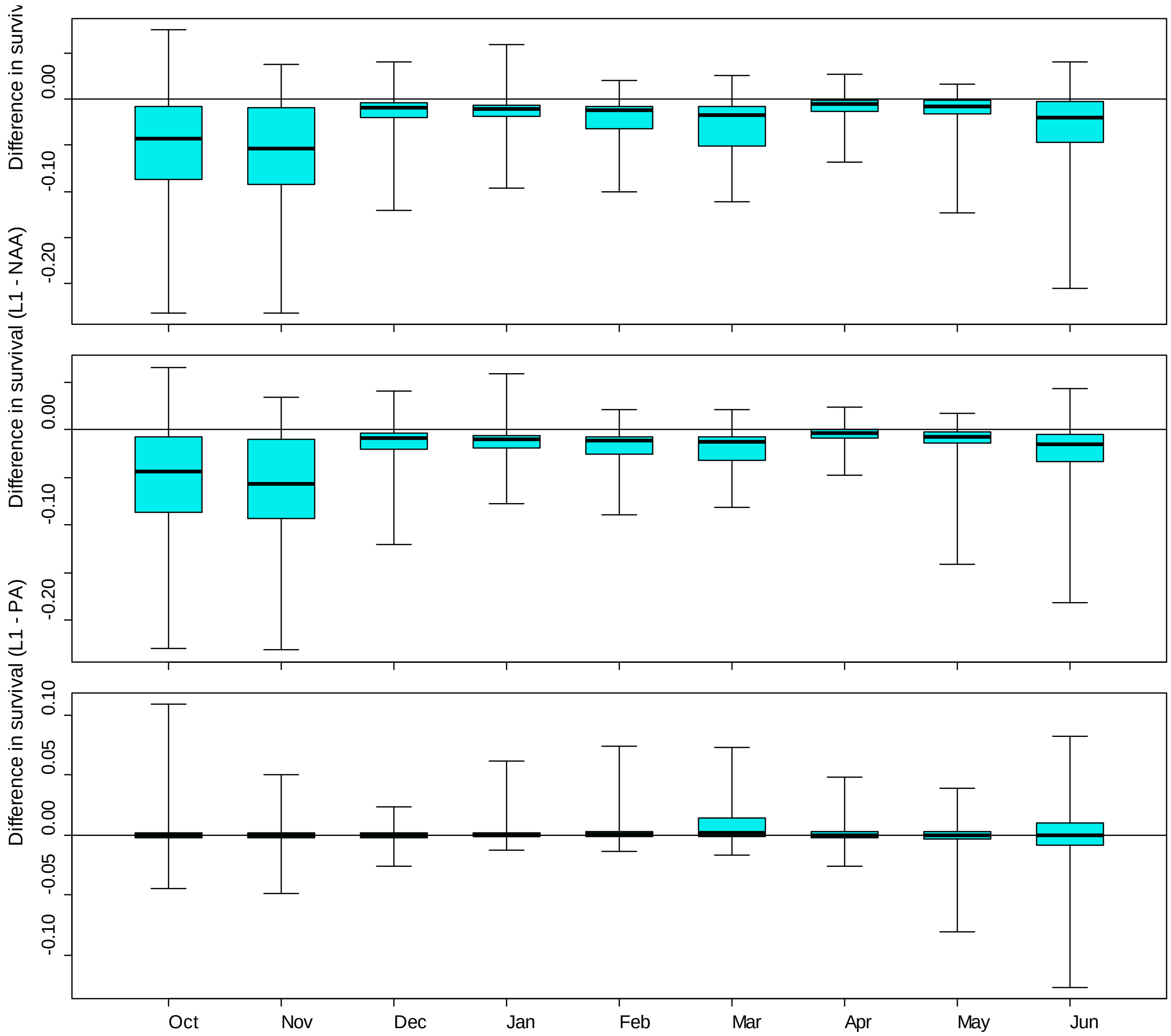


Figure 2-155. Boxplots of Differences in Through-Delta Survival between the NAA, PA, and Level 1 and Between the PA and Level 1.

Each box plot represents the distribution of daily survival differences among years for a given month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

Survival is reduced under operations of the either PA or L1 because reduced Sacramento River flow at Freeport results in lower survival rates for outmigrating smolts (Perry et al. 2010; Perry 2016; Newman 2003). Differences by month and water year type are summarized below for each species based on their unique migratory timing. Operational changes that could occur when following transition criteria that move from pulse protection to Level 3 throughout the migration season are discussed as well.

2.5.1.2.7.4.3.1 Differences in Survival by Month

The median reduction in survival under the PA is greatest in October and November when few juvenile salmon are expected to be in the Delta (Table 2-216). The primary reason survival is predicted to be greatly reduced in these two months is due to the fact that bypass rules are not intended to be protective unless winter-run Chinook are detected and real-time management criteria are triggered. If winter-run Chinook are detected, a pulse protection flow and/or May Level 1 operations criteria will be enacted. Therefore, survival reductions would likely not be as extreme as presented in the model as real-time protection cannot accurately be represented in this modeling effort that relies on CalSim results. Real-time pulse protections are evaluated with a modified approach to the Perry Survival Model analysis, which is presented in Section 2.5.1.2.7.4.1 The Revised PA Unlimited Pulse Protection Scenario of this Opinion. Late-fall run Chinook salmon and undetected winter-run would experience the full range of survival reductions shown here for October (4.3% median reduction) and November (5.4% median reduction) if a trigger is not enacted. Under most circumstances, monitoring a wild population can be difficult especially if current monitoring sites only capture a small proportion of the population on any given day. This would mean there is a high probability that a proportion of a target species will go undetected and therefore unprotected under real-time operations. Without detail on monitoring methods or statistical probability of capture, we must analyze the full range of potential survival impacts; however, NMFS evaluated the impacts to juvenile Chinook salmon survival under real-time pulse protections using an existing monitoring station trigger (see Section 2.5.1.2.7.4.1 The Revised PA Unlimited Pulse Protection Scenario.

Table 2-216. Absolute Percent Change in Survival over All Water Year Types.

Month (all water year types)	Median reduction in survival	Reduction in survival for middle 50% of years (interquartile)	Reduction in survival for 25% of years (minimum to first quartile)	Reduction (or increase) in survival for 25% of years (third quartile to maximum)
October	4.3	8.7 to 0.7	23.3 to 8.7	0.7 to (+7.6)
November	5.4	9.2 to 0.9	23.3 to 9.2	0.9 to (+3.8)

Survival is generally lower in these two months compared to December through May due to seasonally lower inflow at Freeport, negative velocities are more common and adverse routing is more likely to occur especially if the DCC gate is open. The biological effect of lowered and negative velocities is manifested in increased travel time for migrating smolts. October and November have the largest median change when comparing PA and L1 to NAA resulting in approximately 1.2 to 1.3 days longer travel time respectively (see Section 2.5.1.2.7.1 Travel Time).

When the DCC gate is open and velocities are low or negative near the Georgiana Slough junction, the probability of entrainment into the interior Delta is increased. This would tend to happen more during October and November (and sometimes in December and June) because the DCC gate may be open during these months and there is no criteria to avoid reverse flows caused by diversions during October and November unless a flow trigger is initiated.

The months of December through April, the month of May and the month of June all have bypass flow criteria as specified in Appendix A2. The values associated with the boxplots in Figure 2-155 are presented below (Table 2-217). Following the table is a brief synopsis of species presence by month and operational changes during these months.

Table 2-217. Absolute Percent Change in Survival over All Water Year Types.

Monthly survival reduction under PA or L1 compared to NAA	Median reduction in survival	Reduction in survival for middle 50% of years (interquartile)	Reduction in survival for 25% of years (minimum to first quartile)	Reduction (or increase) in survival for 25% of years (third quartile to maximum)
December (PA)	0.9	1.9 to 0.3	12 to 1.9	0.3 to (+4.0)
December (L1)	0.9	2.1 to 0.4	12 to 2.1	0.4 to (+4.1)
January (PA)	1.0	1.9 to 0.6	9.6 to 1.9	0.6 to (+6.0)
January (L1)	1.0	1.9 to 0.6	7.7 to 1.9	0.6 to (+5.9)
February (PA)	1.2	3.2 to 0.7	10.1 to 3.2	0.7 to (+2.1)
February (L1)	1.1	2.5 to 0.7	8.9 to 2.5	0.7 to (+2.1)
March (PA)	1.6	5.0 to 0.8	11.2 to 5.0	0.8 to (+2.6)
March (L1)	1.3	3.2 to 0.7	8.2 to 3.2	0.7 to (+2.1)
April (PA)	0.5	1.2 to 0.0	6.8 to 1.2	0.0 to (+2.7)
April (L1)	0.4	0.0 to 0.0	4.8 to 0.9	0.0 to (+2.4)
May (PA)	0.8	1.6 to 0.1	12.4 to 1.6	0.1 to (+1.7)
May (L1)	0.8	1.4 to 0.2	14.1 to 1.4	0.2 to (+1.7)
June (PA)	2.0	4.6 to 0.3	20.5 to 4.6	0.3 to (+4)
June (L1)	1.5	3.3 to 0.5	18.1 to 3.3	0.5 to (+4.3)

Based on the bypass rules, December is the first month when the NDD meets criteria to operate under the Level 1, 2, and 3 criteria of the PA. In December, the differences in survival between PA and NAA are more modest with median survival reduction under the PA of just under 1%. December will have more juvenile salmonid presence than October and usually more than November with the possibility of several runs being present in the Delta. Level 2 or Level 3 operations are rarely enacted during this month so the results between PA and L1 are very similar.

In January, median reduction in survival under the PA is at 1% with a range from a 9.6% reduction to a 6% increase in survival. Several species at different life-stages start to become common in the Delta during January. Level 1 operations is the common PA operating criteria during this month; therefore, there is little change between PA and L1 survival reductions as compared to NAA.

February median reduction in survival under the PA was 1.2% and ranged from a 10% reduction to a 2% increase in survival. It is possible for all four Chinook salmon runs, as well as steelhead, to be present in the Delta during February. February is the month when transition to Level 2 and 3 pumping occurs more frequently, especially in the wetter years when the criteria to move to the next level are met. Flows are seasonally high enough in February that survival differences between the pumping levels become immaterial, because when Freeport flows are at ~30,000 cfs, all levels are diverting the maximum amount of 9,000 cfs.

March is a key migratory month for many Chinook salmon and a peak month for winter-run Chinook salmon presence. The results in March show some of the larger juvenile survival reductions under the PA. In March, median reduction in survival under the PA is at 1.6% with a range from 11.2% reduction to a 2.6% increase in survival. It is very likely that all salmonids will be rearing or migrating in the Delta during March. L1 operations reduce the percentage of decrease in survival under the PA for the 25% of the years with the biggest increase in survival reductions under the PA.

April is another key migratory month when all Chinook species may be found in the Delta, and it is a peak month for spring-run Chinook salmon in the Delta. Median reduction in survival during April is 0.5% with a range from 6.8% reduction to a 2.7% increase in survival under the PA. April and May are protective because of a spring outflow criteria specifically defined for longfin smelt. Although Level 2 and 3 pumping could be enacted if bypass flow criteria are met, the spring outflow seems to control diversions to the extent that April inflows downstream of the NDD diversions are more similar to NAA than any other month. L1 offers modest improvement over PA operations particularly in the 25% of years that have the largest survival reduction.

Median and relative survival of out-migrating smolts is plotted under L1- only operations of the PA in comparison to the NAA. L1- only operations are displayed here because the PA limits diversions to Level 1 only if winter-run or spring-run Chinook are detected in the Delta after the pulse protection period has ended. So, in theory, many of the winter-run and spring-run smolts would be outmigrating or rearing in the Delta under Level 1 operations, which would impact their survival from reduced in-Delta flows. Some proportion of the winter-run and spring-run populations will likely go undetected in the monitoring effort, which means that those fish could exposed to Level 2 or 3 pumping while migrating through or rearing in the Delta.

The flow-survival analysis in Perry et al. (2017b) quantified the absolute change in survival as a function of diversion rates at a given Freeport discharge for a given bypass rule. Figure 2-156 is helpful in understanding how the amount diverted under L1 operations will affect survival at varying Freeport discharges. The absolute and relative survival differences under the L1 bypass rules for December through April are plotted in Figure 2-156. Understanding the relative impact on survival helps provide information needed to better assess how the population is impacted differentially depending on the base survival rate.

90% of the time survival impacts would be limited to the extent indicated by the orange line (Figure 2-156), which represents a way to address uncertainty in range of survival differences indicated by only assessing the mean or median change in survival between scenarios. The orange line indicates where the reduction in survival expected under the given Freeport discharge and diversion rate has less than a 10% chance of being exceeded.

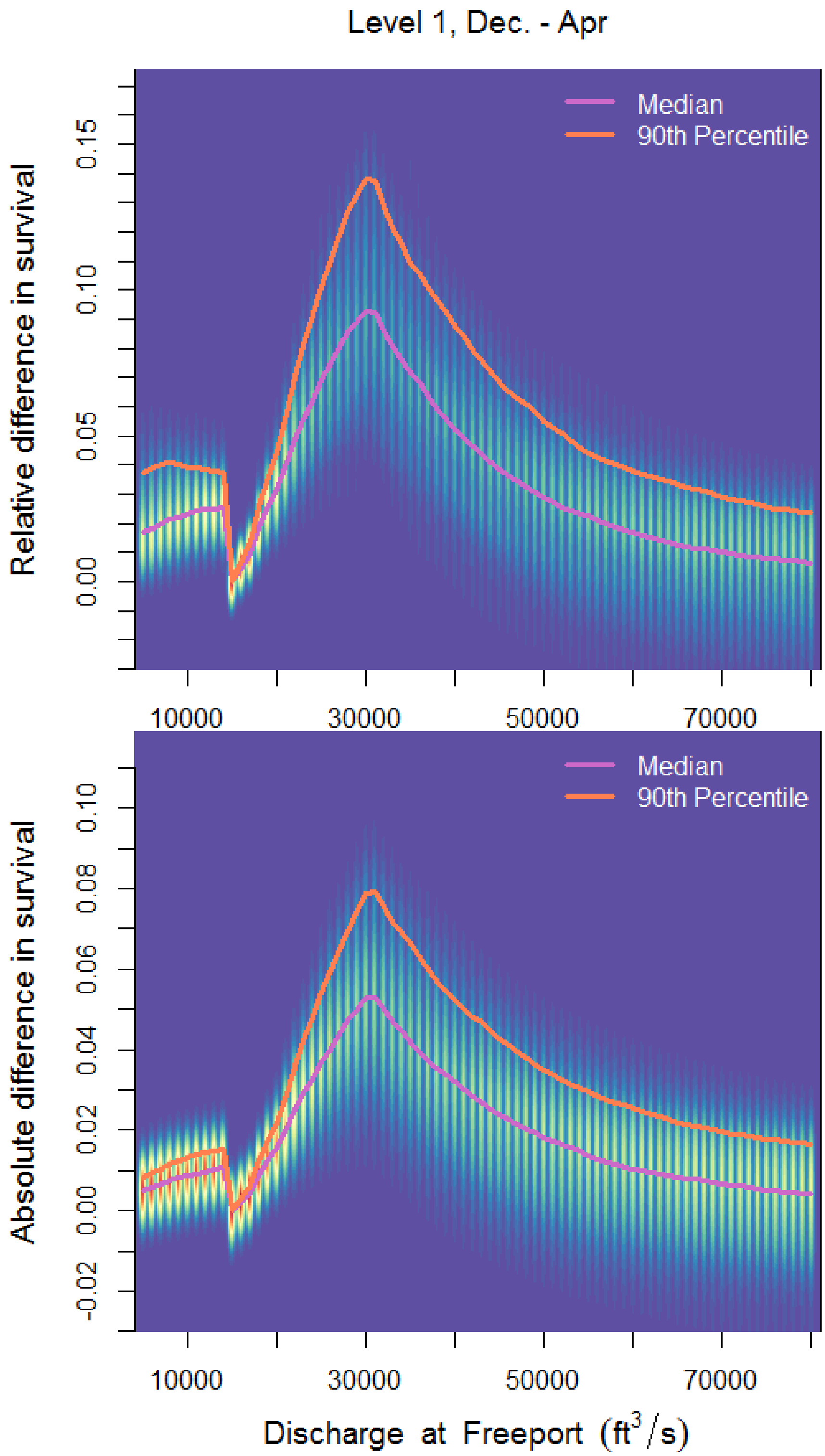


Figure 2-156. Median and 90 Percent Probability of Relative Survival Difference (top panel) and Absolute Survival Differences (bottom panel) under Operations of L1-only Compared to NAA.

All Chinook salmon species could be present in the Delta in May, but it is an important migratory month for at least two Chinook species, spring-run and fall-run. Median reduction in survival under the PA in May is at 0.8% with a range from 12.4% reduction to a 1.7% increase in survival. A separate set of bypass rules apply in May, which allow more diversions under lower flows than possible during December through April rules. This may be one reason why survival reductions are increased when compared to April even though May also benefits from the spring outflow criteria designated for longfin smelt. L1 offers modest improvements over PA operations during this month.

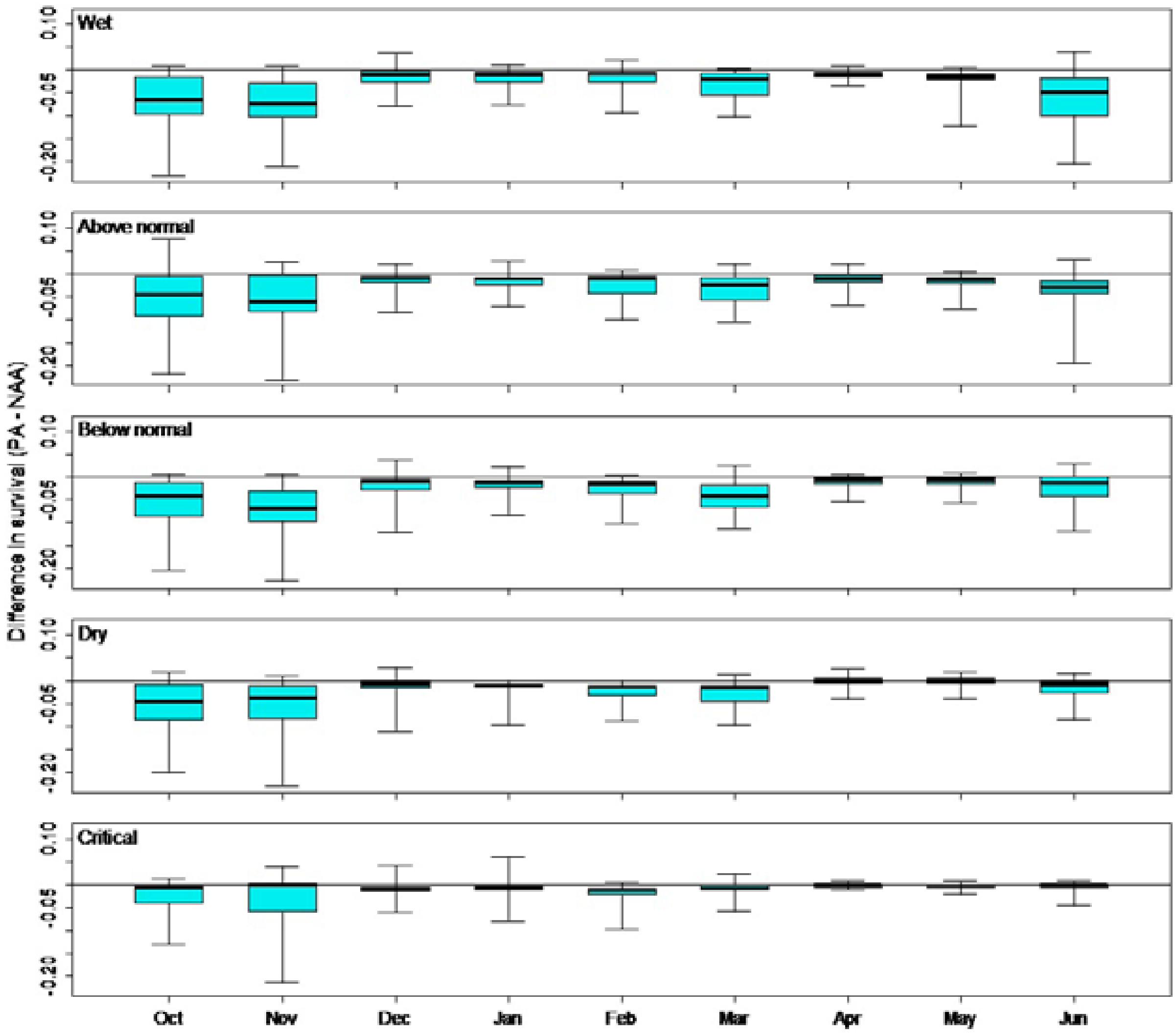
June is the last month in which the different flow levels apply under the NDD bypass rules for post-pulse bypass flow operations. June is operated under a separate set of bypass rules that allow more diversions at lower flows than May. Most Chinook species have exited the Delta by June though it may be possible that three species (spring-run, fall-run and late-fall run) are still present in lower abundance. The spring outflow criteria do not apply in June, and June is a month when Level 2 or 3 would be activated in most but the driest of water year types. Differences in survival are more pronounced in this month. Median reduction in survival under the PA is 2% with a range from 20% reduction to a 4% increase in survival. L1 offers moderate improvement over PA particularly in the 50% of years with the middle range of survival reductions.

For information on what the analysis above means in terms of individual species and their temporal presence during these months, please refer to the Exposure and Risk sections below.

2.5.1.2.7.4.3.2 Differences in Survival by Water Year Type

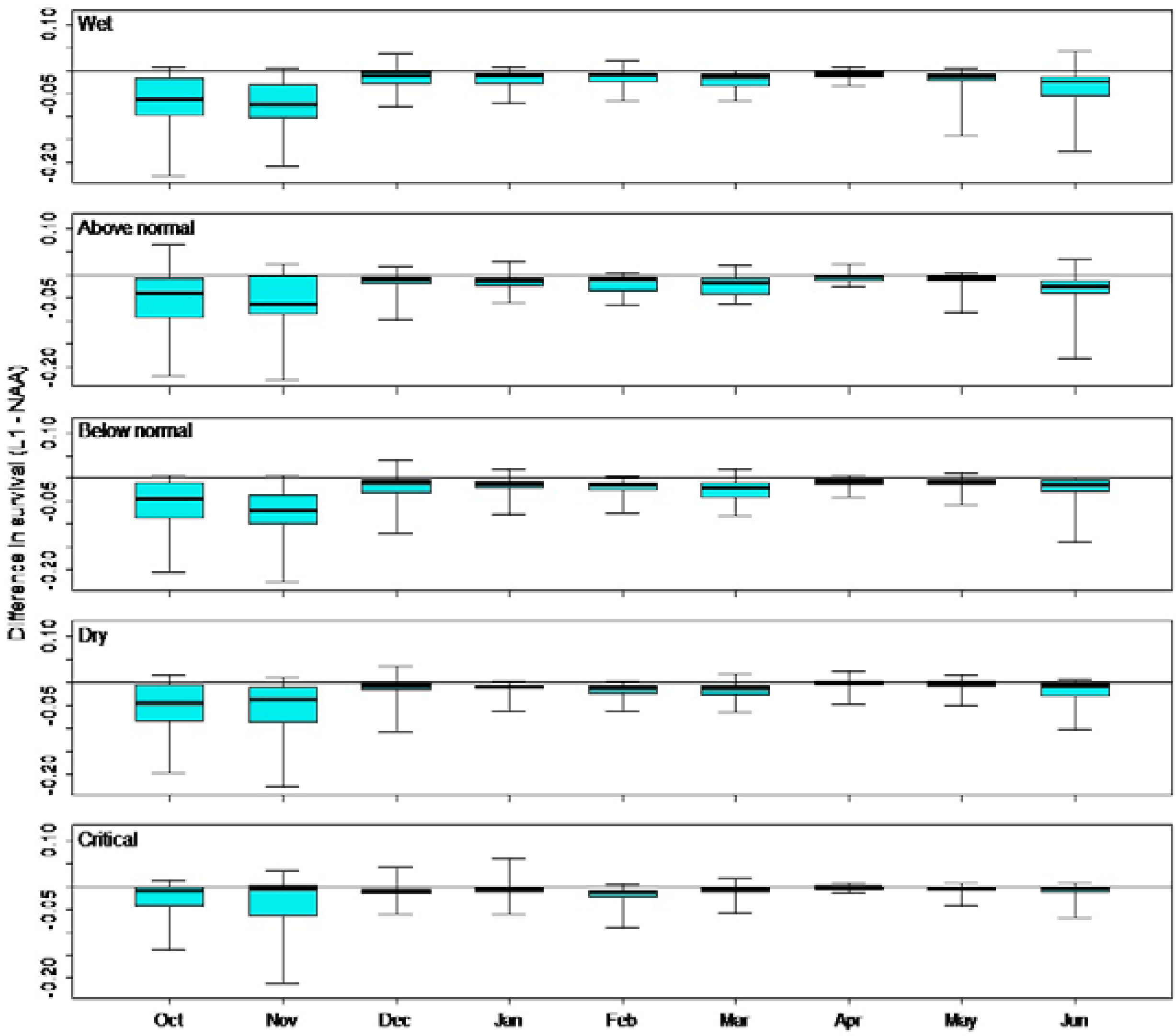
This section will summarize how effects of PA or L1 differ among water year types. Because the NDD diversions contain minimum bypass flows before diversions can occur, it is expected that in critical or dry year types exports may come predominantly from the south Delta facilities. Conversely, during the wetter water year types, exports may come predominantly from the north Delta facilities, so it is helpful to look at effects on species among the different water year types as effects will vary geographically based on operations.

The Perry Survival Model shows a pattern of reduced daily survival probabilities for smolts migrating through the Delta for each month of the salmonid migration period and across each water year type under the PA with the exception of April and May in dry water year types as displayed in Figure 2-157. The boxplots below show reduced survival under the PA during at least 75 percent of the years (e.g., 75th percentile) from October through June, except for April and May of dry water year types (Figure 2-157). Under the more protective Level 1 operations, the survival probabilities remain reduced for 75% of the years during each month of the migration period with the exception of April in dry years (Figure 2-158).



Note: Each box plot represents the distribution of daily survival differences among years of a given water-year type and month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

Figure 2-157. Boxplots of Differences in Through-Delta Survival Between the PA and NAA Scenario by Water Year Type.



Note: Each box plot represents the distribution of daily survival differences among years of a given water-year type and month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

Figure 2-158. Boxplots of Differences in Through-Delta Survival Between the L1 and NAA Scenario by Water Year Type.

The reduction in survival under the PA is greatest in wet water year types during October and November and the least reduction in survival is under critical years (Table 2-218). If listed species are detected during these months, they would be protected under the May Level 1 bypass rule. During October, survival reductions range from 0.7 in critical years to 6.6% in wet years and in November median survival reductions range from 0.2% in critical years to 7.4% in wet years. L1 survival results are not presented here for relative comparison to the PA results because L1 operations do not differ much from PA operations due to bypass rules remaining constant during these months unless there is a real-time management trigger to initiate Level 1 pumping.

Table 2-218. Absolute Percent Change in Survival under the PA Compared to NAA over all Water Year Types.

Month	Water Year Type	Median reduction in survival	Core population reduction (interquartile)	25% of population with biggest reduction	25% experiencing lowest reduction and/or (survival increase)
October	Wet	6.6	9.6 to 1.5	23.1 to 9.6	1.5 to (+1.0)
	AN	4.5	9.2 to 0.6	22 to 9.2	0.6 to (+7.6)
	BN	4.2	8.5 to 1.1	20.6 to 8.5	1.1 to (+0.6)
	Dry	4.4	8.5 to 0.7	20.1 to 8.5	0.7 to (+1.8)
	Critical	0.7	4.1 to 0	13 to 4.1	0 to (+1.2)
November	Wet	7.4	10.1 to 2.9	21 to 10.1	2.9 to (+0.8)
	AN	6.1	8.2 to 0.3	23.3 to 8.2	0.3 to (+2.5)
	BN	6.7	9.7 to 3.1	22.5 to 9.7	3.1 to (+0.7)
	Dry	3.6	8.1 to 1.0	23 to 8.1	1.0 to (+1.1)
	Critical	0.2	6 to (+0.3)	21.4 to 6.0	(+0.3 to +3.8)

For the key migratory months of December through June, the survival reduction tables are grouped by water year type instead of month (Tables 2-219 through 2-223). This allows a better representation of what out-migrating smolts would experience as they transit the Delta in any given water year type. The full range of differences for these months are displayed along with the months that have the largest and smallest reduction in survival under the PA. This allows for comparison between the months when the most and least concerning survival reductions are evident.

In wet water year types, the median reduction in survival during the December through June migration period is expected to be reduced between 0.8–4.9% under the PA (Table 2-219). For half of the wet years (i.e., the interquartile), survival is expected to be reduced by up to 10%. For 25% of the years, survival will be reduced by up to 20.5%. The remaining 25% of the years will range between a survival decrease of 1.9% to a survival increase up to 4% (Table 2-219). The two months that have the largest and the smallest survival reductions during wet years under the PA within the December to April operating rules are March and April, respectively (Table 2-219). Overall, under the PA, the largest survival reduction is expected for March and June (see Appendix G of this Opinion).

Table 2-219. Absolute Percent Change in Survival over all Months in *Wet* Water Year Types under the PA Compared to the NAA.

Month	Median reduction in survival in Wet years	Reduction in survival for middle 50% of Wet years (interquartile)	Reduction in survival for 25% of Wet years (minimum to first quartile)	Reduction (or increase) in survival for 25% of Wet years (third quartile to maximum)
December to June	4.9 to 0.8	10 to 0.3	20.5 to 1.5	1.9 to (+4)
March (largest survival reduction)	1.9	5.4 to 0.7	10.2 to 5.4	0.7 to (+0.3)
April (smallest survival reduction)	0.9	1.5 to 0.4	3.4 to 1.5	0.4 to (+0.8)

In above normal water year types, the median survival during the December through June migration period is expected to be reduced between 0.9 - 3% under the PA (Table 2-220). For half of the years (interquartile), survival is expected to be reduced by up to 5.9%, and for 25% of the years, survival will be reduced by up to 19.6%. The remaining 25% of the years is expected to have either a survival reduction of 1.7% or an increase in survival up to 3.1% (Table 2-220). December, January April, and May had less overall survival reduction in above normal water years then the months of February, March, and June (see Appendix G of this Opinion). The months that have the largest and the smallest survival reductions under the PA in above normal years within the December to April operating criteria are March and April, respectively (Table 2-220). Overall, under the PA, the largest survival reduction is expected for February, March, and June (see Appendix G of this Opinion).

Table 2-220. Absolute Percent Change in Survival over all Months in *Above Normal* Water Year Types under the PA Compared to the NAA.

Month	Median reduction in survival in AN years	Reduction in survival for middle 50% of AN years (interquartile)	Reduction in survival for 25% of AN years (minimum to first quartile)	Reduction (or increase) in survival for 25% of AN years (third quartile to maximum)
December to June (PA)	3 to 0.9	5.9 to 0.3	19.6 to 1.8	0.3 to (+3.1)
March (largest survival reduction)	2.3	5.9 to 0.9	10.5 to 5.9	0.9 to (+2.0)
April (smallest survival reduction)	1	1.8 to 0.3	6.8 to 1.8	0.3 to (+2.0)

In below normal water year types, the median survival during the December through June migration period is expected to be reduced between 0.7 - 4% under the PA (Table 2-221). For half of the years (interquartile), survival is expected to be reduced by up to 6.4%, and for 25% of the years, survival will be reduced by up to 12.1%. The remaining 25% of the years is expected to have either a survival decrease of up to 1.7% or a survival increase up to 3.8% (Table 2-221). April and May had less overall survival reduction in below normal water years than the other migratory months (see Appendix G of this Opinion). The months that have the largest and the smallest survival reductions under the PA during below normal years within the December to

April operating criteria are March and April, respectively (Table 2-221). Overall, under the PA, the largest survival reduction is expected for February, March, and June (Appendix C, D).

Table 2-221. Absolute Percent Change in Survival over all Months in *Below Normal* Water Year Types under the PA Compared to the NAA.

Month	Median reduction in survival in BN years	Reduction in survival for middle 50% of BN years (interquartile)	Reduction in survival for 25% of BN years (minimum to first quartile)	Reduction (or increase) in survival for 25% of BN years (third quartile to maximum)
December through June	4 to 0.7	6.4 to 0.1	12.1 to 1.4	1.7 to (+3.8)
March (largest survival reduction)	4.0	6.4 to 1.7	11.2 to 6.4	1.7 to (+2.6)
April (smallest survival reduction)	0.7	1.4 to 0.1	5.5 to 1.4	0.1 to (+0.8)

In dry water year types, the median survival during the December through June migration period is expected to be reduced by up to 1.6% under the PA with the exception of April and May when median survival is increased by 0.1% in April (Table 2-222) and equal in May. For half of the years (interquartile), survival is expected to be reduced by up to 4.6%, and for 25% of the years, survival will be reduced by up to 11%. The remaining 25% of the years is expected to either have a survival decrease up to 0.9% or a survival increase up to 3% (Table 2-222). The months that have the largest and the smallest survival reductions under the PA during dry years within the December to April operating criteria are March and April (Table 2-222), respectively. Overall, under the PA, the largest survival reduction is expected for February and March (see Appendix G of this Opinion).

Table 2-222. Absolute Percent Change in Survival over all Months in *Dry* Water Year Types under the PA Compared to the NAA.

Month	Median reduction in survival in Dry years	Reduction in survival for middle 50% of Dry years (interquartile)	Reduction in survival for 25% of Dry years (minimum to first quartile)	Reduction (or increase) in survival for 25% of Dry years (third quartile to maximum)
December to June	1.6 to (+0.1)	4.6 to (+0.5)	9.7 to 0.5	0.9 to (+3.0)
March (largest survival reduction)	1.6	4.6 to 0.9	9.7 to 4.6	0.9 to (+1.4)
April (smallest survival reduction)	0.1	0.5 to (+0.5)	3.9 to 0.5	(+0.5) to (+2.7)

In critical water year types, the median survival during the migration period is expected to be reduced by up to 1.2% during the months of December through June under the PA (Table 2-223). For half of the years (interquartile) during December through June, survival is expected to be reduced by up to 2.1%. For 25% of the years, survival will be reduced by up to 9.9% during December through June. The remaining 25% of the years is expected to have either a survival decrease of up to 0.9% or a survival increase up to 6% (Table 2-223). The months that have the largest and the smallest survival reductions under the PA during critical years within the December to April operating criteria are February and April (Table 2-223). Overall, under the

PA, the largest survival reduction is expected for January, February, and March (see Appendix G of this Opinion).

Median reductions in survival under the PA ranged around 1% during critical years. Diversions at the north Delta will be limited by the low inflow common in this water year type so inflows are similar between scenarios.

Table 2-223. Absolute Percent Change in Survival over all Months in *Critical* Water Year Types.

Monthly survival reduction in Critical years under PA compared to NAA	Median reduction in survival in Critical years	Reduction in survival for middle 50% of Critical years (interquartile)	Reduction in survival for 25% of Critical years (minimum to first quartile)	Reduction (or increase) in survival for 25% of Critical years (third quartile to maximum)
December to June	1.2 to 0.2	2.1 to 0	9.9 to 0.5	0.9 to (+6.0)
February (largest survival reduction)	1.2	2.1 to 0.9	9.9 to 2.1	0.9 to (+0.5)
April (smallest survival reduction)	0.2	0.5 to 0	1.2 to 0.5	0 to (+0.8)

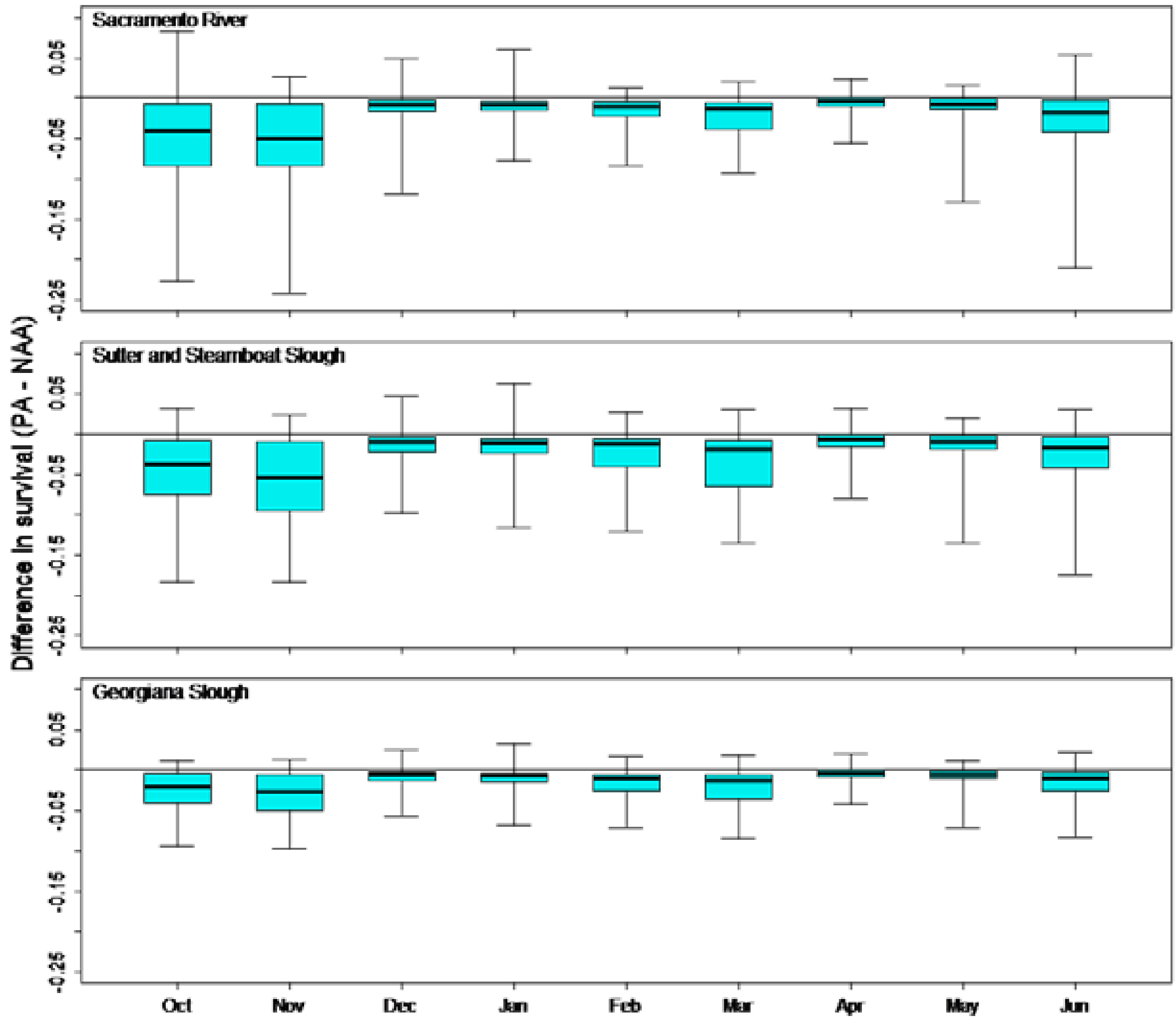
2.5.1.2.7.4.3.3 Differences in Survival by Route

There are four major migratory routes that fish can access from the north Delta to rear and migrate through: Sutter Slough, Steamboat Slough, Georgiana Slough and mainstem Sacramento River. All were examined individually in the Perry Survival Model. These four migratory routes comprise the overall through-Delta survival probability. Results for the distributaries Sutter and Steamboat Slough were combined together as these routes merge in the western Delta and funnel into the Cache Slough. Sutter and Steamboat Slough have monthly and yearly variation in survival and entrainment probabilities but, whether results are combined together or given separately, these two distributaries exhibit survival similar to the mainstem Sacramento migratory route. Therefore, they are considered high survival routes in comparison to the interior Delta routes of Georgiana Slough and the Delta Cross Channel (DCC). DCC was not included in this analysis as it is closed during most of the peak salmonid migratory activity.

Figure 2-159 shows daily boxplots of survival differences between the NAA and the PA for the mainstem Sacramento River, Sutter and Steamboat Slough, and Georgiana Slough. Overall results show that in the mainstem Sacramento River, survival probabilities are reduced under the PA for at least 75% of the years for all months with the exception of April when survival differences are lower and median survival is reduced by -0.04% (Figure 2-159, top panel).

In the Sutter and Steamboat Slough migratory routes, survival is reduced under the PA for at least 75% of the years for all months with the exception of April when the survival difference is lower than the other months and median survival is reduced by -0.06% (Figure 2-159, middle panel).

In Georgiana Slough, survival is reduced under the PA for at least 75% of the years for all months with the exception of May when the survival difference is lower than the other months and median survival is reduced by -0.04% (Figure 2-159, bottom panel).



Note: Each box plot represents the distribution of daily survival differences among years for a given month. The point in each box represents the median, the box hinges represent the 25th and 75th percentile, and the whiskers display the minimum and maximum.

Figure 2-159. Boxplots of Differences in Through-Delta Survival Between the NAA and PA Scenario for Chinook Salmon using Different Migration Routes through the Delta.

The results of the survival by migratory route show trends similar to the overall through Delta survival results. All migratory routes in the north Delta are anticipated to result in reduced survival for juvenile salmonids under the PA. This finding is significant and is different from the results shown in the other flow survival model, the Delta Passage Model (DPM) (Section 2.5.1.2.7.4.2, Delta Passage Model). The DPM results showed that smolts using the Georgiana Slough migratory route had higher survival under the PA. The likely reason for the different outcomes is the following: the Perry 2010 analysis modeled survival as a function of flow through a subset of the reaches used in the more recent (2017) analysis. In the 2010 analysis, there was no effect of flow on survival through the interior Delta from the confluence of the Mokelumne and San Joaquin Rivers to Chipps Island (Appendix G Reach 8, Figure 1). The Perry Survival Model also showed no flow effect in Reach 8, so these findings are consistent between models. However, the Perry Survival Model analysis also included the reach from the entrance of Georgiana Slough to the confluence of the Mokelumne and San Joaquin Rivers (Appendix G

Reach 5, Figure 1 summary methods), which was not included in the 2010 analysis. It is in Reach 5 where a strong flow relationship exists (Appendix G Figure 3), driving the flow-survival relationship for fish that enter Georgiana Slough (Appendix G Figure 4, bottom panel). Additionally, the DPM uses the export dependent relationship (Newman and Brandes 2010) as part of the model structure. This would influence survival on smolts entering the interior Delta from the Georgiana Slough. Since south Delta exports are generally lower under the PA, this would be a beneficial effect by reducing entrainment into the south Delta facilities and increasing probability of migratory success within this reach.

NMFS considers the Perry Survival Model (Perry 2016) as the best scientific and commercial data available to assess survival through the Delta for Sacramento basin smolts because it incorporates the most recent Chinook salmon CWT release and migration tracking data and most accurately represents the flow routing dynamics at in the north Delta at Georgiana Slough. NMFS considers the benefits of reduced south Delta operations and the inclusion of a HOR gate under the PA with several other methods and also evaluates the overall impacts to survival from south Delta operations (see Section 2.5.2.1.2.7.3 South Delta Operations). Therefore, the finding that the migratory route of Georgiana Slough also has a flow survival relationship will help guide the effects analysis on how flow changes between scenarios affect survival in this route and overall through Delta survival.

Additionally, NMFS uses life cycle models that consider the system in a more holistic way by considering effects on all life-stages and in key geographic areas including the north and south Delta along with the operational differences under the PA and NAA scenarios (Section 2.5.1.2.7.5 Life Cycle Modeling).

2.5.1.2.7.4.3.4 Winter-run Exposure and Risk

The Perry Survival Model comprehensively looks at factors that affect survival, such as travel time and migratory route taken, to evaluate how changes in Delta inflow will affect smolt migratory success between the scenarios. Since results are segregated by month and then further by water year type, we can thoroughly examine the exposure and risk associated with these changes for winter-run Chinook salmon smolts.

The main migratory period for winter-run Chinook salmon juveniles is November through April. Within this migratory window, November has the least protection and the largest survival reductions due to static bypass rules that leave a minimum flow in river unless real-time management operations are triggered. The remaining months fall under the December through April NDD bypass operations when the largest survival reductions are expected to occur in March and the lowest survival reductions under the PA would occur in April.

Winter-run Chinook salmon primarily enter the Delta during November and December at mean sizes of 63 mm and 75 mm, respectively. Although peak entrance into the Delta for juveniles is November and December, outmigration activity observed at Chipps Island during those months' averages less than 1% of the population sampled. Winter-run Chinook salmon can spend months in freshwater before out-migrating en masse. On average, 66% of the annual population exits Chipps Island during the month of March at a mean size of 111 mm. The long-term monitoring data reveals that winter-run Chinook salmon spend considerable time growing and rearing in and upstream of the Delta based on average timing and size patterns of entrance and exit from the Delta.

To best apply the Perry Survival Model to winter-run, we restrict the survival differences between scenarios to smolt-sized fish over 70 mm. The entrainment and flow survival models (Perry et al. 2016, Perry 2016) are based on acoustic tag data of smolt-sized fish exhibiting migratory behavior. This results in the core migratory window for winter-run Chinook salmon smolts being December through April. Although November is an important migratory month especially in wetter years, winter-run Chinook salmon tend to be under 70 mm and will most likely rear and remain in the Delta for several weeks or months. PA operations have been developed to manage diversions in a more protective manner should winter-run sized fish be detected in October and November by operating under pulse flow protections or Level 1. Changes in hydrology (flow timing and quantity) under the PA that will be experienced by the smaller juveniles as well and implications for rearing habitat and shelter are evaluated in Section 2.5.2 Effects to Critical Habitat, Section 2.5.1.2.7.4.3.7.3 Chinook salmon fry-life-stage survival and Section 2.5.1.2.8 Reduced Delta Outflows below.

Migratory patterns for winter-run Chinook salmon into the Delta have been found to be hydrology driven and influenced by upstream flow pulses (del Rosario et al. 2013). We use water year type characterization to help understand in which months during drier or wetter year types there will be increased exposure and risk of winter-run Chinook to diversion effects of the PA in the north Delta. Since migration stimulus for winter-run juveniles is a flow pulse that can potentially happen in any water year type, the water year characterizations are just an approximation of what is likely to occur in wetter versus drier year type hydrology.

During wetter year hydrology (wet and above normal water year types), winter-run Chinook salmon smolts will begin entering the Delta in November and will experience the largest survival reductions during this month unless real-time operations (RTO) diversion restrictions are applied. This is expected to affect 5% of the smolt population during these year types. If RTO are enacted, the survival reductions for approximately 5% of the population will likely range from a 0.3 to 10.1% reduction in over 75% of years. For the remaining 25% of years there could be a survival reduction of 0.9% to an increase in survival under the PA of 2.5% (Table 2-224). If winter-run go undetected, the full range of survival reduction under the PA of 23% could be experienced (Table 2-224).

During December, approximately 25% of winter run Chinook salmon smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years. Survival reductions under the PA for 75% of the years range from 0.2 to 8.5%. For the remaining 25% of years there would be a survival reduction of 0.05 to 3.8% increase in survival under the PA (Table 2-224).

In January, approximately 9% of winter run Chinook salmon smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years. Survival reductions under the PA for 75% of the years range from 0.5 to 7.7%. For the remaining 25% of years there would be a survival reduction of 0.07% to 2.9% increase in survival under the PA (Table 2-224).

In February, approximately 22% of winter run Chinook salmon smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years. Survival reductions under the PA for 75% of the years range from 0.5 to 10%. For the remaining 25% of years there would be a survival reduction of 0.06 to 2.1% increase in survival under the PA (Table 2-224).

In March, approximately 30% of winter run Chinook salmon smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years. Survival reductions under the PA for 75% of the years range from 0.7 to 10.5%. For the remaining 25% of years there would be a survival reduction of 0.9 to 2.0% increase in survival under the PA (Table 2-224).

In April, approximately 9% of winter run Chinook salmon smolts could be exposed to reduced survival due to reduced flows in migratory corridors in wetter years. Survival reductions under the PA for 75% of the years range from 0.3 to 6.8%. For the remaining 25% of years there would be a survival reduction of 0.4 to 2.0% increase in survival under the PA (Table 2-224).

Overall results show that March, which has the largest smolt (>70 mm) entrance into the Delta in wetter years, coincides with when operations of the PA would cause the largest survival reductions. During wetter year hydrology, the risk of exposure is spread out over 6 months (November through April) which is in contrast to the exposure risk during drier year hydrology when the Delta migratory window is shortened to 3 or 4 months (January through April).

Table 2-224. Summary of Adverse Effects on Survival of Winter-run Chinook Salmon Expected under the PA Due to Reduced In-Delta Flow by Month and Water Year Types.

Wetter year hydrology (Wet and AN)	Proportion of population exposed	Survival reduction for 75% of years	Survival reduction or increase for 25% of years	Adverse effect on Winter run smolts from reduced in-Delta Flows
November	5%	23% to 0.3%	0.9% to (+2.5%)	Medium
December	25%	8.5% to 0.2%	0.05% to (+3.8%)	High
January	9%	7.7% to 0.5%	0.07 to (+2.9%)	Medium
February	22%	10% to 0.5%	0.06% to (+2.1%)	High
March	30%	10.5% to 0.7%	0.9% to (+2%)	High
April	9%	6.8% to 0.3%	0.4% (+2%)	Medium

Note:

Includes full range of survival probabilities without real-time operations that might be implemented if winter-run are detected and protective flow pulses are enacted.

In drier year hydrology (below normal, dry, and critical), winter-run Chinook salmon enter the Delta after December and primarily in February.

During January, approximately 18% of winter-run Chinook salmon could be exposed to reduced survival due to reduced flows in migratory corridors in drier years. Survival reductions under the PA for 75% of the years range from 0.4 to 9.6%. For the remaining 25% of years there would be a survival reduction of 0.4 to 6.0% increase in survival under the PA (Table 2-225).

In February, approximately 50% of winter-run Chinook salmon could be exposed to reduced survival due to reduced flows in migratory corridors in drier years. Survival reductions under the PA for 75% of the years range from 0.9 to 10.1%. For the remaining 25% of years there would be a survival reduction of 0.4 to a 0.5% increase in survival under the PA (Table 2-225).

In March, approximately 30% of winter run Chinook salmon could be exposed to reduced survival due to reduced flows in migratory corridors in drier years. Survival reductions under the PA for 75% of the years range from 0.2 to 11.2%. For the remaining 25% of years there would be a survival reduction of 1.7 to a 2.2% increase in survival under the PA (Table 2-225).

In April, approximately 2% of winter run Chinook salmon could be exposed to reduced survival due to reduced flows in migratory corridors in drier years. Survival is quite similar under the scenarios for critical and dry water years ranging from a 3.9% reduction in survival to a 2.7% increase in survival under the PA. In below normal years, 75% of the time there would be a survival reduction from 0.1 to 5.5% under the PA and survival in the remaining 25% of years would be similar ranging from 0.1% reduction to 0.8% increase under the PA (Table 2-225).

Table 2-225. Summary of Adverse Effects on Survival of Winter-run Chinook Salmon Expected under the PA by Month for Below Normal (BN), Dry, and Critical Water Year Types.

Drier year hydrology (BN, Dry, Critical)	Proportion of population exposed	Survival reduction for 75% of years	Survival reduction or increase for 25% of years	Adverse effect on Winter run smolts from reduced in-Delta flows
November	<1%	23% to 0.3%	0.9% to (+2.5%)	Insignificant/None
December	<1%	8.5% to 0.2%	0.05% to (+3.8%)	Insignificant/None
January	18%	7.7% to 0.5%	.0.07 to (+2.9%)	High
February	50%	10% to 0.5%	0.06% to (+2.1%)	High
March	30%	10.5% to 0.7%	0.9% to (+2%)	High
April	2%	6.8% to 0.3%	0.4% (+2%)	Low

Overall, the winter run Chinook salmon smolt (>70 mm) population is concentrated in the Delta in February and March (approximately 80%) and the largest survival reductions under the PA occur during these months in drier water years.

This analysis indicates that the PA increases mortality consistently (over 75% of the time) for winter-run Chinook salmon over the NAA scenario. Additionally, the extent of the survival reduction experienced during 75% of the time is larger (sometimes reaching 11%) during the core migratory months of December to April than the less common survival increases the PA occasionally has (sometimes reaching 6%). The NDD bypass operations of the PA result in an adverse effect from reduced Delta flows on the majority of outmigrating winter run Chinook salmon smolts. Although effects of the diversions vary from month to month and over water year types, the results show that the biggest reductions in survival under the PA occur when the majority of winter run Chinook salmon smolts are migrating through the Delta.

2.5.1.2.7.4.3.5 Spring-run Exposure and Risk

The main migratory window for spring run Chinook salmon encompasses December through May. The majority of spring run Chinook salmon (>60%) primarily enter and exit the Delta during the month of April and are smolt sized (>70 mm). Therefore, the month when changes in Delta flows may have the most influence is during the month of April. Approximately 16% of the population will enter as fry-sized fish during the months of December through February with average fork length ranging from 38 to 59 mm and would likely rear in the Delta until reaching smolt size. The remaining population tends to enter and exit the Delta as smolt sized fish during the months of March and May. Therefore, there is considerable diversity in life-stage and behavior for spring-run despite the vast majority migrating through the Delta in April. As with any listed species, life history diversity and protection of early and late migrants are important aspects of management and recovery.

To best apply the Perry Survival Model to winter-run, we restrict the survival differences between scenarios to smolt sized fish over 70 mm; this same approach is used here to apply the modeling to spring-run Chinook salmon. As explained earlier, the Perry Survival Model is best applied to migrating smolt sized fish (>70 mm). We therefore look at changes in survival between scenarios for the months of March through May because that is the primary migration period for spring-run Chinook salmon smolts. The effects of the PA's changes in hydrology (flow timing and quantity) on smaller juveniles (<70 mm) and the implications for rearing habitat and shelter are analyzed in Section and Section 2.5.1 Critical Habitat.

During March, approximately 20% of spring-run Chinook salmon smolts could be exposed to reduced survival due to reduced flows in migratory corridors. Survival reductions under the PA for 75% of the years range from 0.8 to 11.2%. For the remaining 25% of years there would be a survival reduction of 0.8 to 2.6% increase in survival under the PA.

In April, approximately 67% of spring-run Chinook salmon smolts could be exposed to reduced survival due to reduced flows in migratory corridors. Survival reductions under the PA for 75% of the years range from 0.0 to 6.8%. For the remaining 25% of years there would be a survival reduction of 0.0 to 2.7% increase in survival under the PA.

In May, approximately 13% of the spring-run Chinook salmon smolts could be exposed to reduced survival due to reduced flows in migratory corridors. Survival reductions under the PA for 75% of the years range from 0.1 to 12.4%. For the remaining 25% of years there would be a survival reduction of 0.1 to 1.7% increase in survival under the PA.

The PA would have an adverse effect to smolt survival during at least 75% of the years during the spring run smolt migratory period. During April, when most of spring-run would be out-migrating, the PA has the least effect on survival. The 0.0 to 6.8% decrease in survival for 75% of years is partially mitigated by the 0.0 to 2.7% increase in survival for 25% of the years. However, the survival reductions in the months of March and May are larger (up to 12.4%) and affect a larger proportion of the years (>75%) than the reductions in April.

This analysis indicates that the PA increases mortality consistently (usually over 75% of the time) over the NAA scenario. Additionally, the extent of the survival reduction experienced under the PA during 75% of the time is larger (sometimes reaching 12%) than the less common survival increases the PA occasionally has (<25% of the time) that improve survival by 2.7%. The reduced in-Delta flows caused by the NDD bypass operations of the PA result in an adverse effect of reduced survival on the majority of outmigrating spring-run Chinook salmon smolts. Although effects of the diversions vary from month to month and over water year types, the results show that the smallest reductions in survival under the PA does occur when the majority of spring-run Chinook salmon smolts are migrating through the Delta in April and the larger survival impacts found under the PA occur during the month of March.

2.5.1.2.7.4.3.6 Green Sturgeon Exposure and Risk

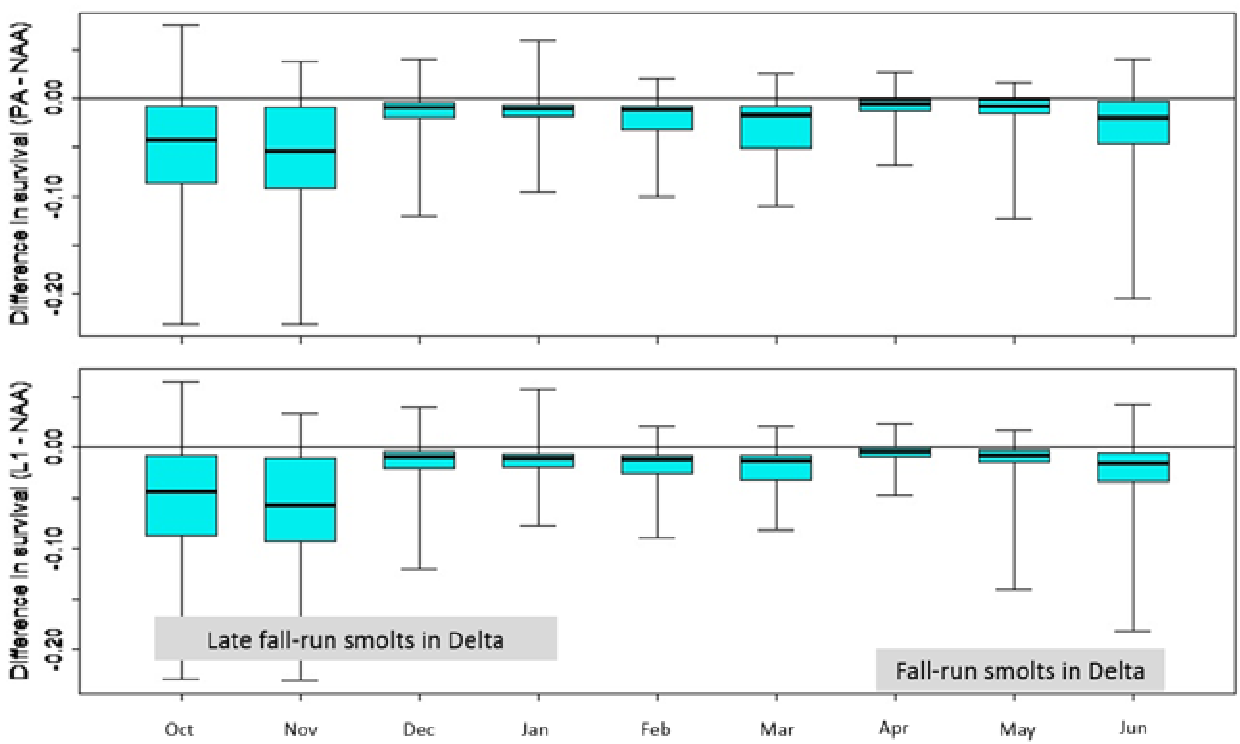
This modeling does not apply to green sturgeon.

2.5.1.2.7.4.3.7 Fall-run and Late-fall run Exposure and Risk

Details of the Perry Survival Model analysis are described in the through-Delta survival section on winter-run Chinook salmon (see Section 2.5.1.2.7.4.3 Perry 2017 Flow-Survival Model). Here we focus on differences in through-Delta survival of Sacramento River juvenile fall- and late fall-run Chinook salmon smolts between the PA and NAA and between Level 1 and the NAA. The PA scenario contains diversions at all three levels, whereas the Level 1 scenario restricts diversions to no greater than Level 1 during December to June, which is more protective than what is modeled under the PA scenario. The Level 1 scenario is evaluated to provide context for the range of effects that may be experienced by migrating salmonids given that the PA states that post-pulse bypass flow operations will remain at Level 1 pumping while juvenile salmonids are migrating through and rearing in the north Delta.

2.5.1.2.7.4.3.7.1 Fall-run Chinook Salmon

For all months of fall-run Chinook salmon smolt occurrence in the Delta analyzed with the Perry Survival Model, survival under the PA is generally lower than the NAA for 75% of the years and higher for 25% of the years (Figure 2-160, upper plot). During the period of peak fall-run smolt occurrence in the Delta (i.e., April through June), median survival is reduced under the PA relative to the NAA, ranging from a 0.5% reduction in April to a 2.0% reduction in June (Figure 2-160). Survival during that time frame is expected to range from as much as 12.4% lower (May) up to 2.7% higher (April) under the PA, relative to the NAA.



Note: Grey boxes indicate months that fall- and late fall-run Chinook salmon juveniles occur in the Delta.

Figure 2-160. Boxplots of Differences in Through-Delta Survival Between the NAA, PA, and Level 1 based on Perry Survival Model (2017).

For all months of fall-run Chinook salmon smolt occurrence in the Delta analyzed with the Perry Survival Model, survival under the Level 1 relative to the NAA generally matches the results just described for PA versus NAA, with roughly 75% of the years having lower survival under Level 1 relative to the NAA and higher survival for 25% of the years (Figure 2-160, lower plot). During the period of peak fall-run smolt occurrence in the Delta (i.e., April through June), median survival is reduced under Level 1 relative to the NAA, ranging from a 0.4% reduction in April to a 1.5% reduction in June (Figure 2-160). During that time frame survival is expected to range from as much as 14.1% lower (May) up to 2.4% higher (April) under the PA, relative to the NAA.

These results indicate an adverse effect from an overall reduction in through-Delta survival for Sacramento River juvenile fall-run Chinook salmon under both the PA and Level 1 scenarios, relative to the NAA.

2.5.1.2.7.4.3.7.2 Late Fall-run Chinook Salmon

For all months of juvenile late fall-run Chinook salmon occurrence in the Delta analyzed with the Perry Survival Model (i.e., October through January), survival under the PA is generally lower than the NAA for 75% of the years and higher for 25% of the years (Figure 2-160, upper plot). Over the October through January time frame, median survival is reduced under the PA relative to the NAA, ranging from a 0.9% reduction in December to a 5.4% reduction in November (Table 2-216). During the month of peak late fall-run occurrence in the Delta (December), survival is expected to range from as much as 12.0% lower up to 4.0% higher under the PA, relative to the NAA.

Over all months analyzed with the Perry Survival Model, the reduction in survival under the PA is greatest in October and November largely because the bypass rules are not implemented unless winter-run Chinook salmon are detected and real-time management criteria are triggered. If winter-run Chinook salmon are detected, a pulse protection flow and/or May Level 1 operations criteria will be enacted. Late fall-run Chinook salmon would experience the full range of survival reductions shown under the PA if a trigger is not enacted.

These results indicate an adverse effect from overall reduction in through-Delta survival for Sacramento River juvenile late fall-run Chinook salmon under the PA, relative to the NAA.

2.5.1.2.7.4.3.7.3 Chinook salmon fry life stage survival

In recent years, telemetry studies of smolt movement through the Delta have revealed how flow influences migration rate (travel time), migratory routes used and overall survival (Perry 2010, Perry et al. 2012, Michel et al. 2013). These telemetry studies greatly increase our scientific understanding of migratory success or failure of smolts in the San Joaquin-Sacramento Delta and we have emphasized these finding throughout this Opinion. These studies have been limited to larger smolt sized fish due to lack of technology to apply acoustic tags to smaller sized fish. This results in a continuing data gap on understanding movement and survival of individual fry sized fish or smaller smolts. Previous CWT studies help inform what we understand about general survival and movement trends of smaller juveniles. Newman (2008) found that for fish released in Georgiana Slough and subject to the interior Delta, survival was only 35% to 44% of that experienced by fish remaining in the main stem Sacramento River. Newman (2008) also found a flow-survival relationship for the fish released in the multiple year CWT studies. This flow-survival relationship has been corroborated by the findings of the telemetry studies that were done on larger fish. The mean fork length for the telemetry studies was 156 mm which is beyond the expected mean size for winter-run or spring-run in the Delta. However, the CWT studies used fish with a mean fork length of 81 mm (61 mm to 96 mm) which would encompass the size of winter-run, spring-run and fall-run Chinook salmon smolts that transit the Delta. What was also revealed through the CWT and telemetry studies is that fork length affects survival rates with larger fish surviving better (Figure 2-161). Figure 2-161 shows the similar flow-survival relationships between the telemetry and CWT studies and how the mean fork length affected overall probability of survival. This is revealing for the fate of smaller smolts and fry-sized fish that depend on the Delta. Although the findings from the two methods corroborate each other on flow and size influenced survival rates, the findings do not account for the variable of wild versus hatchery fish survival. Nevertheless, the wild fish are still subject to the same stressors that the hatchery fish experience when in the Delta but at a generally smaller size than the acoustically tagged fish. If the wild fish are at a generally smaller size than hatchery fish used in the survival studies and Figure 2-161 shows a relationship between the two groups of fish, then survival probabilities for all actively migrating chinook juveniles would likely fall within the range of the CWT and telemetry studies conducted.

Since fry-sized fish or physiologically immature smolts need to use the Delta and estuary as rearing grounds, they will spend more time under the influence of water operations and the accompanying infrastructure of the CWF. We cannot directly apply the telemetry studies to survival rates of juveniles not actively outmigrating, but we can make assumptions about rearing fry on the importance of flow and its influence on route entrainment, predator evasion, and habitat quality (see Section 2.5.1.2.7.4.3 Perry 2017 Flow-Survival Model).

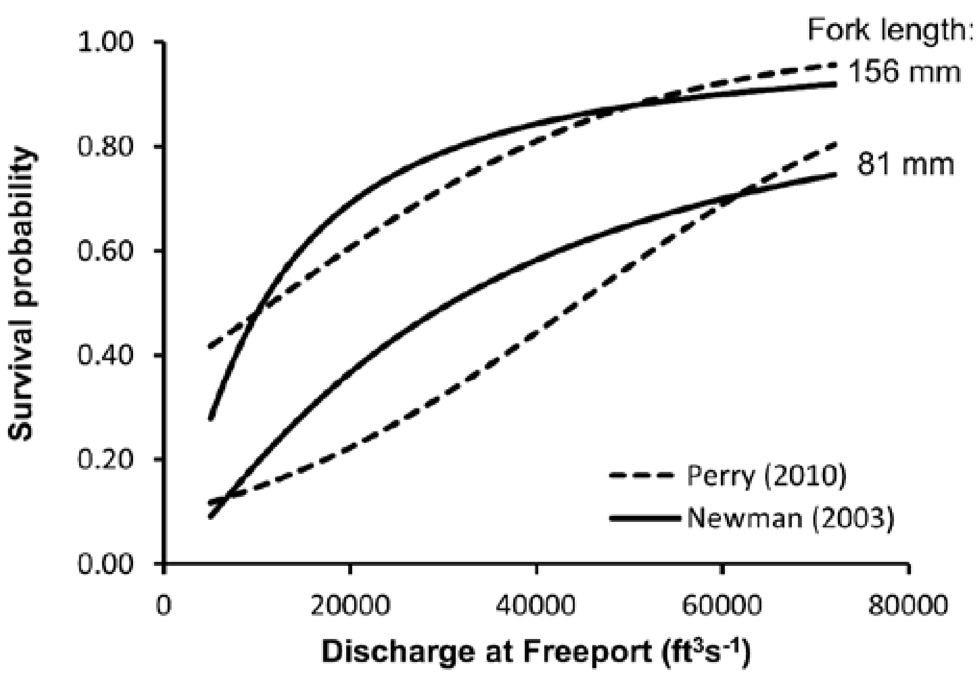


Figure 2-161. Comparison of Survival Probabilities Between Fry-sized versus Smolt-sized Chinook Salmon Relative to Flow Discharge at Freeport (Sacramento River) from Perry 2010 and Newman 2003.

2.5.1.2.7.4.4 The Revised PA Unlimited Pulse Protection Scenario (UPP)

As described in Section 2.5.1.2.7.4.1, the Proposed Action was revised in June 2017 to include changes to the north Delta diversion operations, referred to here as the Unlimited Pulse Protection scenario (UPP). The UPP relies on real-time detection of salmonids to inform adjustments to the north Delta diversion, which include operations at low-level pumping, and Levels 1, 2, and 3. Based on these revisions, NMFS supplements the Delta survival analyses to consider the full range of effects on juvenile survival by evaluating effects of the Revised PA, which includes the UPP scenario, as well as the analyses for PA and L1 described earlier in Section 2.5.1.2.7.4 Delta Survival. NMFS evaluates the probability of survival of salmonids in the Delta using results from a range of scenarios: PA, L1, and UPP. This approach addresses potential exposure of Chinook salmon juveniles in the Delta downstream of the NDD intakes to reduced flows under operations at Levels 1, 2, or 3 (rather than at low level pumping) even with unlimited pulse protection. This is possible for several reasons, including: winter-run and spring-run captures on a given day do not reach the trigger level for pulse protection, the duration of the pulse protection may not extend long enough for all the migrants, the real-time operations may not be adjusted quickly enough to cover sudden migration events, and the majority of the winter-run and spring-run Chinook salmon juvenile population may evade capture resulting in false negatives. Therefore, it is likely that some winter-run and spring-run Chinook salmon would be subjected to reduced survival as described in the analyses under PA and L1.

The UPP scenario includes low-level pumping as well as Levels 1, 2, and 3 based on real-time operations adjustments. The mechanism in which the UPP scenario mitigates for adverse effects on winter-run and spring-run Chinook salmon juveniles evident under the PA and L1 scenarios can be evaluated as follows: the new operating scenario (UPP) will be at low-level pumping (or ≥35,000 cfs bypass flow) when primary juvenile winter-run and spring-run Chinook salmon migration is occurring. NMFS has evaluated the effects of low-level pumping on juvenile survival throughout the entire range of Freeport flows and the expected survival reduction can be quantified by examining the low-level pumping flow-survival relationship (Figure 2-152). We can use the same flow-survival relationship to assess the survival reduction for bypass flows of 35,000 cfs and diversions up to the maximum of 9,000 cfs, as described in the UPP scenario. NMFS uses these flow-survival relationships to evaluate how real-time operational adjustments under UPP would affect winter-run and spring-run Chinook salmon smolts.

To assess how the real-time operations of the UPP scenario may reduce the survival impacts identified from analysis of the PA, the survival probabilities for the UPP scenario are modeled. This approach, which is further described in Appendix G of this Opinion, applies real-time operations rules to recent empirical flow and Chinook salmon monitoring data, resulting in a characterization of north Delta diversion rates and Sacramento River bypass flows as specified by the fish-based triggers of the criteria (it is important to note that application of the rules to empirical data does not include other operational constraints such as water quality requirements or storage targets). This analysis was applied to Freeport flow and Knights Landing (KL) Chinook salmon catch index data for 2003-2012 and 2014 to determine diversion levels and bypass requirements (data from 2013 were not used because monitoring at KL ceased due to exceeding winter-run Chinook salmon take limits). The Perry Survival Model analysis, described in Section 2.5.1.2.7.4.3 Perry 2017 Flow-Survival Model was applied to evaluate the effects of the UPP operational scenario on survival.

2.5.1.2.7.4.4.1 UPP effects analysis

The UPP scenario is challenging to evaluate because it involves real-time operations that will occur under varying fish presence and hydrologic conditions. Under the revised PA, specific fish abundance trigger criteria will be developed as part of the adaptive management and monitoring program of the PA. However, as described in the revised PA (see Section 2.5.1.2.7.4.1. The Revised PA unlimited pulse protection scenario and Appendix A2 of this Opinion), CDFW's draft permit for CWF under California Fish and Game Code Section 2081 includes a condition related to pulse protection which triggers a pulse protection based on a Knights Landing rotary screw trap catch index (Xp) greater than or equal to 5 winter-run-sized and spring-run-sized fish. In addition, CDFW's draft permit for CWF under California Fish and Game Code Section 2081 includes a condition related to pulse protection which considers a pulse to be over when Xp is less than 5 for a duration (X) of 5 days. Furthermore, this evaluation of proposed operations effects uses a minimum off-ramp bypass flow of 35,000 cfs, developed from existing data: 35,000 cfs at Freeport, which is approximately where the flow-survival relationship described by Perry et al. 2017 asymptotes (see Appendix G of this Opinion). It is important to note that the values assigned here to the KL catch index and the pulse duration are not specifically part of the revised PA but are expected to be included as conditions for operation of the CWF under a CDFW permit, assuming these permit conditions are included in the final permit. Therefore, the draft CDFW permit condition triggers form the basis of our analysis of the Revised PA UPP Scenario, with the understanding that 1) any change in the conditions from the draft to the final permit may trigger reinitiation of consultation for this Opinion; and 2) the triggers may be revised through the Adaptive Management Program (see further discussion of adaptive management program in Appendix A2 of this Opinion), and any such adaptation would be accompanied by additional analysis of effects to determine consistency with this Opinion.

Other important clarifications on this evaluation include the following assumptions:

- Assumption #1: Annual survivals were calculated by weighting each daily survival by the fraction of the total Knights Landing Catch Index for each day. In addition, the difference in annual survival of each scenario relative to NAA (i.e., no diversion from the new NDD facility) were calculated. Because this analytical method is bound by the frequency of monitoring and capture efficiency at Knights Landing, the reliance on the existing Knights Landing monitoring data could underestimate both the abundance and the temporal extent of winter-run and spring-run Chinook salmon presence during the migration season. As described in PA, the final development of the trigger values and monitoring location would depend on: 1) operation of a new or additional monitoring station(s) closer to the NDD, 2) the method used to identify winter-run and spring-run Chinook salmon, and 3) the collection of sufficient fish monitoring data collected during the appropriate time of year with a large enough sample size with appropriate sampling gear to estimate fish abundance not just presence.
- Assumption #2: The violin plots used to describe mean annual survival are not inclusive of all daily survival probabilities that could occur during the winter-run and spring-run Chinook salmon migration window for any given year (Appendix E of this Opinion). These only include survival probabilities for those days when winter-run and spring-run Chinook salmon were captured at Knights Landing. If no catch occurred, the daily survival rates were not included in the estimate of mean annual survival because the proportion of total annual catch for those days was zero. Therefore, the results may

underestimate the survival reductions experienced in any given year since fish presence is solely dependent on fish catch at Knights Landing. In other words, this modeling exercise assumes any fish present would be captured with 100 percent accuracy, which is an overestimate given that 100 percent catch is extremely unlikely. Furthermore, UPP would cease when capture of fish is fewer than 5 winter-run or spring-run Chinook sized fish for five consecutive days, thereby exposing any fish still present near or downstream of the intakes to the more adverse L1, L2, or L3 operating scenarios

- Assumption #3: Fish passing Knights Landing on a given day experience the calculated bypass flows on that day. This means that for the purposes of this analysis: 1) no lag time was applied to the weighted survival values to account for fish travel time from Knights Landing to the north Delta diversion, and 2) no travel times were applied to different reaches within the Delta to account for flow variation over a given cohort of fish. When real-time operations are implemented, new/additional monitoring locations and information from baseline studies are expected to allow a better characterization of the typical travel time and, therefore, lag time, from monitoring stations closer to the diversion locations. This would allow better resolution of fish presence and abundance to coordinate operations.

NMFS' analysis uses the available information to characterize the initial approach to real-time operations of the north Delta diversions and the effects of that initial approach on the survival of winter-run and spring-run Chinook salmon as captured at Knights Landing. This provides an understanding of the expected effect on survival for fish that experience the pulse protection operations. The eleven years included in this analysis (see Appendix E of this Opinion) reflect inter-annual variation in hydrology, fish abundance, and fish migratory patterns. This is helpful for assessing the dynamic conditions the fish will experience when evaluating the mitigation of adverse impacts that were identified for operations of the PA and L1 scenarios. Detailed modeled results for water year 2012 are included below. This is for illustrative purposes to show how each year's results were summarized (Figure 2-162).

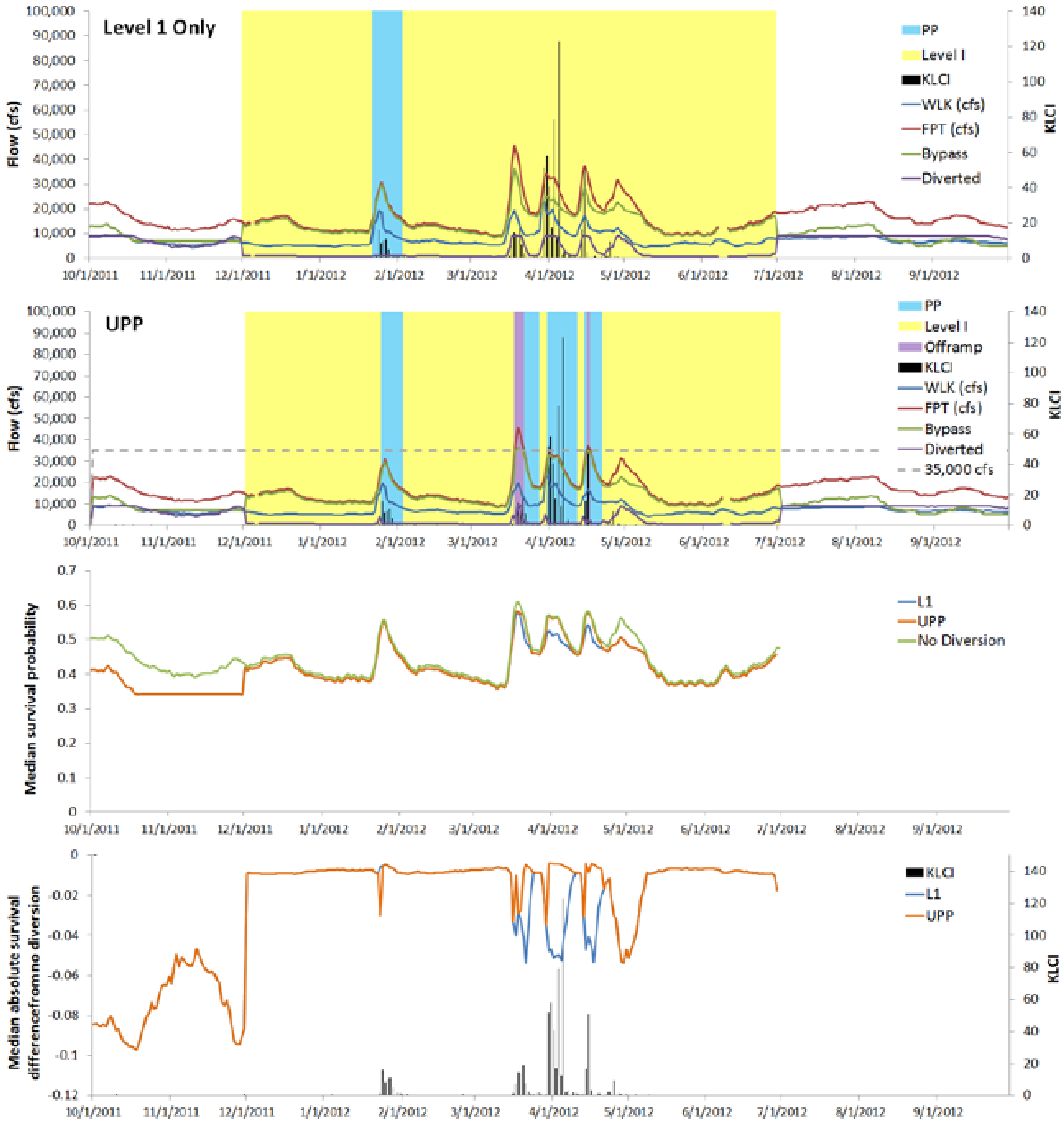


Figure 2-162. Summary for 2012 of Level 1 Real-time Operations (top panel), Revised Real-time Operations (UPP) (2nd panel), Median Daily Through-Delta Survival (3rd panel), and Median Daily Difference in Survival Relative to No Diversion (bottom panel). Note: "Revised" represents UPP scenario (see Appendix E of this Opinion).

In water year 2012, the multiple pulse protections provided by the UPP scenario reduced impacts to the majority of fish for that year over several migration events throughout the migration period (Figure 2-162, panel 2), which is the intended goal of the UPP criteria. For contrast, the L1 scenario pulse protection for this year protected only a small proportion of the migrants

(Figure 2-162, panel 1). This is because the L1 pulse protection is triggered by a flow event in the modeling runs, not fish triggers, and only 1 to 2 pulses are enacted under L1 operating criteria for the entire migration season. This protection is reflected in the survival results (Figure 2-162, panel 3 and 4) which show the increased protection afforded to the later migration events for the UPP scenario that would not have been covered with the other scenarios.

This evaluation of the UPP scenario reveals that median survival is still lower than the NAA for the eleven years modeled (Table 2-226). The median reduction in survival averages 1% and median survival under the UPP scenario does not exceed 3%. Additionally, under the UPP, maximum survival reduction does not exceed 4.5% and on average is 2%. Although the survival reduction under the UPP still occurs due to the PA diverting flows in the north Delta, the adverse impacts that were quantified under the PA scenario (see Section 2.5.1.2.7.4.3 Perry 2017 Flow-Survival Model) have been mitigated to a large degree. This is because this new UPP scenario would divert at low level pumping during multiple migration events.

Table 2-226. Median and 10th Percentile Mortality Compared to NAA.

Year	UPP Ops median absolute mortality (50th percentile) compared to NAA.	UPP Ops extent of absolute mortality (10th percentile) compared to NAA.
2003	1.9%	3%
2004	1%	1.5%
2005	1.1%	1.6%
2006	1.1%	2.5%
2007	3%	4.3%
2008	2%	2.9%
2009	1.2%	1.7%
2010	0.9%	1.4%
2011	2.1%	3.3%
2012	0.7%	1.1%
2014	0.7%	1%
Average	1%	2%

Note:

The 10th percentile mortality means that 90% of the population experienced less mortality and 10% of the population experienced higher mortality.

Low-level pumping under the UPP scenario reduces the impact of Delta diversions to winter-run and spring-run Chinook salmon migrants as shown by the comparison of survival under the NAA and the PA with UPP in the Perry Survival Model plots (Figure 2-152).

This analysis illustrates that survival reductions are minimized for the majority of winter-run and spring-run that were migrating under low-level pumping. However, the modeling in this analysis is based on assumptions described above that do not necessarily capture what may occur during actual implementation of the UPP scenario. For instance, under the modeling, when the 5-fish trigger is reached, immediate low level pumping mortality rates were applied to that population, which lasted throughout the hypothesized migration window of those captured fish. This is because of Assumption #3, which states that “Fish passing Knights Landing on a given day experience the calculated bypass flows on that day. This means that for the purposes of this analysis: (1) no lag time was applied to the weighted survival values to account for fish travel time from Knights Landing to the north Delta diversion; and (2) no travel times were applied to different reaches within the Delta to account for flow variation over a given cohort of fish.” So essentially, the survival reduction is realized by a fish captured on the day that the trigger is met which enacts a bypass flow rate under low-level pumping. A monitoring location closer to the NDD would provide a better trigger because the fish passing the NDD at the exact timing of the pulse protection would realize the benefit; such a monitoring location will be determined in pre-construction monitoring studies.

This analysis also assumes that capture rates at Knights Landing (which is at river mile 90) represent all of the fish that are migrating past at the North Delta diversion intakes. This is another limitation in the analysis explained in Assumptions #1 and #2. Therefore, the reduction in impacts described under this analysis of the UPP scenario in this analysis may underestimate the reduction in impacts under the real-time implementation of the UPP scenario. This is in part due to catch efficiencies at monitoring sites, varying travel times, varying lag time in reporting and operations, and the unknown element of varying fish behavior. Winter-run and spring-run Chinook salmon smolts will not necessarily migrate out of the Delta as is mostly evidenced from telemetry studies of the larger late-fall run Chinook, which exposes them to reduced in-Delta flows occurring after NDD pulse protection has ended (post-pulse).

Therefore, based on this analysis, low level pumping under the UPP scenario when primary juvenile winter-run and spring-run Chinook salmon migration is occurring decreases the survival reductions (Table 2-226) that were described under the PA and L1 scenario. However, the implementation of the real-time adjustments is difficult to model with the data and knowledge we have at this time. These data gaps will have to be informed during initial studies and adaptive management. For purposes of the analysis in this Opinion, NMFS assumes that the unlimited pulse protection will be at least as protective as modeled using the specific fish triggers.

2.5.1.2.7.4.5 Newman (2003) Model

Another NMFS used to evaluate the effects of the PA on through Delta survival is the Newman Model. The BA used analysis based on Newman (2003) to evaluate the potential effects of the PA on juvenile spring- and fall-run Chinook salmon migrating through the Delta from the Sacramento River basin (BA section 5.4.1.3.1.2.1.3.2 Analysis Based on Newman (2003): Sacramento River Spring-run Chinook Salmon). Newman (2003) is primarily used for spring-run and fall-run Chinook salmon due to the existence of the more refined telemetry studies that occur during the winter-run migratory period. Although correlations can be made for all Chinook salmon species, the Newman (2003) Model was only applied to spring-run and fall-run Chinook salmon as several other models including full life cycle models are applied to winter-run Chinook salmon. This method allows estimation of through-Delta survival as a function of river flow (Sacramento River downstream of the NDD, to capture flow-survival effects), south Delta exports, and other covariates, including salinity, turbidity, DCC position, and water temperature. The timing of the coded-wire tagged smolts for this model coincide with the peak spring-run and fall-run smolt migratory period.

2.5.1.2.7.4.5.1 Spring-run Exposure and Risk

The results of the analysis based on Newman Model suggested that difference in overall mean survival between the NAA and PA for spring-run Chinook salmon would be very small across all water year type (Figure 2-163 and Figure 2-164). When examined by NDD bypass flow level, the minor differences between NAA and PA were also apparent (Table 2-227).[4]

The results are driven by several factors. The timing of spring-run Chinook salmon entry into the Delta was assumed to be the same as that used for the DPM, for which entry occurs during spring (March–May), with a pronounced unimodal peak in April (see BA Figure 5.D-42 in Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale). During April under the PA, south Delta exports and Sacramento River flow downstream of the NDD are similar in their absolute differences from the NAA. See Table 2-228 for additional south Delta exports information. See also BA Figures 5.A.6-27-1 to 5.A.6-27-6, Figures 5.A.6-27-7 to 5.A.6-27-19, and Table 5.A.6-27 in Appendix 5.A, CalSim II Modeling and Results). In other words, less Sacramento River flow downstream of the NDD is offset by less south Delta exports. The analysis based on Newman (2003) includes a rate of change in juvenile Chinook salmon survival per unit of flow that is similar for the Sacramento River and south Delta exports (see BA Figure 5.D-61 in Appendix 5.D), so that a similar change in Sacramento River flows (less) and exports (less) results in similar survival, as the analysis showed.[5] As noted in the previous section describing the DPM results, this results in differences in the results compared to DPM results, for which survival under the PA was slightly lower than under the NAA.

[4] Based on agency request, an unweighted version of these data is presented in Appendix 5.D of the BA, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.3.3, *Results* (Table 5.D-46), which again shows the similarity between NAA and PA.

[5] The relative effect of south Delta exports and Sacramento River flow downstream of the NDD are illustrated in the BA Figure 5.D-64 in Appendix 5.D, Section 5.D.1.2.3, *and Analysis Based on Newman (2003)*.

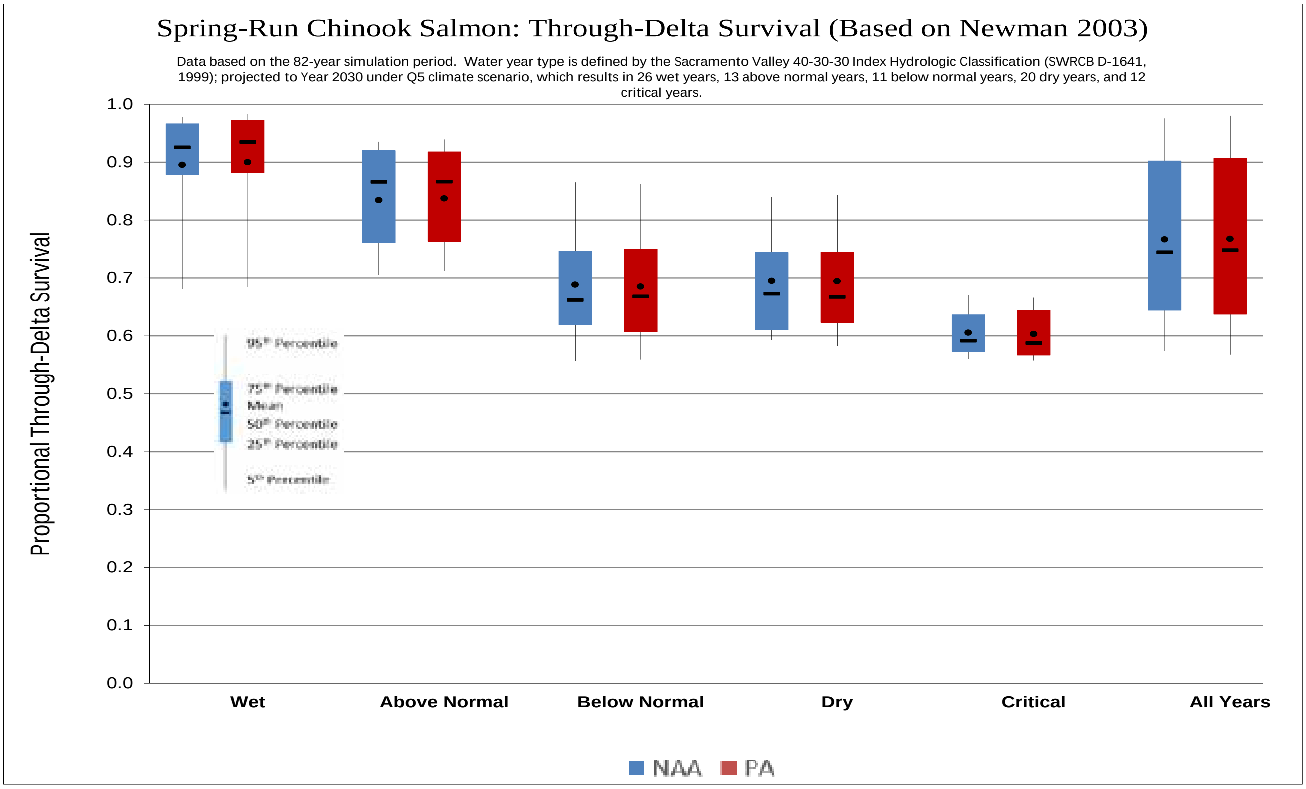


Figure 2-163. Box Plots of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Grouped by Water Year Type.

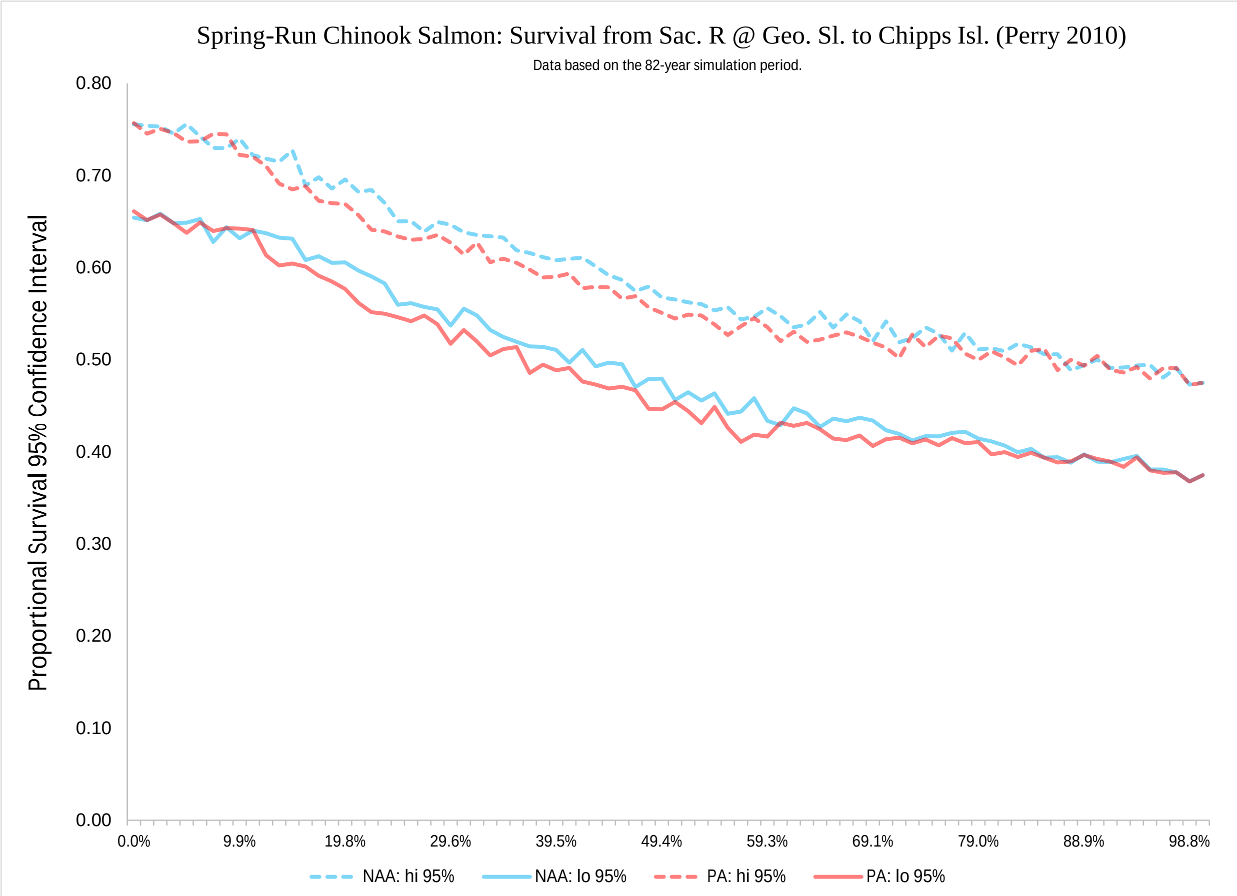


Figure 2-164. Exceedance Plot of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003).

Table 2-227. Mean Annual Spring-run Chinook Salmon Weighted Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Divided into Each NDD Bypass Flow Level.

WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.00	0.00	0.00 (0%)	0.00	0.00	0.00 (2%)	0.04	0.04	0.00 (1%)	0.85	0.85	0.00 (0%)	0.90	0.90	0.00 (0%)
AN	0.00	0.00	0.00 (1%)	0.01	0.01	0.00 (0%)	0.06	0.06	0.00 (2%)	0.77	0.77	0.00 (0%)	0.83	0.84	0.00 (0%)
BN	0.00	0.00	0.00 (0%)	0.25	0.24	0.00 (-1%)	0.31	0.31	0.00 (0%)	0.13	0.13	0.00 (-1%)	0.69	0.69	0.00 (0%)
D	0.00	0.00	0.00 (-1%)	0.21	0.21	0.00 (0%)	0.39	0.39	0.00 (0%)	0.09	0.09	0.00 (0%)	0.69	0.69	0.00 (0%)
C	0.01	0.01	0.00 (-1%)	0.51	0.50	0.00 (-1%)	0.09	0.09	0.00 (1%)	0.00	0.00	0.00 (0%)	0.61	0.60	0.00 (0%)

Table 2-228. Mean South Delta Exports and Sacramento River Flow Downstream of the NDD in March-May, by Water Year Type.

WY	**South Delta Exports**								
	March			**April**			**May**		
	NAA	**PA**	**PA vs. NAA**	**NAA**	**PA**	**PA vs. NAA**	**NAA**	**PA**	**PA vs. NAA**
W	9,461	1,706	-7,755 (-82%)	2,977	395	-2,582 (-87%)	3,378	570	-2,808 (-83%)
AN	7,826	902	-6,924 (-88%)	1,801	369	-1,432 (-80%)	1,720	411	-1,309 (-76%)
BN	6,089	3,825	-2,264 (-37%)	1,774	1,340	-435 (-24%)	1,624	1,034	-590 (-36%)
D	4,868	3,619	-1,249 (-26%)	2,052	1,493	-559 (-27%)	2,054	1,337	-717 (-35%)
C	2,701	2,139	-561 (-21%)	1,430	1,267	-163 (-11%)	1,415	1,207	-208 (-15%)

Sacramento River Flow Downstream of the NDD (Bypass Flows)								
March			**April**			**May**		
NAA	**PA**	**PA vs. NAA**	**NAA**	**PA**	**PA vs. NAA**	**NAA**	**PA**	**PA vs. NAA**
47,988	40,145	-7,844 (-16%)	34,998	32,406	-2,592 (-7%)	29,839	26,747	-3,092 (-10%)
40,801	34,100	-6,700 (-16%)	24,080	22,944	-1,136 (-5%)	16,711	15,444	-1,266 (-8%)
18,542	15,051	-3,492 (-19%)	14,076	13,607	-469 (-3%)	12,460	12,027	-433 (-3%_
21,284	17,259	-4,025 (-19%)	14,895	14,348	-547 (-4%)	11,633	11,382	-251 (-2%_
12,529	11,683	-846 (-7%)	10,290	10,144	-147 (-1%)	8,214	8,031	-184 (-2%)

The Newman Model analysis shows very little change in through Delta survival for spring-run under the two scenarios. The two model co-variates that dominate the flow survival relationship were south Delta export rates (or difference between scenarios) and flow at Freeport (or difference between the scenarios). This model applies hydrological changes in Delta conditions on a broader scale since there is no tracking of individual fish performance. These CWT tag studies were the basis of understanding flow and route specific survival differences within the Delta. However, the Newman 2003 analysis applied to the CWF scenarios cannot expand on which fish were entrained into central Delta and may have benefitted from changes in South Delta exports under the PA so the benefit is applied to all the smolts in the model. As we have seen with the acoustic tag studies, a range from 10 to 40% tends to enter the central Delta and a fraction of those fish may then be exposed to changes in velocities in the South Delta (Perry et al. 2010, Perry 2016.

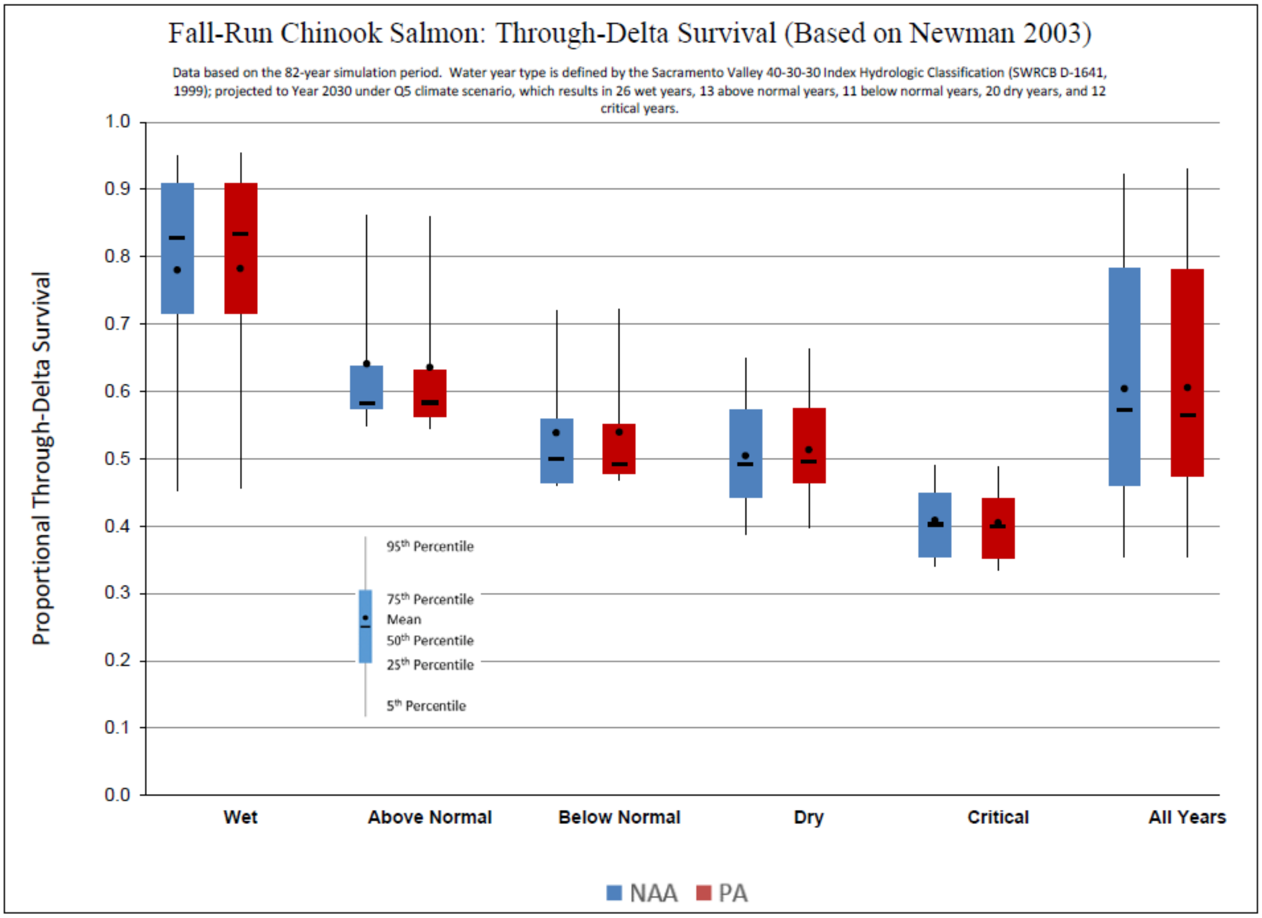
Although the Newman Model results indicate no or slight difference in survival probabilities between the scenarios, it is another method and analysis that corroborates the flow survival relationships in the north and south Delta. This model is not structured to give an adequate assessment of the risk unique to the major migratory routes in the Delta. Therefore, this model is given a lower weight of evidence due to the model limitations described in this section.

2.5.1.2.7.4.5.2 Fall-run Exposure and Risk

The analysis based on Newman (2003) assesses the potential effect of the PA on fall-run Chinook salmon smolts migrating through the Delta from the Sacramento River basin as a function of river flow (Sacramento River below the NDD, to capture flow-survival effects), south Delta exports, and other covariates, including salinity, turbidity, DCC position, and water temperature.

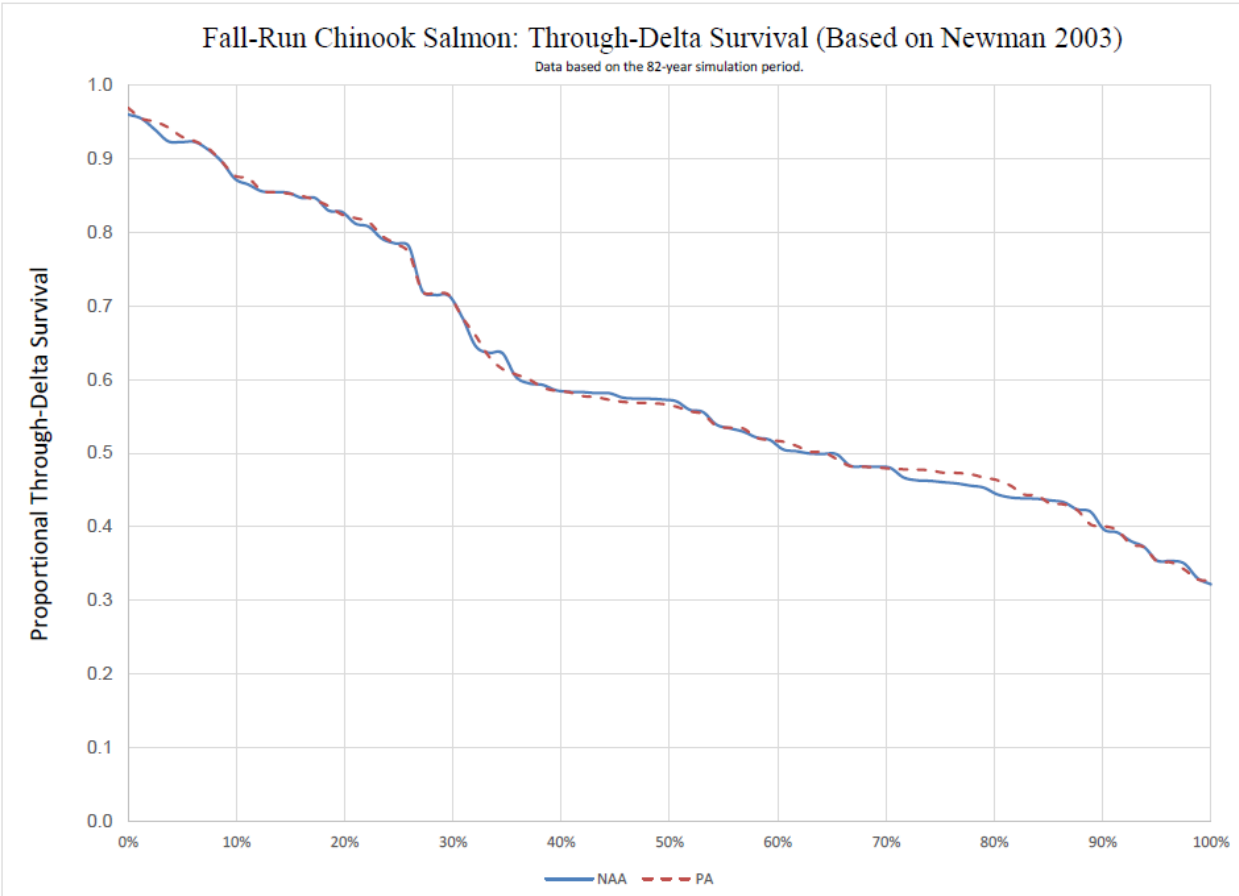
The results of the analysis based on Newman (2003) were similar to those found for spring-run Chinook salmon in that they suggested that there would be very little difference in overall mean smolt survival between the NAA and PA for fall-run Chinook salmon across all water year types (Figure 2-165; Figure 2-166; Figure 2-167). When examined by NDD bypass flow level, the minor differences between NAA and PA were also clear (Table 2-229).

The results are explained by the timing of fall-run Chinook salmon entry into the Delta and the operations occurring during that time. The entry distribution of fall-run Chinook salmon was assumed to be the same as that used for the DPM, for which entry occurs during spring (principally April-June), with a pronounced unimodal peak in May (see BA Figure 5.D-42 in Appendix 5.D, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale). During April-June under the PA, south Delta exports and Sacramento River flow downstream of the NDD are very similar in their absolute differences from the NAA (for additional south Delta exports information, see also Figures 5.A.6-27-1 to 5.A.6-27-6, Figures 5.A.6-27-7 to 5.A.6-27-19, and Table 5.A.6-27 in BA Appendix 5.A, CalSim II Modeling and Results). As noted above for spring-run Chinook salmon, less Sacramento River flow downstream of the NDD is offset by less south Delta exports, given that Delta outflow is very similar between NAA and PA in these months. The analysis based on Newman (2003) includes a rate of change in juvenile Chinook salmon survival per unit of flow that is similar for the Sacramento River and south Delta exports (see Figure 5.D-61 in BA Appendix 5.D), so that a similar change in Sacramento River flows (less under PA) and south Delta exports (also less under PA) results in similar survival, as the analysis showed. This contrasts with the results for the DPM described below, for which smolt survival under PA was marginally lower than under NAA because the flow survival-relationship generally is stronger than the export survival relationship and only fish entering the interior Delta at Georgiana Slough/DCC experience the export-survival relationship.



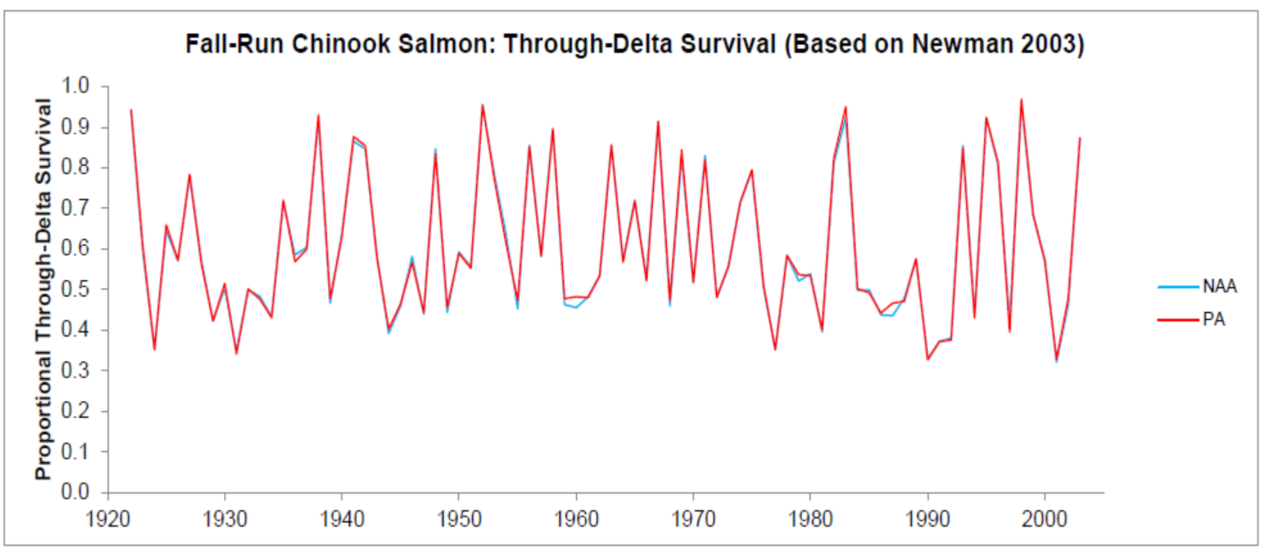
Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-165. Box Plots of Fall-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Grouped by Water Year Type.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-166. Exceedance Plot of Fall-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003).



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-167. Time Series of Fall-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003).

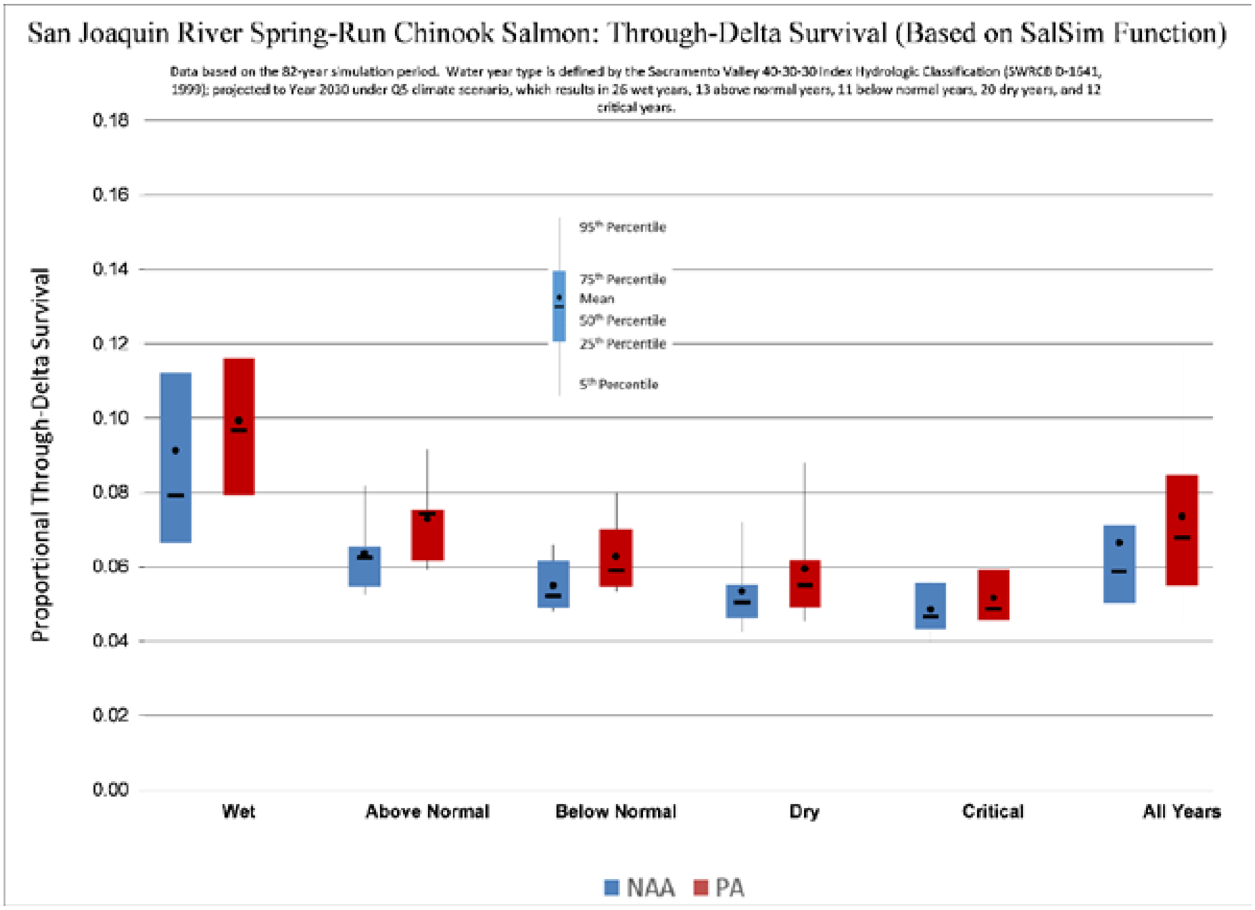
Table 2-229. Mean Annual Fall-run Chinook Salmon Weighted Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Divided into Each NDD Bypass Flow Level.

WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.00	0.00	0.00 (0%)	0.00	0.00	0.00 (0%)	0.02	0.02	0.00 (1%)	0.76	0.76	0.00 (0%)	0.78	0.78	0.00 (0%)
AN	0.00	0.00	0.00 (0%)	0.00	0.00	0.00 (0%)	0.04	0.04	0.00 (0%)	0.60	0.59	-0.01 (-1%)	0.64	0.64	0.00 (1%)
BN	0.00	0.00	0.00 (0%)	0.21	0.21	0.00 (0%)	0.24	0.24	0.00 (1%)	0.10	0.09	0.00 (0%)	0.54	0.54	0.00 (0%)
D	0.00	0.00	0.00 (0%)	0.14	0.14	0.00 (2%)	0.28	0.29	0.00 (2%)	0.08	0.08	0.00 (1%)	0.50	0.51	0.00 (-1%)
C	0.00	0.00	0.00 (-1%)	0.34	0.33	0.00 (-1%)	0.07	0.07	0.00 (-1%)	0.00	0.00	0.00 (0%)	0.41	0.40	0.00 (-1%)

2.5.1.2.7.4.6 SalSim Through-Delta Survival Function: San Joaquin River Basin Spring-Run Chinook Salmon

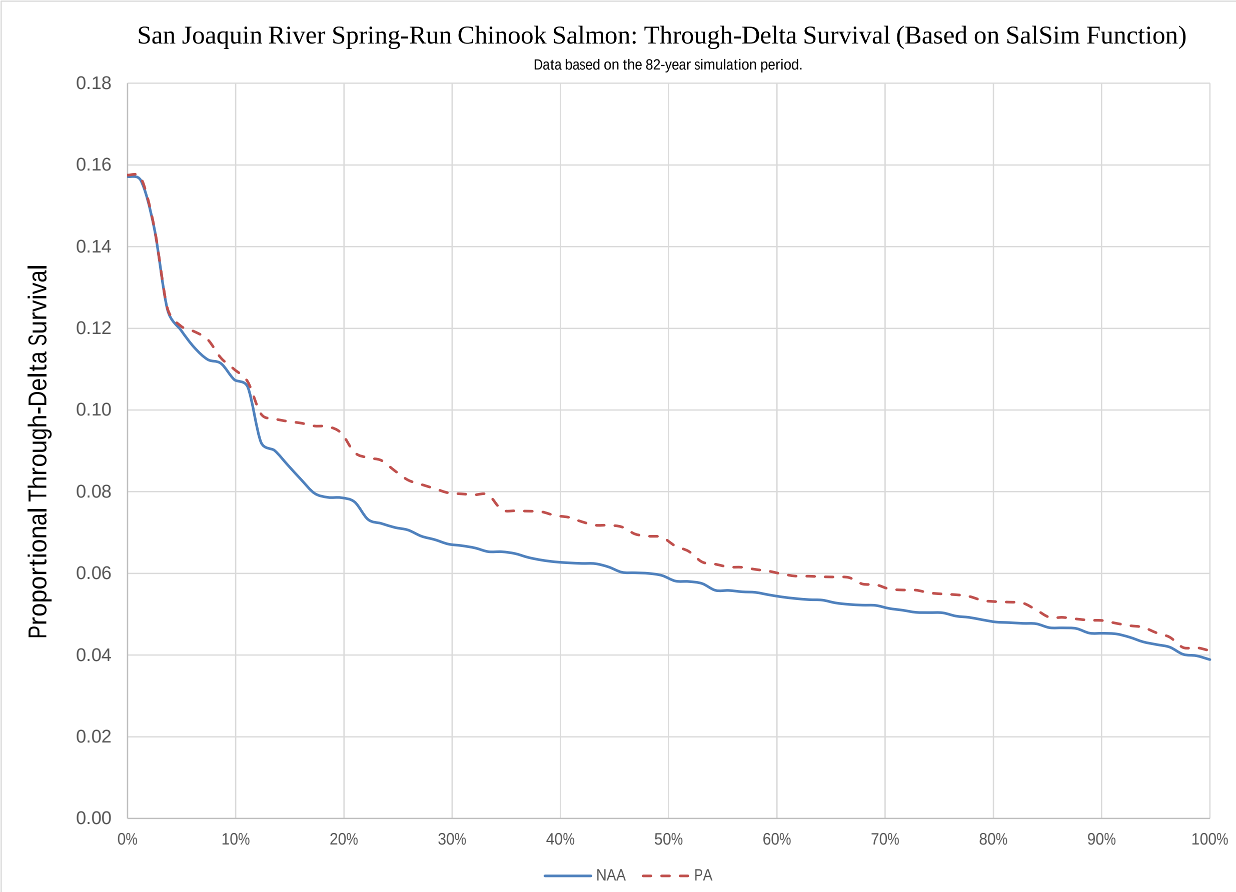
Through-Delta survival for spring-run Chinook salmon from the San Joaquin River basin was estimated using the survival function from the Juvenile Delta Module of the Salmon Simulator (SalSim; AD Consultants 2014). Whereas SalSim is a standalone life cycle modeling tool, the coefficients of the survival function from its Delta Module were used in a spreadsheet to compare potential survival differences between the NAA and PA. The details of the method as applied for fall-run Chinook salmon are described in the BA under: SalSim Through-Delta Survival Function: Fall-Run Chinook Salmon subsection of Appendix 5.E., Essential Fish Habitat, Section 5.E.5.3.1.2.1.2.1, Indirect Mortality within the Delta. The DPM timing for spring-run Chinook salmon entering the Delta from the Sacramento River basin was assumed for this analysis to be representative of the timing for entry of San Joaquin River spring-run Chinook salmon.

The results of the analysis based on the SalSim through-Delta survival function suggested that the through-Delta survival of San Joaquin River spring-run Chinook salmon under the PA would be greater under the PA than NAA (Figure 2-168 and Figure 2-169, and Table 2-230). This is the result of the implementation of the HOR gate, which was modeled to be closed 50% of the time during the main period of spring-run Chinook salmon migration, with the result that flow into the Stockton Deepwater Ship Channel is considerably greater under the PA. The increased flow into the Deepwater Ship Channel is indicative of higher San Joaquin River flow that is correlated to increased survival of outmigrating smolts because they do not migrate into the south Delta where they are exposed to the south Delta pumping facilities. The relative differences in survival between the NAA and PA were greatest in intermediate water-year types (above normal, below normal, and dry), as a result of two factors. First, the HOR gate would not be closed when Vernalis flow is greater than 10,000 cfs; this results in the top 5% of survival estimates being identical between NAA and PA (Figure 2-169), which limits the overall differences in wet years. Second, in critical years when flows are very low and water temperature would be high, the rate of change in survival is considerably less than with more flow and lower temperature, as shown in the flatness of the flow-survival curve in CWF BA Appendix 5.E, Essential Fish Habitat. Overall, the analysis based on the SalSim Juvenile Delta Module survival function suggested that operations under the PA would likely have a positive effect on survival of San Joaquin River spring-run Chinook salmon in the Delta compared to the NAA.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-168. Box Plots of San Joaquin River Spring-Run Chinook Salmon Smolt Annual Through-Delta Survival Estimated from the Juvenile Delta Module Survival Function of SalSim, Grouped by Water Year Type.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-169. Exceedance Plot of San Joaquin River Spring-Run Chinook Salmon Smolt Annual Through-Delta Survival Estimated from the Juvenile Delta Module Survival Function of SalSim.

Table 2-230. Mean Annual San Joaquin River Spring-run Chinook Salmon Smolt Through-Delta Survival Estimated from the Juvenile Delta Module Survival Function of SalSim, Together with Weighted-Mean Flow into the Stockton Deepwater Ship Channel, Grouped by Water Year Type.

Water Year Type	Through-Delta Survival Probability			Flow into Stockton Deepwater Ship Channel (cfs) Weighted by Proportion of Fish Entering the Delta		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.091	0.099	0.008 (9%)	4,568	5,380	811 (18%)
AN	0.064	0.073	0.009 (15%)	2,305	3,386	1,081 (47%)
BN	0.055	0.063	0.008 (14%)	1,471	2,456	986 (67%)
D	0.053	0.059	0.006 (11%)	1,124	1,883	759 (68%)
C	0.049	0.052	0.003 (6%)	483	929	446 (92%)

Although flows entering the Delta from the San Joaquin River do not change between scenarios, the effect of having the HOR gate in place under the PA enhances the flow that remains in the San Joaquin River. This has a positive migratory effect on San Joaquin basin smolts although smolts are still impacted by south Delta operations as described in Section 2.5.1.2.7.3 South Delta Exports.

Currently, spring-run primarily spawn in the Sacramento River and upper basin tributaries and the vast majority will be entering the Delta from the Sacramento basin. Historically, spring-run were the most populous salmon species spawning and migrating in the San Joaquin River basin prior to construction of Friant Dam; however, they were essentially extirpated by the 1940s. More recently, adult spring running Chinook salmon have been observed in San Joaquin River tributaries, as well as the presence of recently re-introduced spring-run, part of an experimental population. The PA, through the operations of the HOR gate, is expected to be beneficial for any spring-run Chinook present in the San Joaquin River basin. Benefits are expected to expand to a larger proportion of spring-run as they become more established in the San Joaquin River Basin.

2.5.1.2.7.4.7 Analysis Based on Salsim Through-Delta Survival Function: Steelhead

As discussed above for Sacramento River basin steelhead, survival modeling using spring-run Chinook salmon in the San Joaquin River Basin will be used as a proxy for steelhead in that basin, using only a general trend approach. Through-Delta survival modeling for spring-run Chinook salmon entering the Delta from the San Joaquin River basin used the survival function from the Juvenile Delta Module of the Salmon Simulator (SalSim; AD Consultants 2014). The results of the analysis based on the SalSim through-Delta survival function suggested that the through-Delta survival of San Joaquin River spring-run Chinook salmon under the PA would be greater under the PA than NAA (Figure 2-169, Figure 2-170, and Table 2-230). This is the result of the implementation of the HOR gate, which was modeled to be closed 50% of the time during the main period of spring-run Chinook salmon migration, with the result that flow into the Stockton Deepwater Ship Channel is considerably greater under the PA (BA Table 5.4-20). The relative differences in survival between NAA and PA were greatest in intermediate water-year types (above normal, below normal, and dry) as a result of two factors. First, the HOR gate would not be closed when Vernalis flow is greater than 10,000 cfs; this results in the top 5% of survival estimates being identical between NAA and PA (BA Figure 5.4-25), which limits the overall differences in wet years. Second, in critical years when flows are very low and water temperature would be high, the rate of change in survival is considerably less than with more flow and lower temperature. Overall, the analysis based on the SalSim Juvenile Delta Module survival function suggested that the PA would likely have a positive effect on San Joaquin River spring-run Chinook salmon in the Delta. Since the emigration of steelhead smolts from the San Joaquin River basin would overlap substantially with the emigration of spring-run Chinook salmon from the basin, the SalSim results are believed to generally apply to steelhead, too, as both species would experience the same hydrology and PA operations during their smolt outmigration.

2.5.1.2.7.4.8 Analysis Based on SalSim Through-Delta Survival Function: Fall-Run Chinook Salmon

To provide perspective on through-Delta survival for fall-run Chinook salmon from the San Joaquin River basin, the survival function from the Juvenile Delta Module of the Salmon Simulator (SalSim; AD Consultants 2014) was applied and is incorporated from the BA. Whereas SalSim is a standalone life cycle modeling tool, the coefficients of the survival function from its Delta Module were used in a spreadsheet to compare potential survival differences between the NAA and PA. The methods to generate this comparison are described in the BA in Appendix 5.E.

The results of the analysis suggested that the through-Delta survival of San Joaquin River fall-run Chinook salmon under the PA would be greater under the PA than NAA (Figure 2-170 and Figure 2-171; Table 2-231). This is the result of the implementation of the HOR gate, which was assumed to be closed 50% of the time during the main period of fall-run Chinook salmon migration, with the result that flow into the Stockton Deepwater Ship Channel is considerably greater under the PA (Table 2-231). The relative differences in survival between NAA and PA were greatest in intermediate water-year types (above normal, below normal, and dry) as a result of two factors. First, and as previously discussed for the DPM, the HOR gate is assumed not to be closed when Vernalis flow is greater than 10,000 cfs; this results in the top 10% of survival estimates being identical between NAA and PA (Figure 2-171), which limits the overall differences in wet years. Second, in critical years when flows are very low and water temperature would be high, the rate of change in survival is considerably less than with more flow and lower temperature. Overall, the analysis based on the SalSim Juvenile Delta Module survival function suggested that the PA would provide a beneficial effect to survival of San Joaquin River fall-run Chinook salmon in the Delta compared to the NAA.

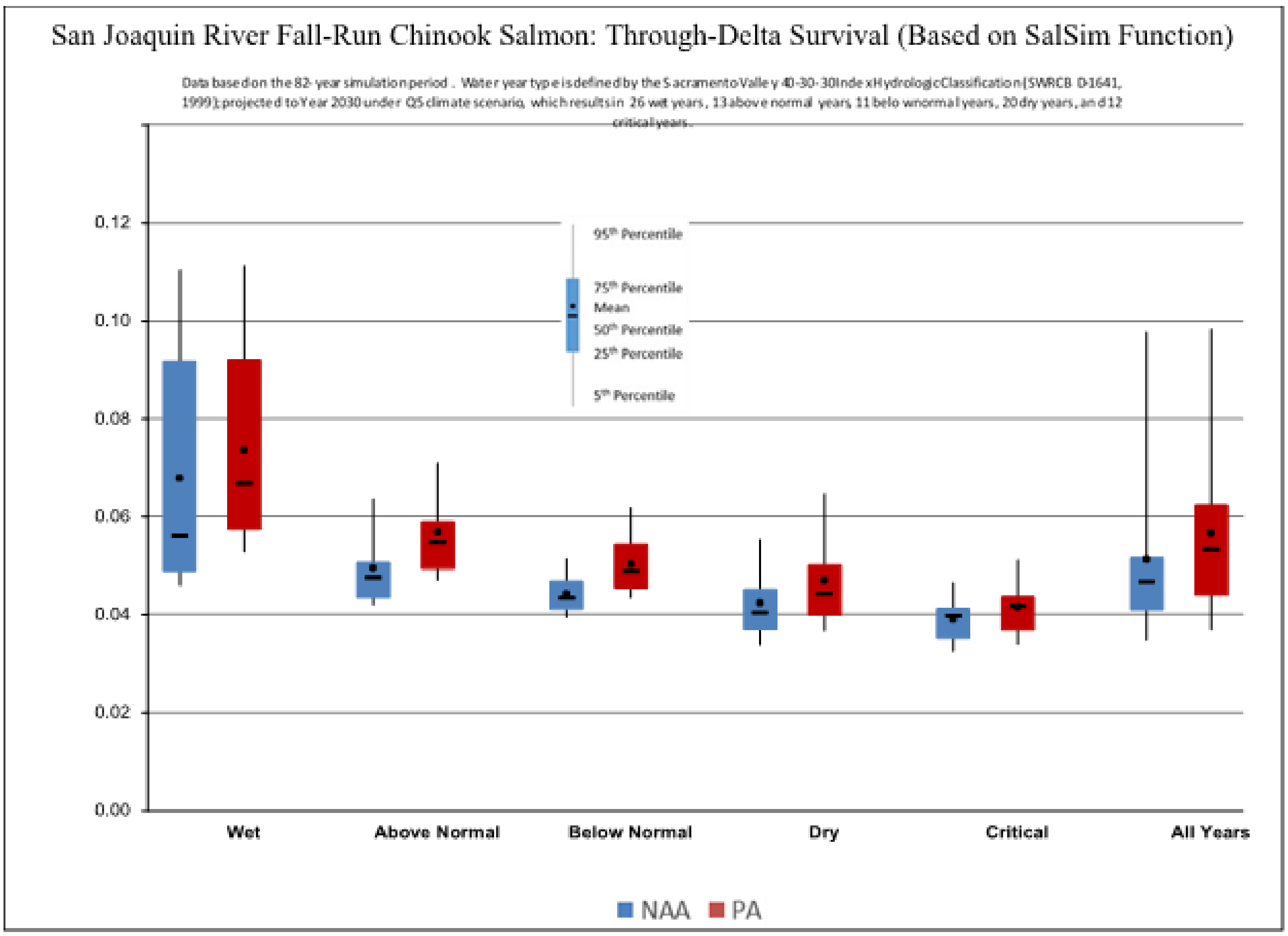
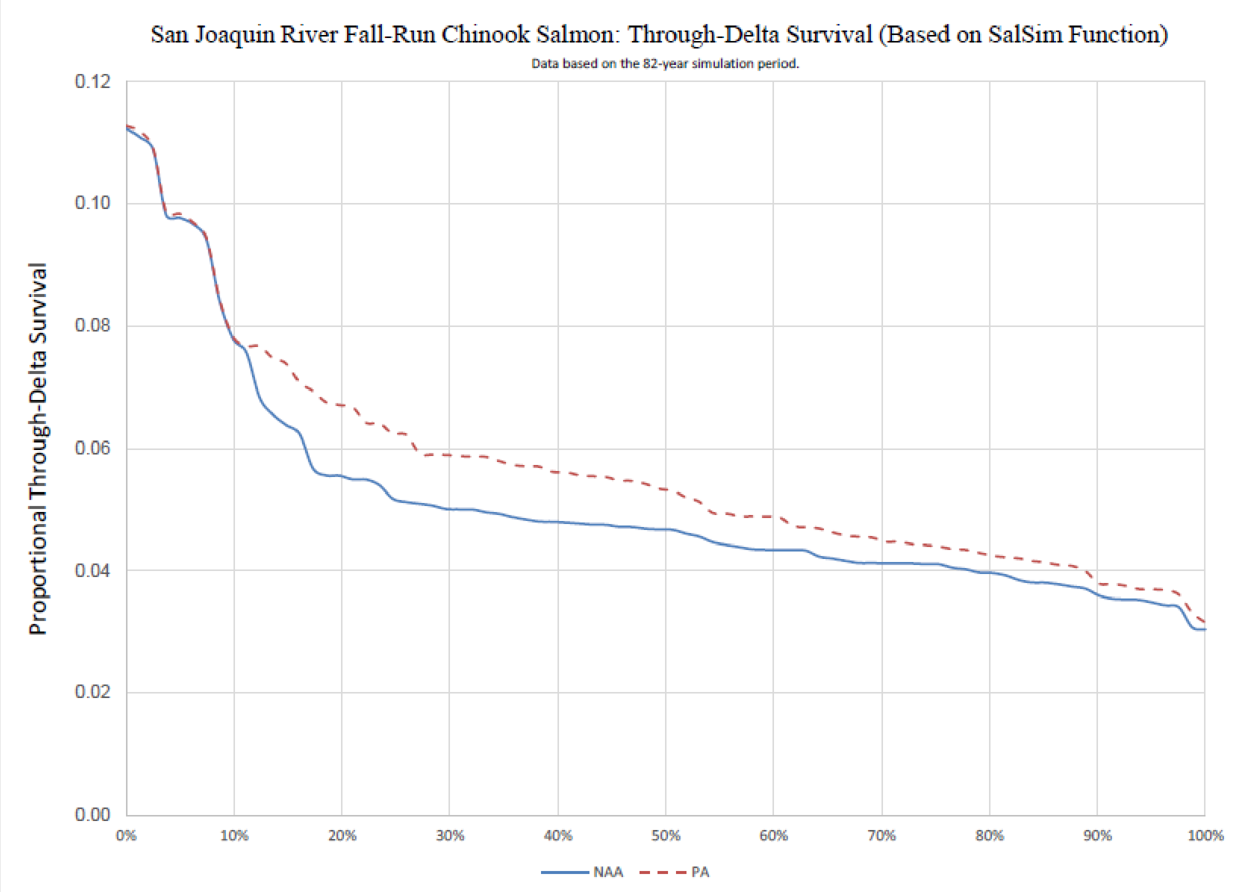


Figure 2-170. Box Plots of San Joaquin River Fall-Run Chinook Salmon Smolt Annual Through-Delta Survival Estimated from the Juvenile Delta Module Survival Function of SalSim, Grouped by Water Year Type.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-171. Exceedance Plot of San Joaquin River Fall-Run Chinook Salmon Smolt Annual Through-Delta Survival Estimated from the Juvenile Delta Module Survival Function of SalSim.

Table 2-231. Mean Annual San Joaquin River Fall-Run Chinook Salmon Smolt Through-Delta Survival Estimated from the Juvenile Delta Module Survival Function of SalSim, Together with Weighted-Mean Flow into the Stockton Deepwater Ship Channel, Grouped by Water Year Type.

Water Year Type	Through-Delta Survival Probability			Flow into Stockton Deepwater Ship Channel (cfs) Weighted by Proportion of Fish Entering the Delta		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.068	0.074	0.006 (8%)	4,254	5,029	775 (18%)
AN	0.049	0.057	0.007 (15%)	2,227	3,292	1,065 (48%)
BN	0.044	0.050	0.006 (14%)	1,437	2,391	953 (66%)
D	0.042	0.047	0.005 (11%)	1,120	1,855	735 (66%)
C	0.039	0.042	0.002 (6%)	474	901	427 (90%)

A summary of the modeling results for the through-Delta survival analyses is provided in Table 2-232.

Table 2-232. Summary of Through-Delta Survival Analyses Results By Model.

Model	Overall Trend in Results
Delta Passage Model	For all Chinook salmon runs, there is a mean decrease in relative survival due to effects of lowered Delta inflow. The survival reduction is most evident in winter-run Chinook salmon (2% to 7%) with more modest survival reductions for spring and fall-run Chinook salmon (1% to 4%).
Newman 2003	Survival between scenarios are very similar resulting in 0% change in survival for spring-run Chinook salmon. This method assesses the Delta and all its channels as one region and applies a reduced south Delta export survival benefit and a north Delta reduced flow survival impact to all smolts.
Salsim	Survival increases under the PA for San Joaquin River basin spring-run and fall-run Chinook salmon (6% to 15% relative increase in survival). This is due to reduced south Delta exports and inclusion of the HOR gate which both increase positive velocities in the San Joaquin River and most distributaries.
Perry Survival Model	Survival is reduced for all Chinook salmon smolts under the PA. Median survival reductions are most prominent in the shoulder migratory months of October, November, and June where median survival reduction ranges from 2% to 5.4%. Survival reductions in these months would affect late-fall/fall-run and also winter-run Chinook salmon smolts during certain years. During core migratory months, February and March have the largest median survival reductions of 1.2% and 1.6%. Survival reductions in these months would affect a proportion of all Chinook salmon smolts but primarily winter-run Chinook. For the 50% of the years where survival reductions fall below the median, the range of survival reductions during the core migratory months (Dec-April) range from 0.5% to 12%.
Perry Survival Model – Modified analysis for UPP scenario	Survival is reduced for all Chinook salmon smolts under the PA; however, the unlimited pulse protection minimizes the survival reduction during the primary juvenile winter-run and spring-run migration period. For the years evaluated, 2003-2014, median mortality (reduction in survival) ranges from 0.7% to 3%. Although this analysis did not generate reduction in survival values by month, inherent in the analysis is the data regarding the fish triggers which only occur during the winter and spring Chinook salmon migration period. This range of reduction in survival is greatly reduced from the results of the PA with one-two pulse protections.

2.5.1.2.7.5 Life Cycle Models

Life cycle models of Sacramento River winter-run Chinook salmon were used to analyze population abundance, cohort replacement rate, habitat use distribution and juvenile survival differences in between the NAA and PA. These models have multiple stages, including eggs, fry, smolts, juveniles in the ocean, and mature adults in the spawning grounds. The two life cycle models considered in this Opinion are the Interactive Object-Oriented Simulation Model (IOS), which was presented in the BA (Appendix 5D Methods Section 5.D.3); and the Southwest Fisheries Science Centers Winter-run Chinook Life Cycle Model (WRLCM) presented in this section. OBAN was also presented in the BA but is not used in the Opinion analysis because it does not represent the physical area of the Delta in a robust way.

2.5.1.2.7.5.1 Interactive Object-Oriented Simulation (IOS) Model Structure (text from BA, App 5D)

5.D.3.1.1 Model Structure

The IOS Model is composed of six model stages defined by a specific spatiotemporal context and are arranged sequentially to account for the entire life cycle of winter-run Chinook salmon, from eggs to returning spawners (Figure 5.D-135). In sequential order, the IOS Model stages are listed below.

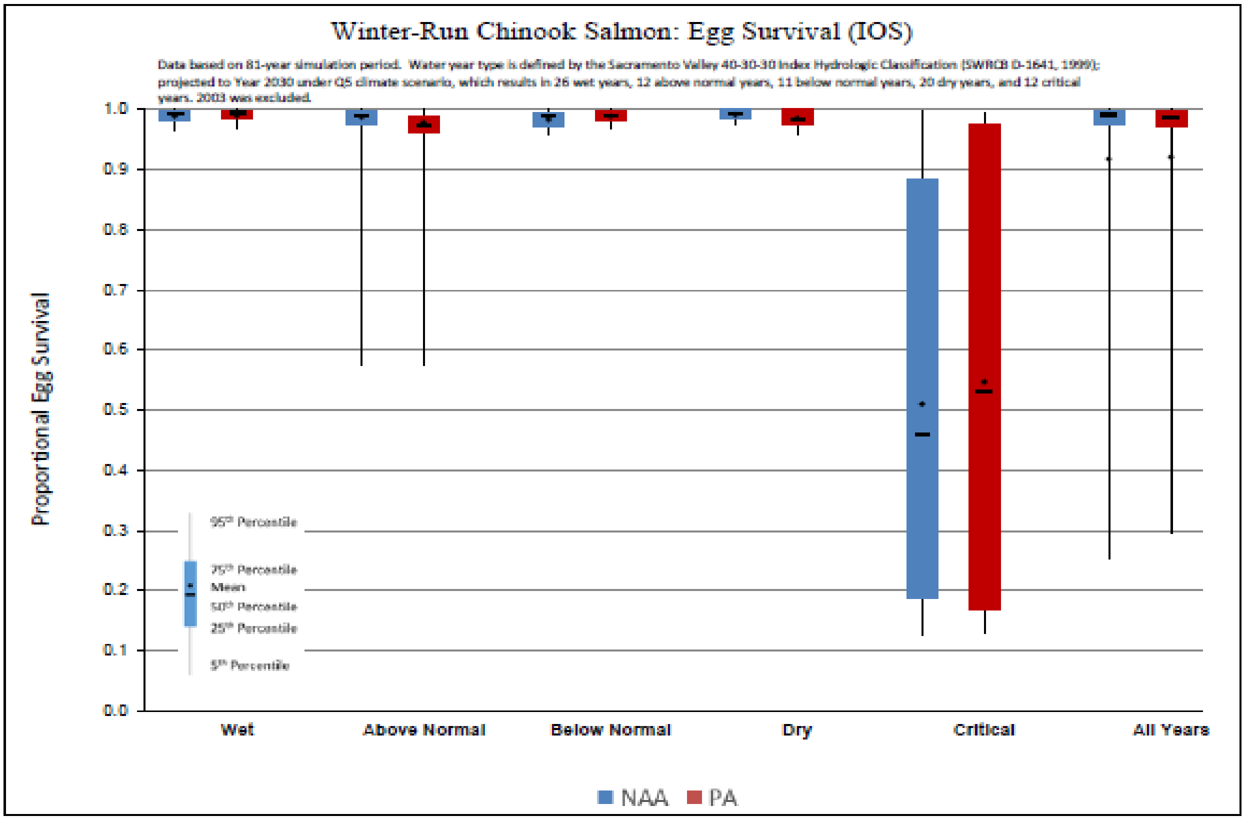
1. Spawning, which models the number and temporal distribution of eggs deposited in the gravel at the spawning grounds in the upper Sacramento River between Red Bluff Diversion Dam and Keswick Dam.
2. Early Development, which models the effect of temperature on maturation timing and mortality of eggs at the spawning grounds.
3. Fry Rearing, which models the relationship between temperature and mortality of fry during the river rearing period in the upper Sacramento River between Red Bluff Diversion Dam and Keswick Dam.
4. River Migration, which estimates mortality of migrating smolts in the Sacramento River between the spawning and rearing grounds and the Delta.
5. Delta Passage, which models the effect of flow, route selection, and water exports on the survival of smolts migrating through the Delta to San Francisco Bay.
6. Ocean Survival, which estimates the effect of natural mortality and ocean harvest to predict survival and spawning returns by age.

For a full description on methods of the IOS model as well as results summary, please refer to BA: Appendix 5D Methods Section 5.D.3 page 5.D 486.

2.5.1.2.7.5.1.1 IOS Model Results

For the first four years of the 82-year simulation period, the starting population for both scenarios are 5,000 of which 3,087.5 are female. In the fifth year, the number of female spawning adults is determined by the model's probabilistic simulation of survival to this life-stage. The model assumes all winter-run entering the Delta are smolts and that there is no flow or temperature related mortality for the river migration (RBDD to Freeport) but a mean survival of 23.5% is applied with a standard error of 1.7%. Once in the Delta, the smolts are in the Delta Passage Model (DPM) (BA, Section 5.D.1.2.2) component where flow, route selection, and water exports determine survival. Only timing into the Delta is altered from the standalone DPM as spawning events and temperature determine migration towards the Delta in IOS.

Egg survival was greatest in wet years and decreased dramatically in critical years as expected, but results between scenarios were similar with median egg survival for the NAA at 0.990 and for PA at 0.991 (Figure 2-172).

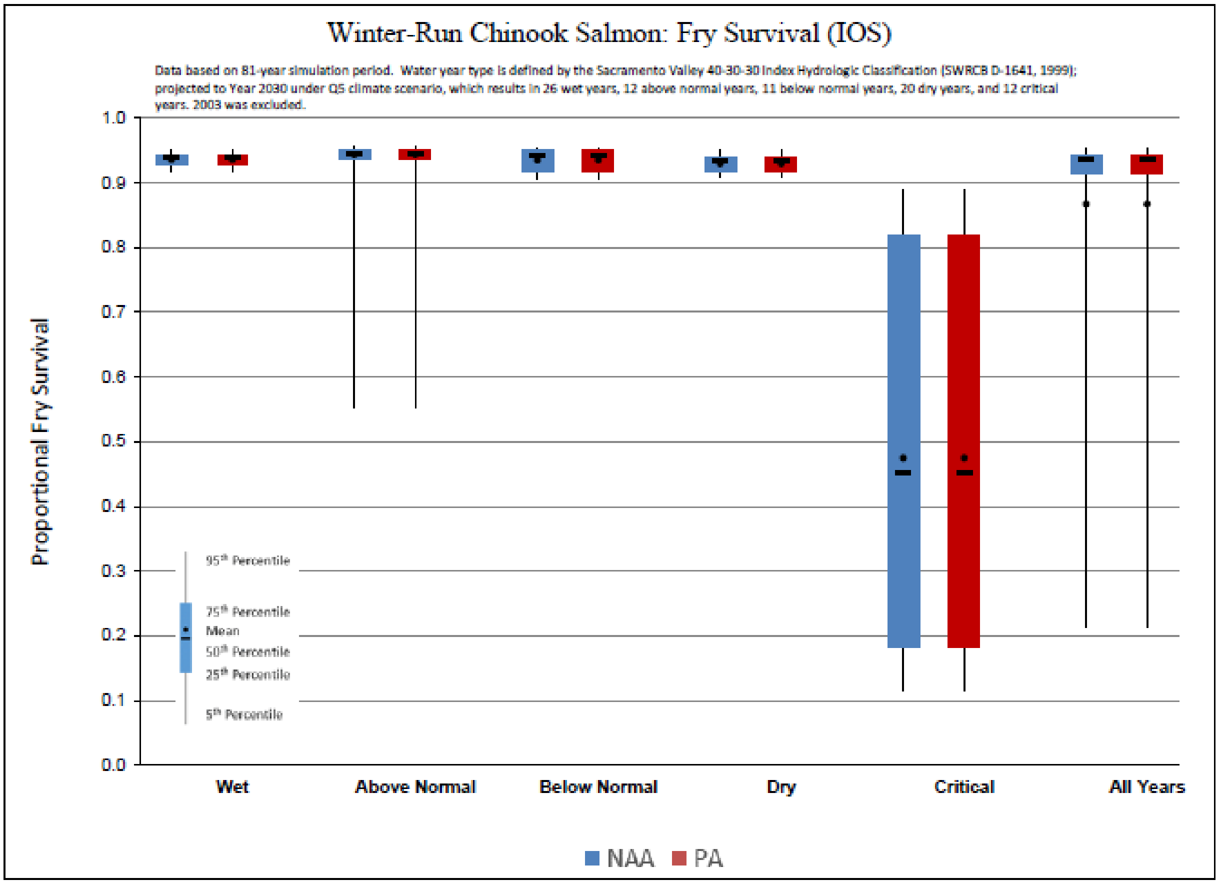


Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-172. Box Plots of Annual Egg Survival for Winter-Run Chinook Salmon Across all 81 Water Years Estimated by the IOS Model for the Comparison Between the NAA and the PA.

Note: This modeling is based on the 82-year CalSim record, which is based on water year type (i.e., starts on October of the previous year), but because the IOS model uses a calendar year cycle, there are technically only 81 years represented.

Likewise, fry survival from Keswick Dam to Red Bluff Diversion Dam is temperature dependent and was very similar between scenarios with median fry survival for NAA at 0.935 and for the PA at 0.936 (Figure 2-173).



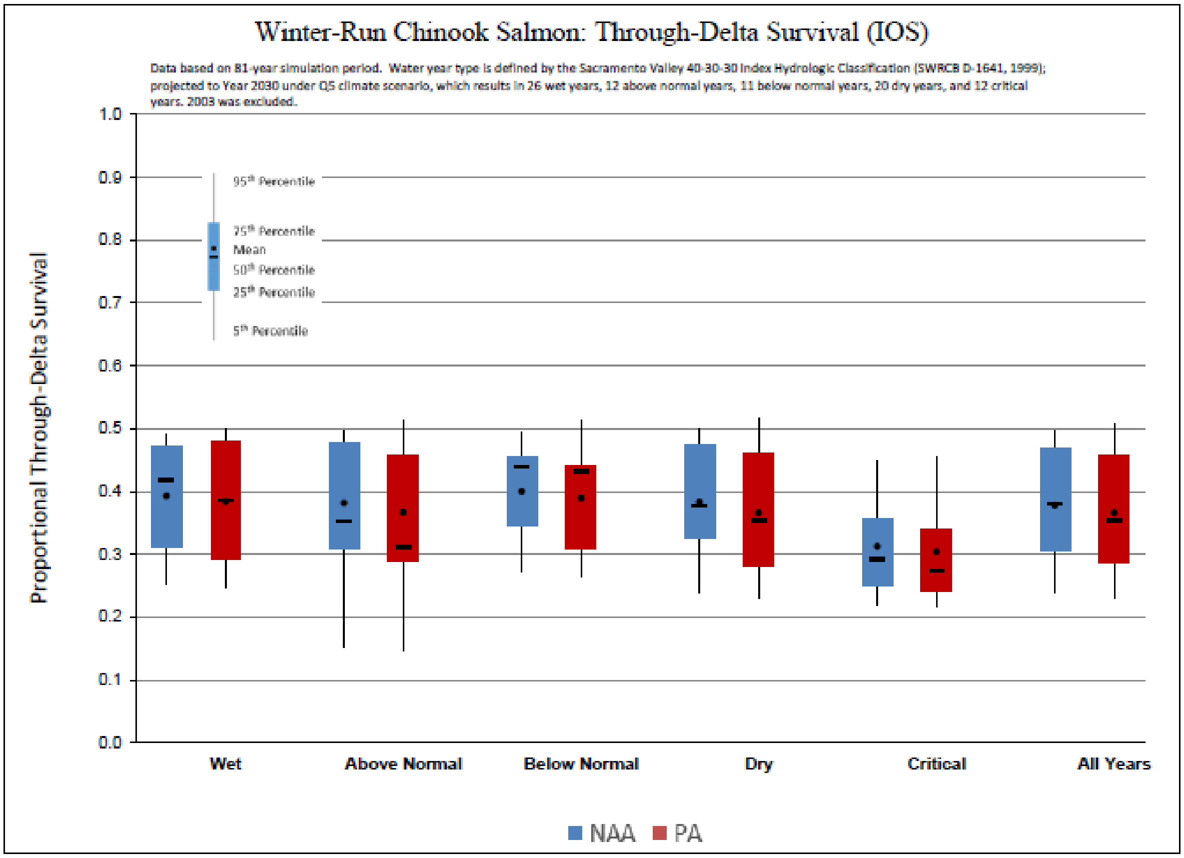
Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-173. Box Plots of Annual Fry Survival for Winter-Run Chinook Salmon Across all 81 Water Years Estimated by the IOS Model for the Comparison Between the NAA and the PA.

Note: This modeling is based on the 82-year CalSim record, which is based on water year type (i.e., starts on October of the previous year), but because the IOS model uses a calendar year cycle, there are technically only 81 years represented.

2.5.1.2.7.5.1.2 IOS Through Delta Survival (From Freeport to Chipps Island) Results

Across all years, the IOS model's median predicted through-Delta survival was 0.380 for the NAA and 0.354 for the PA, a 2.6% absolute difference, which is a relative difference in survival of 7% (Figure 2-174). Across all years, the 25th percentile value of survival for the NAA was 0.306 and 0.287 for the PA, which is a relative difference in survival of 6%. The 75th percentile value of survival for the NAA was 0.469 and for the PA it was 0.457, which is a 3% relative difference in survival.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-174. Box Plots of Annual Through-Delta Survival for Winter-Run Chinook Salmon Across all 81 Water Years Estimated by the IOS Model for the Comparison Between the NAA and the PA.

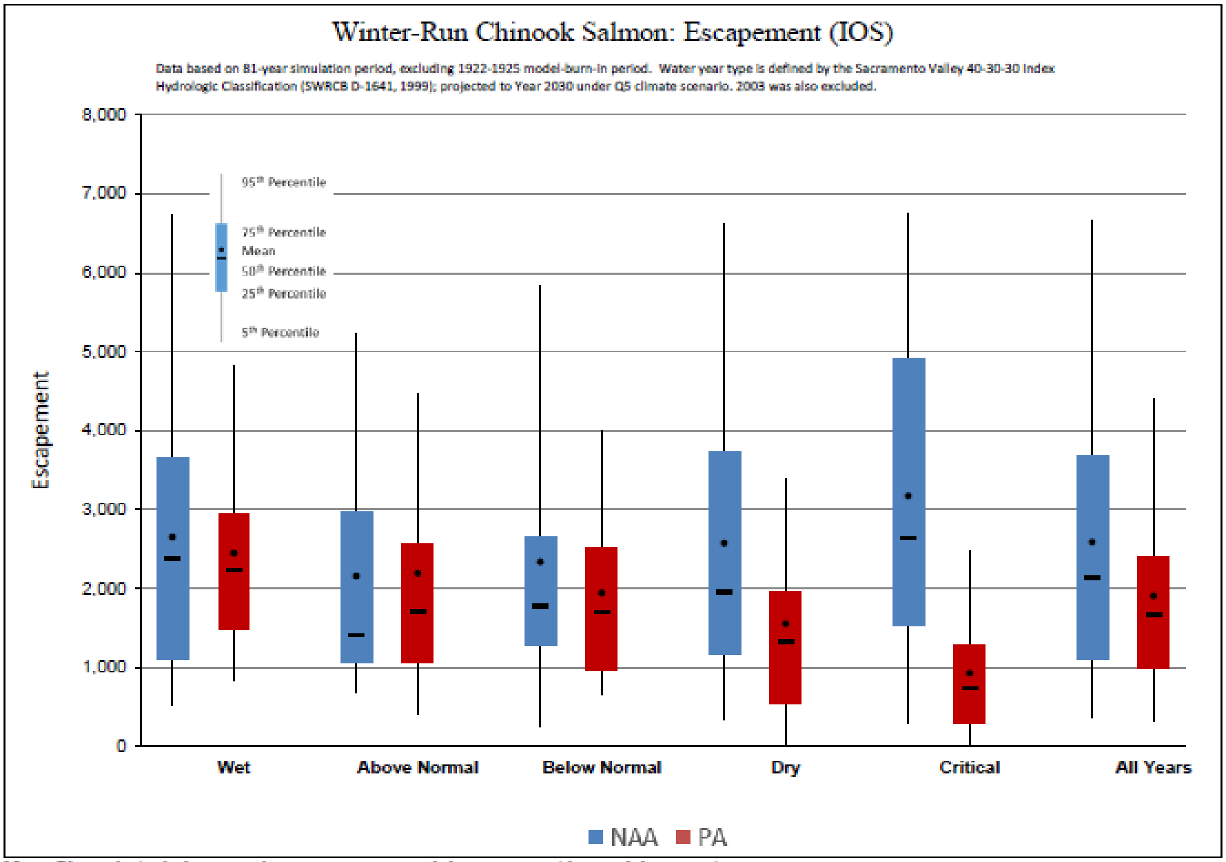
Note: This modeling is based on the 82-year CalSim record, which is based on water year type (i.e., starts on October of the previous year), but because the IOS model uses a calendar year cycle, there are technically only 81 years represented.

2.5.1.2.7.5.1.3 IOS Escapement Results

The IOS model predicted NAA median adult escapement at 2,274 and the PA median escapement of 1,699, a population difference of 25% (Figure 2-175 and Figure 2-176). In other words, the model predicted a 25% reduction of adult spawners under the PA. The 25th percentile escapement for the NAA was 1,119 and 1,007 for the PA while the 75th percentile value was 3,651 for the NAA and 2,858 for the PA which is 10% and 22% lower, respectively.

Throughout the life cycle of winter run Chinook salmon, the IOS model identified the Delta survival to be most affected by the PA, where median survival was reduced by 2.6% translating to a relative difference of 7%. This survival deficit in the Delta is the ultimate cause of the reduced escapement seen under the PA. As stated in the BA Section 5.4.1.3.1.2.1.3.4, “the IOS escapement estimates suggested that lower through-Delta survival would result in increasing divergence of PA and NAA escapement estimates. Resulting in a median 25% lower escapement estimate for the PA over the 81 years simulated.”

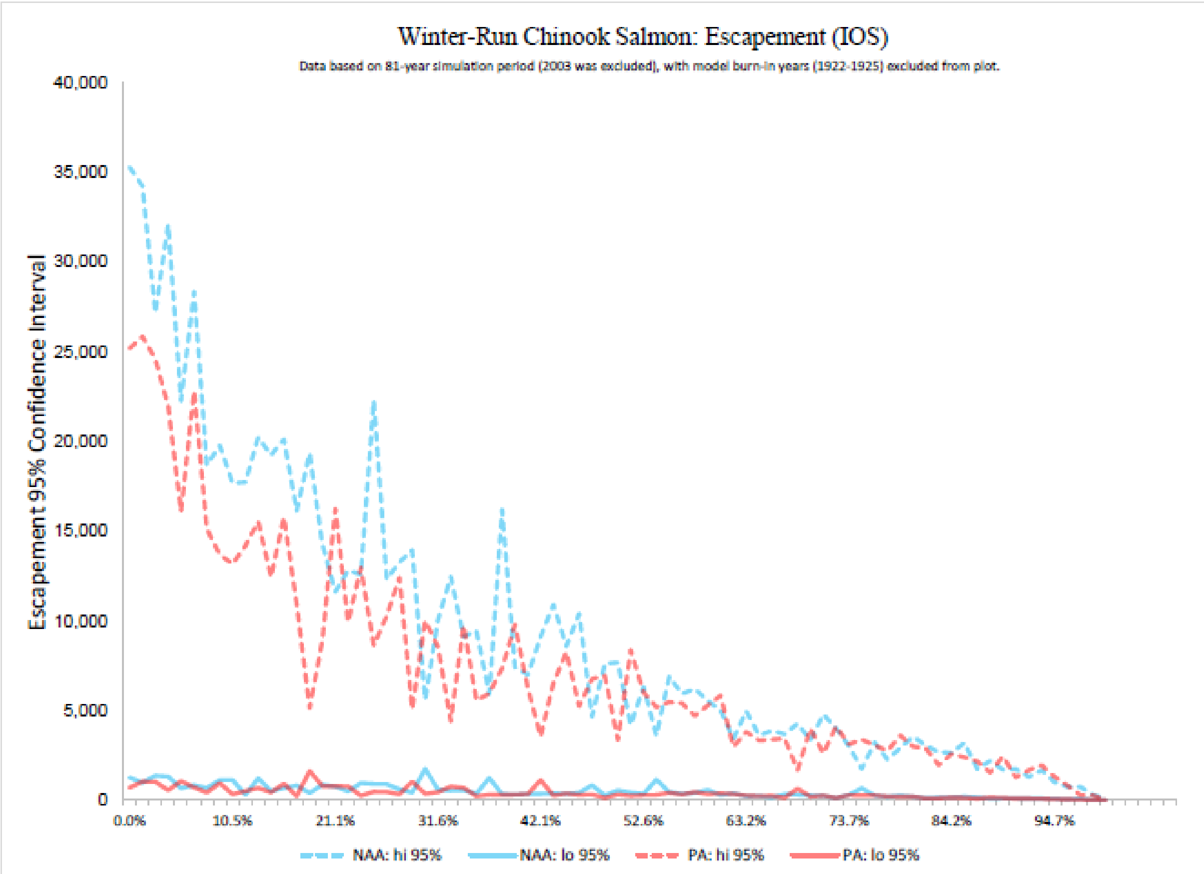
In this model, the probability of survival in the ocean is identical between the PA and NAA. IOS results show survival probabilities are similar between the two scenarios for the egg stage and the fry stage, and attributes the 25% decrease in escapement to the reduced through-Delta survival under the PA. There were differences in escapement based on water year type but this is not a reflection of hydrologic conditions for the outmigrating juveniles. It is simply a classification of hydrology for when adults returned.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 2-175. Box Plots of Annual Escapement for Winter-Run Chinook Salmon Across all 81 Water Years Estimated by the IOS Model for the Comparison Between the NAA and the PA.

Note: This modeling is based on the 82-year CalSim record, which is based on water year type (i.e., starts on October of the previous year), but because the IOS model uses a calendar year cycle, there are technically only 81 years represented.



Note: Data are sorted by mean estimate, with only 95% confidence intervals shown.

Figure 2-176. Exceedance Plots of Annual Escapement for Winter-run Chinook Salmon Across all 81 Water Years Estimated by the IOS Model for the Comparison Between the NAA and PA.

Note: This modeling is based on the 82-year CalSim record, which is based on water year type (i.e., starts on October of the previous year), but because the IOS model uses a calendar year cycle, there are technically only 81 years represented.

2.5.1.2.7.5.2 Sacramento River Winter-run Chinook Salmon Life Cycle Model

A state-space life-cycle model for winter-run Chinook salmon in the Sacramento River (WRLCM) developed by the Southwest Fisheries Science Center was used to analyze differences between the NAA and PA. The model has multiple stages, including eggs, fry, smolts, juveniles in the ocean, and mature adults in the spawning grounds. The model is spatially explicit and includes density-dependent movement among habitats during the fry rearing stage. It also incorporates survival from the habitat of smoltification to Chipps Island from the enhanced particle tracking model (ePTM). The model operates at a monthly time step in the freshwater stages and at an annual time step in the ocean stages. Parameter estimates for the model were obtained from external analyses, expert opinion, and estimation by statistical fitting to observed data. The observed data included winter-run natural origin escapement, juvenile abundance estimates at Red Bluff Diversion Dam, juvenile catches at Knights Landing, and juvenile abundance estimates at Chipps Island. To evaluate alternative management actions, 1000 Monte

Carlo parameter sets were obtained that incorporated parameter uncertainty, process noise, and parameter correlation.

The NAA and the PA were run under each of the 1000 parameter sets. It is important to note that the NAA and PA should be evaluated in a relative sense using the WRLCM, because relative comparisons are more robust than the absolute predictions from the WRLCM. Moreover, it would be incorrect to equate outputs of the model as equating to actual numbers of fish in the Sacramento River. This perspective is adopted for several reasons: 1) the underlying hydrology of the NAA and the PA are based on CalSim model outputs that are a combination of historical hydrology and future expected hydrological conditions, but do not represent actual historic or future hydrology; 2) the WRLCM model and the models used to provide input to the LCM model that use the CalSim results (HEC-RAS, DSM2, and ePTM) require assumptions that would all need to be true; and 3) the WRLCM was not calibrated to produce forecasts of actual abundances. As a result, the WRLCM should be viewed as a tool that can provide guidance on the relative performance of the two actions, and the percent difference (PA – NAA)/NAA * 100% was computed for each of the 1000 model runs.

A detailed description of the model methods and assumptions as well as all the scenario results are contained in Appendix E.

2.5.1.2.7.5.2.1 Scenarios Evaluated

A total of six scenarios were run for the CWF Alternatives that differed in hydrology sequencing, initial abundance, and additional NDD mortality values (range 0 to 5%). The additional mortality for the new North Delta diversions incorporates mortality expected due to large in-river structures and near field diversion screen effects. There is no empirical data for diversion intakes of the size and capacity proposed in the lower Sacramento River so a range of estimates were applied. Table 2-233 includes key parameters of the six scenarios run for the two CWF alternatives.

Table 2-233. Description of Modeling Scenarios Analyzed.

CWF Alternative (PA, NAA) Comparison	Initial Abundance	Hydrology	NDD near-field mortality	Rationale
Scenario 1	10,000	Standard	5%	Original scenario run
Scenario 1A	20,000	Standard	5%	Explore resiliency of larger population
Scenario 1B	10,000	Revised	5%	Test more favorable starting hydrology sequence
Scenario 2	5,000	Revised	5%	Explore smaller population under revised hydrology
Scenario 2A	5,000	Revised	0%	Explore smaller population, revised hydrology, and no near field mortality
Scenario 2B	5,000	Revised	3%	Explore smaller population, revised hydrology and 3% near field mortality.

2.5.1.2.7.5.2.1.1 Initial Abundance

Ranges from 5,000 to 20,000 were selected to allow exploration of varying populations to utilize the habitat and density dependent components of the model. These initial abundances are not necessarily meant to reflect current, historical or projected population trends.

2.5.1.2.7.5.2.1.2 Hydrology

The standard hydrology represents the 82-year historical CalSim record from 1922 to 2002. Revised hydrology represents the same 82 historical years but arranged differently so that the drought years in the 1930s occur later in the simulation run. This allows initial populations in the model to experience extreme drought conditions only after a longer sequence of more moderate hydrologic conditions.

These scenario runs covered a range of starting populations and hydrological sequences as the historical record is not predictive of what will occur in the future. Additionally, results from the original run (scenario 1) were informative in deciding what additional scenarios could provide further insight on different outcomes between the two CWF alternatives. As an example, under the original run, the abundance for both alternatives diminished greatly after the succession of extreme drought years (1929 to 1937) but only the NAA population was able to recover abundance levels over the remaining time series. The PA population was not able to replace itself and therefore not able to approach initial abundance levels throughout the remaining time series. This necessitated an approach to evaluate different scenarios for the alternatives to allow for thorough resolution of the model’s habitat and survival relationships that may not have been realized under scenario 1 for the PA Alternative.

2.5.1.2.7.5.2.1.3 Results of Scenario Evaluations NAA vs PA

Overall, the WRLCM results indicate higher abundances and higher cohort replacement rates (CRR) under the NAA relative to the PA. Under all six scenarios, abundance was higher under NAA relative to PA through the time series. Differences between alternatives were least for the scenario 2A in which NDD mortality was 0, initial abundance was 5,000 and hydrology sequencing was modified; these results are displayed in Figure 2-177. The probability that there would be higher abundance in the PA relative to the NAA at the end of the 82-year time series was approximately 0 (Figure 2-177).

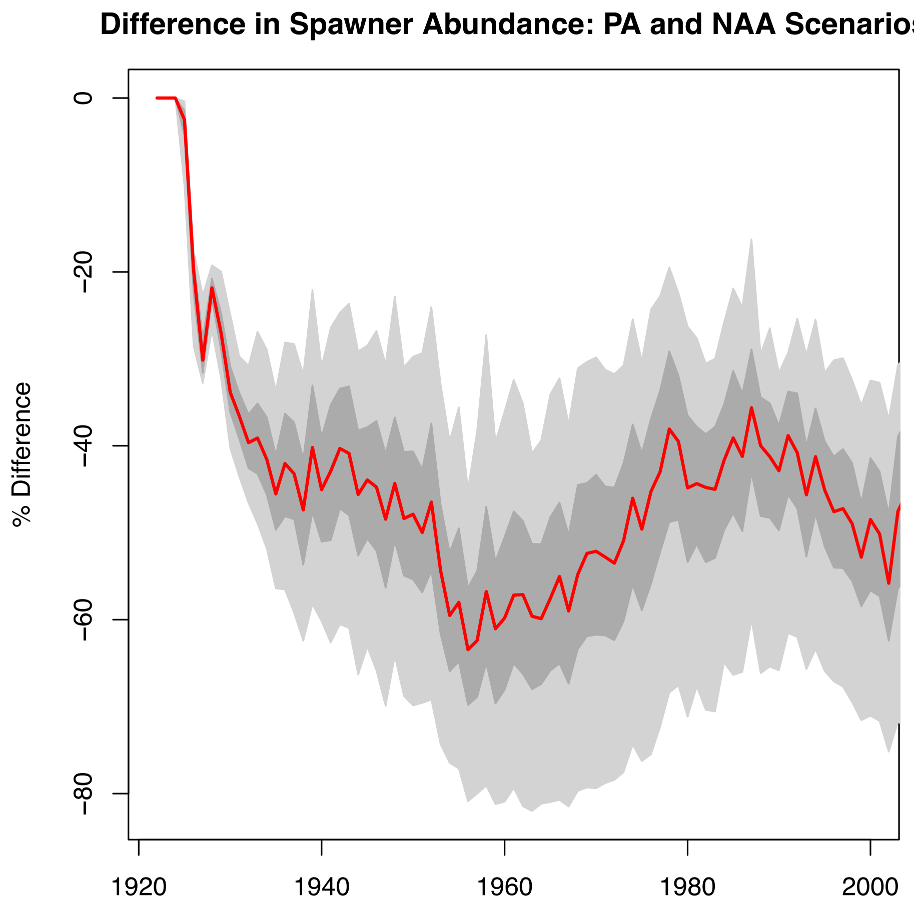


Figure 2-177. Difference in Scenario 2A Abundance (PA – NAA)/NAA X 100% Rate for 1,000 Paired Runs of the LCM Incorporating Parameter Uncertainty and Ocean Variability (NDD = 0, Initial = 5,000, hydrology altered). Median (red line), 50% Interval (dark grey) and 95% Interval (light gray) are Depicted.

The CRR is a key metric used to understand population dynamics, as it is the ability of a population to replace itself. In the six scenario runs, the NAA always had a higher mean and median CRR than the PA (Table 2-234). The relative difference in CRR between the alternatives averaged around 8% lower under the PA for all six scenarios.

Table 2-234. Relative Percent Difference in Mean and Median Cohort Replacement Rate (CRR) between Alternatives and Probability (Pr).

CWF Alternative (PA, NAA) Comparison	Percent Difference in mean CRR (PA-NAA /NAA)	Percent Difference in median CRR (PA-NAA /NAA)	Pr (NAA > PA)
Scenario 1	-8.33%	-8.16%	0.998
Scenario 1A	-8.15%	-7.95%	0.998
Scenario 1B	-8.53%	-8.74%	0.998
Scenario 2	-8.78%	-8.99%	0.998
Scenario 2A	-7.48%	-7.71%	0.998
Scenario 2B	-8.24%	-8.46%	0.998

Notes:

The NAA CRR is greater than the PA CRR over the 1,000 paired runs.

Negative value in mean and median CRR indicates lower relative productivity under the PA.

Estimates of the difference in CRR for 1000 paired runs of Scenario 2A of the LCM indicated that all but 2 paired runs had higher mean CRR for the NAA relative to the PA or a probability of 0.002 (Figure 2-178). In other words, the population is less able to replace itself under the PA.

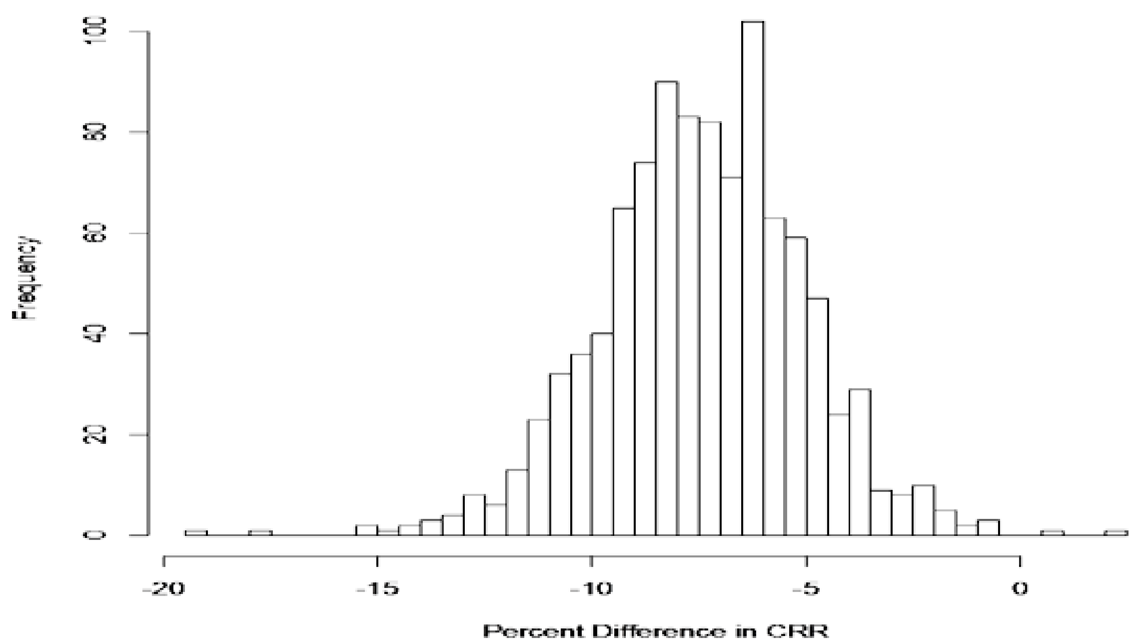


Figure 2-178. Percent Difference (PA – NAA)/NAA * 100% in Cohort Replacement Rate for Scenario 2A (initial abundance of 5000, NDD mortality of 0%, and hydrology time series altered).

The probability that the CRR under the PA will be greater than the NA was grouped for like water year types under scenario 2A to understand whether the water year type affected CRR. The probability of having a higher CRR in the PA relative to the NAA is approximately equal in the wet water year type, but in all other year types there is a low probability that the CRR will be greater in the PA than the NAA, particularly for dry and critical years (Figure 2-179).

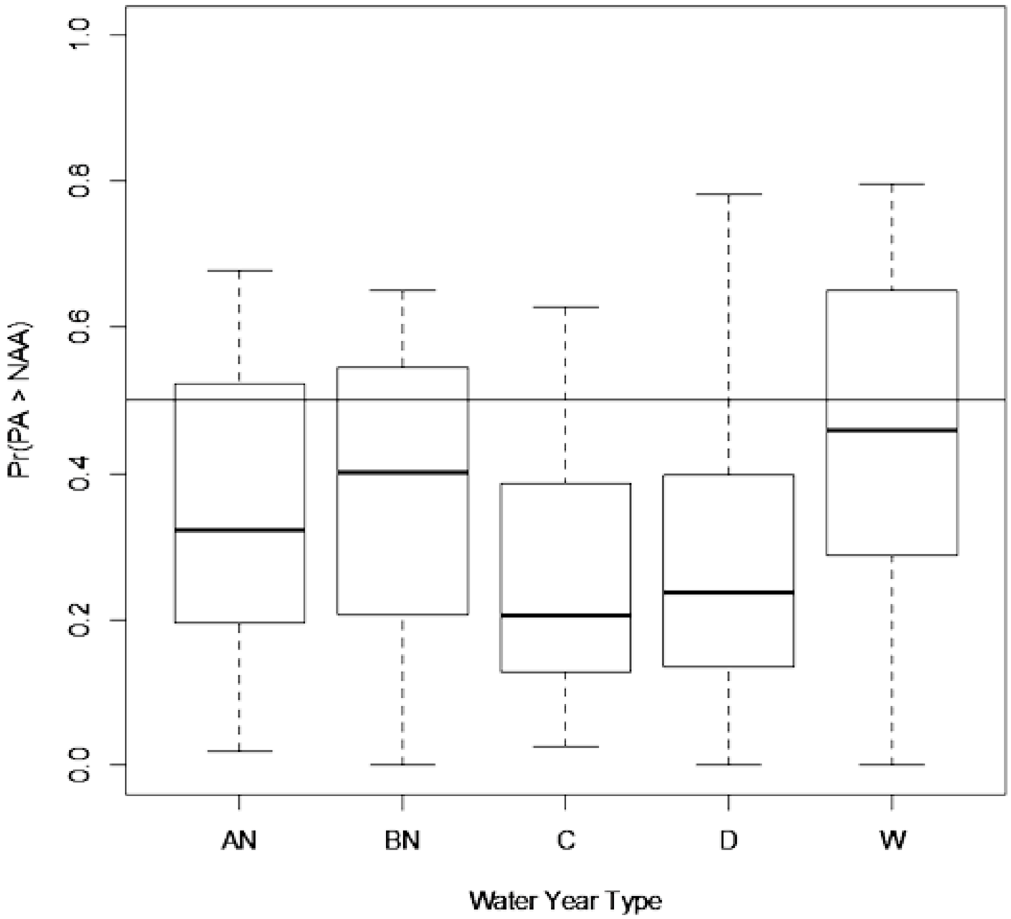


Figure 2-179. Probability that the Cohort Replacement Rate under PA is Greater than NAA by Water Year Type (AN = above normal, BN = below normal, C = critical, D = Dry, W = wet) for Scenario 2A (initial abundance of 5,000, NDD mortality of 0%, and hydrology time series altered).

2.5.1.2.7.5.2.1.4 Dynamics Leading to Differential Abundance and Productivity

The lower abundance and productivity in the PA relative to the NAA are largely due to the dynamics in the Lower River and Delta habitats. There is little difference between the two alternatives in the egg to fry mortality that occurs in the reach from Keswick to Red Bluff Diversion Dam, except for minor differences in Critical years (Figure 2-180). During critical years, the model showed that the PA had increased median survival in July and August by 6.4% and 1.2%, respectively.

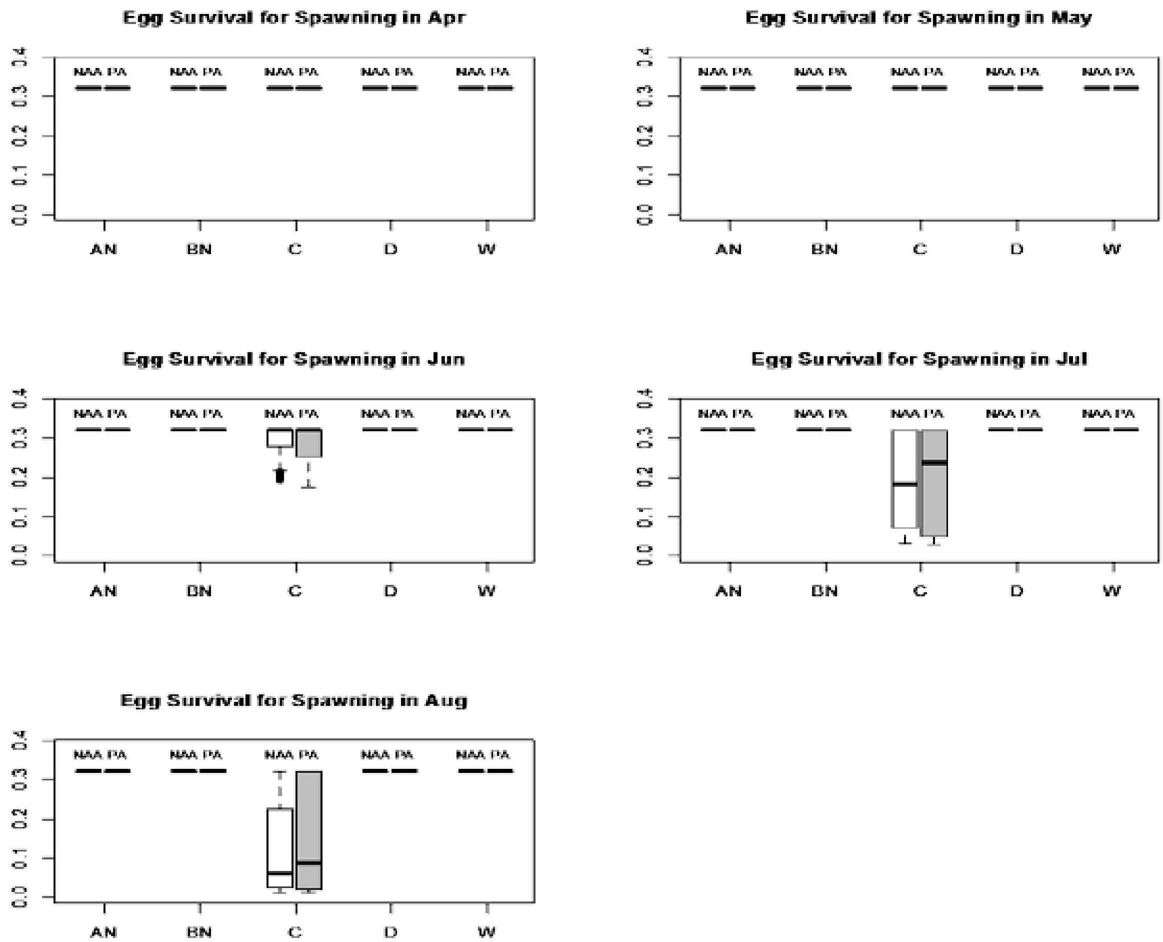


Figure 2-180. Egg to Fry Survival by Month for the NAA and PA Indicating Relatively Similar Levels of Mortality in NAA and PA that Occur only in Critical Years during June – August. (Results applicable for all scenarios.)

In contrast, there is moderate difference in the survival of smolts originating from the Lower River habitat (Figure 2-181); the Lower River habitat begins below RBDD and ends at the Delta. Figure 2-181 shows the proportion of smolts originating from different habitat areas, including the Lower River, by water year type under the NAA and PAA with scenario 2A shown as an example. Under all months and water year types, survival under the PA was lower except for the critical years in April when survival was similar (Figure 2-181). The month of January had lower median survival under the PA ranging from 1.2% in critical to 3.7 in dry and BN years. The month of February had lower median survival under the PA ranging from 2.2 in critical years to 7.0% in dry and BN year types. The month of March had the largest reduction in median survival under the PA ranging from 4.7 in wet to 9.2% in BN years. The month of April had the lowest median survival reduction under the PA ranging from 0.04% in critical years to 3% in BN years. The month of May had lower median survival under the PA ranging from 2% in BN years to 2.6% in dry years. The differences in smolt survival in the PA relative to the NAA reflect differences in flow in the North Delta. Under the PA, North Delta diversions reduce the flow relative to the NAA. The ePTM survival estimates incorporate these flow dynamics leading to reduced survival in this habitat type under PA. As a result, smolts that originate from the Lower

River habitat and then out migrate through the Delta will have higher survival under the NAA than the PA.

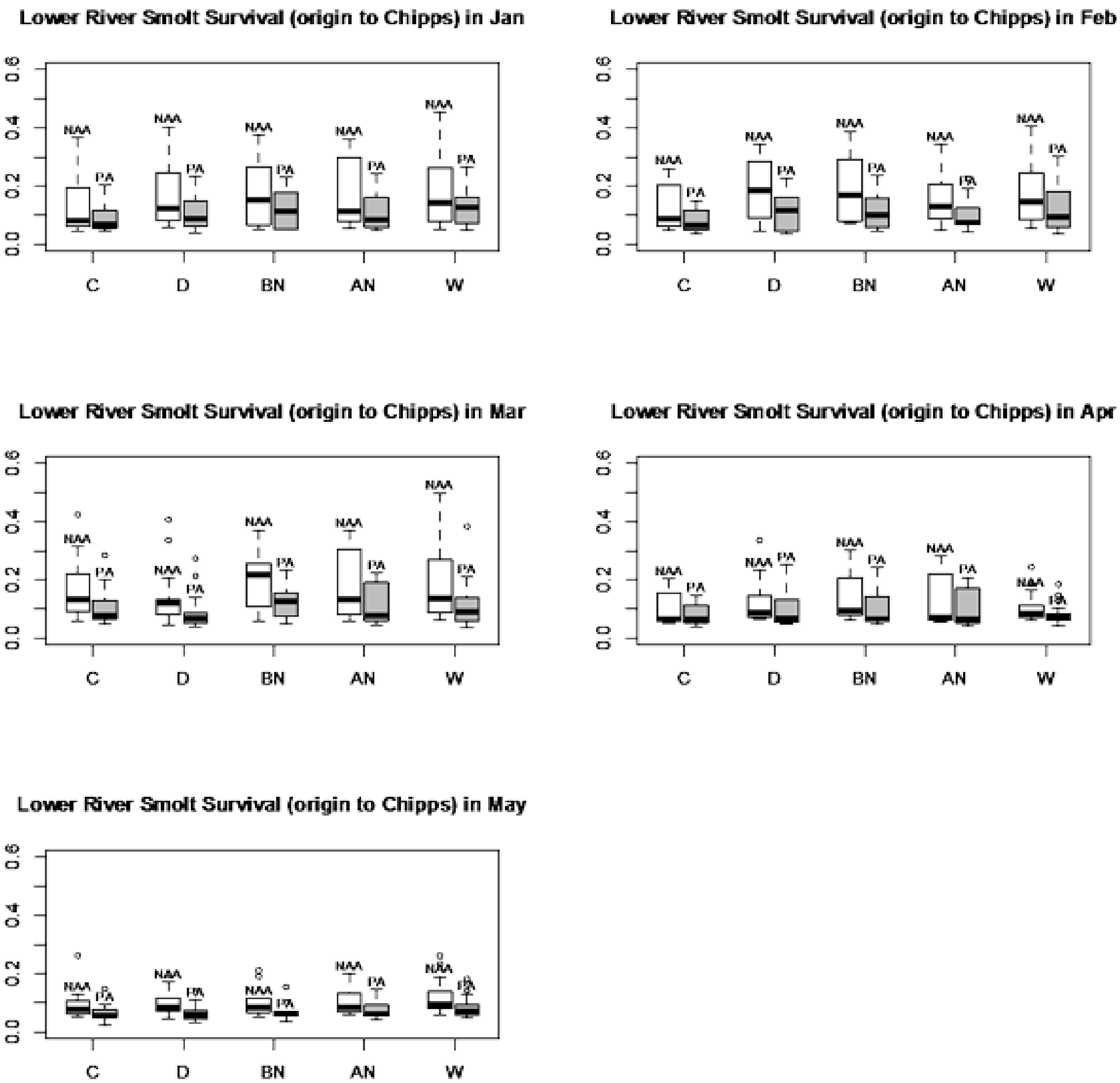


Figure 2-181. Monthly Survival of Smolts Originating from the Lower River Habitat under NAA and PA. (In general, survival results of the PA are lower than the NAA for a given water year type and month. Results applicable for all scenarios.)

There is similar survival for smolts originating from the Delta between the two scenarios (Figure 2-182). Overall, smolts that originate in the Delta have slightly higher median survival under the PA during most months and water year types. All survival increases under the PA are under 1% with the exception of wet years when median survival increase under the PA is 2% in January and 2.2% in March and BN years when median survival increase under the PA is 1.1% in February and 1.2% in April. Any median survival increase under the NAA is less than 1%. The difference in smolt survival in the PA relative to the NAA reflects differences in flow in the Delta region wide. Under the NAA, higher south Delta export levels influence flow leading to reduced survival relative to the PA; therefore, smolts that originate from the Delta habitat may have slightly higher survival under the PA than the NAA.

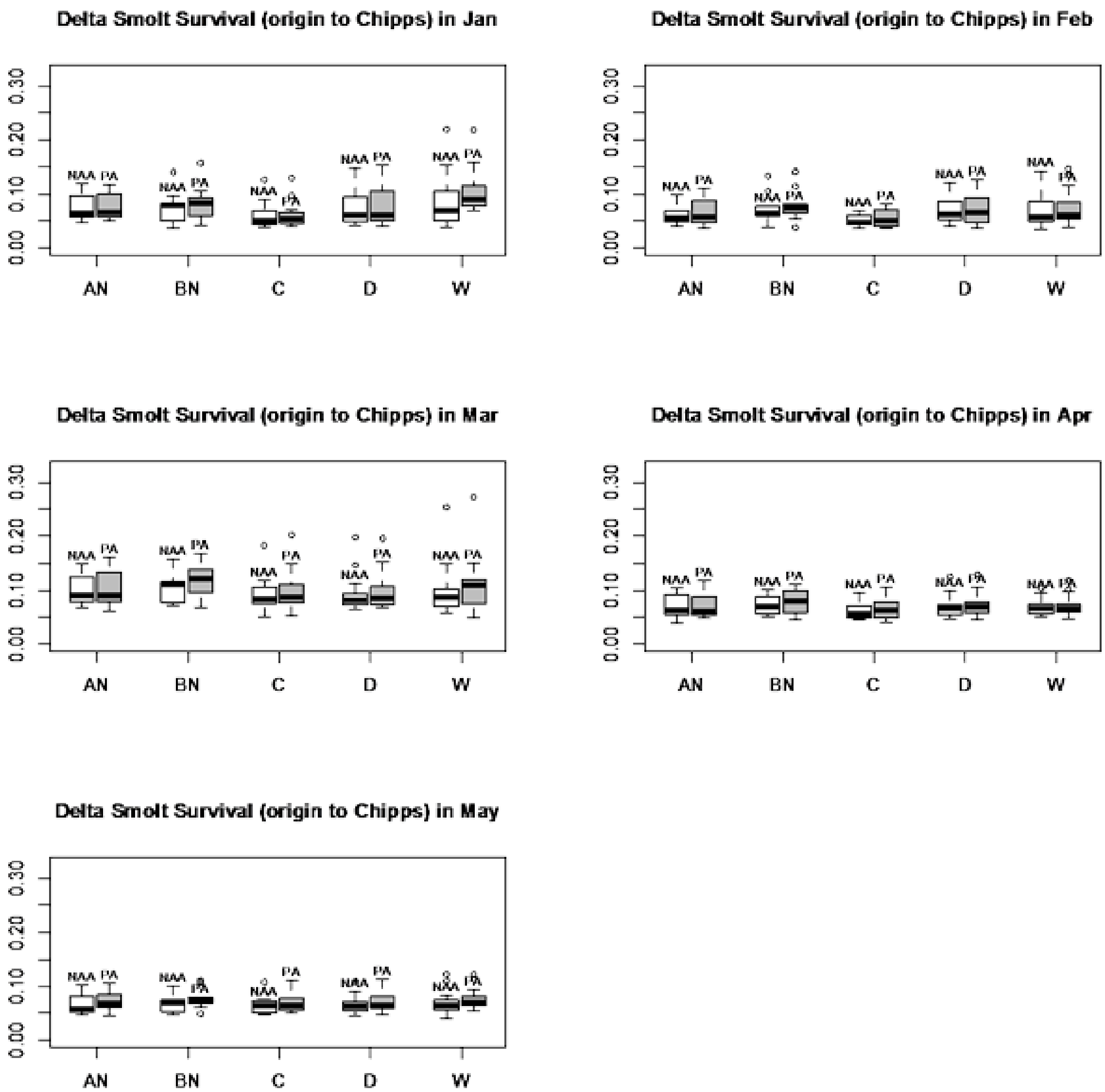


Figure 2-182. Monthly Survival of Smolts Originating from the Delta Habitat under NAA and PA. (In general, survival results of the PA are slightly higher than the NAA during most months and water year types. Results applicable for all scenarios.)

The largest difference between alternatives is the survival in the Lower River. Whether this difference will affect the population dynamics in the WRLCM depends on the proportion of smolts that originate from the Lower River habitat compared to those that originate from the Delta habitat.

Smolts do in fact originate from the Lower River habitat, and constitute the highest proportion among all five habitats with Scenario 2A shown as an example (Figure 2-183). This pattern is true across different water year types in both the NAA and PA. Smolts originate from the Lower River habitat in large proportions because they move there as fry and rear in that habitat until undergoing smoltification. Fry move into the Lower River from the Upper River over the September and October periods consistent with patterns in juvenile passage at Red Bluff Diversion Dam. Fry move out of the Lower River habitat into the Floodplain habitat when there is flow into the Yolo bypass. Fry move out of the Lower River to the Delta habitat as a function of a flow threshold at Wilkins Slough (Wilkins flow > 400 m3s-1), which causes approximately 35% of the fry to move into the Delta in the month that the flow is above the threshold. Density dependence can also cause fry to move into the Delta; higher abundances of fry in the Lower River are closer to the carrying capacity thus leading to density dependent movement into the Delta and Floodplain if it is available. The higher proportions of smolts originating from the Delta in the NAA relative to the PA across all water year types (Figure 2-183) are due in part to this density dependent mechanism.

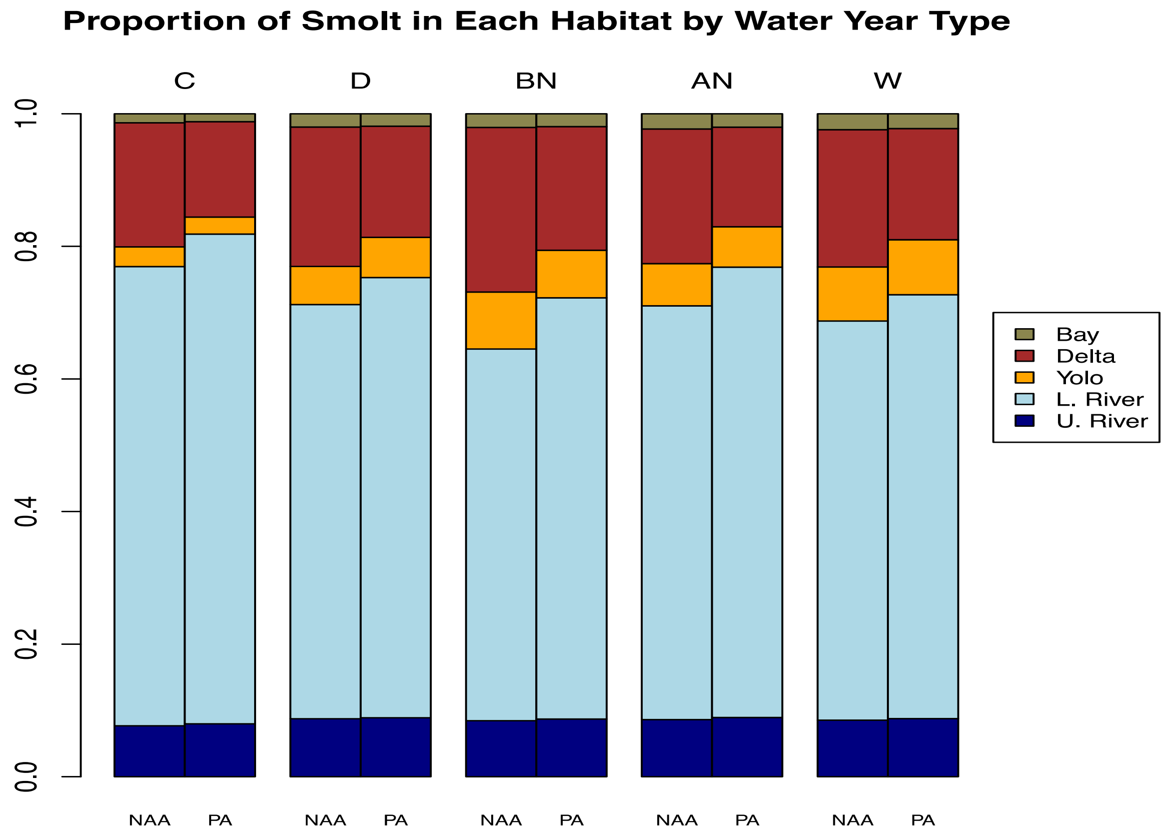


Figure 2-183. Origin of Smolts by Water Year Type under NAA and PA. (Colors represent the habitat of origin. Values represent median levels for Scenario 2A [initial abundance of 5,000, NDD mortality of 0%, and hydrology time series altered]).

This difference in survival between the NAA and PA for the Lower River habitat is causing lower freshwater productivity under the PA relative to the NAA with Scenario 2A shown as an example (Figure 2-184). These differential patterns in habitat use and differential habitat-specific survival rates translate into lower cohort replacement rate (CRR) and lower abundance in the PA relative to the NAA. This pattern is consistent across all six scenarios and across the range of parameter uncertainty used in the WRLCM simulations.

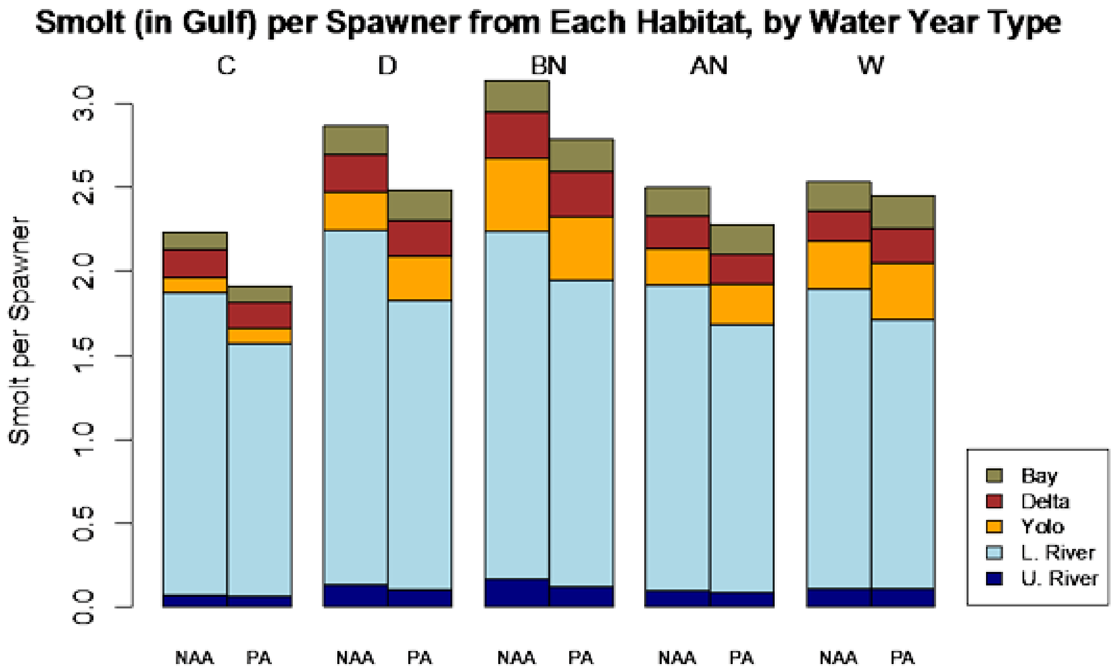


Figure 2-184. Productivity in the Freshwater (number of juveniles in the Gulf [bay estuary] per spawner). (Colors represent the habitat of origin. Values represent median levels for Scenario 2A [initial abundance of 5,000, NDD mortality of 0%, and hydrology time series altered]).

2.5.1.2.7.5.2.2 Habitat and Fish Routing Scenario Evaluation

NMFS used the WRLCM to evaluate the proposed habitat restoration from the Revised PA along with some fish routing actions (Figure 2-185). Scenario #1 was developed as a test-run for the model to implement the various proposed actions and evaluate how the model treated those additions. Scenario #2 captures the habitat restoration being proposed as part of the PA, as well habitat restoration that is being recommitted to in the Revised PA that was originally part of the NMFS 2009 BiOp RPA and/or EcoRestore.

Scenario	Benefit	Proposed Actions							
		Fish Routing				Habitat Restoration			
		Delta Cross Channel Gate Ops	Fremont Weir – Yolo Bypass	Georgiana Slough Barrier (non-physical)	Steamboat Slough Fish Guidance	Sutter Slough Fish Guidance	Upper Sac Convert to natural bank, Backwater/ Floodplain	Lower Sac Non-tidal wetland/ Floodplain	Delta Tidal Marsh
1	Low	NAA	15% more fish migrants into Yolo	Entrainment reduced by a relative 50%	Increase entrainment by 15%	Increase entrainment by 15%	Increase habitat capacity by 80 acres	Increase habitat capacity by 80 acres	Increase habitat capacity by 80 acres
2	Med	NAA	15% more fish migrants into Yolo	Entrainment reduced by a relative 50%	Increase entrainment by 15%	Increase entrainment by 15%	Increase habitat capacity by 80 acres	Increase habitat capacity by 9,000 acres	Increase habitat capacity by 11,000 acres
Model Representation	Current	PA	Proposed Fremont Weir	None	None	None	Existing habitat	Existing habitat	Existing habitat
	New	NAA	An additional percentage of fish enter Yolo	Reduce relative percentage of fish entering GS	Increase percentage of fish entering Steamboat Slough	Increase percentage of fish entering Sutter Slough	Add habitat	Add habitat	Add habitat
	Steps	DCC closure as NAA	Adjust LCM code	1. Adjust Hydrofile 2. ePTM run 3. LCM	1. Adjust Hydrofile 2. ePTM run 3. LCM	1. Adjust Hydrofile 2.ePTM run 3. LCM	1. Alter HEC-RAS geometry to estimate increased habitat capacity 2. LCM	1. Alter HEC-RAS geometry to estimate increased habitat capacity 2. LCM	1. Alter HEC-RAS geometry to estimate increased habitat capacity 2. LCM

Figure 2-185. Habitat Restoration and Fish Routing Scenarios Evaluated with the Winter-run Life Cycle Model.

This analysis focused on the evaluation of change in cohort replacement rate between Scenario 2 and NAA as compared to the original analysis of the change in cohort replacement rate between the PA and NAA to demonstrate the population level benefits of the proposed habitat restoration and fish routing activities. The percent difference in mean cohort replacement rate under SA was approximately 1% better under all the scenarios when compared to the PA (Table 2-235 and Table 2-236). The restored habitat in the Lower River increased the proportion of fry rearing and subsequently smolting in this habitat; however, the Lower River smolts experienced through-delta survival rates that were affected by the north Delta diversions. The implementation of non-physical barriers at Georgiana Slough, Steamboat Slough, and Sacramento Slough under S2 did improve the survival rates of smolts originating in the Lower Sacramento River over the PA. These routing measures did not fully mitigate for the overall reduction in smolt survival due to operation of the North Delta Diversions under the PA, however.

Table 235. Percent Difference in Winter-run Chinook Salmon Cohort Replacement Rate Between Scenario Two (S2) and NAA.

CWF Alternative (S2, NAA) Comparison	Percent Difference in mean CRR (S2-NAA /NAA)	Percent Difference in median CRR (S2-NAA /NAA)	Pr (NAA > S2)
Scenario 1	-7.19%	-6.58%	0.999
Scenario 1A	-7.85%	-6.31%	0.999
Scenario 1B	-8.16%	-6.64%	0.998
Scenario 2	-8.37%	-6.70%	0.998
Scenario 2A	-6.98%	-5.36%	0.998
Scenario 2B	-7.80%	-6.16%	0.998

Table 2-236. Percent Difference in Winter-run Chinook Salmon Cohort Replacement Rate Between PA and NAA.

CWF Alternative (PA, NAA) Comparison	Percent Difference in mean CRR (PA-NAA /NAA)	Percent Difference in median CRR (PA-NAA /NAA)	Pr (NAA > PA)
Scenario 1	-8.72%	-7.72%	0.997
Scenario 1A	-8.51%	-7.53%	0.998
Scenario 1B	-8.92%	-7.92%	0.998
Scenario 2	-9.18%	-7.94%	0.998
Scenario 2A	-7.75%	-6.56%	0.998
Scenario 2B	-8.59%	-7.37%	0.998

NMFS expected the results to show more improvement in the winter-run Chinook salmon cohort replacement rate under S2. This moderate improvement is likely due to the population dynamics of the winter-run Chinook salmon (one population at low abundance) and how the different aspects of the species life-cycle are modeled relative to the fishes habitat use. The proposed Delta habitat restoration did not improve the cohort replacement rate under this scenario because the current low abundance of the winter-run population is not limited by Delta rearing habitat. As the population abundance increases because of recovery action implementation (such as newly reintroduced populations in Battle Creek and upper Sacramento River – above Shasta Reservoir) the availability of additional tidal Delta rearing habitats will become more important for the species.

2.5.1.2.8 Reduced Delta Outflows

The Delta estuary is a transition zone important for salmonid and sturgeon life-stages. Several studies have highlighted the importance of winter and spring outflows on migration, rearing and overall survival for anadromous fish (Kjelson et al. 1981, Kjelson et al. 1982, Kjelson & Brandes 1989, Dettman et al. 1987, Brandes et al. 2006, Stevens & Miller 1970, Fish 2010). Freshwater inflow to the San Francisco Estuary influences the quantity and quality of habitat available for anadromous species and drives key ecological processes. Survival and abundance of juvenile fish and the food web they depend on are greatly influenced by the overall health of the estuary. The San Francisco Estuary is highly altered by changes in land use and hydrological regimes that little resemble historical flows. Food webs have become highly altered by invasive species and native species are continuing to decline. In this section, we examine some of the changes that could occur from reduction in Delta outflow under the PA.

2.5.1.2.8.1 Salmonids

Delta outflows are ecologically important to salmonids as timing and quantity of flow can expand rearing habitat, increasing life history diversity, and stimulate migration to expand distribution, abundance, and overall survival (Sommer et al. 2001, del Rosario et al. 2013, Kjelson et al. 1981, Kjelson et al. 1982, Kjelson and Brandes 1989, Dettman et al. 1987, Brandes et al. 2006, Stevens and Miller 1970, and Fish 2010). Fall-run Chinook salmon likely have the most diverse rearing strategies of the four CV Chinook salmon runs and are the most dependent on suitable rearing habitat in the Delta and estuary. Fall-run Chinook salmon populations can migrate soon after emergence and rear in brackish estuaries (Hatton 1940, Healey 1991, Williams 2006, Bottom et al. 2008). Delta outflows, particularly during wetter water year types, could provide extended rearing habitat for fall-run Chinook salmon fry west of the Delta (i.e., San Pablo and San Francisco bays) by tempering salinity and creating conditions suitable for fry rearing (Redler et al. 2016, Kjelson et al. 1982). Though winter-run Chinook fry (<70 mm) have not been detected in the Bay, they have frequently been detected in the Delta during November as fry-sized fish. They are hypothesized to rear in the Delta for several weeks or months when they enter the Delta in the fall or early winter at fork lengths under 100 mm (del Rosario et al. 2013). Evidence that suggests the Delta and Bay is important for rearing strategies of fall-run and winter-run Chinook salmon can be extended to the other two runs. Spring-run are mainly detected entering the Delta during April as smolts but this is based on length-at-date criteria that often confound spring-run and fall-run due to similar sizes. Spring-run length at date fish have been detected entering the Delta as early as December at forklengths (36 mm to 40 mm) that suggest they would need several weeks/months to become physiologically ready for full ocean salinities. Late fall-run appear to rear upriver for extended periods and enter the Delta during summer through early winter primarily as smolts. Unlike larger Chinook salmon smolts and steelhead, which are physiologically ready for seawater migration, Chinook salmon fry cannot tolerate full ocean salinity (>33 ppt) but commonly use brackish estuaries for rearing (Bottom et al. 2014).

While there is no direct evidence that rearing in San Pablo Bay is beneficial in and of itself, studies have indicated parr and fry residing in brackish waters do contribute to adult returns (e.g., Miller et al. 2010, Sturrock et al. 2015). In addition, diversity in available habitat, including regions such as San Pablo Bay, is beneficial in providing a portfolio of suitable rearing habitat areas.

Steelhead smolts use the lower Delta and estuary primarily as a migratory corridor to reach the marine environment and for limited rearing while transiting these waterbodies (Appendix B Rangewide Status of the Species of this Opinion). Because there are no prescribed criteria for the minimum Delta outflows necessary for steelhead migration to the ocean, and steelhead smolts are of sufficient size and maturity to adapt to full ocean salinity conditions upon entrance into the lower Delta, there is no adverse effect physiologically of entering the brackish water mixing zone at different river miles along the longitudinal axis of the Delta. However, outflows mimicking natural flow magnitudes would assist fish in transiting the lower estuary to the ocean and provide for a healthier ecosystem in the estuary. A healthy estuarine ecosystem would provide adequate forage base for migrating salmonids, including steelhead, to maintain nutritional status and body condition during the smoltification process and enter the marine system in a healthy condition. Maintaining a healthy body condition allows for higher survival when entering the marine environment by allowing smolts to avoid predators and survive until they reach suitable foraging areas in the nearshore environment.

An analysis on potential changes in Delta outflow that could impact expanded rearing habitat for fall-run Chinook salmon fry in San Francisco Bay was described in the BA and found little change between scenarios in exceedance of recommended January through March outflow in wetter years (BA Appendix 5A). Data gaps on the importance of Delta outflow that expand life history diversity for salmonids and fall-run Chinook salmon in particular may be better understood by correlating salinity regimes in San Pablo Bay with fry presence or abundance. Kjelson et al. 1982 hypothesized that fall-run fry chinook salmon (<70 mm) would not find habitat suitable in the Bay when salinities were over 20 ppt. Analysis of San Pablo Bay salinities and fry Chinook salmon presence indicate that when mean monthly outflow is under 20,000 cfs, fry sampling locations in San Pablo Bay always averaged over 20 ppt (Redler et al. 2016). When mean monthly Delta outflow is over 38,000 cfs, salinity in Bay sampling sites always averaged under 20 ppt. What this means in terms of fry presence is that Chinook salmon fry have not been sampled in the Bay when mean Delta outflows were under 20,000 cfs and Bay sampling sites average over 20 ppt (Redler et al. 2016). When mean monthly Delta outflows range between 20,000 cfs to 38,000 cfs, salinity averages between 12 ppt to 27 ppt and fry may or may not be present. When mean monthly outflows were over 38,000 cfs and salinities were under 20 ppt, Chinook salmon fry are commonly sampled in the Bay (Redler et al. 2016). Additionally, it was rare to see fry when averaged salinities rose above 13 ppt and uncommon to not detect Chinook salmon fry when average salinities were under 13 ppt.

Examination of the two scenarios on exceedance of these mean monthly outflows could indicate the probability of salinities in the Bay habitat being suitable for fry rearing (>38,000 cfs) or unsuitable (<20,000 cfs). In between these flows there is variability in salinity regimes and fry presence/absence.

Table 2-237. Exceedance of 20,000 cfs or 38,000 cfs Mean Monthly Delta Outflow During the Months of January, February, and March.

Exceedance of 20,000 cfs monthly outflow	NAA	PA	PA minus NAA
Jan	53%	54%	1%
Feb	69%	67%	(2%)
Mar	59%	54%	(5%)
Exceedance of 38,000 cfs monthly outflow	NAA	PA	PA minus NAA
Jan	37%	35%	(2%)
Feb	49%	48%	(1%)
Mar	35%	35%	0%

The analysis indicates that, of the 82-year historical CalSim record, approximately 35% of years during January and March and almost half the years in February should provide suitable habitat for fry rearing in the Bay under the PA, thus allowing for expression of life history diversity (Table 2-237). Additionally, there are some small changes in exceedance of these monthly flows between the scenarios. The NAA meets the minimum criteria of exceeding 20,000 cfs monthly outflow 2% and 5% more often in February and March, respectively, but 1% less in January (Table 2-237). Exceedance of a monthly flow that would likely promote fry rearing in the Bay (>38,000) is met more frequently under NAA in January and February by 1% to 2%, respectively (Table 2-237).

In addition to providing expanding rearing opportunities, spring outflows in the 20,000 to 30,000 cfs range at Rio Vista results in higher juvenile Chinook salmon abundance at Chipps Island (Brandes et al. 2006, Brandes and McLain 2001, Dekar et al. 2013).

2.5.1.2.8.1.1.1 Green Sturgeon

Sturgeon also benefit from higher Delta ouflows particularly in the spring months. Previous analysis of sturgeon recruitment showed that mean April-May Delta outflow exceeded 25,000 cfs in years of relatively strong recruitment (USFWS 1995 and Kohlhorst 1991). This has been corroborated by more recent studies (Fish 2010, Gingras et al. 2013). Additional analysis of Gingras et al. (2013) year class index data and April-May Delta outflow suggests that a much greater year class index is more likely to occur when outflows are at least 44,000 cfs.

2.5.1.2.9 Facility Maintenance

Ongoing operations of the newly constructed facilities associated with the proposed project will require regular maintenance at the north Delta facilities (intakes, conveyance facilities, and appurtenance structures), the HOR gate, and the south Delta facilities. Maintenance at these facilities (described in more detail below) may result in adverse effects to fish. Assumptions on maintenance type and frequency at each facility were determined jointly between NMFS and Reclamation/DWR, and are based on professional judgement. Reclamation will continue to develop and coordinate regularly planned maintenance with NMFS. Timing of planned maintenance will occur during the same proposed construction in-water work windows at each facility, see Table 2-1 (NDD: June 15 to October 31; CCF: July 1 to October 31; HOR: August 1 to October 31; Barge Landings: July 1 to August 31).

2.5.1.2.9.1 Sediment Concentration and Turbidity Stress, Contaminant Exposure, and Reduced Prey

Several maintenance activities may result in increased sediment mobilization and turbidity, which may also increase release of contaminants into the water column, resulting in adverse effects to fish.

2.5.1.2.9.1.1 Dredging

Periodic dredging at the following facilities may be necessary for ongoing operations to continue as designed.

2.5.1.2.9.1.1.1 North Delta Intake Locations

The assumption for necessary maintenance dredging of the river channel in front of each intake will occur every 3-5 years. Additionally, a larger maintenance dredging effort may be necessary on a less frequent schedule after high flows events. The assumption for the frequency of this larger maintenance dredging effort is approximately every 10-15 years based on recent historic frequency of high flow events (>100,000 cfs). The activity will include suction dredging around the intake structures, and mechanical excavation around intake structures using track-mounted equipment and a clamshell dragline. Mechanical excavation will occur behind a floating turbidity control curtain. Activities will include AMMs as described in the BA.

2.5.1.2.9.1.1.1.1 Anadromous Species Exposure and Risk

Because the activity and in-water work window remains the same as described in the Construction Effects, we refer to the following sections for species exposure and risk, and associated adverse effects: Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress, Section 2.5.1.1.2.4.1 Dredging at North Delta Intake Locations, Section 2.5.1.1.3 Contaminant Exposure, Section 2.5.1.1.3.4.1 Dredging at North Delta Intake Locations, and Section 2.5.1.1.5 Reduced Prey Availability, and Section 2.5.1.1.5.4 Dredging.

2.5.1.2.9.1.2 Clifton Court Forebay

The only assumed necessary maintenance dredging at CCF is of the SCCF, which is assumed to be very infrequent, approximately every 15 years. Dredging would occur in the same manner as described in Section 2.5.1.1.2.4.2, and will include any AMMs described in the BA.

2.5.1.2.9.1.2.1 Anadromous Species Exposure and Risk

Because the activity and in-water work window remains the same as described in the Construction Effects, we refer to the following sections for species exposure and risk, and associated adverse effects: Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress, Section 2.5.1.1.2.4.2 Dredging at CCF, Section 2.5.1.1.3 Contaminant Exposure, Section 2.5.1.1.3.4.2 Dredging at CCF, Section 2.5.1.1.5 Reduced Prey Availability, and Section 2.5.1.1.5.4 Dredging.

2.5.1.2.9.1.3 HOR Gate

The frequency assumption for required maintenance dredging of the river channel at the HOR Gate is every 3-5 years, to remove accumulated sediment from around the gate structure. Periodic removal of accumulated sediment after major flow events (> 30,000 cfs) is assumed will occur every 5-10 years based on recent historic Vernalis flows.

2.5.1.2.9.1.3.1 Anadromous Species Exposure and Risk

Because the activity and in-water work window remain the same as described in the Construction Effects, we refer to the following sections for species exposure and risk, and associated adverse effects: Section 2.5.1.1.2 Sediment Concentration and Turbidity Stress, Section 2.5.1.1.2.4.3 Dredging at HOR gate, Section 2.5.1.1.3 Contaminant Exposure, Section 2.5.1.1.3.4.3 Dredging at HOR gate, and Section 2.5.1.1.5 Reduced Prey, Section 2.5.1.1.5.4 Dredging.

2.5.1.2.9.2 Increased Temperature, Reduced Prey Availability, and Increased Predation Risk

As described in Section 2.5.1.1.4 Increased Temperature, water temperatures can be affected by human induced activity associated with the PA. Maintenance of new facilities have the potential to increase water temperatures, reduce prey availability and increase predation risk.

2.5.1.2.9.2.1 Maintenance Clearing and Grubbing

Reclamation/DWR may determine the need to clear vegetation from the levees/banks associated with the new PA facilities periodically. This will be performed in the same manner described in Section 2.5.1.1.4.1 Clearing and Grubbing at Construction Sites, but is only anticipated to occur at the CCF.

2.5.1.2.9.2.1.1 Clifton Court Forebay

The assumptions for necessary embankment maintenance include vegetation control approximately two times a year, for approximately 20 days of disturbance a year.

2.5.1.2.9.2.1.1.1 Anadromous Species Exposure and Risk

Because the activity and in-water work window remain the same as described in the Construction Effects, we refer to the following section for species exposure and risk, and associated adverse effects: Section 2.5.1.1.4 Increased Temperature, Section 2.5.1.1.4.1 Clearing and Grubbing at Construction Sites, Section 2.5.1.1.5 Reduced Prey Availability, and Section 2.5.1.1.5.5 Clearing and Grubbing at Construction Sites. Although fish that have become entrained into the SCCF will be susceptible to increased water temperatures, any increases due to the continuation of vegetation removal along the embankments of such a wide-open water area would be difficult to detect; therefore, fish species are not expected to be adversely affected as a result. Any fish entrained into the CCF would continue to forage, and therefore loss of inputs due to vegetation removal has the potential to adversely affect fish. Section 2.5.1.1.5.5.1 Species Exposure and Risk describes the extent of effects expected.

2.5.1.2.9.3 Physical Impacts to Fish

Physical disturbance may occur as a result of necessary maintenance of new facilities of the PA. The physical disturbance may be through displacement or disruption of normal behaviors. Displacement may temporarily expose juvenile fish to a greater risk of predation. Some adult and juvenile anadromous fish may experience migration delay during maintenance activities. Disturbances may also potentially increase stress levels, which could result in lower reproductive success in adults and reduced growth in juveniles.

2.5.1.2.9.4 Maintenance Dredging

Periodic dredging may be needed for ongoing operations of the PA. Juvenile fish are especially vulnerable to crushing by equipment that enters the water for dredging and juvenile fish can become entrained into the dredger.

2.5.1.2.9.5 North Delta Intake Locations

The frequency of necessary maintenance dredging at the NDD locations is described above in Section 2.5.1.2.6.1.1.1 North Delta Intake Locations.

2.5.1.2.9.5.1 Anadromous Species Exposure and Risk

Because the activity and in-water work window remain the same as described in the Construction Effects, we refer to the following section for species exposure and risk, and associated adverse effects: Section 2.5.1.1.7.2. Dredging Entrainment.

2.5.1.2.9.6 Clifton Court Forebay

The frequency of necessary maintenance dredging at the CCF is described above in Section 2.5.1.2.6.1.1.2 Clifton Court Forebay.

2.5.1.2.9.6.1 Anadromous Species Exposure and Risk

Because the activity and in-water work window remain the same as described in the Construction Effects, we refer to the following section for species exposure and risk, and associated adverse effects: Section 2.5.1.1.7.2. Dredging Entrainment.

2.5.1.2.9.7 HOR Gate

The frequency of necessary maintenance dredging at the HOR gate location is described above in Section 2.5.1.2.6.1.1.3.

2.5.1.2.9.7.1 Anadromous Species Exposure and Risk

Because the activity and in-water work window remain the same as described in the Construction Effects, we refer to the following section for species exposure and risk, and associated adverse effects: Section 2.5.1.1.7.2. Dredging Entrainment.

2.5.1.2.9.8 Dewatering Capture/Release

Necessary maintenance of the HOR gate and associated boat lock will periodically include dewatering for repairs. The assumed frequency for this maintenance was determined to be approximately every 5 to 10 years. As described in Section 2.5.1.1.7.4 Dewatering

Capture/Release, any fish present during dewatering, which will include fish capture and release, are expected to be subject to adverse effects.

2.5.1.2.9.8.1 Anadromous Species Exposure and Risk

Dewatering for maintenance of the HOR gate and boat lock will occur during the same in-water work window as identified for construction of the HOR gate, and will therefore be expected to result in similar adverse effects to those fish present, as described in Section 2.5.1.1.7.4.3 HOR Gate.

2.5.1.3 Ancillary Delta Facilities

2.5.1.3.1 Suisun Marsh

The Suisun Marsh facilities are jointly operated by the CVP and SWP, and include the Suisun Marsh Salinity Control Gates (SMSCG), Roaring River Distribution System (RRDS), Morrow Island Distribution System (MIDS), and Goodyear Slough Outfall. No changes to the operations of the Suisun Marsh facilities from those described in the USFWS (2008) and NMFS (2009) BiOps are proposed for the PA.

2.5.1.3.1.1 Suisun Marsh Salinity Control Gates (SMSCG)

Tidal gates are operated in specific locations of Suisun Marsh to control water salinity levels. When Delta outflow is low to moderate and SMSCG are not operating, tidal flow past the gate is approximately 5,000 to 6,000 cfs while the net flow is near zero. When operating, flood tide flows are arrested, while ebb tide flows remain in the range of 5,000 to 6,000 cfs. The net flow in Montezuma Slough, a primary waterway of Suisun Marsh, becomes approximately 2,500 to 2,800 cfs. The Corps permit for operating SMSCG requires that it be operated between October and May only when needed to meet Suisun Marsh salinity standards. Historically, the gate has been operated as early as October 1, while in some years (e.g., 1996) the gate was not operated at all. When the channel water salinity decreases sufficiently below the salinity standards, or at the end of the control season, the flashboards are removed and the gates are raised to allow unrestricted movement through Montezuma Slough. Details of annual gate operations can be found in “Summary of Salinity Conditions in Suisun Marsh during water years 1984–1992”, or the “Suisun Marsh Monitoring Program Data Summary” produced annually by DWR, Division of Environmental Services (http://www.water.ca.gov/suisun/dataReports/.)

The approximately 2,800 cfs net flow induced by SMSCG operation is effective at moving salinity downstream in Montezuma Slough. Salinity is reduced by roughly one-hundred percent at Beldons Landing, and lesser amounts further west along Montezuma Slough. At the same time, the salinity field in Suisun Bay moves upstream as net Delta outflow (measured nominally at Chipps Island) is reduced by gate operation. Net outflow through Carquinez Strait is not affected.

The boat lock portion of SMSCG is held open at all times during SMSCG operation to allow for continuous salmonid passage opportunities. With increased understanding of the effectiveness of the gates at lowering salinity levels in Montezuma Slough, salinity standards have been met with less frequent gate operation compared to the early years of operations (prior to 2006). For example, despite very low outflow in the fall of 2007 and 2008, gate operation was not required at all in 2007, and was limited to 17 days during the winter of 2008. Assuming no significant long-term changes in the drivers mentioned above, this level of operational frequency (10 to 20 days per year) can generally be expected to continue to meet standards in the future, except perhaps during the most critical hydrologic conditions and/or as a result of other circumstances that affect Delta outflow.

2.5.1.3.1.1.1 Salmonid Risk and Exposure

The principal potential effect of the Suisun Marsh Salinity Control Gates (SMSCG) being closed for up to 20 days per year from October through May is delay of upstream-migrating adult winter-run Chinook salmon, spring-run Chinook salmon, and steelhead that have entered Montezuma Slough from its westward end, and are seeking to exit the slough at its eastward end. Vincik (2013) found some evidence that opening of the boat lock improved passage rates of acoustically tagged adult Chinook salmon, and that even with the gates up, ~30-40% of fish returned downstream. Adult salmonids that do not continue upstream past the SMSCG are expected to return downstream by backtracking through Montezuma Slough to Suisun Bay, and they likely find the alternative upstream route to their natal Central Valley streams through Suisun and Honker Bays (National Marine Fisheries Service 2009: 435). NMFS (2009: 436) noted that the effect of closure of the SMSCG on adult salmonids was uncertain, but suggested that if the ultimate destination of adult spring-run Chinook salmon and steelhead in natal tributaries is reliant on access provided by short-duration, high-streamflow events, delay in the Delta could affect reproductive viability. This would be less of an issue for winter-run Chinook salmon, which when in the Delta are typically several weeks or months away from spawning, and use the mainstem Sacramento River, to which access would not be dependent on short-duration streamflow events.

Operational criteria for the SMSCG would not change under the PA relative to NAA, and, as previously shown, operations modeling suggested that there would be little difference between NAA and PA in terms of SMSCG opening. Therefore, the potential for adverse near-field effects on downstream-migrating juvenile salmonids would be limited. Adult salmonids are at risk of delay if encountering closed SMSCG but could backtrack around the structure. The proportion of individuals that would do so is uncertain, and as described by NMFS (2009: 436), spring-run Chinook salmon and steelhead would likely experience greater delays than winter-run Chinook salmon, because spring-run and steelhead are more reliant on short-term high flow events in smaller tributaries to provide access to suitable spawning habitat. With respect to juvenile salmonids migrating downstream, near-field predation and passage obstruction for migrants are not expected to significantly increase the risk at the SMSCG (NMFS 2009L 436-437), and there would be little difference in the number of days that the SMSCG would be operated between the PA and the NAA in any event.

2.5.1.3.1.1.2 Effects to Green Sturgeon from Suisun Marsh Salinity Control Gates

As described by NMFS (2009: 435-436), little is known about adult green sturgeon upstream passage at the SMSCG, with existing studies suggesting that Suisun and Honker Bays are more utilized than Montezuma Slough where the SMSCG are located. NMFS (2009: 435-436) suggested that adult green sturgeon would have the opportunity to pass the SMSCG through the boat locks or gates (when open), as adult salmonids do, but that they could be delayed. However, any delays would not affect access to spawning habitat in the upper Sacramento River because adult green sturgeon tend to spawn in deeper water (Poytress et al. 2015) that would not be affected by temporary changes in flow. In addition, previous concerns from NMFS (2009: 436) regarding potentially delaying arrival at Red Bluff Diversion Dam (where passage was previously restricted) no longer apply, because of the decommissioning of the RBDD. The potential for predation near the SMSCG that was previously discussed for juvenile salmonids would be of minimal concern for juvenile green sturgeon because they are relatively large and unlikely prey for striped bass and Sacramento pikeminnow (National Marine Fisheries Service 2009: 439). In addition, as noted by NMFS (2009: 436), the multi-year estuarine residence of juvenile green sturgeon often includes long periods of localized, non-directional movement interspersed with occasional long-distance movements (Kelley et al. 2007), and such movements are unlikely to be negatively affected by periodic delays ranging from a few hours to a few days at the SMSCG.

As discussed for salmonids, operational criteria for the SMSCG would not change under the PA relative to NAA, and operations modeling suggested that there would be little difference between NAA and PA in terms of SMSCG opening. Therefore any effects to green sturgeon from the SMSCG would be similar under the NAA and PA. Although there may be greater potential for effects to green sturgeon from operations of the SMSCG than from the other Suisun Marsh facilities, the risk may also be insignificant. This is because delays to upstream adult migration would not affect access to deep spawning habitat in the upper Sacramento River, such habitat being available regardless of temporary changes in flow, unlike some spawning habitat for steelhead and spring-run Chinook salmon in smaller tributaries, for example, and any delays to juvenile green sturgeon would not be expected to adversely affect their long periods of localized, non-directional, and occasional long-distance, movements.

2.5.1.3.1.2 Roaring River Distribution System (RRDS)

The Roaring River Distribution System (RRDS) operates by water being diverted through a bank of eight 60-inch-diameter culverts. RRDS is equipped with fish screens into the Roaring River intake pond during high tides, in order to raise the water surface elevation in RRDS above the adjacent managed wetlands. Managed wetlands north and south of the RRDS receive water, as needed, through publicly and privately owned turnouts on the system.

The intake to RRDS is screened to prevent entrainment of fish larger than approximately 25 mm. DWR designed and installed the screens based on CDFW and NMFS fish screen criteria. The screen is a stationary vertical screen constructed of continuous-slot stainless steel wedge wire. All screens have 3/32-inch slot openings. To minimize the risk of delta smelt entrainment, RRDS diversion rates are controlled to maintain an average approach velocity below 0.2 ft/s at the intake fish screen, which provides protection against salmonid entrainment. Initially, the intake culverts were held at about 20% capacity to meet the velocity criterion at high tide. Since 1996, the motorized slide gates have been operated remotely to allow hourly adjustment of gate openings to maximize diversion throughout the tide.

2.5.1.3.1.2.1 Salmonid Risk and Exposure

The RDS’s water diversion intake is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s (for Delta Smelt protection), so that juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead would be excluded from entrainment (NMFS 2009: 437). Any effects to salmonids from the RRDS are therefore expected to be discountable.

2.5.1.3.1.2.2 Green Sturgeon Risk and Exposure

As previously described for juvenile salmonids, the low screen velocity at the RRDS diversion intake culverts, combined with a small fish screen mesh size, are expected to prevent entrainment of green sturgeon (NMFS 2009: 437).

2.5.1.3.1.3 Morrow Island Distribution System (MIDS)

The MIDS is used year-round, but most intensively from September through June. When managed wetlands are filling and circulating, water is tidally diverted from Goodyear Slough just south of Pierce Harbor through three 48-inch culverts. Drainage water from Morrow Island is discharged into Grizzly Bay by way of the C-Line Outfall (two 36-inch culverts) and into the mouth of Suisun Slough by way of the M-Line Outfall (three 48- inch culverts), rather than back into Goodyear Slough. This helps prevent increases in salinity due to drainage water discharges into Goodyear Slough. The M-Line ditch is approximately 1.6 miles in length and the C-Line ditch is approximately 0.8 miles in length.

2.5.1.3.1.3.1 Salmonids from Morrow Island Distribution System (MIDS)

It is unlikely that juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead would be entrained by the three unscreened 48-inch culverts that form the Morrow Island Distribution System (MIDS) water intake, as a result of their larger size and better swimming ability relative to the size of fall-run Chinook salmon observed to have been entrained (<45 mm). It is also unlikely that juvenile salmonids would be entrained by the MIDS, because the location of the MIDS intake on Goodyear Slough is not on a migratory corridor for listed juvenile salmonids. It is for these reasons, therefore, that any potential effects to listed salmonids from the MIDS would be discountable.

2.5.1.3.1.3.2 Green Sturgeon from Morrow Island Distribution System (MIDS)

The MIDS is not located on a migratory corridor for green sturgeon, however seine surveys in Goodyear Slough did collect one juvenile white sturgeon between 2005-2006 (Enos et al. 2007), indicating that sturgeons can be present in the area. Overall however, it is unlikely that green sturgeon would be entrained by the MIDS, and if any entrainment does occur it would not be as a result of the project action (since differences in operations at MIDS between NAA and PA would be negligible).

2.5.1.3.1.4 Goodyear Slough Outfall

The Goodyear Slough Outfall control structure consists of four 48-inch culverts, with flap gates located on the bay-facing side of the structure. On ebb tides, Goodyear Slough receives watershed runoff from Green Valley Creek and, to a lesser extent, Suisun Creek. The system was designed to draw creek flow south into Goodyear Slough, and thereby reduce salinity by draining water one-way from the lower end of Goodyear Slough into Suisun Bay on the ebb tide. The one-way flap gates at the Outfall close on flood tide keeping higher salinity bay water from mixing into the slough. The system creates a small net flow in the southerly direction overlaid on a larger, bidirectional tidal flow. The system provides lower salinity water to the wetland managers who flood their ponds with Goodyear Slough water. Another initial facility, the MIDS, diverts from Goodyear Slough and receives lower salinity water. Since the gates are passively operated (in response to water surface elevation differentials) there are no operations schedules or records. The system is open for free fish movement except very near the Outfall when flap gates are closed during flood tides.

2.5.1.3.1.4.1 Salmonids Risk and Exposure

It would be unlikely that winter-run Chinook salmon, spring-run Chinook salmon, and steelhead would be negatively affected by the Goodyear Slough outfall, given by the structure's location and design. Because Goodyear Slough was intended to improve water circulation in Suisun Marsh, any impacts to listed salmonids by Goodyear Sough would likely be entirely beneficial, including improved water quality and foraging habitat.

2.5.1.3.1.5 Green Sturgeon Risk and Exposure

The Goodyear Slough outfall is designed to improve water circulation in Suisun Marsh, so any effects by Goodyear Slough outfall to green sturgeon under the PA are expected to be entirely beneficial.

2.5.1.3.2 North Bay Aqueduct

The Barker Slough Pumping Plant diverts water from Barker Slough into the North Bay Aqueduct (NBA) for delivery in Napa and Solano Counties. Maximum pumping capacity is 175 cubic feet per second (cfs) (pipeline capacity). During the past few years, daily pumping rates have ranged between 0 and 140 cfs. The current maximum pumping rate is 140 cfs due to the physical limitations of the existing pumps. Growth of biofilm in a portion of the pipeline also limits the NBA ability to reach its full pumping capacity.

The NBA intake is located approximately 10 miles from the mainstem Sacramento River at the end of Barker Slough (Appendix 3.A Map Book for the Proposed Action, Sheet 17). Each of the ten NBA pump bays is individually screened with a positive barrier fish screen consisting of a series of flat, stainless steel, wedge-wire panels with a slot width of 3/32 inch that meets CDFW and NMFS fish screening criteria. This configuration is designed to exclude fish approximately one inch or larger from being entrained. The bays tied to the two smaller units have an approach velocity of about 0.2 feet per second (ft/s). The larger units were designed for a 0.5 ft/s approach velocity, but actual approach velocity is about 0.44 ft/s. The screens are routinely cleaned to prevent excessive head loss, thereby minimizing increased localized approach velocities.

2.5.1.3.2.1 Salmonid Risk and Exposure

Pumping rates at the North Bay Aqueduct Barker Slough Intake generally would be similar under the NAA and PA. Regardless of differences in the rate of pumping and any resulting differences in exposure to the intake under NAA and PA, the basic conclusions from NMFS (2009: 417) would still apply:

> *"[The] screens, which were designed to protect juvenile salmonids per NMFS criteria, should prevent entrainment and greatly minimize any impingement of fish against the screen itself. Furthermore, the location of the pumping plant on Barker Slough is substantially removed from the expected migrational corridors utilized by emigrating Chinook salmon and steelhead smolts in the North Delta system."*

Therefore, a minimal adverse effect from the North Bay Aqueduct intake on juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead from the Sacramento River basin is expected, although the level of effect is not expected to be significantly different between the NAA and PA.

Listed salmonids could occur in the vicinity of the NBA's Barker Slough pumping plant, however the fish screens used at the facility are designed to protect juvenile salmonids per NMFS criteria. In addition, the location of the facility is well off the typical migration corridor of juvenile salmonids (NMFS 2009: 417). These factors indicate that the risk to listed salmonids from the NBA intake is insignificant.

2.5.1.3.2.2 Green Sturgeon Risk and Exposure

The similar pumping rates for NAA and PA and full screening of the North Bay Aqueduct Barker Slough Intake indicate that the risk to green sturgeon from this facility would continue to be insignificant.

2.5.1.3.3 Contra Costa Canal Rock Slough Intake

The CCWD includes the Mallard Slough, Rock Slough, Old River, and Middle River (on Victoria Canal) intakes; the Contra Costa Canal and shortcut pipeline; and the Los Vaqueros Reservoir. The Rock Slough Intake facilities, the Contra Costa Canal, and the shortcut pipeline are owned by Reclamation, and operated and maintained by CCWD under contract with Reclamation. Reclamation completed construction of the fish screen at the Rock Slough intake in 2011, and testing and the transfer of operation and maintenance to CCWD is ongoing. Mallard Slough Intake, Old River Intake, Middle River Intake, and Los Vaqueros Reservoir are owned and operated by CCWD. The operation of the Rock Slough intake is included in the PA; the operation of the other intakes, and Los Vaqueros Reservoir, are not included in the PA.

The Rock Slough Intake is located about four miles southeast of Oakley, where water flows through a positive barrier fish screen into the earth-lined portion of the Contra Costa Canal. The fish screen at this intake was constructed by Reclamation in accordance with the CVPIA and the 1993 USFWS BiOp for the Los Vaqueros Project to reduce take of fish through entrainment at the Rock Slough Intake. The Canal connects the fish screen at Rock Slough to Pumping Plant 1, approximately four miles to the west. The Canal is earth-lined and open to tidal influence for approximately 3.7 miles from the Rock Slough fish screen. Approximately 0.3 miles of the Canal immediately east (upstream) of Pumping Plant 1 have been encased in concrete pipe, the first portion of the Contra Costa Canal Encasement Project to be completed. When fully completed, the Canal Encasement Project will eliminate tidal flows into the Canal because the encased pipeline will be located below the tidal range elevation. Pumping Plant 1 has capacity to pump up to 350 cfs into the concrete-lined portion of the Canal. Diversions at Rock Slough Intake are typically taken under CVP contract. With completion of the Rock Slough fish screen, CCWD can divert approximately 30% to 50% of its total annual supply (approximately 127 TAF) through the Rock Slough Intake depending upon water quality there.

The Rock Slough fish screen has experienced problems; the current rake cleaning system on the screens is unable to handle the large amounts of aquatic vegetation that end up on the fish screen (National Marine Fisheries Service 2015: 2). Reclamation is testing alternative technology to improve vegetation removal, an action that NMFS (2015: 4) has concluded will improve screen efficiency by minimizing the risk of fish entrainment or impingement at the fish screen. Reclamation's testing program is expected to continue at least until 2018. The PA presumes continued operation and maintenance of the fish screen design that is operational when north Delta diversion operations commence, subject to any constraints imposed pursuant to the ongoing ESA Section 7 consultation on Rock Slough fish screen operations.

2.5.1.3.3.1 Salmonid Risk and Exposure

Winter-run Chinook salmon are present from approximately December through June based on salvage records from the CVP/SWP fish collection facilities. The peak occurrence of winter-run in the south Delta is from January through March. Juvenile spring-run are present in the South Delta in the vicinity of the CCWD diversions from January through June with peak occurrence from March through May. Central Valley steelhead may also be present in the waters of the South Delta from October through July, but have peak occurrence from January through March (National Marine Fisheries Service 2009: 411).

The 1.75-mm-opening, 0.2 ft/s-approach-velocity fish screen installed at the Rock Slough intake is intended to prevent entrainment of listed fish, including juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead, into the Contra Costa Canal. However, the 4 mechanical rakes making up the screen cleaning system are unable to handle the large amount of aquatic vegetation that ends up on the fish screen (National Marine Fisheries Service 2015a: 2). This has resulted in a number of operational issues that have resulted in problems such as capture of adult salmon by rake heads (Seedall 2015) and operation of the fish screen only on ebb tides (National Marine Fisheries Service 2015b). This has led Reclamation to test alternative technology (a prototype rake) to improve vegetation removal, an action that NMFS (2015a: 4) concluded would improve fish protection (i.e., screen efficiency) by minimizing the chance a listed fish would be entrained or impinged on the fish screen. In addition, mechanical removal of aquatic weeds within Rock Slough in 2015 to facilitate testing of the new rake design was expected by NMFS (2015b: 4) to improve screen efficiency, reduce predation of juvenile salmonids by vegetation-associated predatory fishes, and reduce adult salmonid mortality during screen maintenance. As noted by NMFS (2015a: 4), Rock Slough is off the main migratory routes through the Delta for listed fish species, however, due to tidal action, salmon and steelhead occasionally stray into Rock Slough. Modeled pumping suggest that diversions under the PA generally would be similar to the NAA, with the exception of April and May, when diversions were modeled to be greater under the PA (see Table 5.B.5-36 in Appendix 5.B, DSM2 Methods and Results). Greater use of the Rock Slough intake would be likely to increase take of juvenile salmonids under the PA compared to the NAA. However, resolution of the aforementioned issues regarding screen effectiveness is expected to eliminate incidental take of listed salmonids from operation of the Rock Slough Intake, or at least minimize the potential for any adverse effects associated with entrainment and impingement to the point of insignificance.

2.5.1.3.3.2 Green Sturgeon Risk and Exposure

Both juvenile and sub-adult green sturgeon are expected to be present year round in the South Delta as indicated by the salvage record (NMFS 2009: 411). Adult green sturgeon have been caught by sport fisherman in the mainstem of the San Joaquin River from Sherman Island to the Port of Stockton in most months of the year based on the draft 2007 sturgeon report card (California Department of Fish and Game 2008). Presence in the South Delta is assumed to be year round. During the 75 day pumping reduction from March 15 to May 31 and the 30 day no pumping period (April 1 to April 30), the effects of the CCWD action is significantly reduced or eliminated. In addition, Rock Slough is not part of designated critical habitat for green sturgeon (74 FR 52300).

Although Rock Slough is not part of designated critical habitat for green sturgeon, individuals could still occur at this location, and be exposed to the Rock Slough intake structure. Although pumping may be somewhat greater under the PA than the NAA, resolution of the screening effectiveness issues currently being addressed as discussed above would lower any risks to green sturgeon from the Rock Slough intake down to insignificant levels.

2.5.1.4 Programmatic Activities

The PA includes activities at various stages of development, for which insufficient detail exists at this time in order to specifically assess the types or extent of effects to listed species or critical habitat. These activities include: 1) compensatory mitigation for temporary, permanent, and ongoing operational impacts; 2) habitat restoration; 3) monitoring; and 4) adaptive management of several aspects of the proposed action. The effects to species or critical habitat as a result of these activities are expected to be further addressed by either subsequent consultations or reinitiating this consultation, depending on the triggers and processes associated with each activity encompassed within the PA; and thus, are analyzed at a framework programmatic level in this Opinion.

2.5.1.4.1 Compensatory Mitigation

The PA includes that species-specific compensatory mitigation will be completed prior to construction, operations, and other activities at the ratios or acreages identified in Description of the Proposed Action (Appendix A2 of this Opinion) for each species. One or more of the following options will be used to implement the species-specific mitigation: (1) habitat restoration with protection in perpetuity; (2) habitat enhancement with protection in perpetuity; (3) purchasing credits at an approved conservation bank; (4) creating and establishing a conservation bank; and (5) protection in perpetuity without restoration or enhancement. NMFS expects that this compensatory mitigation will minimize effects to each listed species impacted by certain aspects of the PA by replacing the function of the habitat that will be lost, altered, or degraded as a result of construction, maintenance, and operations of the proposed action in the action area, unless otherwise specifically identified in the species-specific effects sections. The PA includes development and implementation of management plans for the mitigation lands, but has not yet identified specific sites. Through the monitoring and adaptive management processes (described below), DWR and Reclamation will work with NMFS to ensure the specific mitigation occurring addresses the specific species and habitat impacts identified.

Although any mitigation sites that will undergo restoration or enhancement will likely have localized, short-term impacts to fish or habitat from ground and in-water disturbance, NMFS expects that habitat improvements will begin by the time PA operations commence, and for those habitat improvements to continue for listed species in the long-term. The BA and this Opinion do not identify or analyze specific effects to listed species or critical habitat from implementation of the compensatory mitigation because, without knowing when, where, and how the mitigation will occur and how large individual parcels will be, specific effects are speculative at this time. Such information about the compensatory mitigation sites and construction timelines are important to determining the extent, frequency, and duration of adverse effects, if any, to listed species and critical habitat.

All compensatory mitigation activities will be subject to approvals by either Reclamation or the Corps, depending on the nature of the activity and which agency has authority and oversight. If it is determined that listed species or designated critical habitat are present and may be adversely affected as a result of implementing the compensatory mitigation, the Corps or Reclamation will be required to initiate a subsequent consultation in order to address those effects.

The action agencies associated with the PA have committed to protecting and managing mitigation sites in perpetuity and ensuring adequate funding for the perpetual management of all compensatory mitigation. Management plans will be developed for each compensatory mitigation site with a conservation easement or other conservation recommendation(s) proposed by NMFS. DWR will secure an endowment or other NMFS approved financial assurance that will be sufficient to fund any monitoring, operations, maintenance, and adaptive management of the mitigation or restoration sites. Further, the endowment or other NMFS-approved financial assurance will designate the party or entity that will be responsible for the long-term management of these lands and associated waterways as applicable. NMFS will be provided with written documentation that funding and management of mitigation lands will be provided in perpetuity.

Therefore, based on these commitments and assurances provided by Reclamation and DWR as described in the BA, NMFS anticipates that the proposed compensatory mitigation will minimize the adverse effects of associated PA activities to each species and critical habitat by replacing the function of the habitat that will be lost, altered, or degraded as a result of implementing the PA. Where appropriate, the proposed species-specific habitat ratios or acreages are described within this Opinion's analysis of each species.

2.5.1.4.2 Habitat Restoration

Additionally, the PA (Appendix A2 of this Opinion) includes 80 acres of expanded rearing habitat on the Sacramento River upstream of RBDD, and 1,800 acres of tidal habitat restoration in the Delta to provide juvenile anadromous fish with improved freshwater rearing habitat, which in addition to the mitigation actions described above, may also serve to further offset impacts from construction and operations of the PA.

Although any creation or restoration of habitat activities is likely to have localized, short-term impacts to fish or habitat from ground and in-water disturbance, NMFS expects that the habitat improvements will begin by the time PA operations commence, and for those habitat improvements to continue for listed species in the long-term. The BA and this Opinion do not identify or analyze specific effects to listed species or critical habitat from implementation of these habitat restoration activities because, without knowing when, where, and how the restoration will occur, specific effects are speculative at this time. Such information about the habitat restoration sites and implementation timelines are important to determining the extent, frequency, and duration of adverse effects, if any, to listed species and critical habitat.

All habitat restoration activities will likely be subject to approvals by either Reclamation or the Corps, depending on the nature of the activity and which agency has authority and oversight. If it is determined that listed species or designated critical habitat are present and may be adversely affected as a result of implementing the compensatory mitigation, the Corps or Reclamation will be required to initiate a subsequent consultation in order to address those effects.

2.5.1.4.3 Monitoring

Monitoring activities as described in Description of the Proposed Action (Appendix A2 of this Opinion), will occur prior to operations and after operations commence. Monitoring and studies of listed fish species will occur at the construction sites for the conveyance facilities. This monitoring will begin with baseline data collection of listed species and predator species presence needed to compare with post-construction results.

Reclamation and DWR have committed to working with NMFS and other agencies to develop the specifics (including timeframes) of monitoring using various technical teams. Monitoring and studies related to operations that must occur after operation of the new facilities has commenced consist of four types: monitoring addressing the operation of the proposed new facilities, monitoring related to species condition and habitat that may be influenced by operations of the new facilities, monitoring to evaluate the effectiveness of the proposed facilities, and monitoring addressing the performance of the habitat protection and restoration sites. DWR and Reclamation have committed to develop a monitoring plan prior to commencement of monitoring as part of the adaptive management program (described below), which will include modifications to the mitigation/restoration approach as necessary to offset the effects of the PA as they are better understood.

Although some monitoring activities will likely result in localized brief disturbances to fish or habitat, other activities will likely be passive observation or even located away from the action area in a laboratory. The BA and this Opinion do not identify or analyze specific effects to listed species or critical habitat from implementation of the monitoring because, without knowing more information about when, where and how the monitoring will occur, effects are speculative at this time. Information about when, where and how the monitoring will occur is important to determining the extent, frequency, and duration of adverse effects, if any, to listed species and critical habitat. Addressing effects resulting from monitoring activities could include a combination of continuing existing monitoring authorized under the USFWS 2008 and NMFS 2009 biological opinions (i.e., principally salvage monitoring at the south Delta export facilities) as well as additional monitoring of the NDD (principally entrainment and impingement monitoring). If there are additional monitoring activities that are not subject to existing or subsequent ESA section 7 consultation and that may adversely affect listed species or their designated critical habitat, reinitiation of this consultation will likely be required to address those effects. Monitoring activities associated with all other aspects of the PA will require subsequent approvals as described in the Description of the Proposed Action and will be subject to subsequent consultations if those activities may affect listed species or designated critical habitat.

2.5.1.4.4 Adaptive Management

Reclamation, DWR, USFWS, NMFS, and CDFW (the Five Agencies) with certain State Water Project and Central Valley Project contractor water agencies (SWP/CVP Contractors) have developed a framework for implementation of a program of collaborative science, monitoring, and adaptive management in support of CWF (Appendix A2 of this Opinion). Commitments to, and details of, the adaptive management approach are described in the Adaptive Management Plan for the California Water Fix and Current Biological Opinions on the Coordinated Operations of the Central Valley and State Water Projects (AMP), Agreement for Implementation of an Adaptive Management Program for Project Operations, and Implementation Schedule for the Adaptive Management Program for the Existing Biological Opinions and CESA Authorization for the Long-term Operation of the CVP and SWP and for the CWF, which are included in Appendix A2 of this Opinion. The AMP outlines a collaborative process for assessing and adapting to effects to listed species stemming from the ongoing operation of the CVP and SWP, including future implementation and operation of the CWF, which is the proposed action for this Opinion. With the AMP, new information attained during the course of implementation is expected to inform future operational decisions and conservation tactics. New information will be developed through scientific research to understand the ecological changes that the CWF may have on the Bay-Delta ecosystem. Currently, little information is known about what, when, where, and how these effects will be adaptively managed, and much less is known about the adaptive management options that may be available and decisions about adaptive management measures that may be made. Information about when, where and how adaptive management measures will occur is important to determining the extent, frequency, and duration of adverse effects, if any, to listed species and critical habitat. Therefore, the BA and this Opinion do not analyze how or if activities associated with adaptive management would affect listed species or designated critical habitat. Addressing effects resulting from the implementation of the AMP would be speculative at this time. The AMP and associated agreement and schedule do, however, commit the Five Agencies (with Reclamation and DWR ultimately responsible for implementation of the AMP) and SWP/CVP Contractors to the adaptive management process, detailing the governance structure, annual reporting and funding commitments as well as identifying an initial set of key uncertainties regarding listed species and CVP/SWP water operations. NMFS retains the authority to assess the effects on listed species and critical habitat resulting from the implementation of the adaptive management plan as required under the ESA. Furthermore, if activities that are identified as part of the AMP may adversely affect listed species or designated critical habitat, Reclamation and DWR will evaluate the scope of effects and work with NMFS to determine if the scope of effects are not analyzed in this Opinion. If not, and the activities are not subject to subsequent consultation under ESA section 7, or the activities are not subject to a permit under ESA section 10, then reinitiation of this consultation will likely be required to address those effects.

2.5.1.5 Southern Resident Killer Whale Effects Analysis

The primary potential impact of the PA on Southern Residents that has been identified in the BA (Reclamation 2016) and in this Opinion is through potential reductions in availability of preferred prey, Chinook salmon, in the coastal waters where Chinook salmon from the Central Valley of California may be encountered by Southern Residents. Because the PA also may expose Chinook salmon to contaminants, NMFS considers the potential impact of this exposure for the preferred prey of Southern Residents.

Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area describes the evaluation by the Science Panel (Hilborn et al. 2012) of the state of the science regarding the effects of salmon fisheries on Southern Residents. While there is uncertainty in the extension of the statistical correlations to precise predictions of the effect of Chinook salmon abundance on the Southern Resident population, to date there are no data or alternative explanations that contradict fundamental principles of ecology that wildlife populations respond to prey availability in a manner generally consistent with the analyses that link Chinook salmon abundance and Southern Residents. As a result, and based on evidence discussed in Section 2.2.5 Rangewide Status of Southern Resident Killer Whale and Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area, NMFS concludes that the best available science suggests that relative changes in Chinook salmon abundances are likely to influence the Southern Resident population.

2.5.1.5.1 Impacts to the Abundance of Chinook as a Result of the Proposed Action

In terms of productivity and abundance, Central Valley Chinook salmon is largely comprised of the non-ESA listed fall-run and, to a much lesser degree, non-ESA listed late fall-run. This is reflected in annual spawning escapement estimates for the Sacramento River and its associated tributaries; fall-run Chinook salmon escapement estimates are typically on the order of several hundred thousand adults, compared to several thousand for winter- and spring-run Chinook salmon combined (PFMC 2016b). As a result, NMFS' approach in this Opinion to analyzing the effects of the PA on Southern Residents includes analysis of fall-run and late fall-run similar to the analyses of the ESA-listed species of salmon. In addition, the effects analysis for Southern Residents also considers the impact to ESA-listed winter-run and spring-run Chinook in the Central Valley since they are also potential prey for Southern Residents along the coast.

Detailed descriptions regarding the exposure, response, and risk of each of the Chinook salmon ESUs found in the action area and affected by the PA (winter-, spring-, fall-/late fall-run) to stressors associated with the PA are presented in Section 2.5 Effects of the Action (and summarized in Section 2.7 Integration and Synthesis). The PA-related effects to Chinook salmon are separated into those related to construction and those related to operations. Given that the potential effect to Southern Residents as a result of the PA is reduced prey availability associated with effects to Chinook salmon, the effects to Southern Residents are similarly separated. As a result, the analysis will look at potential reduced Southern Resident prey for the duration of construction and in the future when project operations are expected to commence.

2.5.1.5.1.1 Construction-related Impacts to Chinook Abundance

The construction-related effects on fall-run and late fall-run Chinook salmon in the Central Valley that are expected to occur during the 8-year construction period are described in Section 2.5.1.1 Construction Effects (and summarized in Table 2-264 of Section 2.7.9 Integration and Synthesis of Fall-run and Late Fall-run Chinook Salmon). The table characterizes the relative magnitude and certainty of individual stressors in general relative terms of "low", "medium", and "high",[1] along with the anticipated types of responses and rationale for the characterization. These characterizations represent a qualitative assessment of the expected impacts to Chinook salmon at an individual fitness level in combination with the extent of the impact at the population level.

Several activities associated with the PA – including pile driving, barge operations, geotechnical analysis, clearing and grubbing, and use of temporary in-water structures – are expected to mostly affect a small proportion of juvenile and adult stages of fall-run and late fall-run Chinook salmon but a medium proportion during pile driving and for increased predation. Adverse impacts to juveniles and adults resulting from exposure to pile-driving and increased barge traffic that include injury and mortality, as well as physical stress from acoustics and turbidity, are likely. In total, various stressors will reduce the fitness and survival of a small proportion of fall-run and late fall-run Chinook salmon ESUs as a result of construction, although most impacts described are expected to be limited to sublethal effects. The summation of the impacts from all construction activities on fall-run and late fall-run Chinook salmon is expected to reduce the number of juvenile Chinook salmon migrating out of the Central Valley and adult Chinook salmon returning to spawning grounds during the construction period. This will reduce the abundance of fall-run and late fall-run Chinook salmon in ocean and consequently reduce prey

[1] High: Lethal effect due to stressor that has a broad effect on the population at significant frequency.
Medium: Effect between high and low definitions.
Low: Generally, sublethal effect, or lethal effect on a very small percentage of one population at a very infrequent interval.

for Southern Residents during the construction period. However, chapter 3 of the BA, and the revised PA (Appendix A2 of this Opinion), include a commitment of 80 acres of expanded rearing habitat through restoration in the upper Sacramento River between Keswick Dam and RBDD, and 1,800 acres of tidal rearing habitat restoration in the Delta. Although these additional habitat restoration activities will have short-term impacts to habitat from ground and in-water disturbance the restoration is expected to improve these PBFs for all salmonids in the long-term, resulting in improved survival.

Section 2.7 Integration and Synthesis also summarizes effects from the proposed construction activities on winter-run and spring-run Chinook salmon. The relative magnitude of effects of construction-related impacts to these Chinook ESUs are very similar to the effects on fall-run and late fall-run Chinook salmon. Although impacts resulting from pile driving and increased barge traffic are expected to reduce winter-run and spring-run Chinook salmon relative abundance, productivity, spatial structure, and diversity as a result of construction-related impacts (Table 2-242 and Table 2-248), the revised PA is expected to minimize impacts to a minimal level.

2.5.1.5.1.2 Operational Impacts to Chinook Abundance

A number of effects related to operations of the PA are expected to reduce the abundance and/or productivity of a small proportion of fall-run and late fall-run Chinook salmon. The post-construction operational effects of the action on fall-run and late fall-run Chinook salmon are described in Section 2.5.1.2 Operations Effects and summarized in Table 2-264 in the Integration and Synthesis. The operational-related impacts describe no to low impact in terms of increased temperatures upstream of the NDD; dewatering and scour impacts to redds and stranding of young fish, as well as juvenile outmigration survival. Impacts of impingement or entrainment and increased risk of predation at the NDD, and increased predation risks associated with permanent structures are expected to result in a medium level of impact, as is routing, and south Delta impacts.

For impacts associated with upstream temperature influences on egg survival, fry rearing and outmigration that influence the survival rates of early stages of fall-run and late fall-run Chinook, there is a small or marginal difference in the expected effect of the PA compared to the NAA (Table 2-265). The information presented and analyzed in Section 2.5.1.2 Operations Effects shows that egg and early life stage survival rates are currently limited and reduced by water temperatures in the action area, which has the potential to reduce survival and fitness of a small proportion of fall-run and late fall-run Chinook salmon in some years.

The analyses of redd dewatering, scouring, and stranding described in Section 2.5.1.2 Operations Effects show a small difference in the expected effect for the PA compared to the NAA; this difference would affect the survival, reproductive success, and fitness of fall-run and late fall-run Chinook salmon (Table 2-265).

Impacts associated with impingement and entrainment and increased predation at NDD for fall-run and late fall-run Chinook salmon described in Section 2.5.1.2 Operations Effects are expected as a result of PA operations. Mortality rates of 7% for fish passing the NDD screen (impingement), along with additional mortality resulting from increased predation around the new permanent structures, is expected to reduce survival and fitness of fall-run and late fall-run Chinook salmon (Table 2-265). However, the PA describes the incorporation of refugia along the

NDD structure that may provide additional minimization to screen impingement and associated predation risk. Phased testing and operation of the three NDD intakes will ensure that the screens are functioning to NMFS screening criteria or if not, impacting PBFs or fish beyond the analysis in this Opinion would trigger subsequent consultation or reinitiation of consultation.

As described in Section 2.5.1.2 Operations Effects, reduced in-Delta flows resulting from PA operations are expected to result in mortality caused by increased migration times and changes to Delta routing and entrainment that increase exposure of juvenile fall-run and late fall-run Chinook salmon to predators, reducing the survival of a small proportion of juvenile fall-run and late fall-run Chinook salmon compared to the NAA (Table 2-265).

An array of significant stressors to fall-run and late fall-run Chinook salmon are expected to decrease abundance as a result of PA operations. For some stressors, such as reduced survival of early life stages associated with increased water temperatures and redd dewatering and stranding, there is only a small difference between the effects of the PA compared to the effect of the NAA. Impacts associated with impingement and entrainment at the NDD, along with impacts from reduced Delta flows, are adverse compared to the NAA for fall-run and late fall-run Chinook salmon. Because these impacts result in mortality and reduced fitness for early life stage and juvenile fall-run and late fall-run Chinook salmon, survival of juvenile fall-run and late fall-run Chinook salmon transiting through the Delta will be reduced. As these impacts are expected to reduce the abundance of fall-run and late fall-run Chinook salmon in the ocean, they also consequently reduce the prey in the ocean for Southern Residents. While it is difficult to distinguish between the ongoing limitations to the abundance of Chinook salmon entering the ocean resulting solely from operations of the PA, some operational impacts such as impingement and entrainment at the NDD are clearly attributable to PA operations.

However, Chapter 3 of the BA, and the revised PA (Appendix A2), describes a commitment to 80 acres of expanded rearing habitat through restoration in the upper Sacramento River between Keswick Dam and RBDD, and 1,800 acres of tidal rearing habitat restoration in the Delta. Although these additional habitat restoration activities will have short-term impacts to habitat from ground and in-water disturbance the restoration is expected to improve these PBFs for all salmonids in the long-term, and increase survival of fish.

Based on the PA and the analyses and information that is currently available, we expect impacts from PA operations will reduce prey for Southern Residents by reducing a small proportion of fall-run and late fall-run Chinook salmon in the ocean throughout the duration of operations, however reductions of abundance analyzed is expected to be minimized through the revised PA including the commitment to implement an adaptive management program.

Effects of the PA operations on winter-run and spring-run Chinook salmon are similar to the effects on fall-run and late fall-run Chinook salmon. The relative abundance and productivity of these ESUs are not expected to be reduced or diminished beyond a minimal amount (Table 2-264 and Table 2-265). Furthermore, the revised PA is expected to minimize impacts to listed Chinook salmon to a minimal level, through RTOs, adaptive management, and mitigation and restoration improvements to habitat.

2.5.1.5.1.3 Effect of Reduced Prey Base for Southern Residents

The information described above suggests that the population dynamics of Southern Residents are related to the abundance of Chinook salmon available as prey throughout the range of

Southern Residents. As a result, reductions in availability of preferred prey (Chinook salmon) may affect the survival and reproductive success of Southern Residents. As described in Section 2.2.5 Rangewide Status of Southern Resident Killer Whale and Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area, during the winter and spring, Southern Residents (particularly members of K and L pod) are likely spend at least some time in coastal waters where they would be affected by reductions in Central Valley Chinook salmon abundance due to the PA. As described in Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area, Chinook salmon from the Central Valley, especially fall-run Chinook salmon, constitute a significant proportion of the total abundance of Chinook salmon that is available throughout the coastal range of Southern Residents (~ 20% on average based on the SI, but varying substantially during any given year). As described in Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area, Central Valley Chinook salmon become an increasingly significant portion of Chinook present along the southern portion of the Southern Resident range in Oregon and California. As described in Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area, Southern Residents (particularly members of K and L pod) have also been linked to consumption of Chinook salmon from California based on the contaminant signatures discussed above.

Southern Residents could abandon particular areas in search of more abundant prey or expend substantial effort to find prey resources in response to a decrease in the amount of available Chinook salmon due to the PA. These changes in behavior can result in increased energy demands for foraging individuals as well as reductions in overall energy intake, increasing the risks of being unable to acquire adequate energy and nutrients from available prey resources (i.e., nutritional stress). Southern Residents are known to consume other species of fish, including other salmon, but the relative energetic value of these species is substantially less than that of Chinook salmon. Reduced availability of Chinook salmon would likely increase predation activity on other species (and energy expenditures) and/or reduce energy intake. Numerous studies have demonstrated the effects of energetic stress (caused by incremental increases in energy expenditures or incremental reductions in available energy) leading to reduced body size and condition and lower reproductive and survival rates for adults (e.g., Daan et al. 1996; Gamel et al. 2005) and juveniles (e.g., Trites and Donnelly 2003; Noren et al. 2009). In the absence of sufficient food supply, adult females may not successfully become pregnant or give birth and juveniles may grow more slowly. Any individual may lose vitality, succumb to disease or other factors as a result of decreased fitness, and subsequently die or not contribute effectively to future productivity of offspring necessary to avoid extinction and promote recovery of a population. Small, incremental increases in energy demands are expected to have the same effect on an animal’s energy budget as small, incremental reductions in available energy, such as reduced prey availability.

2.5.1.5.1.3.1 Construction-related Impacts of Reduced Prey Base for Southern Residents

Based on the analyses of expected impacts to Chinook salmon populations in the Central Valley affected by the proposed construction activities, minimal reductions in the survival and productivity of Chinook salmon populations are expected to last the duration of construction. These reductions would decrease the abundance of Chinook salmon populations in the ocean and subsequent availability as prey for Southern Residents. In particular, although some construction-related impacts are expected for fall-run Chinook salmon from the Central Valley, which is likely an important prey source for Southern Residents in portions of their coastal range, the revised PA is expected to reduce these impacts. While the available analytical tools are best used in a comparative approach, limiting their application to a determination of absolute magnitude, construction-related impacts are expected to affect a small proportion of Chinook salmon populations. These impacts would likely reduce the number of Chinook salmon available in the ocean in some years in the southern portion of the coastal range of Southern Residents. The reduced abundance of prey could be detected by all members of K and L pod during foraging on a reduced prey field, leading to increased expenditures of energy during foraging. The exposure of members of J pod to reduced Chinook salmon abundance in coastal waters is not as clear based on the current understanding of their distributions and contaminant signatures as described in Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area, but available data considered here suggest their exposure may be much more limited or nonexistent. The expected consequences of significant reductions in the abundance of preferred prey for these Southern Residents are reductions in the fitness of individuals because of increased energy expended to find sufficient prey and nutritional stress, which can lower reproductive rates and increase mortality rates. Based on the general relative analyses that have been described, all members of K and L pod are expected to be at risk of reduced fitness due to decreased Chinook salmon abundance in the ocean resulting from project-related construction.

2.5.1.5.1.3.2 Operational-related Impacts of Reduced Prey Base for Southern Residents

Based on the analyses of expected impacts to Central Valley Chinook salmon populations exposed to the operations of the PA, and including the revised PA (Appendix A2), and the RTO and adaptive management and monitoring provisions included in the PA, which provide additional opportunities to refine the operating criteria and make adjustments to CVP/SWP Delta operations to minimize the risks of incidental take while maximizing water supply, the conditions for Chinook salmon during operations of the PA will likely still result in a small proportion of decreased abundances for Chinook salmon populations in some years.

Any reductions and limitations in juvenile Chinook salmon survival and fitness occurring in the action area under PA operations, are expected to reduce the abundance of Central Valley Chinook salmon populations in the ocean. Any reductions in available prey are most likely to be detected by all members of K and L pod, during foraging on a reduced prey field, leading to increased expenditures of energy during foraging. The expected consequences of reduced abundance of preferred prey for Southern Residents are reduced fitness of individual Southern Residents through increased energy expended to find sufficient prey and nutritional stress, which can lower reproductive rates and increase mortality rates. Based on the general relative analyses that have been described, members of K and L pod are expected to be at risk of reduced fitness due to the small proportion of decreased Chinook salmon abundance in the ocean in some years resulting from PA-related operations. However, the revised PA is expected to reduce impacts to a minimal level.

2.5.1.5.1.4 Conclusion of Reduced Prey Base Effects for Southern Residents

Based on the analysis above, NMFS expects that the PA will reduce the amount of a small proportion of Central Valley Chinook salmon (especially fall-run Chinook salmon) available in the ocean for Southern Residents to forage in some years. The result of reduced ocean abundance of Central Valley Chinook salmon, is that at least some individuals will be required to spend more time foraging, which increases energy expenditures and the potential for nutritional stress, which can lead to reduced body size and condition, and potentially contribute to lower reproductive and survival rates, especially for K and L pod whales.

Members of K and L pod constitute a sizeable portion of the entire Southern Resident population, with 54 of the 78 members. As a result, the potential risk of reduced fitness and decreased survival and reproductive rates for members of K and L pod presents a risk for the Southern Resident population as a whole. Because the PA is likely to increase the risks of nutritional stress in some years, potentially reducing reproductive and survival rates for a large portion of the individuals in the Southern Resident population, the population growth and recovery potential of the Southern Resident population could be affected by the increased risks to survival and reproduction that may be associated with decreased abundances of preferred prey in the ocean.

As it is described in Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area, it is clear that Chinook salmon from the Central Valley are expected to constitute a component of the diet of Southern Residents in coastal waters, but the extent of the contribution of Central Valley Chinook salmon to the diet or the expected reliance on them by Southern Residents is less clear. Southern Residents are expected to detect and respond to reduced Central Valley Chinook salmon abundance and a reduced prey field during foraging, likely resulting in Southern Residents searching for more abundant prey fields in other parts of their range where Chinook salmon from the Central Valley may not constitute much, if any, of the available prey. While Chinook salmon are expected to be the preferred prey with high nutritional value, Southern Residents are capable of taking advantage of other prey sources to supplement their nutritional needs and are assumed to do so in the immediate absence of sufficient Chinook salmon resources. Based on the distribution of Central Valley Chinook salmon described in Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area, any nutritional and energetic stress impacts caused by the PA are most likely to occur in the more southerly range of Southern Residents. Based on research and the known distribution of Southern Residents described in Section 2.2.5 Rangewide Status of Southern Resident Killer Whale and Section 2.4.5.2 Factors Affecting the Prey of Southern Residents in the Action Area, we conclude that while Southern Residents are known to occasionally use the southerly end of their range during some years, it is also likely that this population may limit or avoid use of this area altogether during some years.

Ford and Ellis (2006) report that Southern Residents engage in prey sharing about 76% of the time during foraging activities. Prey sharing presumably would distribute more evenly any effects of prey limitation across individuals of the population than would otherwise be the case (i.e., if the most successful foragers did not share with other individuals). Considering this, along with their ability to take advantage of other prey sources to supplement their nutritional needs in the immediate absence of sufficient Chinook salmon resources, we conclude that relatively small reductions in Central Valley Chinook salmon prey compared to the several millions of Chinook that are expected to be available to Southern Residents in the ocean each year over the duration of the PA would likely not alter the fitness of individuals enough to further reduce survival and reproduction rates, assuming Southern Residents only spend part of their time foraging in the southern portion of their range in the ocean where Central Valley Chinook salmon would occur in relative abundance during that time period. However, larger reductions in prey likely could alter the fitness of individuals enough to compromise survival and reproduction rates at any time over the duration of the PA. During times when Chinook salmon populations are not doing well and abundances are relatively low in the ocean, it is likely that reductions in Central Valley Chinook are more noticeable to Southern Residents as additional energy expenditures and potential nutritional stress resulting from moving around to find areas where prey resources maybe more abundant are more likely to occur.

2.5.1.5.2 Effects of Chinook Exposure to Contaminants for Southern Residents

Benthic sediments in the Delta are known to contain toxic contaminants including heavy metals, pesticides, and other toxic organic compounds. These contaminants will be released when sediments are disturbed and resuspended into the water column during numerous construction activities such as pile driving and dredging. In Section 2.5 Effects of the Action and Section 2.7 Integration and Synthesis, the analyses describe how the contaminant exposure effects of the PA will adversely affect all Chinook salmon populations throughout the Delta through consumption of contaminated prey during their Delta migratory phase, particularly zooplankton or small invertebrates that reside in the areas affected by the PA. These effects are generally expected to be limited to sublethal effects that are constrained to small proportions of Chinook salmon populations. However, the nature of outcomes for Chinook salmon regarding exposure is unpredictable owing to uncertainty regarding sediment composition and extent of exposure that may occur based on the details of proposed construction that are available. As described in Section 2.7 Integration and Synthesis, the exposure duration to any potential contaminants will be transitory and the concentration of those contaminants in the water column are expected be below levels that will cause acute or lethal responses in exposed fish that could affect the abundance of Chinook salmon in the action area. As a result, the risk for Southern Residents from exposure to contaminants resulting from the PA is associated with the consumption of Chinook salmon that are carrying increased contaminant loads, ultimately bioaccumulating these contaminants over the course of their lifetime, rather than a risk to abundance of their prey species.

Legacy contaminants such as mercury, methyl mercury, polychlorinated biphenyls (PCBs), heavy metals, and persistent organochlorine pesticides continue to be found in watersheds throughout the Central Valley. One of the contaminants potentially present throughout sediments in the action area in relatively large quantities is selenium, which was identified as one of the pollutants in San Francisco Bay and the western Delta on the Clean Water Act Section 303(d) List (State Water Resources Control Board 2011). However, most metals (with the exception of methylmercury), do not appear to bioaccumulate, and are regulated and excreted by many marine organisms (Gray 2002, EPA 2007). Consequently, we do not anticipate that selenium and most other metals would bioaccumulate in Southern Residents as a result of the PA. However, there may be a number of organic pollutants present in the action area that have the ability to bioaccumulate. PCBs and other persistent organic pollutants can cause endocrine disruption, reproductive disruption, or failure, immunotoxicity, neurotoxicity, neurobehavioral disruption, and cancer, and are known to already be present in high concentration in Southern Residents (see Mongillo et al. 2016 for a review).

There is little information available specific to the PA regarding the composition of sediments that may be resuspended or levels of persistent organic pollutants that may be introduced into the environment and food chain for Southern Residents during proposed construction or operational activities. As a result, the nature of outcomes from any potential bioaccumulation that may result from the release of contaminated sediments into the environment for Southern Residents is unknown. It is expected that the geotechnical exploration described in the PA will provide analysis of sediment composition and that consideration of potential exposure to toxic contaminants from resuspended sediments will occur in line with criteria set by the EPA for water quality standards. Increases in the accumulation of persistent organic pollutants by Southern Residents as a result of the PA could lead to increases in probabilities of the types of effects on individual health described above, although the potential exposure of Southern Residents to any increased contaminant levels in Central Valley Chinook salmon is expected to be moderated by some degree based on information described above that they most likely only encounter Central Valley Chinook salmon while foraging in the southern portion of their range in the ocean, and not consistently throughout the year.

2.5.2 Effects of the Action to Critical Habitat

The PA is expected to result in numerous adverse impacts to designated critical habitat within the action area for the species addressed in this Opinion. The critical habitat designations for Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, CCV steelhead, and sDPS green sturgeon list the physical or biological features (PBFs) for critical habitat for these species, and these PBFs are described in Appendix B. Section 2.5.2.1 provides a description of general impacts to critical habitat that are expected to occur as a result of the PA, and then Sections 2.5.2.2. and 2.5.2.3 describe specific impacts to each PBF for each ESA-listed anadromous fish species analyzed in this Opinion.

2.5.2.1 General Habitat Impacts

2.5.2.1.1 Sedimentation and Turbidity

The PA includes construction and maintenance activities that are likely to result in adverse effects to critical habitat through re-suspension and deposition of sediments already existing in river reaches within the action area or from PA activities along river banks that will disturb sediments and release them into the water. Specific activities include: construction dredging; geotechnical borings; clearing and grubbing at construction sites; pile driving at intake sites, HOR, CCF, and at barge landings; increased vessel traffic during construction; and periodic maintenance dredging at new water diversion facilities and habitat restoration.

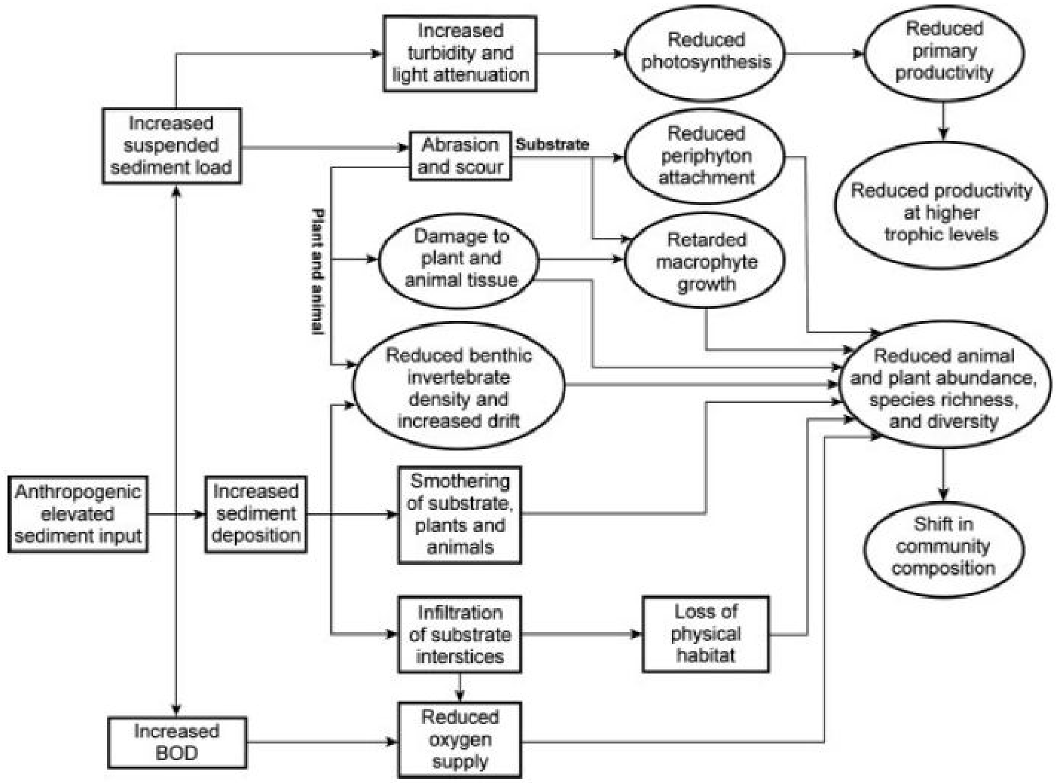


Figure 2-186. Negative Impacts of Anthropogenically Enhanced Sediment Input to Lotic Aquatic Systems at Lower Trophic Levels. Rectangles and ovals respectively denote physiochemical effects and direct and long-term biological and ecological responses. From: (Kemp et al. 2011).

Kemp et al. (2011) discusses the impacts of sediment input to aquatic ecosystems and includes Figure 2-186, graphically depicting direct and indirect effects of sedimentary processes. A number of key components of the PBFs defined for listed fish species have the potential to be impacted by enhanced sedimentation (Wood and Armitage 1997, Kemp et al. 2011). This is of particular concern downstream of the north Delta intake sites during the construction phase, and downstream of sites in which maintenance dredging will occur. Sediment influx and transport can lead to geomorphologic changes in the action area that are part of natural physical processes in the Delta, creating floodplain habitat for additional recruitment of riparian vegetation (Richardson et al. 2007, Schoellhamer et al. 2012), and may also affect habitat heterogeneity in the main stem Sacramento River (Yarnell et al. 2006), increasing the complexity of benthic habitat. Although habitat complexity is generally viewed as beneficial for fish in lotic systems, sediment deposition also has negative impacts to habitat features that contribute to its functionality. Sediment deposition has been shown to have direct effects to aquatic macroinvertebrates in lowland river systems due to smothering (Kefford et al. 2010), creation of low-light conditions limiting macrophyte food sources (Sand-Jlnsen et al. 1989), and impact to macroinvertebrate community structure (Bo et al. 2007). These organisms provide a food source for listed fish species rearing and migrating through the action area. Although emergent aquatic vegetation generally benefits from sediment deposition (Richardson et al. 2007), submerged aquatic vegetation may be adversely impacted by sediment suspension and deposition through light attenuation (Kemp et al. 1983). Loss of vegetation can reduce available cover, increasing exposure of listed fish to predators (Kemp et al. 2011).

Increased levels of turbidity resulting from sediment influx and resuspension may impede predator avoidance behavior by reducing the perceived threat of predation. Gregory (1992) demonstrated that elevated levels of turbidity reduced the magnitude of predator avoidance responses in juvenile salmonids. From a perspective of critical habitat, the effects of sedimentation and turbidity may reduce the habitat quality of those portions of the action area that are used for rearing and migration.

2.5.2.1.2 Water Temperatures

Water temperatures in aquatic ecosystems are particularly important for early life stages of anadromous fish. Thermal tolerances and optima for early life stages of Chinook salmon and green sturgeon have been well-documented and are discussed in the Rangewide Status of the Species and Critical Habitat sections for each of the listed species addressed in this Opinion (Appendix B). Temperature is an important component of several critical habitat PBFs among these species, as water temperatures play a large role in the suitability of habitat within the action area. For the purposes of this analysis, concerns of adverse impacts to critical habitat PBFs resulting from temperature effects are greatest at the most upstream extent of the action area (upper reaches of the Sacramento River and Lower American River between Nimbus Dam and the SR-160 Bridge). The Sacramento River contains spawning habitat for all four fish species and the Lower American River contains spawning habitat for CCV steelhead. There are no anticipated construction-related activities in these upper reaches included in the PA; therefore, localized changes in water temperature are expected to be operations-related and not due to disturbance of riparian vegetation. Specific PBFs that may be impacted by temperature and/or flow-related effects are discussed below in Sections 2.5.2.2.1 and 2.5.2.3.1.

2.5.2.1.3 Loss of Riparian Vegetation

Riparian vegetation will be removed as a result of the PA principally through clearing and grubbing at construction sites, and also may be removed temporarily at restoration sites. Riparian vegetation plays a key role in the rearing habitat for various salmonid and green sturgeon life stages. It provides shading to lower stream temperatures; increases the recruitment of LWM into the river, increasing habitat complexity; provides shelter from predators; and enhances the productivity of aquatic macro invertebrates (Anderson and Sedell 1979, Pusey and Arthington 2003). It has also been shown to directly influence channel morphology and may be directly correlated with improved water quality in aquatic systems (Schlosser and Karr 1981; Dosskey et al. 2010). It has been suggested by Dosskey et al. (2010) that presence and abundance of riparian vegetation can be directly correlated with water quality in riverine systems through biogeochemical cycling, soil and channel chemistry, water movement and erosion.

Riparian vegetation also plays a key role in the functionality of estuarine habitat. The majority of riparian habitat that is to be disturbed in the course of this project will be upstream of the Delta (north Delta diversions and compensatory mitigation sites), but some disturbance is expected to occur in the course of constructing barge landings in the Delta. Riparian vegetation provides rearing habitat in inundated floodplains for estuarine fish species (Sommer et al. 2001a, Sommer et al. 2001b). In some estuarine habitat types such as saltmarshes (Williams and Williams 1998), and supralittoral zones (Romanuk and Levings 2003), it contributes to proliferation of aquatic macro invertebrates. Riparian vegetation also influences geomorphic features in tidally-influenced estuarine areas, facilitating natural erosional and depositional processes (Tabacchi et al. 1998, Temmerman et al. 2007).

2.5.2.1.4 Reduction in Habitat Complexity

Loss of habitat complexity for salmonids is anticipated as a result of the PA in channel margin and riparian areas at NDD sites, and at barge landing sites in the Delta. Removal of riparian vegetation and disturbance to substrate, coupled with the installation of rip rap, sheet piles, and other infrastructure components will result in simplified habitat for rearing and migration. Additionally, disturbance to benthic substrate for green sturgeon from dredging activities may result in simplified benthic habitat.

2.5.2.1.5 Prey Availability

One of the most important habitat attributes of the riverbed to listed anadromous fish species in the action area is the production of food items for rearing and migrating juveniles. Salmonid and sturgeon prey items will be impacted primarily by dredging activities and barge operations which adversely impact juvenile rearing and migratory habitat. Oligochaetes and chironomids (dipterans) are the dominant juvenile Chinook salmon, steelhead, and sDPS green sturgeon food items produced in the silty and sandy substrates in this area. Radtke (1966) inspected the stomach contents of juvenile green sturgeon (range: 200-580 mm) in the Delta and found food items to include mysid shrimp (*Neomysis awatschensis)*, amphipods (*Corophium sp.)*, and other unidentified shrimp. Populations of these organisms would be entrained by the hydraulic suction dredge, particularly small demersal fish and benthic invertebrates. Reine and Clark (1998) estimated that the mean entrainment rate of a typical benthic invertebrate, represented by the grass shrimp, when the cutterhead was positioned at or near the bottom was 0.69 shrimp/cubic yard but rose sharply to 3.4 shrimp/cubic yard when the cutterhead was raised above the substrate to clean the pipeline and cutterhead assembly. Likewise, benthic infauna, such as clams, would be entrained by the suction dredge in rates equivalent to their density on the channel bottom, as they have no ability to escape. Chronic, long-term disturbance would be expected to have a negative impact (Bishop 2004), but short-term disturbances could have a beneficial effect of increasing prey availability (Gabel et al. 2011) through resuspension.

2.5.2.1.6 Water Quality

Degradation of water quality in the action area may have adverse impacts to certain PBFs for designated critical habitat through the following mechanisms: re-suspension of contaminated sediment; elevated water temperatures; and decreased flow. These mechanisms are expected to result in negative impacts to critical habitat for the species addressed in this Opinion with the exception of reduced DO, which is not expected to occur at a magnitude which would adversely impact habitat. A detailed discussion of water quality impacts to listed fish species can be found in Section 2.5.1.1.3 Contaminant Exposure. The majority of contaminant-related impacts to habitat are expected to occur due to the resuspension of contaminated sediment during dredging activities. The potential for contaminant incursion due to spills from construction or barge operations exists. However, there will be BMPs and avoidance and minimization measures in place that are expected to minimize the potential for introduction of contaminants to surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials: Worker Awareness Training; Construction Best Management Practices and

Monitoring; Stormwater Pollution Prevention Plan; Erosion and Sediment Control Plan; Hazardous Materials Management Plan; Spill Prevention, Containment, and Countermeasure Plan; Disposal of Spoils, Reusable Tunnel Material, and Dredged Material; and Barge Operations Plan.

In addition to the impacts to species as described above, water quality degradation due to contamination has the potential to reduce the abundance of aquatic macroinvertebrates, reducing the abundance of food resources at lower trophic levels for listed fish species (Phipps et al. 1995, Fleeger et al. 2003). Prey availability is a common component of critical habitat PBFs as described below in Sections 2.5.2.2 through 2.5.2.5.

2.5.2.2 Effects to Designated Critical Habitat PBFs for ESA-listed Salmonids

This section addresses impacts to designated critical habitat for the following species: Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and California Central Valley steelhead. Habitat impacts are structured by habitat types that occur within the action area. Specific PBFs that correspond to ESA-listed critical habitat for each fish species are identified within the associated habitat type. The detailed analysis of stressors to the species is contained in Section 2.5.1 Effects of the Action on Species and will be referred to throughout this section as those analyses are relevant to the impacts to critical habitat. In many cases, the species effects analysis is relied on as underlying support for the critical habitat analysis.

Critical habitat for both CV spring-run Chinook salmon and CCV steelhead was designated concurrently, and they share the same PBFs. The PBFs for winter-run Chinook salmon are generally related to the same habitat types as the other listed salmonids, but are described with more specificity in the designation. In this section, discussion of effects to the components of each PBF are delineated by species where necessary. Differences in habitat impacts are generally due to the spatial and temporal distribution of each species within the action area. In some cases, effects to one or more component of a PBF apply in the same way to each species' habitat.

2.5.2.2.1 Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry

Sacramento River winter-run Chinook salmon PBFs:

- Availability of clean gravel for spawning substrate
- Adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles
- Water temperatures between 42.5–57.5°F (5.8–14.1°C) for successful spawning, egg incubation, and fry development
- Habitat areas and adequate prey that are not contaminated

CV spring-run Chinook salmon and CCV steelhead PBFs:

- Freshwater Spawning Sites

Spawning habitat in the action area occurs for all three species in the upper reaches of the Sacramento River (primarily from RBDD to Keswick Dam). Spawning habitat also occurs for CCV steelhead in the Lower American River. Upstream temperature changes, redd dewatering and redd scour impacts are summarized here in the context of habitat effects. Modeling and results are discussed in greater detail in the context of species effects in Section 2.5.1.2 Operations Effects.

For Sacramento River winter-run Chinook salmon, the certainty of the three biological tools' (threshold analysis, SALMOD, and the SWFSC's temperature-dependent Chinook salmon egg mortality model) respective ability to accurately estimate temperature-related impacts to spawning habitat in the Sacramento River under the PA is low because all three models utilize daily (thresholds analysis, egg mortality model) or weekly (SALMOD) water temperatures downscaled from the same modeled monthly values. In other words, none of the models are able to accurately estimate the daily temperatures, which are critical to winter-run spawning, egg incubation, rearing, and outmigration. Spawning habitat in the Sacramento River experiences a thermal regime that varies between day and night and from one day to the next. The downscaled water temperature modeling utilized in all the biological models does not capture that level of thermal variation. As discussed in Section 2.5.1.2, temperature analyses indicate that there would be little difference in degradation of critical habitat PBFs for spawning between the PA and NAA.

Overall, the monthly temperature modeling results, exceedance plots and biological tools all indicate that thermal impacts to critical habitat PBFs for spawning will largely be the same with implementation of either the NAA or PA operations. Under the PA, adverse effects to critical habitat due to elevated temperatures in spawning habitat (RBDD to Keswick Dam) are likely to occur, particularly in drier water years (i.e., the requirements defined in the winter-run PBF 'water temperatures between 42.5–57.5°F [5.8–14.1°C] for successful spawning, egg incubation, and fry development' are not being met). It is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. NMFS does not have sufficient information to specifically describe the extent to which adverse effects indicated by the modeling would be minimized by real-time operations. However, there are extensive real-time operations management processes currently in place for CVP/SWP operations that affect water temperatures upstream of the Delta (see BA 3.1.5.1 Ongoing Processes to support Real-Time Decision Making), those processes have minimized such impacts in the past (Swart 2016), and the PA does not propose changing the existing real-time operational processes. Therefore, NMFS concludes that the real-time operations management process would minimize adverse effects indicated in the modeling for the PA to a similar extent as the real-time operations process has minimized such impacts in the past.

Additionally, the Shasta Operations RPA adjustment described in the BA (Section 3.1.4.5 Annual/Seasonal Temperature Management Upstream of the Delta), which is intended to provide more protective temperatures for winter- and spring-run Chinook salmon is in development, and as such, has not been incorporated into the modeling results. Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater degradation of critical habitat beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Based on previous climate change modeling for the Central Valley (Cayan et al. 2009), NMFS expects that climate conditions will follow a trajectory of higher temperatures beyond 2030. Not only are annual air temperatures expected to continue to increase throughout the 21st century, but the rate of increase is projected to increase with time. That is, in the early part of the 21st century, the amount of warming in the Sacramento region is projected to be less than it is in the latter part of the century under both low and high carbon emission scenarios (Cayan et al. 2009). Because water temperatures are influenced by air temperatures, NMFS expects that climate change will amplify adverse thermal effects of the PA combined with the environmental baseline and modeled climate change past 2030.

The mean percent redds dewatered under the PA is predicted to range between three and seven percent greater (raw difference) than the means under the NAA during June of all water year types except wet years, and to be between three and six percent greater during August of wet and above normal years, respectively. The percent change (relative change rather than raw change) in the means for these months and water year types ranged from 26 percent to 89 percent greater under the PA than under the NAA. The large percentages for many of the months and water year types are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes. During April and May, redd dewatering would differ insignificantly between the PA and NAA. The estimated percentage of redd dewatering presented in the exceedance plots (included in Section 2.5.1.2.2.1, Figure 2-37 through Figure 2-42) indicate that there is a medium degree of certainty that Sacramento River redd dewatering under the PA will cause a medium-level magnitude of degradation to Sacramento River winter-run Chinook salmon in all water years except critically dry years, when dewatering under the PA is projected to result in a low level of degradation. The redd scour analysis suggests there is little degradation to spawning habitat resulting from high PA flows during the April through October spawning and egg incubation period. As discussed in Section 2.5.1.2.3.1, increases in projected flow-related mortality suggest that spawning PBFs utilized by early life stages of winter-run Chinook salmon will not be degraded, except in very rare cases (less than 1% of months).

For CV spring-run Chinook salmon, a similar level of uncertainty must be considered in the temperature analyses included in Section 2.5.1.2. A temperature threshold analysis, SALMOD model analysis, and the SWFSC's egg mortality model analysis were performed for CV spring-run Chinook salmon as well. Overall, the thresholds analysis indicates that there would be more exceedances (five percent or greater) in certain months and water year types under the PA. Overall, the monthly temperature modeling results, exceedance plots and biological tools all indicate that thermal impacts on the PBFs of spring-run Chinook salmon critical habitat that relate to spawning will largely be the same with implementation of either the NAA or PA operations. Adverse thermal effects on these PBFs from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in substantial degradation to spawning PBFs in critically dry years. As discussed above for Sacramento River winter-run Chinook salmon, it is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. Additionally, the Shasta Operations RPA adjustment described in the BA (Section 3.1.4.5 Annual/Seasonal Temperature Management Upstream of the Delta), which is intended to provide more protective temperatures for winter- and spring-run Chinook salmon is in development, and as such, has not been incorporated into the modeling results. Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater degradation of critical habitat beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. The redd dewatering analysis found that the largest increases in projected dewatering, about 30 percent, would be for wet, above normal and below normal water year types. Redd dewatering under the PA will cause a medium-level magnitude of degradation to spring-run Chinook salmon spawning habitat PBFs based on the modeling results which show that at least a small percentage ranging up to 32% of redds will be dewatered in every water year type during peak spawning and egg incubation months. The certainty of this magnitude ranking is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts to critical habitat that occur over daily time scale as well as some difficulty in quantifying adverse effects when considering the uncertainties of spring-run Chinook salmon spawning in the upper Sacramento River. Overall, redd scour under the PA is not expected to degrade spawning habitat utilized by CV spring-run Chinook salmon in the Sacramento River, except for rare cases (less than three percent of months).

A temperature threshold analysis was performed for CCV steelhead in the Sacramento River using two different threshold levels for egg/alevin incubation - 53°F (McCullough et al. 2001) and 56°F (McEwan and Jackson 1996). Modeling results indicate that although there is little difference in the number of water temperature exceedances between the PA and NAA scenarios, the actual water temperature conditions in the river are deleterious to spawning and egg/alevin incubation. Although the environmental baseline temperature conditions of spawning habitat for CCV steelhead in the Sacramento River are degraded from their historical condition, there is little additional degradation anticipated due to temperature changes resulting from the PA. Overall, in the American River, the PA would change mean water temperatures very little (less than 1°F) throughout the reach in all months and water year types of the period. As discussed above for Sacramento River winter-run Chinook salmon, it is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. Additionally, the Shasta Operations RPA adjustment described in the BA (Section 3.1.4.5 Annual/Seasonal Temperature Management Upstream of the Delta), which is intended to provide more protective temperatures for winter- and spring-run Chinook salmon is in development, and as such, has not been incorporated into the modeling results. Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater degradation of critical habitat beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated.

Modeling results indicate that the PA would minimally affect CCV steelhead redd dewatering in the Sacramento River, except for reductions in the mean percent of redds dewatered during November of wet and above normal water year types. In the American River, differences in the mean maximum flow reduction, expressed as a percentage of the spawning flow, for each month of spawning under each water year type and all water year types combined indicate that steelhead redd dewatering would generally be little affected by the PA (less than five percent raw difference), except for a five percent increase in the maximum flow reduction for January of critical years and six and seven percent increases for February of below normal and critical years, respectively. These results suggest that the PA will result in minimal degradation to spawning habitat utilized by CCV steelhead in the Sacramento River and American River.

As discussed in Section 2.5.1.2, in the Sacramento River, about 5 percent of months at Keswick Dam and about 15 percent of months at Red Bluff would have flows above the redd scouring thresholds during the November through April spawning and incubation period of CCV steelhead. The relatively high percentage of months with scouring flows in the steelhead spawning and incubation period is expected, given that the period encompasses the wettest months of the year. There would be no difference between the PA and the NAA in the percentage of months with scouring flows at Keswick Dam. The percentage of months with scouring flows at Red Bluff would be one percent higher under the PA than under the NAA. Redd scour is expected rarely to result in degradation to spawning habitat in the American River, as modeling results indicate very minor differences in flow between the PA and NAA.

The BA contains a spawning Weighted Usable Area (WUA) analysis for salmonid species. Spawning WUA provides a metric of spawning habitat availability that accounts for the spawning requirements of the fish with respect to water depth, flow velocity, and substrate. Spawning WUA for winter-run Chinook salmon was determined by USFWS (2003a, 2006) for a range of flows in three segments of the Sacramento River between Keswick Dam and the Battle Creek confluence (Appendix 5.D of the BA, Section 5.D.2.2, Spawning Flows Methods). Segment 4 stretches 8 miles from Battle Creek to the confluence with Cow Creek; Segment 5 reaches 16 miles from Cow Creek to the A.C.I.D. Dam; and Segment 6 covers 2 miles from A.C.I.D. Dam to Keswick Dam. The Cow Creek confluence is about midway between the Airport Road Bridge and Balls Ferry and, therefore, based on CDFW aerial survey results (BA Table 5.4-26), 45% of winter-run Chinook salmon redds occur within Segment 6 and most of the remainder are found within Segment 5. To estimate changes in spawning WUA that would result from the PA, the flow-versus-spawning habitat WUA relationship developed for each of these segments was used with mean monthly CALSIM II flow estimates for the midpoint of each segment under the PA and the NAA during the winter-run spawning and egg incubation period.

As described in Appendix 5.D of the BA, Section 5.D.2.2, Spawning Flows Methods, spawning habitat for spring-run Chinook salmon was not estimated directly by USFWS (2003b, 2006) and no spring-run Chinook salmon WUA curves were provided in the BA. Spring-run Chinook salmon spawning habitat was modeled using the WUA curves provided for fall-run Chinook salmon. The spawning WUA curves for fall-run Chinook salmon were used because the spawning and incubation period of fall-run is similar to that of spring-run, and because this substitution follows previous practice (Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods). However, as noted by USFWS (2003a) the validity of using the fall-run WUA curves to characterize spring-run spawning habitat is uncertain. To evaluate the effects of the PA on spring-run spawning habitat, spring-run spawning WUA was estimated for flows during the August through December spawning period under the NAA and the PA in the same three segments of the Sacramento River that were used for winter-run Chinook salmon.

Spawning WUA for Central Valley steelhead in the Sacramento River was determined by USFWS (2003a, 2006) in the same manner that it was determined for winter-run Chinook salmon, except that habitat suitability criteria (HSC) previously determined for Central Valley steelhead in the American River (U.S. Fish and Wildlife Service 2003b) were used in developing the Sacramento River steelhead WUA curves (Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods). HSC data were not collected by USFWS for steelhead in the Sacramento River because very few steelhead redds were observed and because the steelhead redds could not be distinguished from those of resident rainbow trout. The validity of this substitution could not be tested and is uncertain (U.S. Fish and Wildlife Service 2003a). To evaluate the effects of the PA on steelhead spawning habitat, steelhead spawning WUA was estimated for flows during the November through April spawning period under the NAA and the PA in the same three segments of the Sacramento River that were used for winter-run and spring-run Chinook salmon.

Further information on the spawning WUA analysis methods for winter-run Chinook salmon, spring-run Chinook salmon, and steelhead is provided in Appendix 5.D of the BA, Section 5.D.2.2, Spawning Flows Methods.

Differences in spawning WUA under the PA and NAA were examined using exceedance plots of monthly mean WUA for the spawning period of these three species in each of the river segments for each water year type and all water year types combined. The exceedance curves for the PA generally match those of the NAA for all water year types in all three segments. In some instances, WUA was higher under the PA than the NAA. Table 2-238 summarizes percent differences in spawning WUA in which the WUA under the PA was ≥5% less than the WUA under the NAA. Exceedance curves associated with these instances are also included below (Figures 2-187 through 2-200).

Table 2-238. Spawning Weighted Usable Area (WUA) Units for Winter-run Chinook Salmon, Spring-run Chinook Salmon, and Steelhead; and a Summary of Percent Differences Between the PA and NAA in which WUA was ≥5% less under the PA than under the NAA.

Species	River Segment	Month	Water Year Type	NAA	PA	PA vs. NAA
Winter-run	6	September	Below Normal	202,678	178,020	-24,658 (-12%)
			Dry	176,018	164,981	-11,038 (-6%)
			Critical	172,765	156,462	-16,303 (-9%)
		October	Wet	272,932	253,563	-19,368 (-7%)
	5	June	Below Normal	732,040	690,204	-41,836 (-6%)
Spring-run	6	September	Critical	295,609	280,631	-14,979 (-5%)
		November	Critical	263,119	246,772	-16,348 (-6%)
	5	August	Dry	430,234	408,673	-21,561 (-5%)
		December	Above Normal	493,732	461,657	-32,075 (-6%)
	4	October	Below Normal	194,636	169,106	-25,530 (-13%)
			Dry	203,681	188,415	-15,266 (-7%)
		November	Critical	261,540	245,589	-15,950 (-6%)
Steelhead	6	January	Wet	47,991	44,845	-3,146 (-7%)
		February	Below Normal	52,430	49,679	-2,752 (-5%)
		March	Above Normal	49,551	46,630	-2,921 (-6%)

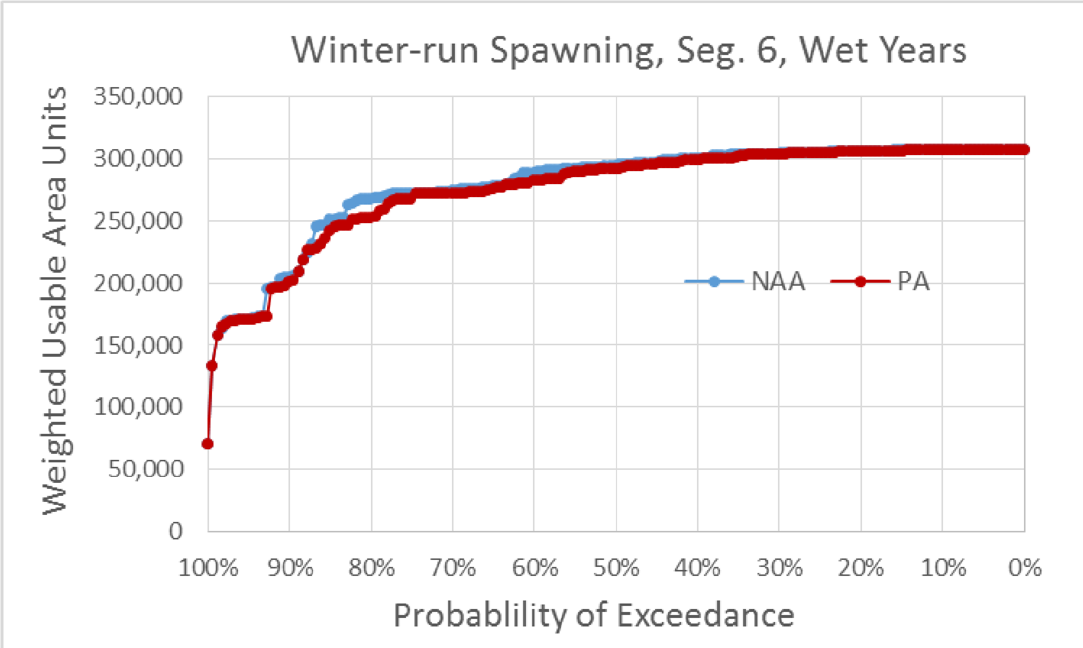


Figure 2-187. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years.

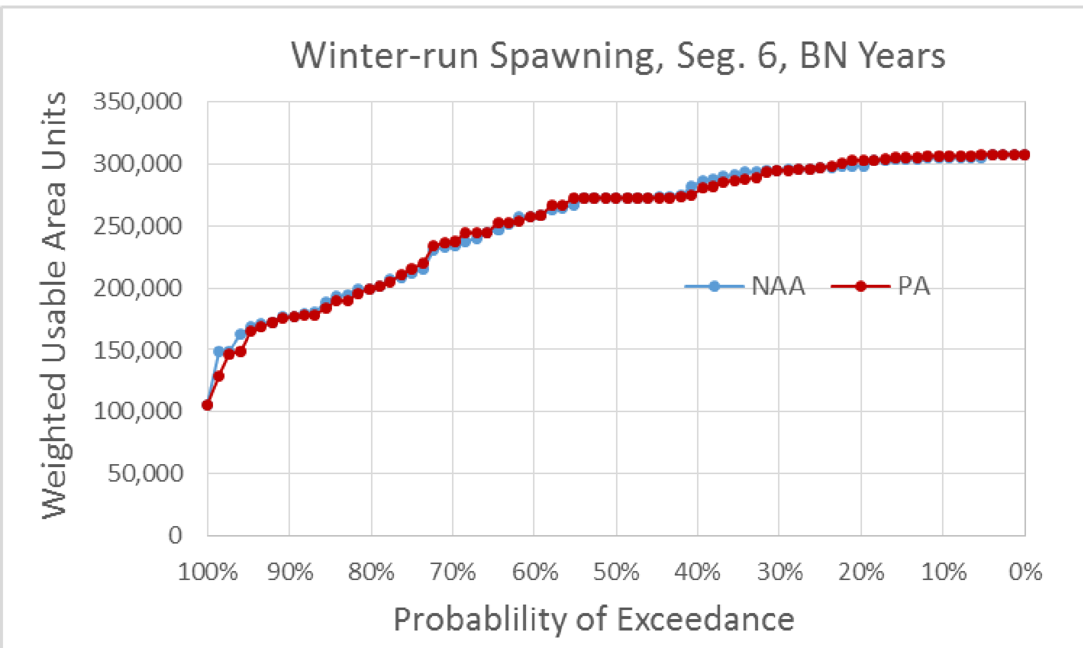


Figure 2-188. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years.

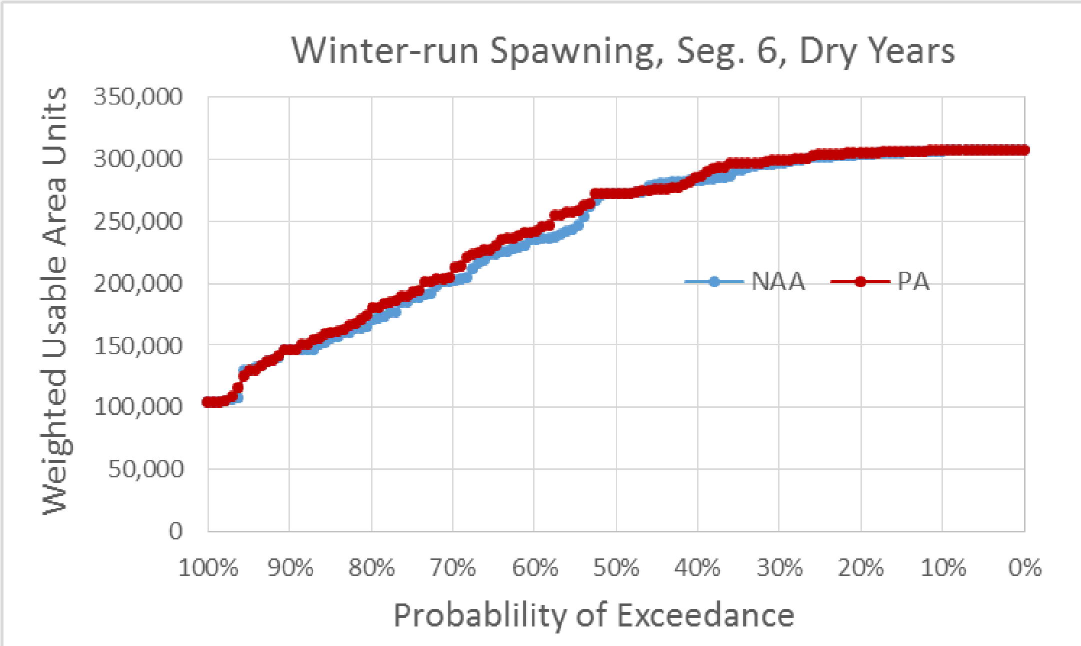


Figure 2-189. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years.

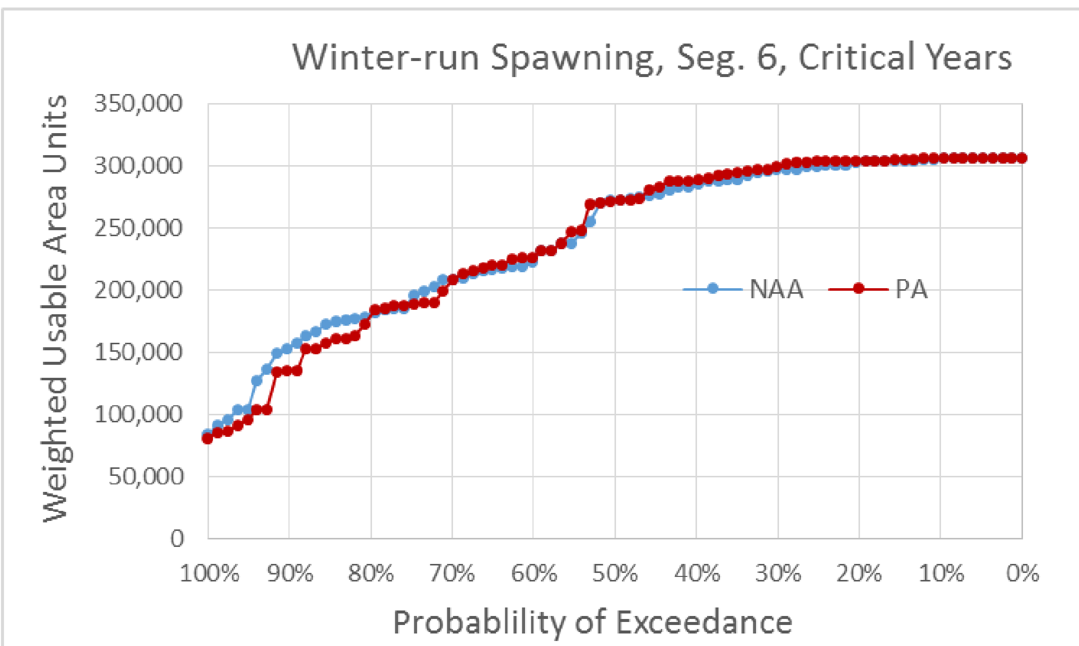


Figure 2-190. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years.

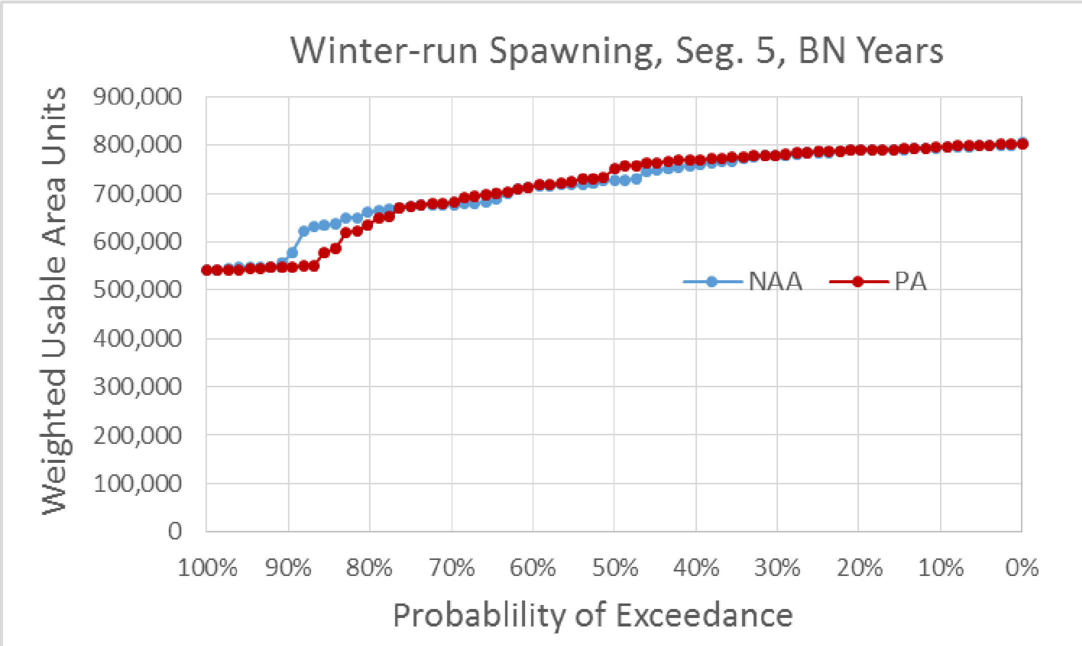


Figure 2-191. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years.

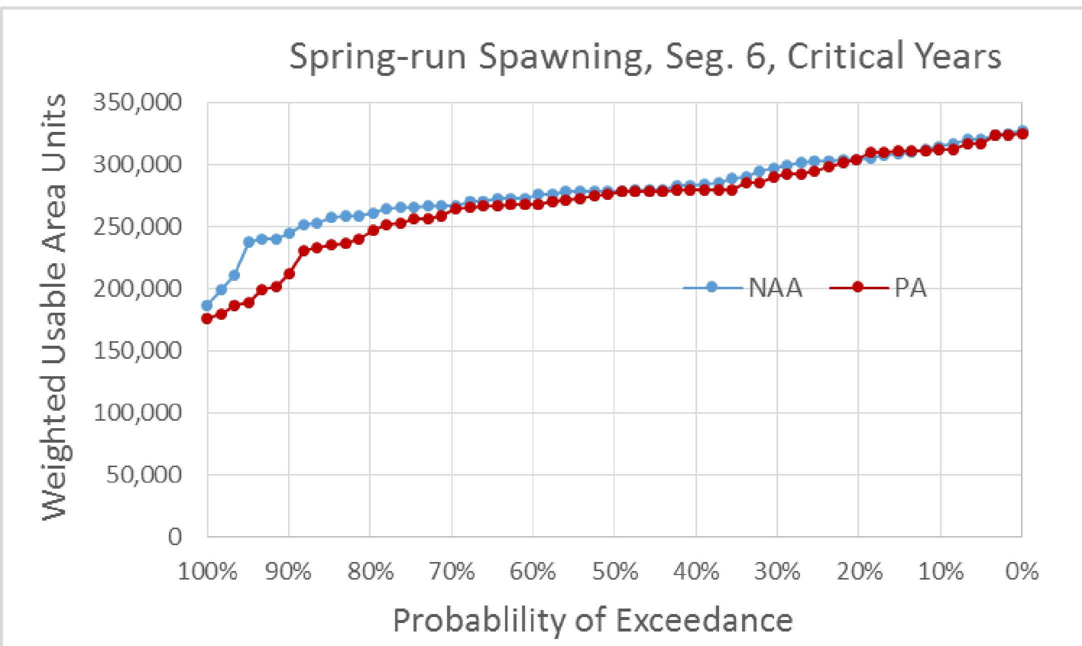


Figure 2-192. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years.

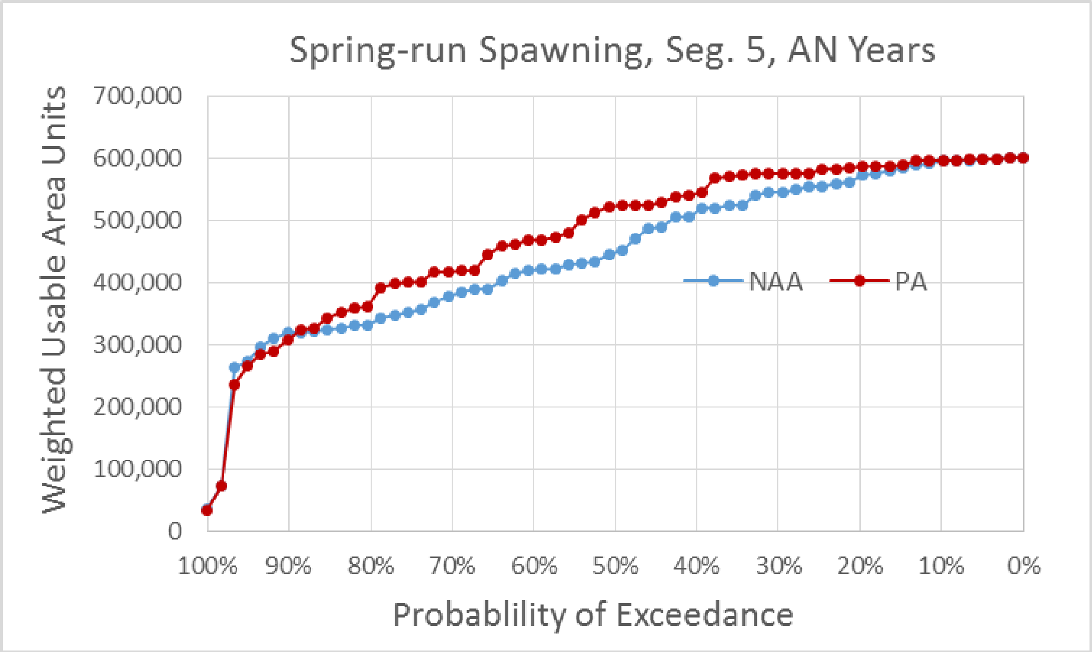


Figure 2-193. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years.

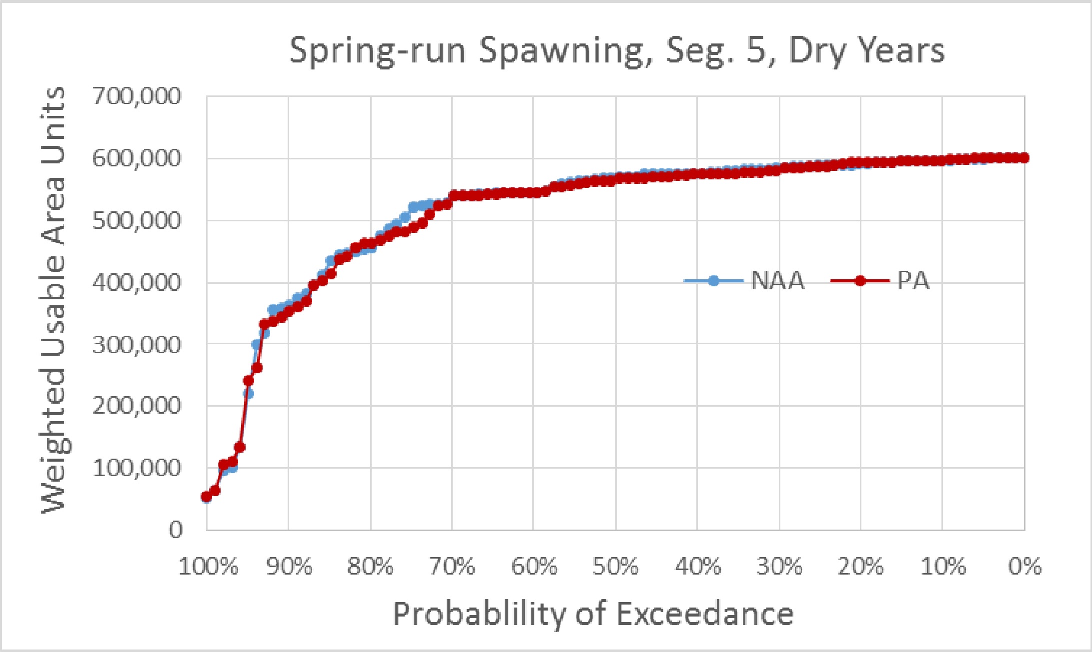


Figure 2-194. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years.

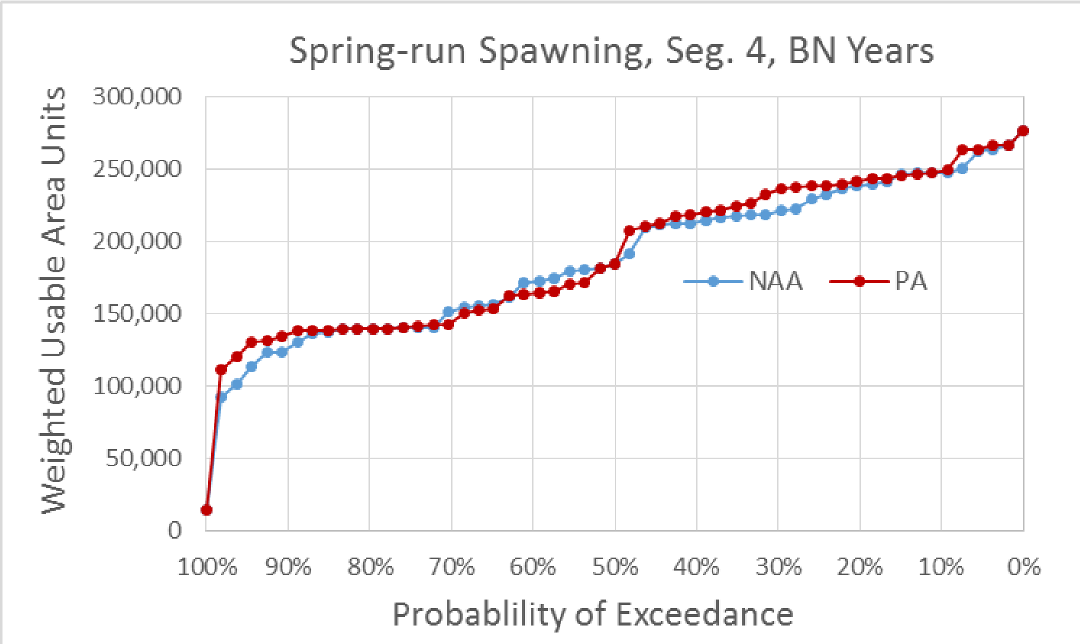


Figure 2-195. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years.

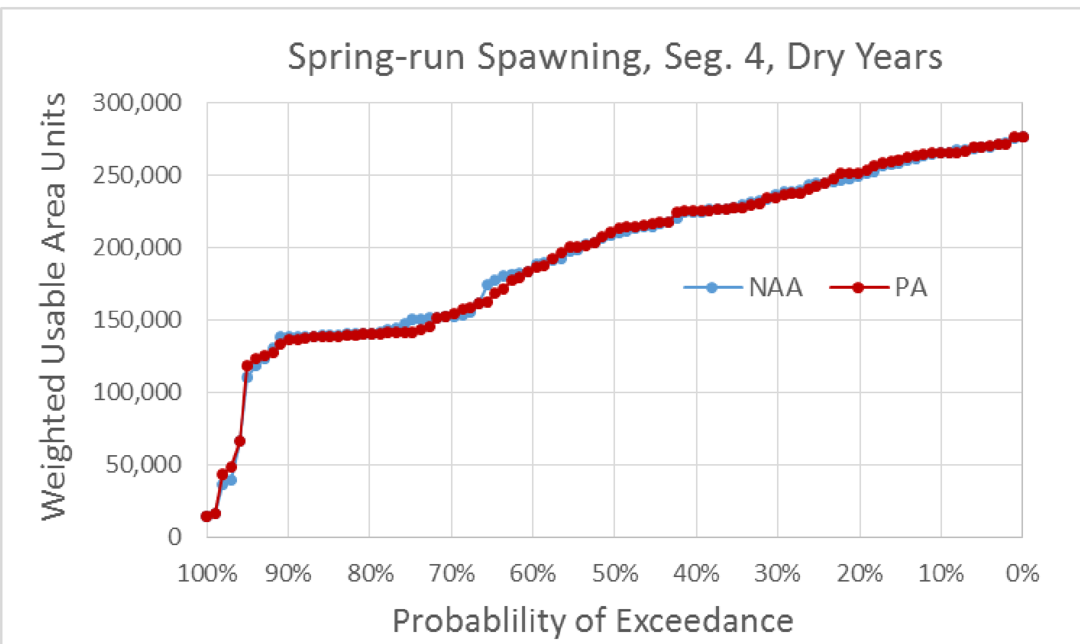


Figure 2-196. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years.

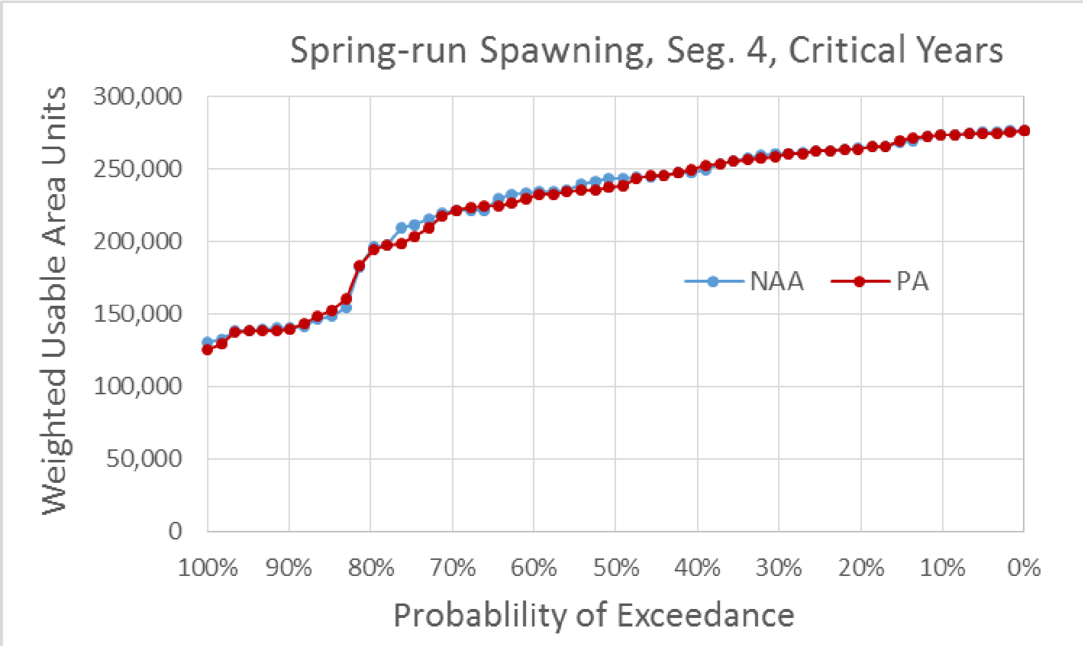


Figure 2-197. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years.

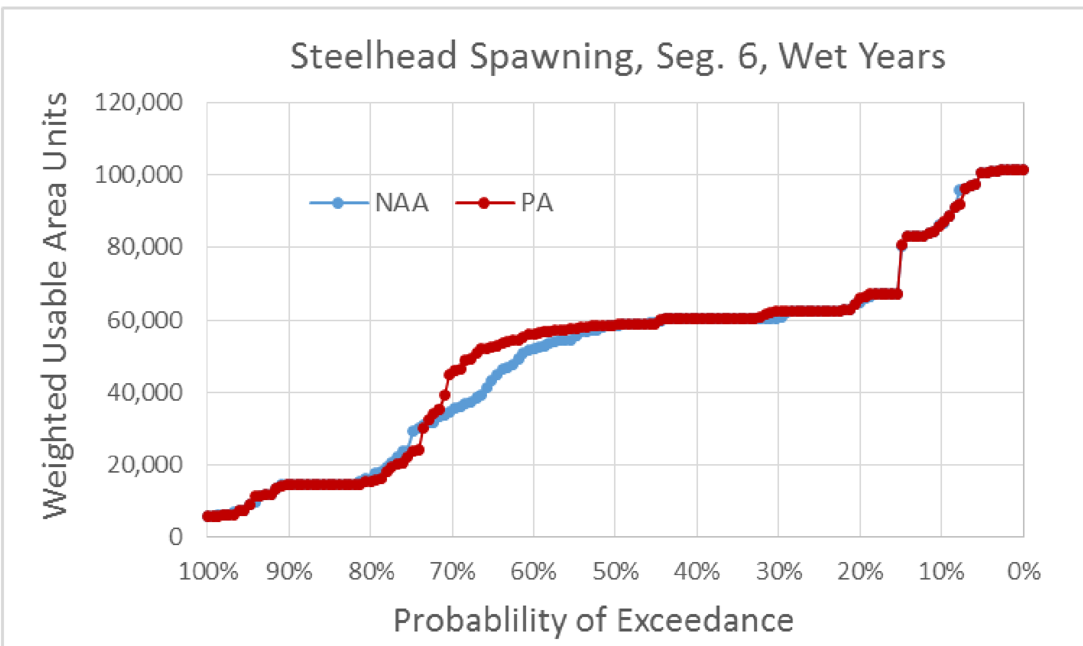


Figure 2-198. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years.

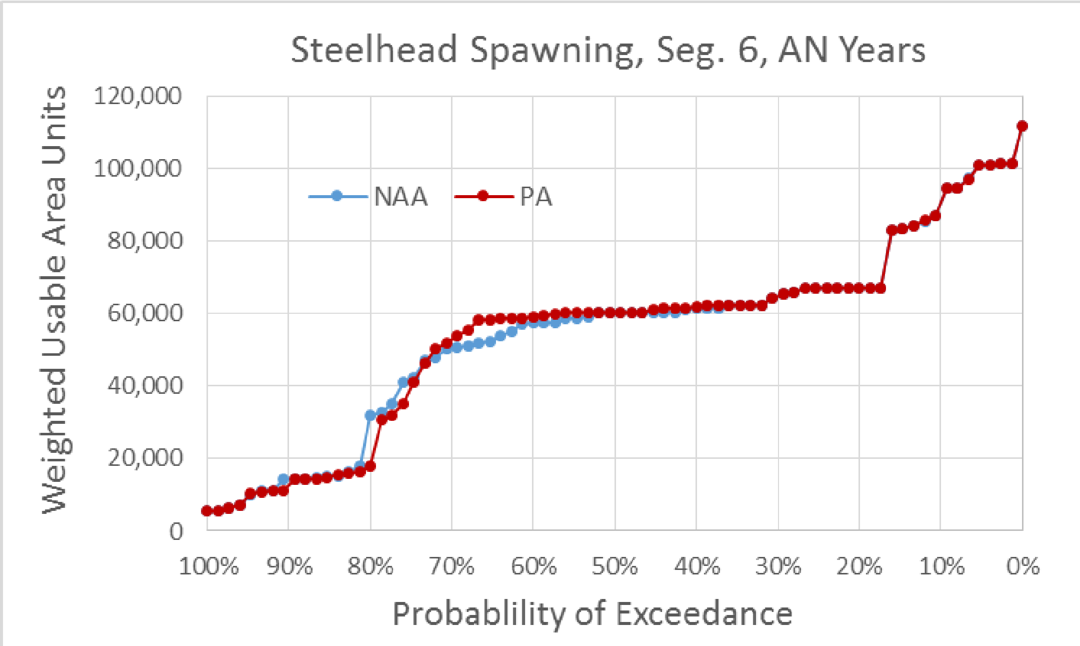


Figure 2-199. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years.

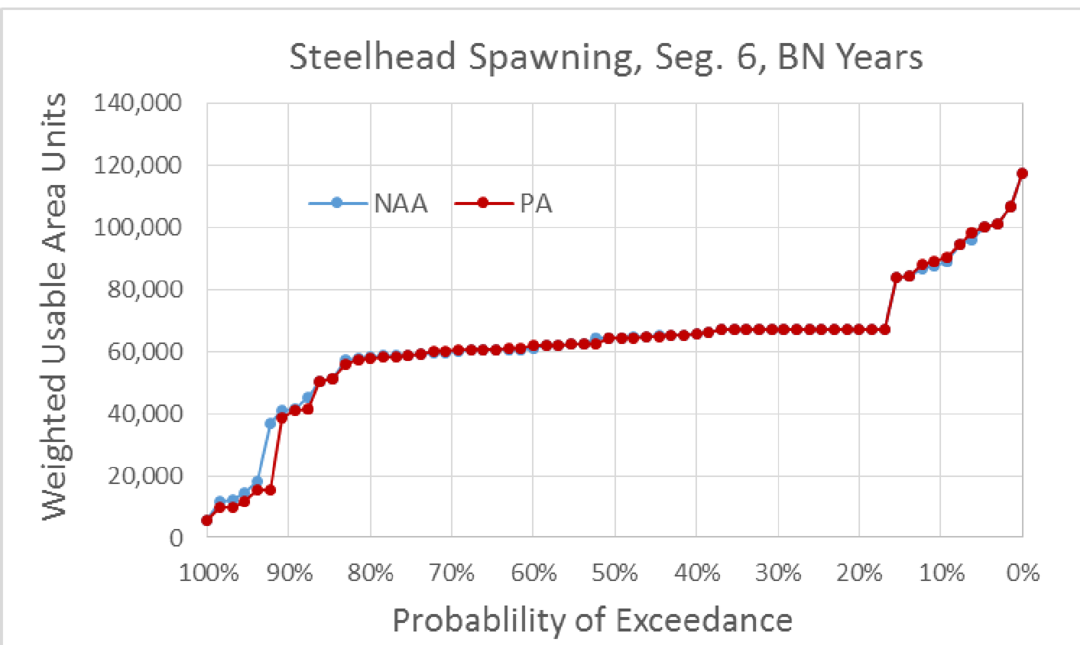


Figure 2-200. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years.

Spawning WUA for steelhead in the Lower American River was determined by USFWS(2003b)for several river segments located within about 6 miles of Nimbus Dam, where most steelhead spawning occurs. To evaluate the effects of the PA on steelhead spawning habitat, steelhead spawning WUA was estimated for CALSIM II flows at Nimbus Dam under the NAA and the PA during the December through May spawning period for all of the river segments combined (see Appendix 5.D of the BA, Section 5.D.2.2, Spawning Flows Methods).

Differences in steelhead spawning WUA under the PA and NAA were examined using exceedance plots of monthly mean WUA during the steelhead spawning period for each water year type and all water year types combined. The exceedance curves for the PA generally match those of the NAA for all water year types in all three segments. In one instance, WUA was higher under the PA than the NAA (January – Dry WYT). In only one instance was the percent difference in spawning WUA ≥5% less under the PA than under the NAA. This occurred in: March, Critical WYT, and yielded a negative difference in WUA units of -23,291 (a -9% difference). The exceedance curve associated with this result is included below (Figure 2-201).

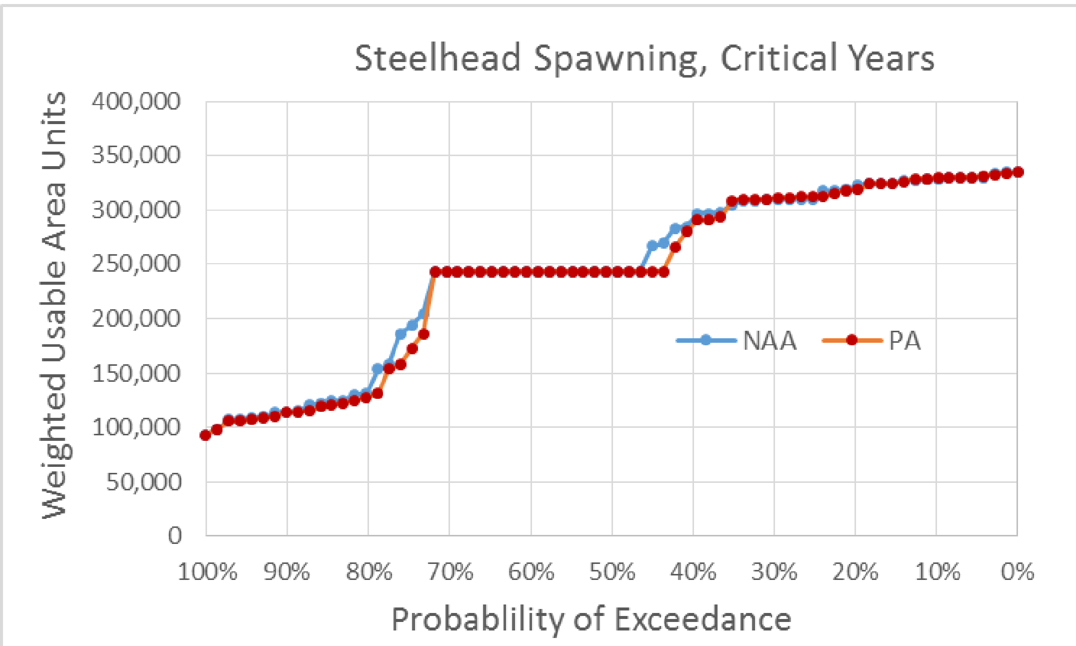


Figure 2-201. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios, Critical Water Years.

As indicated in Table 2-238, there are several months and water types in which spawning WUA was projected to be ≥5% less under the PA as compared to the NAA. This is of particular concern for winter-run Chinook, as that ESU consists of a single population, and the spawning habitat available between RBDD and Keswick Dam on the Sacramento River is the only spawning habitat utilized by this ESU. The projected difference in spawning WUA was greatest in September of below normal water year types (12% less under the PA as compared to the NAA). Reduction in WUA under the PA will cause a medium-level magnitude of degradation to winter-run Chinook salmon spawning habitat PBFs based on the modeling results described in this section. It will cause a low-level magnitude of degradation to spawning habitat PBFs for spring-run Chinook and steelhead.

The revised PA (Appendix A2) includes a recommitment to expanding the available habitat for spawning adults, incubation of eggs, and rearing for fry, specifically, in Battle Creek and above Shasta Dam, into the McCloud River. Although the target species for these efforts is winter-run Chinook salmon, spring-run Chinook salmon and steelhead will likely benefit from this expanded habitat, which will begin improving these PBFs before proposed action operations commence and improve these PBFs over the long-term.

The PA does not include any construction-related in-water activity that would disturb, contaminate, remove, or otherwise degrade spawning gravel within the known primary spawning range for Chinook salmon and steelhead in the Sacramento River or American River. Due to a lack of any construction activity within spawning areas in these rivers, there is not expected to be any contaminant incursion to any habitat component of this area.

2.5.2.2.2 Freshwater Rearing Habitat for Juveniles

Sacramento River winter-run Chinook PBFs:

- Habitat areas and adequate prey that are not contaminated
- Riparian habitat that provides for successful juvenile development and survival

CV spring-run Chinook and CCV steelhead PBFs:

- Freshwater Rearing Sites

Freshwater rearing habitat occurs for all three species in the mainstem Sacramento River downstream to the Delta. As discussed in Section 2.5.1.1.4.1 Clearing, Grubbing, and Maintenance, removal of riparian vegetation will occur in the action area at construction sites for the NDD. These impacts total approximately 20.1 acres of tidal perennial habitat and 1.02 linear miles of channel margin habitat that encompass the in-water work areas and permanent footprints of intake structures. The footprint of each intake structure, including cofferdams, transition wall structures, and bank protection (riprap), would result in the permanent loss of approximately 6.6 acres of tidal perennial habitat and 1.02 linear miles of shoreline and associated riparian vegetation. At each intake location, these structures would encompass 1,600-2,000 linear feet of shoreline and 35 feet (5-7%) of the total channel width. General effects to anadromous fish habitat resulting from disturbance to riparian vegetation include loss of shading, recruitment of LWM into the river, habitat complexity, and shelter from predators. It also may result in a loss of aquatic macro invertebrate production and may have adverse effects to water quality. These effects are discussed in greater detail in Section 2.5.2.1.3 Loss of Riparian Vegetation. These impacts are expected to occur within the footprint of the NDD as a result of the PA.

The acreage of loss for each structure, including areas located in designated critical habitat that could be affected by placement of permanent in-water structures, and the temporary areas of loss (i.e., areas that will only be affected during construction activities) were calculated and will be sufficiently offset for through channel margin and tidal perennial habitat creation/restoration in the appropriate areas (see Appendix A2 Proposed Action). In addition, the revised PA includes 80 acres of expanded rearing habitat through restoration in the upper Sacramento River between Keswick Dam and RBDD and 1,800 acres of tidal rearing habitat restoration in the Delta. Although these additional habitat restoration activities will have short-term impacts to habitat from ground and in-water disturbance the restoration is expected to begin improving these PBFs before proposed action operations commence and improve this PBF for all listed salmonids in the long-term.

Given the relative scale of permanent loss of riparian vegetation compared to the total abundance of vegetation in the immediate area, and as coupled with the habitat mitigation proposed as part of the PA, it is unlikely that the resultant reduction of aquatic macroinvertebrate productivity or loss of shading will lead to significant degradation of these PBFs.

Installation of interim structures and reduction of habitat complexity at the NDD sites are expected to result in increased predation, as artificial structures in the water can create predator habitat (see section 2.5.1.1.6.3). Freshwater rearing PBFs, such as those affecting rearing and survival, will also be degraded in the vicinity of the NDD resulting from barge operations. As described in 2.5.1.1.7.3 Barge Propeller Injury and Entrainment, rearing juvenile salmonids will be at risk of propeller entrainment as barge operations are expected to occur year-round during the period of barge operations. In-water work involving acoustic impacts and additional construction-related disturbances are expected to occur during months in which juvenile CCV steelhead are rearing near the NDD sites. Likewise, sedimentation events affecting CCV steelhead are likely to occur during in-water work windows as a result of dredging, geotechnical boring, and pile driving. Sedimentation resulting from barge operations is expected year-round during the period of barge operations and will affect freshwater rearing habitat, prey availability, and predator avoidance. As discussed in Section 2.5.1.2.5 Screen Impingement and Entrainment North Delta Intakes, risk of impingement exists at the NDD screens, reducing the quantity and quality of freshwater rearing habitat PBFs in those locations for salmonids. Although the screens will be designed to minimize approach velocities such that they do not exceed salmonid swimming capabilities, the area will be tidally influenced and sweeping velocities may decrease to a point at which risk of impingement may occur, degrading the functionality of rearing habitat. The PA describes the incorporation of refugia along the NDD structure that may provide additional minimization to screen impingement and associated predation risk. Phased testing and operation of the three NDD intakes will ensure that the screens are functioning to NMFS screening criteria. Additional degradation to freshwater rearing PBFs in the Sacramento River is anticipated as a result of physical and acoustic (steelhead only – due to timing/presence of the juvenile life stage) disturbance; increased predation risk; sedimentation; risk of impingement; and loss of habitat complexity.

As discussed in Section 2.5.1.1.3 Contaminant Exposure, due to the implementation of avoidance and minimization measures and BMPs, it is unlikely that construction-related spills or contaminants will impact freshwater rearing habitat in the action area. However, some contaminant exposure is anticipated in the vicinity of the NDD sites as a result of re-suspension of contaminated sediment due to barge operations, which will result in some degradation of these PBFs.

Overall, the PA would change mean water temperatures very little (less than 1°F) throughout the juvenile rearing reach of Keswick Dam to Knights Landing in all months and water year types in the juvenile rearing period for both winter-run and spring-run Chinook salmon. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F and would occur at Knights Landing in below normal years during August. Minimal difference in degradation to juvenile rearing habitat PBFs for winter-run and spring-run Chinook salmon are anticipated as a result of temperature increases under the PA. Overall, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, NMFS concludes that the environmental conditions as portrayed by riverine water temperatures associated with the PA and NAA operational scenarios will adversely affect CCV steelhead juvenile rearing habitat during the August through October period from Keswick Dam downstream to Red Bluff based on modeling results. In the farthest downstream reach modeled (Red Bluff), water temperatures under both the PA and NAA operational scenarios have the potential to degrade rearing habitat for CCV steelhead in June and July as well. In the American River, the PA would change mean water temperatures very little (predominantly less than 1°F) throughout the juvenile rearing reach in all months and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F, and would occur at Watt Avenue in critical water years during August. Minimal degradation of juvenile rearing habitat for CCV steelhead in the American River is anticipated as a result of temperature increases under the PA. As discussed in Section 2.5.2.2.1 Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry, it is important to note that adverse effects indicated by the modeling would to some extent be minimized by real-time operational management described in the BA in Section 3.1.5, Real-Time Operations Upstream of the Delta, and Section 3.3.3, Real-Time Operational Decision-Making Process. Additionally, the Shasta Operations RPA adjustment described in the BA (Section 3.1.4.5 Annual/Seasonal Temperature Management Upstream of the Delta), which is intended to provide more protective temperatures for winter- and spring-run Chinook salmon is in development, and as such, has not been incorporated into the modeling results. Another important overall consideration is that the water temperature modeling reflects projected climate change to 2030 and to the extent that climate change creates greater degradation of critical habitat beyond what is projected for 2030, any adverse effects seen in the modeling will accordingly be exacerbated. Section 2.5.1.2 Operations Effects discusses the modeling and results of this temperature analysis in greater detail.

Some functional overlap exists just downstream of the NDD sites between the PBFs of freshwater rearing habitat and estuarine habitat because of tidal fluctuations. Loss of rearing habitat downstream of the NDD sites due to operations under the PA is discussed in Section 2.5.2.2.4 Estuarine Habitat for Rearing and Migration and a detailed analysis is included in Section 5.4.1.3.2.2 of the BA Habitat Suitability.

All three species are known to exhibit juvenile rearing (non-natal for winter-run and spring-run) in the Lower American River. Because there will not be any construction activity in these areas, there are no anticipated NDD construction-related impacts to these PBFs in the Lower American River as a result of the PA. Construction work on the HOR gate on the San Joaquin River will occur during an in-water work window that is designed to protect migrating juvenile steelhead, and spring-run Chinook salmon, so minimal impacts to the freshwater rearing PBF utilized by juvenile steelhead are anticipated. Diversions at the existing CVP and SWP export facilities in the south Delta are expected to cause changes in hydrodynamic conditions that are likely to result in some degradation to the freshwater rearing PBF for juvenile CCV steelhead in the south Delta.

Similar to the spawning WUA analysis discussed above in Section 2.5.2.2.1 Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry, rearing WUA provides an index of rearing habitat availability that takes into consideration the rearing requirements of the fish with respect to water depth, flow velocity, and cover. Rearing WUA for winter-run Chinook salmon fry and juveniles was determined by USFWS (2005b) for a range of flows in the same river segments used for the spawning habitat WUA studies (U.S. Fish and Wildlife Service 2003a, 2006). To estimate changes in rearing WUA that would result from the PA relative to the NAA, the rearing habitat WUA curve developed for each of these segments was used with mean monthly CALSIM II flow estimates under the PA and the NAA for the midpoint of each segment during each month of the winter-run fry (July through October) and juvenile (September through November) rearing periods (Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods, Table 5.D-62). For this analysis, fry were defined as fish less than 60 mm, and juveniles were those greater than 60 mm.

As with the spawning WUA analysis for spring-run Chinook salmon described above in Section 2.5.2.2.1, rearing habitat WUA for spring-run Chinook salmon was not estimated directly by USFWS (2005b but was modeled using the rearing habitat WUA curves obtained for fall-run Chinook salmon in Segments 4, 5 and 6 (U.S. Fish and Wildlife Service 2003a, 2006), the fall-run WUA curves for these three segments were also used in this effects analysis to model spring-run Chinook salmon rearing habitat. The rearing WUA curves for fall-run Chinook salmon were used because the fry rearing period of fall-run is similar to that of spring-run, and because this substitution follows previous practice (Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods). However, as noted by USFWS (2005b), the validity of using the fall-run Chinook salmon rearing WUA curves to characterize spring-run Chinook salmon rearing habitat is uncertain. To estimate changes in rearing WUA that would result from the PA, the fall-run Chinook salmon WUA curves developed for each of the river segments was used with mean monthly CALSIM II flow estimates for the midpoint of each segment under the PA and the NAA during the rearing periods for spring-run fry (November through February) and juveniles (year-round) (Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods, Table RFM-1). Fry were defined in this analysis as fish less than 60 mm, and juveniles were those greater than 60 mm.

As described in Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods, rearing habitat WUA for Central Valley steelhead was not estimated directly by USFWS (2005b), but was modeled using the rearing WUA curves obtained for late fall-run Chinook salmon, in the same three Sacramento River segments that were used for the winter-run Chinook salmon rearing habitat WUA studies (USFWS 2005b). The rearing WUA curves for late fall-run Chinook salmon were used because the fry rearing period of late fall-run Chinook salmon is similar to that of Central Valley steelhead, and because this substitution follows previous practice (Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods). However, the validity of using the late fall-run Chinook salmon WUA curves to characterize Central Valley steelhead rearing habitat is uncertain. To estimate changes in rearing WUA that would result from the PA, the late fall-run Chinook salmon WUA curves developed for each of the river segments was used with mean monthly CALSIM II flow estimates for the midpoint of each segment under the PA and the NAA during the rearing periods for CCV steelhead fry (February through May) and juveniles (year-round) (Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods, Table RFM-1). Fry were defined as fish less than 60 mm and juveniles were those greater than 60 mm.

Further information on the rearing WUA analysis methods for winter-run Chinook salmon, spring-run Chinook salmon, and steelhead is provided in Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods.

Differences in rearing WUA under the PA and NAA were examined for both fry and juvenile life stages using exceedance plots of monthly mean WUA for the rearing period of these three species in each of the river segments for each water year type and all water year types combined. The exceedance curves for the PA generally match those of the NAA for all water year types in all three segments. Table 2-239 summarizes percent differences in rearing WUA in which the WUA under the PA was ≥5% less than the WUA under the NAA for each species. Exceedance curves associated with these instances are also included below (Figures 2-202 through 2-223).

Table 2-239. Rearing Weighted Usable Area (WUA) units for fry and juvenile life stages of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead; and a summary of percent differences between the PA and NAA in which WUA was ≥5% less under the PA than under the NAA.

Species	Life Stage	River Segment	Month	Water Year Type	NAA	PA	PA vs. NAA
Winter-run	Fry	6	October	Below Normal	84,215	76,898	-7,317 (-9%)
		5	July	Critical	571,751	541,702	-30,049 (-5%)
			August	Below Normal	524,955	476,186	-48,770 (-9%)
			October	Below Normal	555,774	519,724	-36,051 (-6%)
	Juvenile	6	November	Above Normal	34,792	30,646	-4,145 (-12%)
		4	October	Below Normal	70,765	66,612	-4,152 (-6%)
Spring-run	Fry	4	November	Critical	258,353	242,021	-16,332 (-6%)
	Juvenile	6	June	Dry	35,461	33,581	-1,880 (-5%)
			October	Below Normal	45,982	43,621	-2,361 (-5%)
		5	October	Below Normal	456,276	429,635	-26,640 (-6%)
		4	January	Wet	105,561	96,786	-8774 (-8%)
			March	Above Normal	101,342	95,175	-6,167 (-6%)
			May	Dry	113,644	107,550	-6,093 (-5%)
			June	Dry	61,880	53,985	-7,895 (-13%)
				Critical	72,830	66,683	-6,147 (-8%)
			August	Dry	81,374	76,801	-4,573 (-6%)
			October	Below Normal	134,904	116,236	-18,667 (-14%)
Steelhead	Fry	6	May	Dry	92,012	87,286	-4,726 (-5%)
	Juvenile	6	June	Dry	36,548	34,685	-1,863 (-5%)
		5	October	Below Normal	414,535	391,634	-22,902 (-6%)
		4	January	Wet	97,853	90,372	-7,480 (-8%)
			March	Above Normal	94,398	89,099	-5,299 (-6%)
			May	Dry	104,706	99,470	-5,236 (-5%)
			June	Dry	59,726	55,659	-4,067 (-7%)
				Critical	70,307	64,770	-5,537 (-8%)
			August	Dry	77,174	72,790	-4,384 (-6%)
			October	Below Normal	123,137	107,044	-16,093 (-13%)

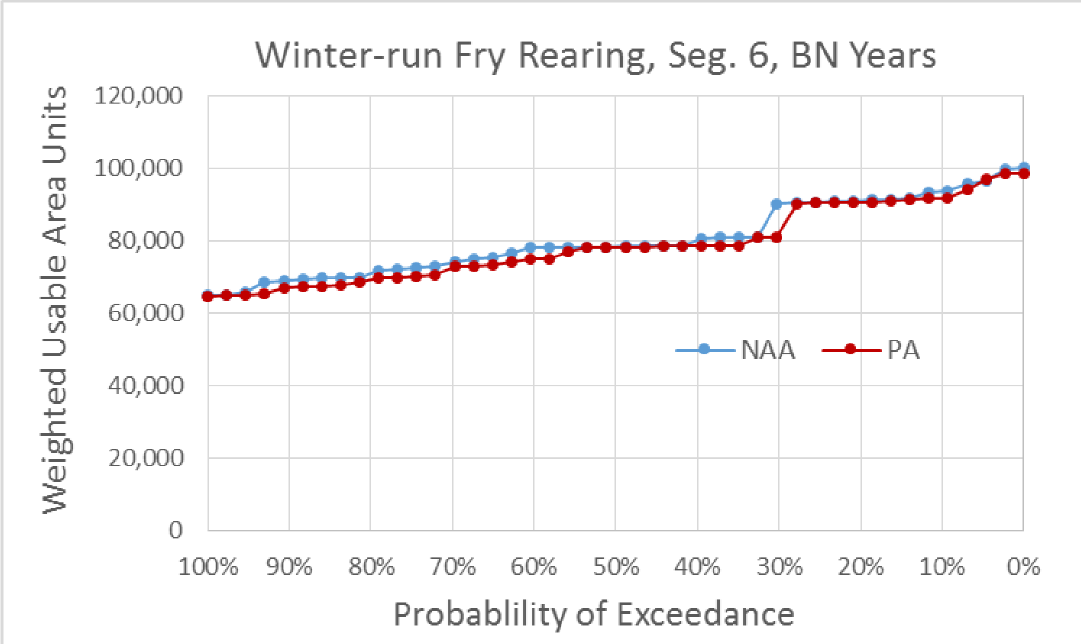


Figure 2-202. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years.

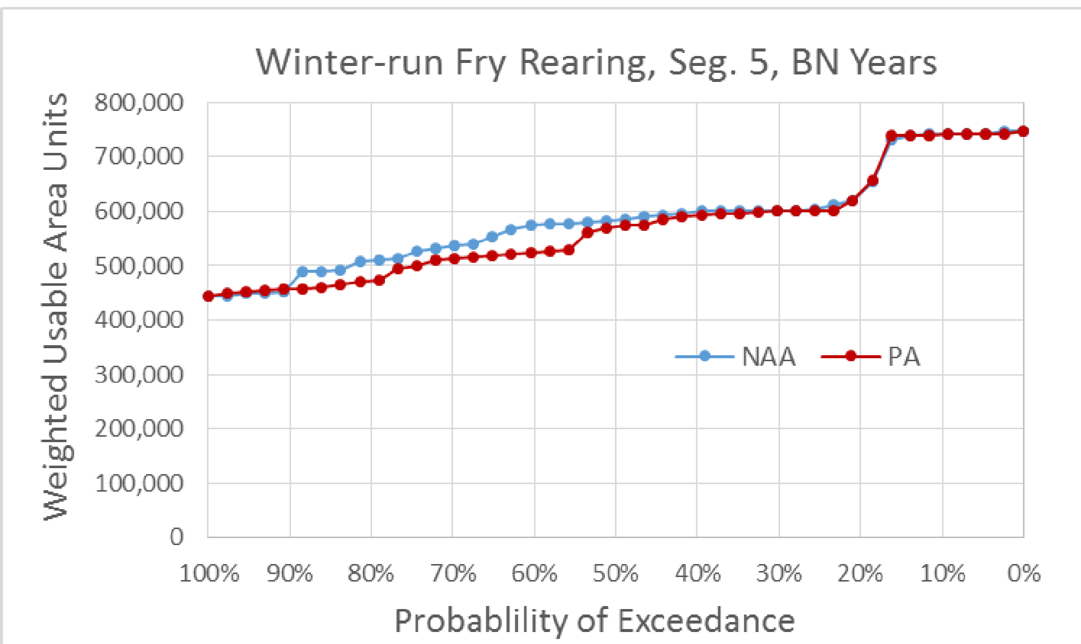


Figure 2-203. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years.

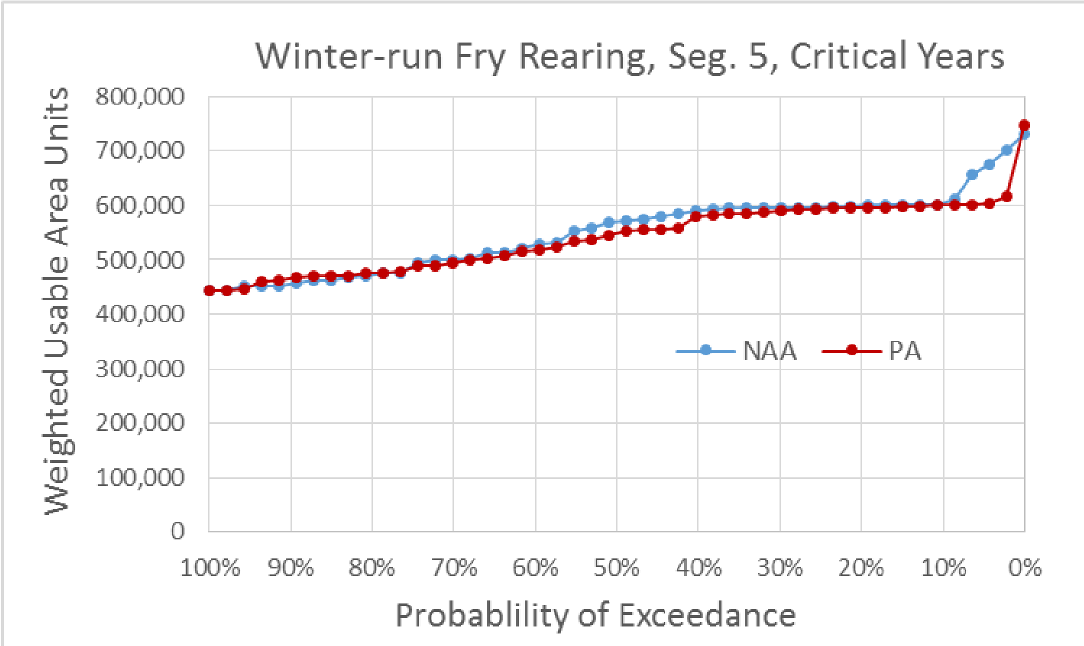


Figure 2-204. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years.

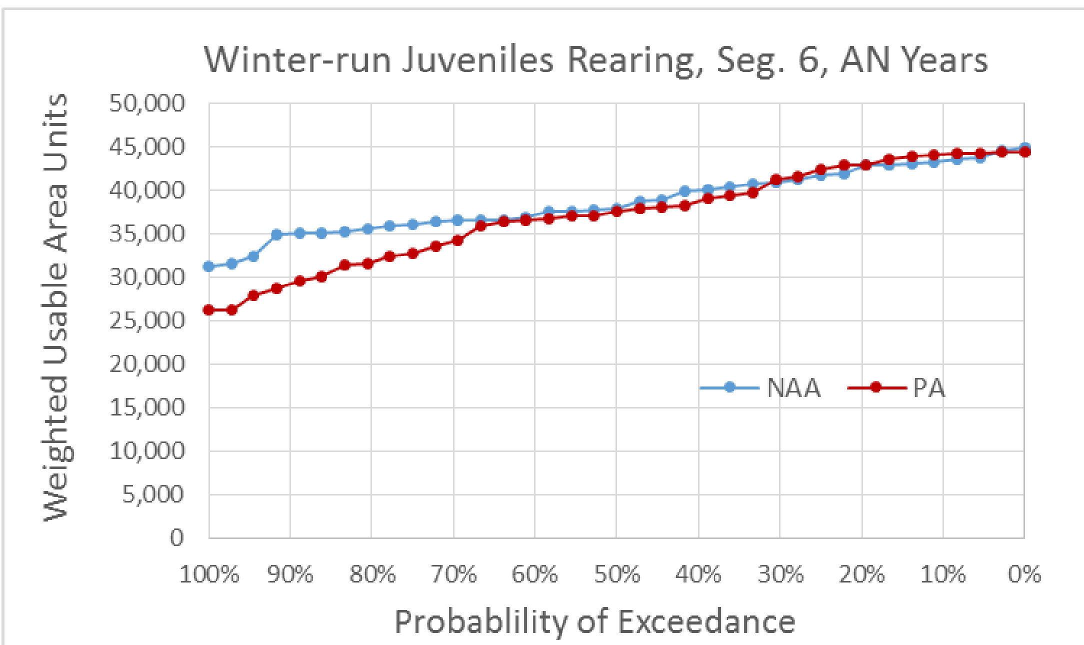


Figure 2-205. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years.

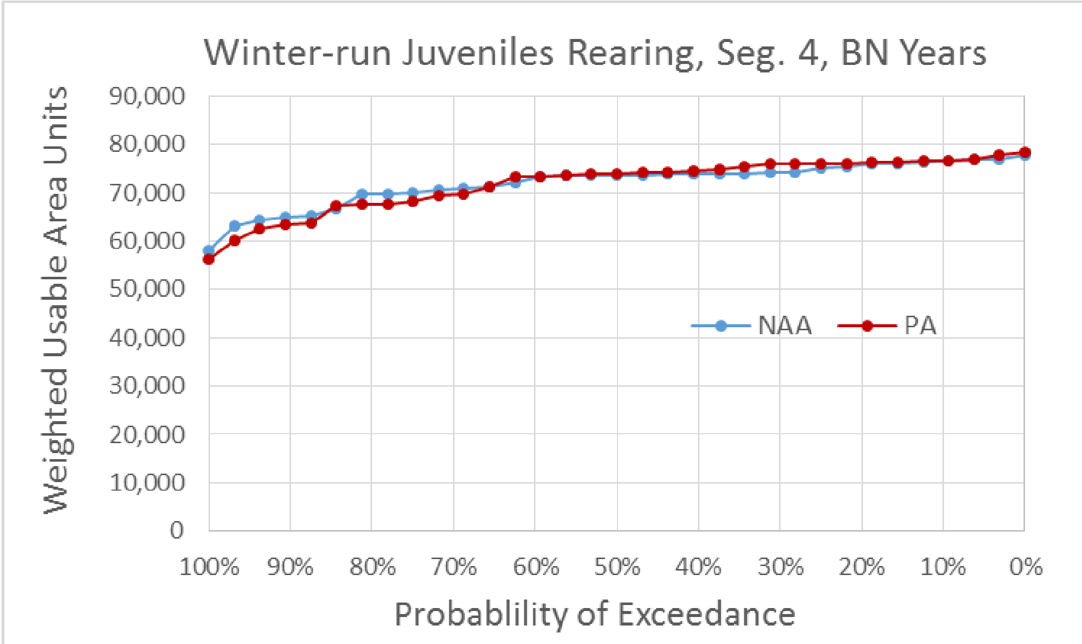


Figure 2-206. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years.

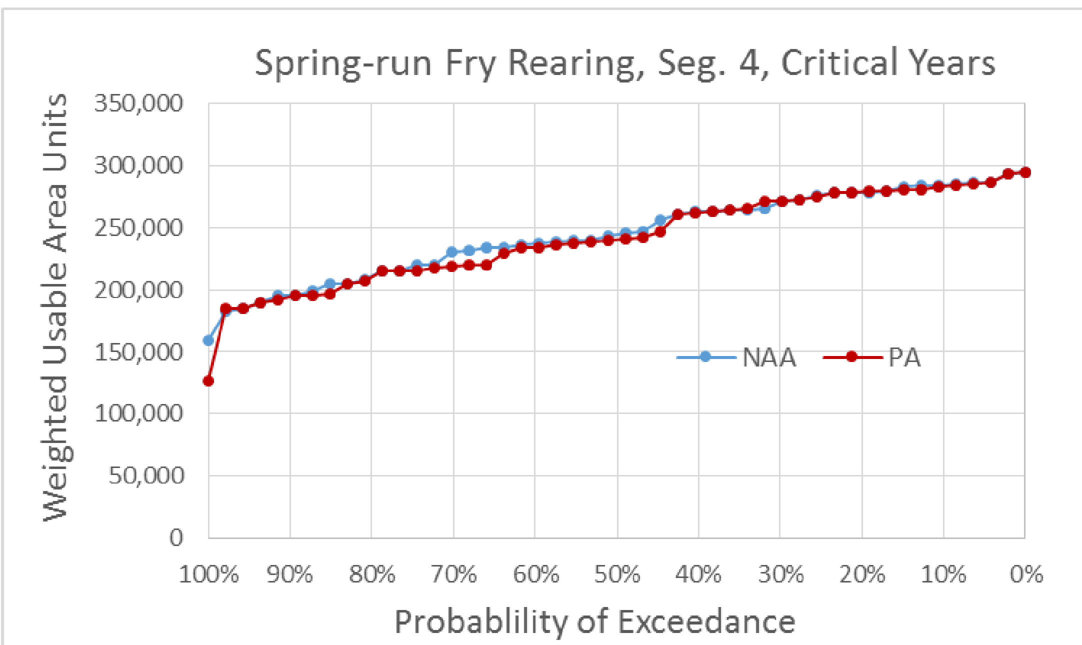


Figure 2-207. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years.

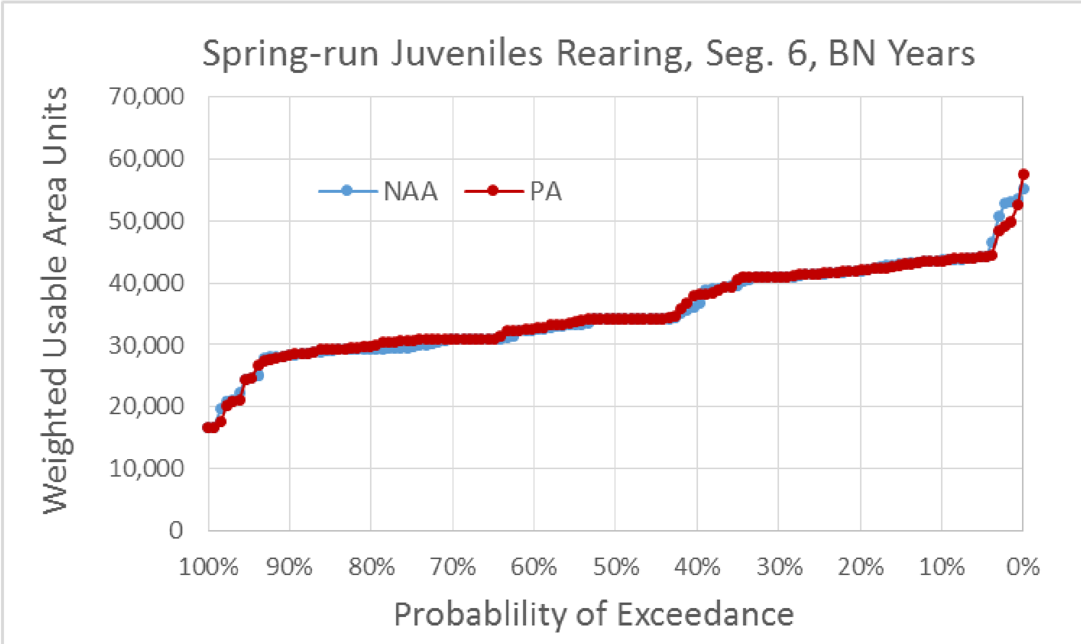


Figure 2-208. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years.

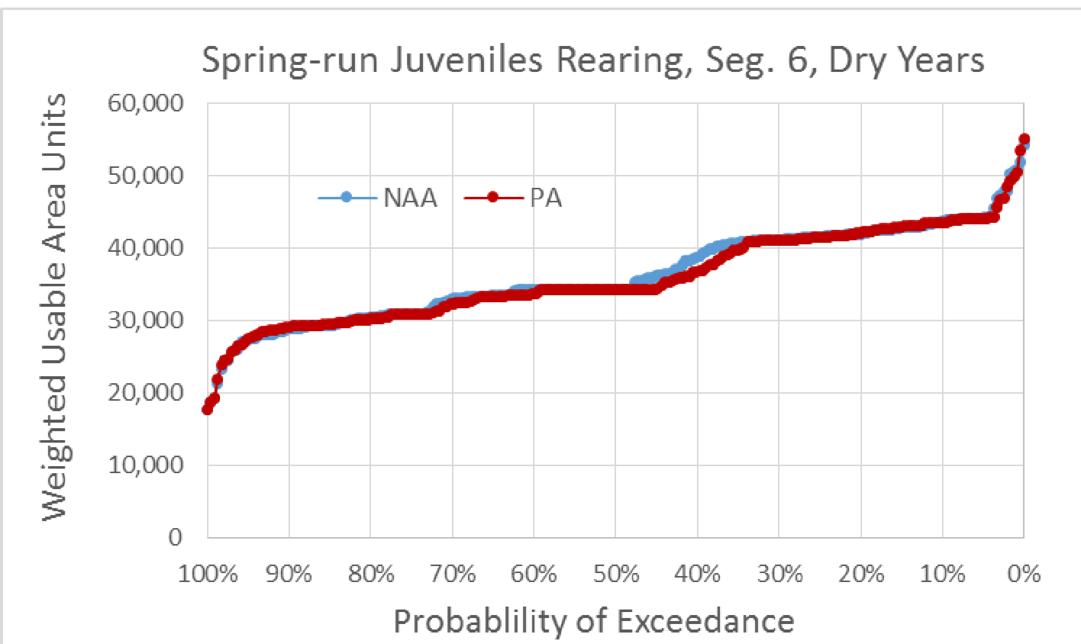


Figure 2-209. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years.

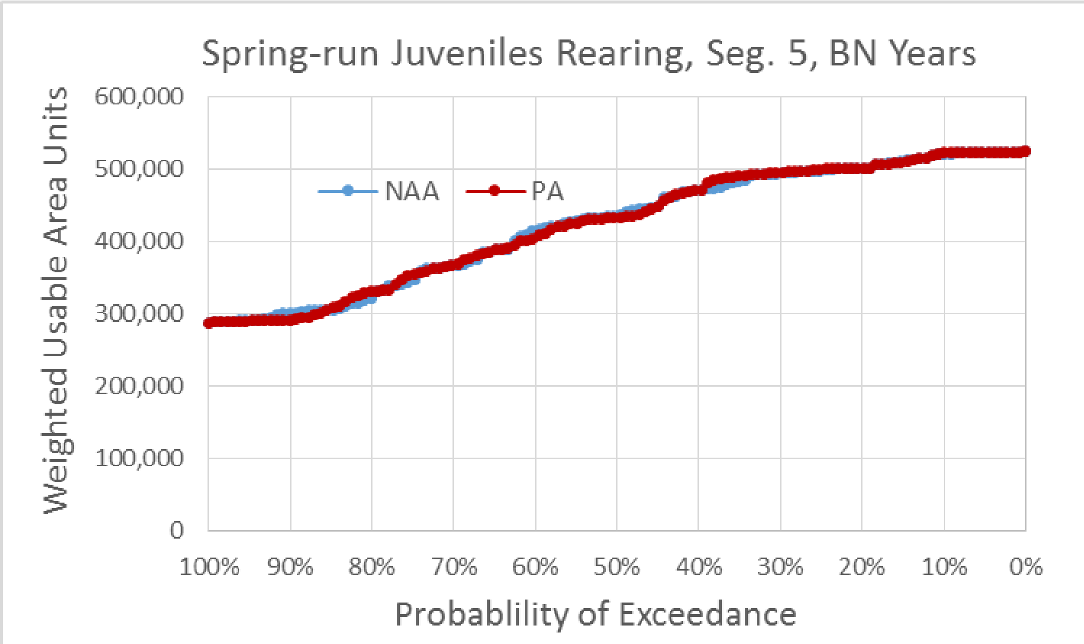


Figure 2-210. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years.

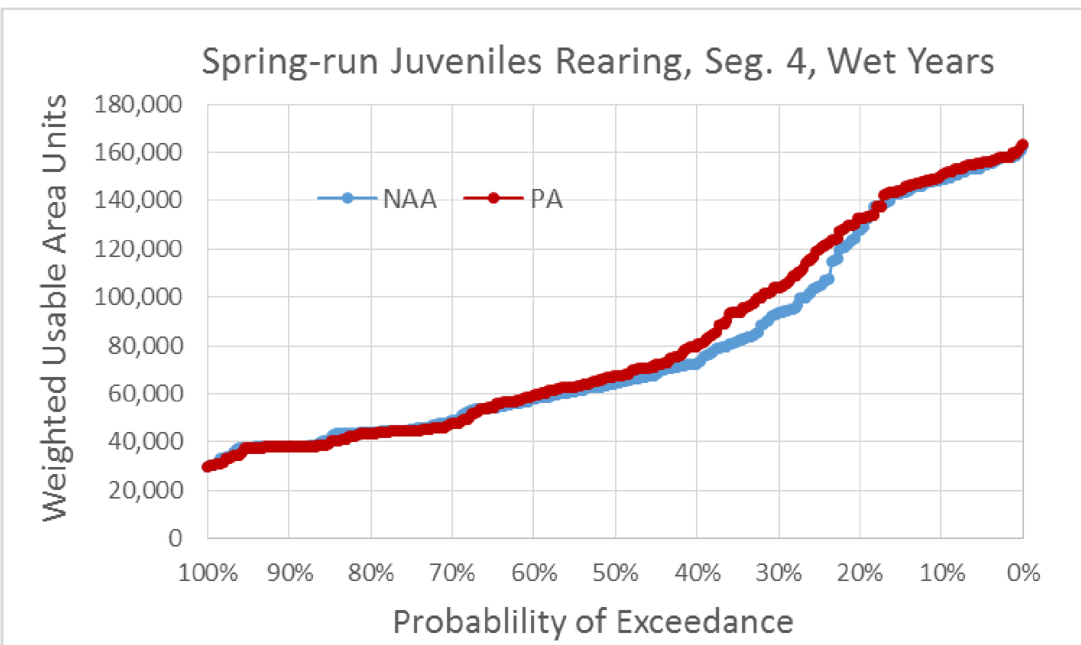


Figure 2-211. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years.

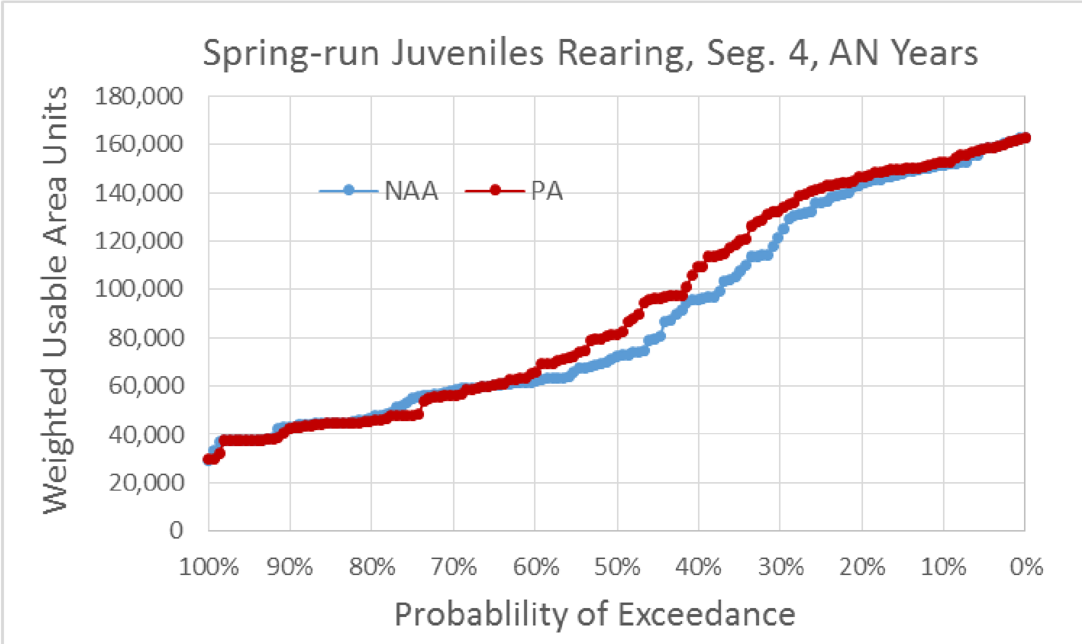


Figure 2-212. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years.

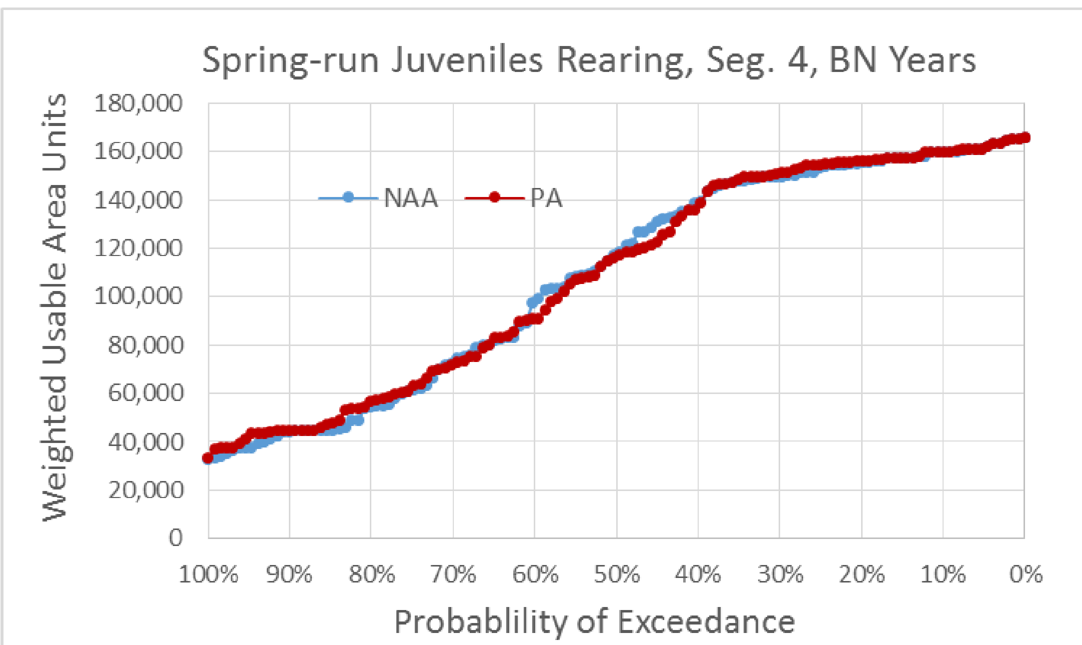


Figure 2-213. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years.

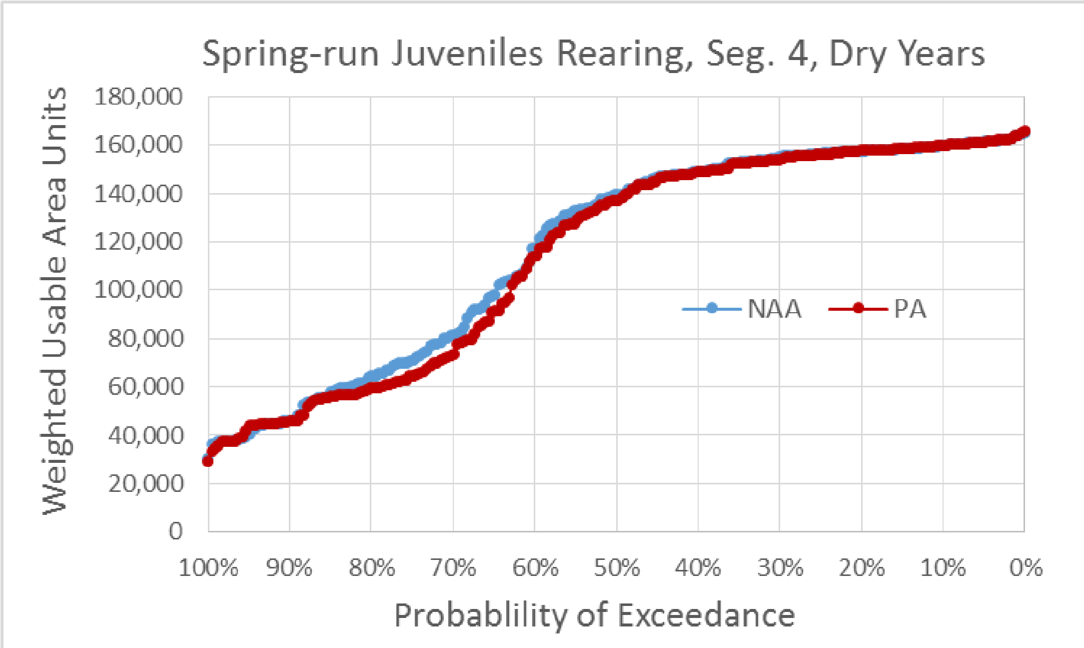


Figure 2-214. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years.

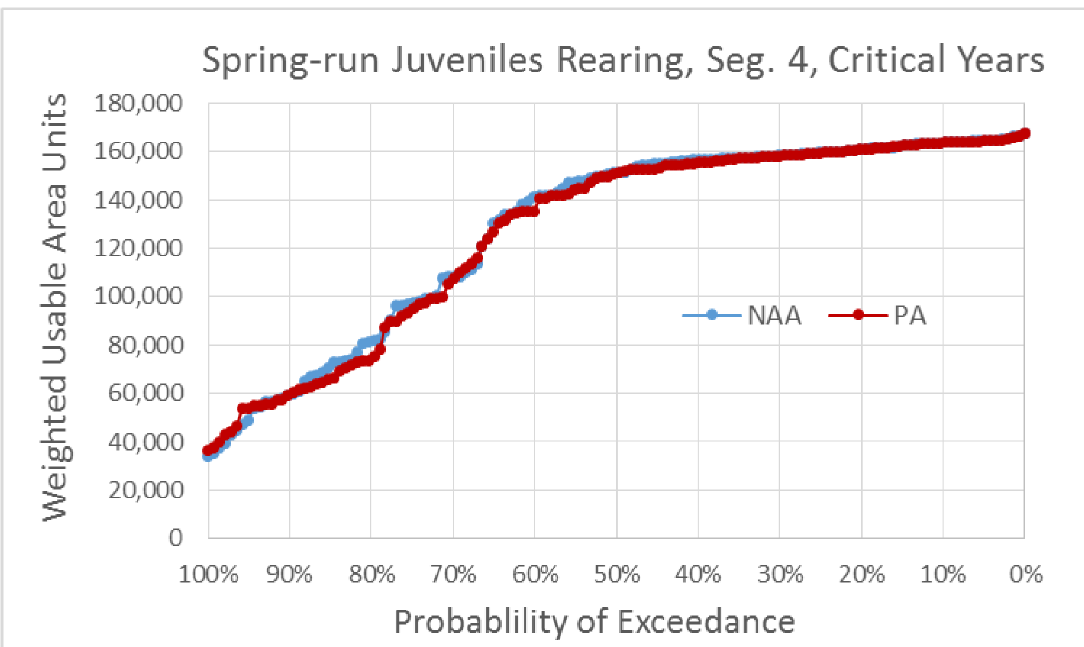


Figure 2-215. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years.

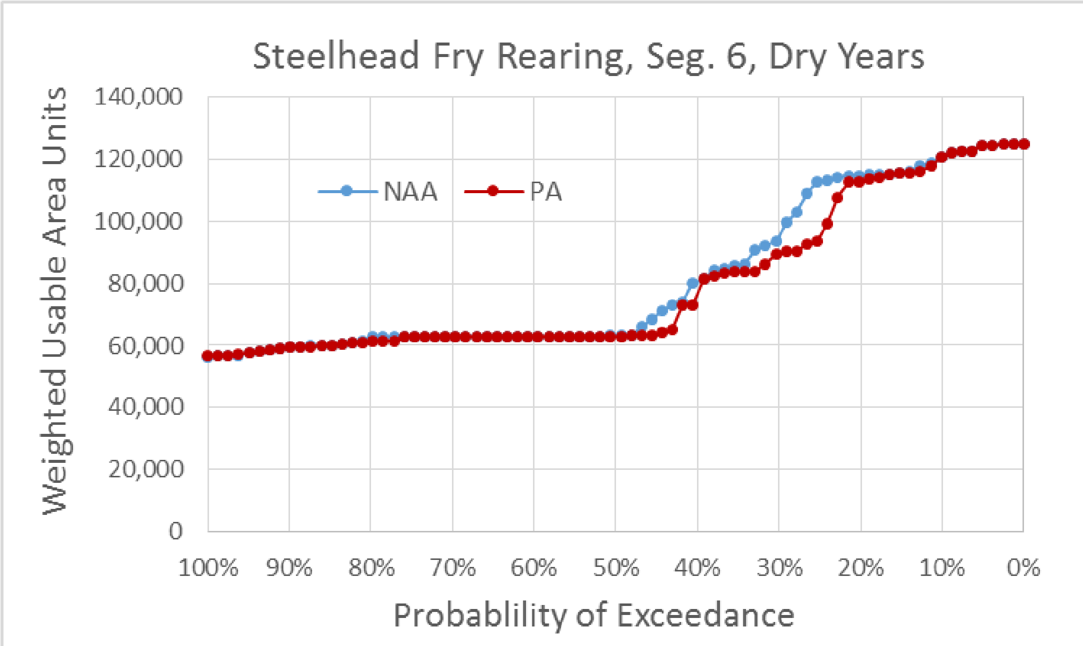


Figure 2-216. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years.

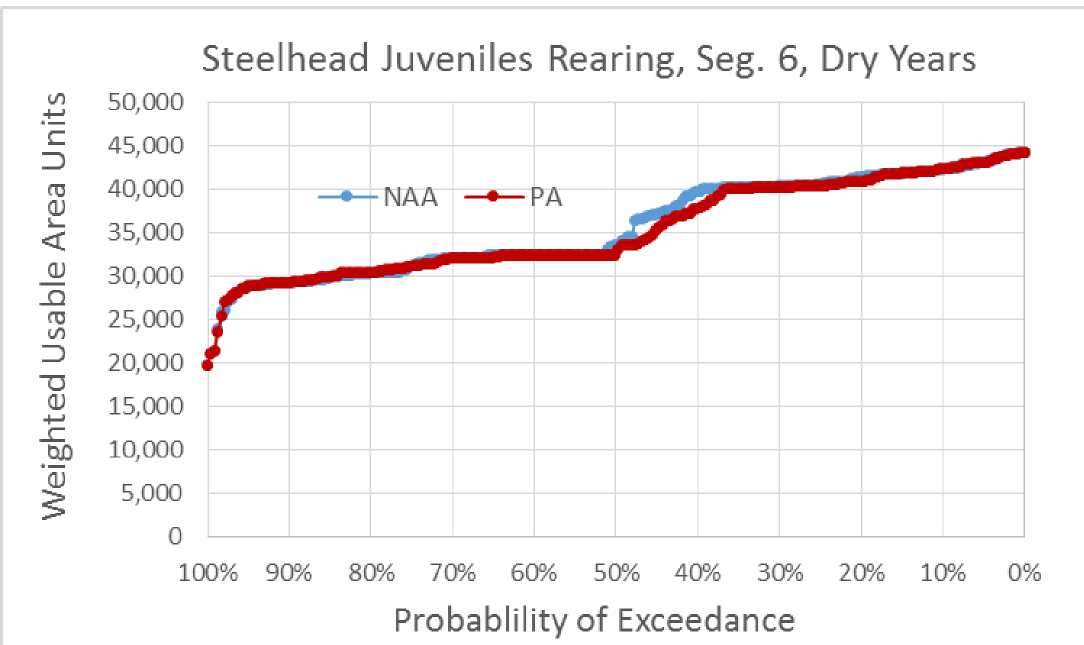


Figure 2-217. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years.

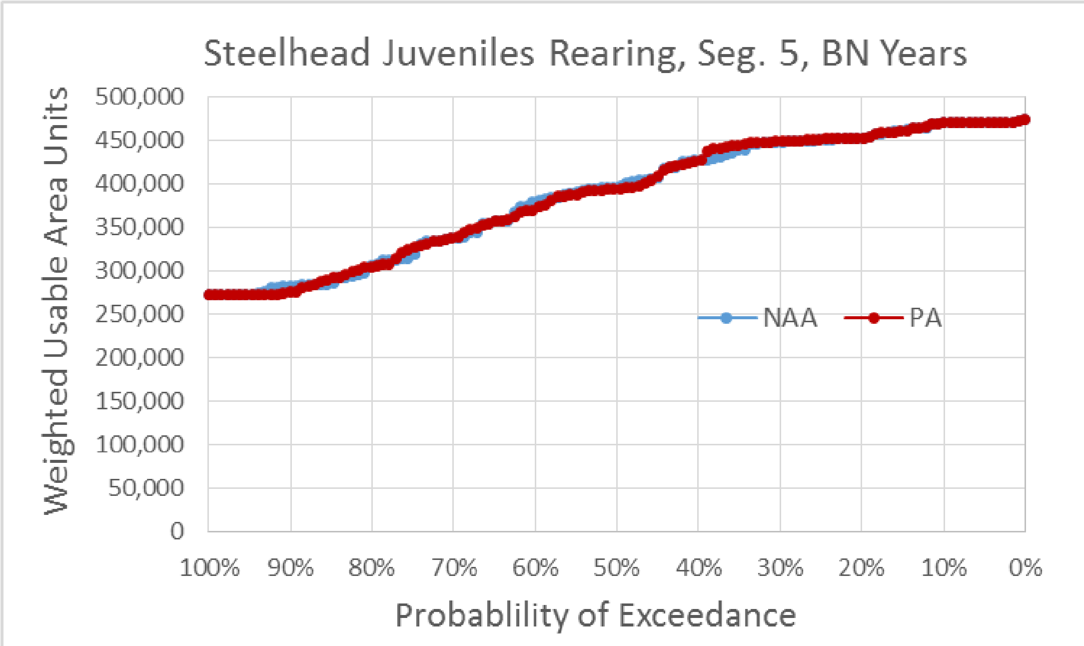


Figure 2-218. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years.

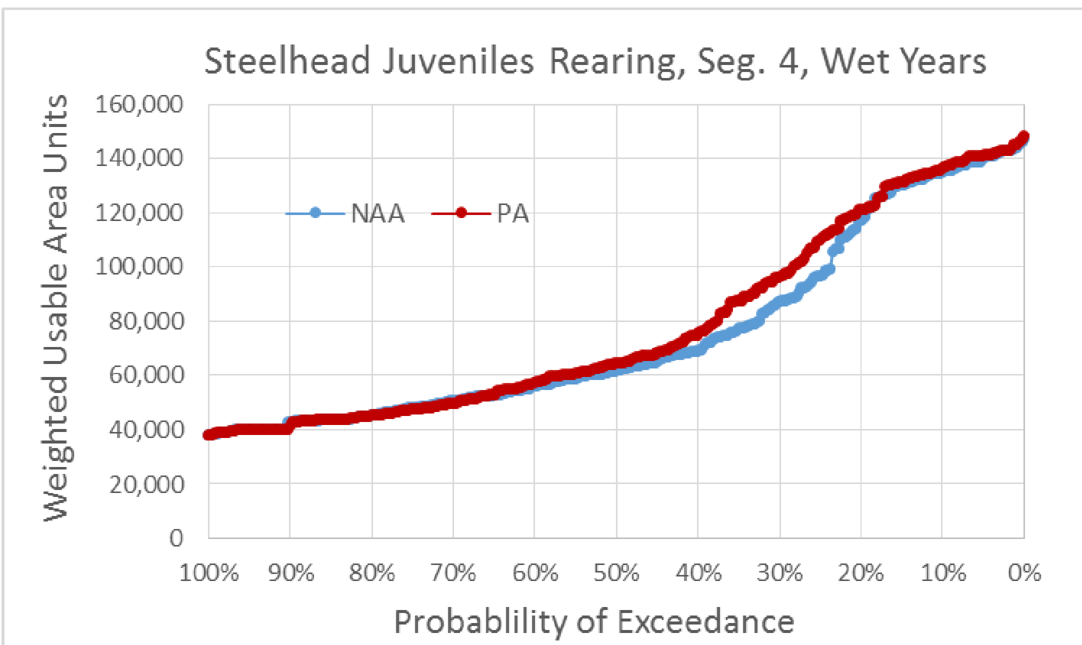


Figure 2-219. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years.

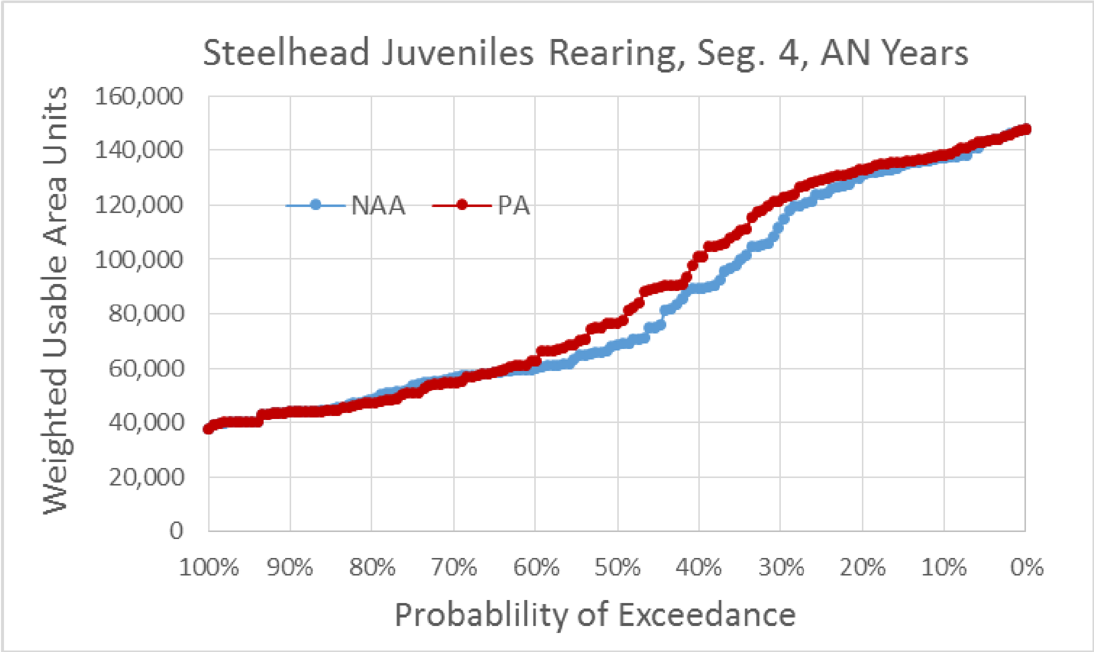


Figure 2-220. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years.

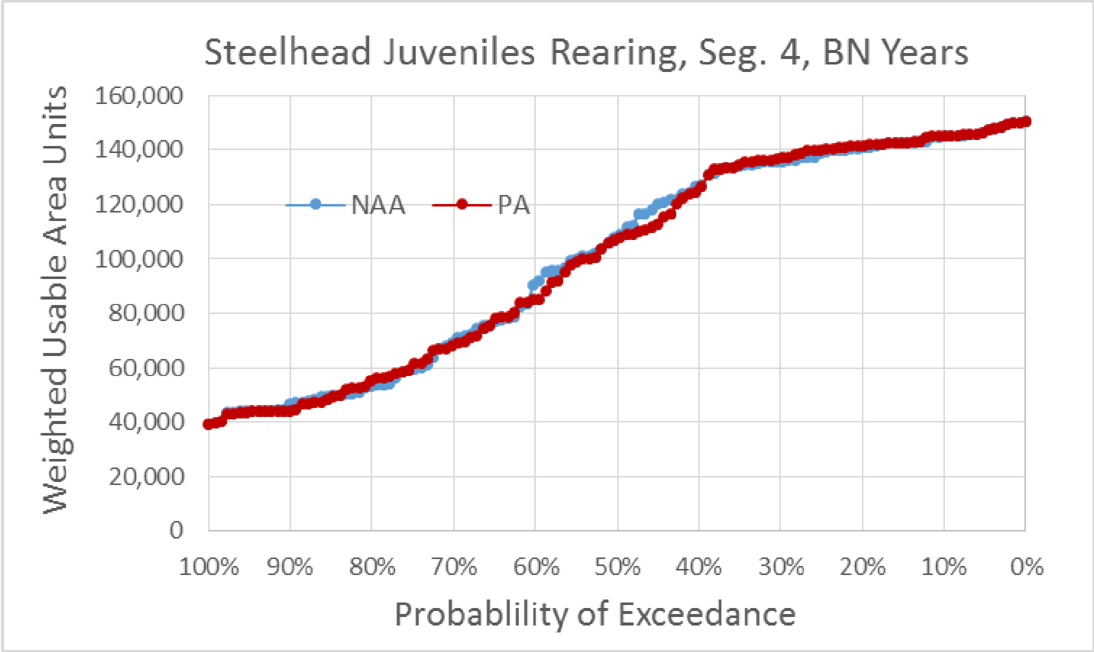


Figure 2-221. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years.

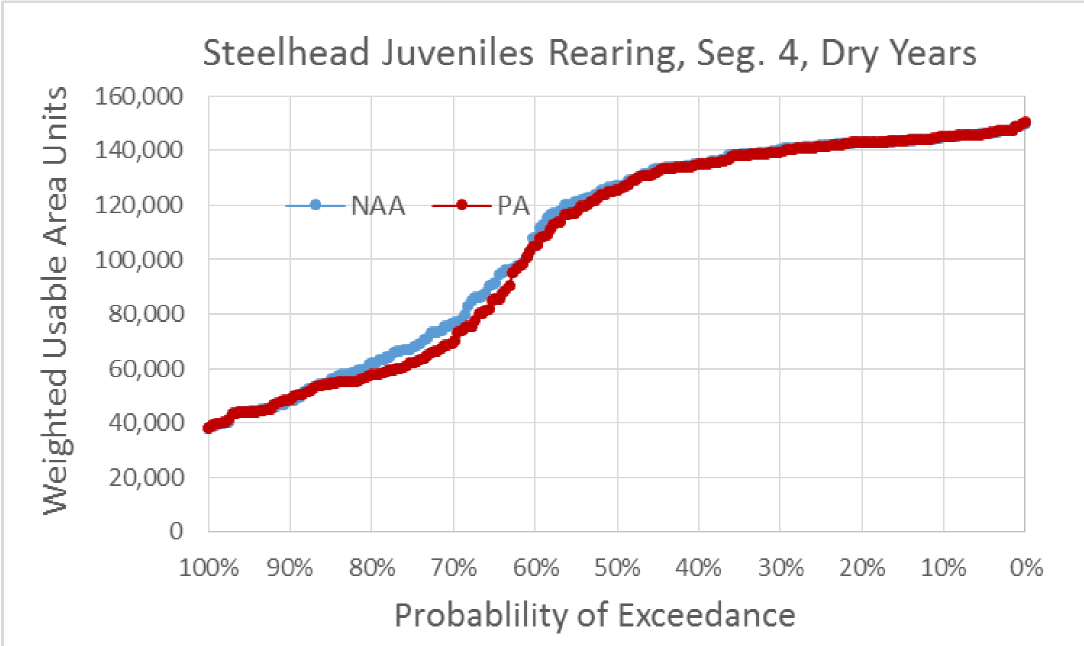


Figure 2-222. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years.

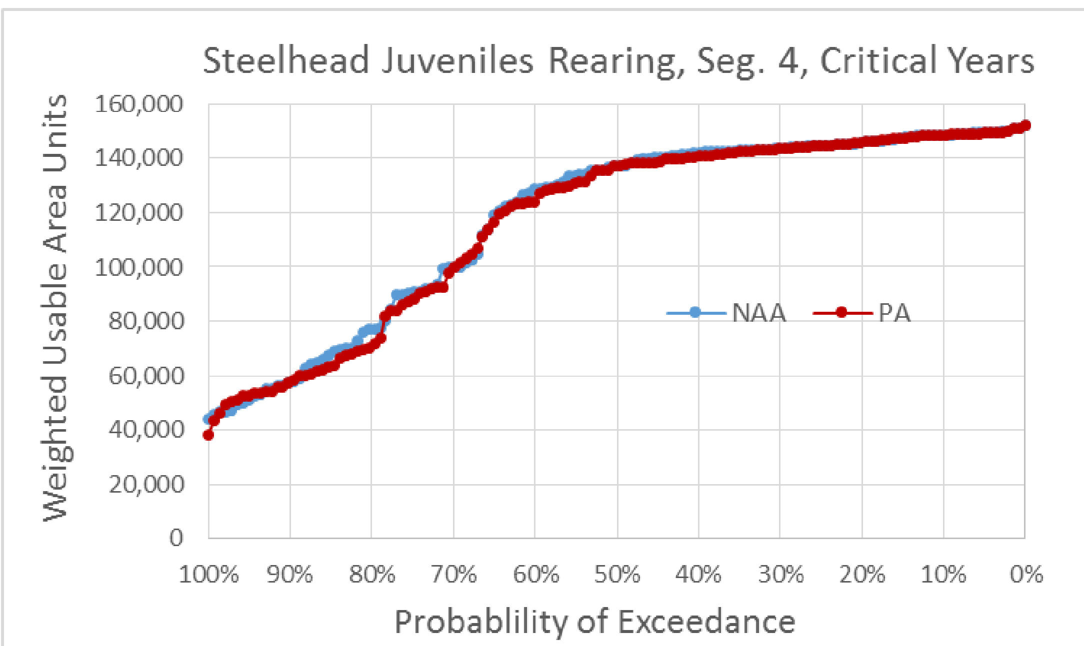


Figure 2-223. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years.

As indicated in Table 2-239, there are several months and water types in which fry and juvenile rearing WUA was projected to be ≥5% less under the PA as compared to the NAA. This is of particular concern for winter-run Chinook, as that ESU consists of a single population, and the rearing habitat on the Sacramento River that was included in this WUA analysis is a significant portion of the total juvenile rearing habitat utilized by this ESU. The projected difference in fry and juvenile rearing WUA was greatest in November of above normal water year types (12% less under the PA as compared to the NAA). Reduction in WUA under the PA will cause a medium-level magnitude of degradation to winter-run Chinook salmon rearing habitat PBFs based on the modeling results described in this section. It will cause a low-level magnitude of degradation to rearing habitat PBFs for spring-run Chinook and steelhead.

As described in Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods, no rearing habitat WUA curves were available for CCV steelhead or any other salmonid in the American River. Although, as evidenced by the rearing habitat WUA curves for Sacramento River winter-run, fall-run, and late fall-run Chinook salmon provided in Appendix 5.D of the BA, Section 5.D.2.3, Rearing Flows Methods, effects of river flow on rearing habitat are generally complex, it is assumed for the purposes of this effects analysis that increased flow would increase the availability and quality of rearing habitat on the Lower American River and thereby benefit steelhead. As such, effects of the PA on CCV steelhead rearing habitat are expected to be positive during June for all water year types except critical water years, when the effects are expected to be negative. Effects during the months of September and November would also be negative for most water year types. During July, August and October, both positive and negative effects are predicted, depending on the water year type (Appendix 5.A of the BA, CALSIM Methods and Results). It should be noted that the assumed monotonically increasing relationship between flow and CCV steelhead rearing habitat, on which the above conclusions are based, has low certainty. The CALSIM modeling results given here indicate that the PA would reduce flow in several months and water year types and thereby result in some degradation to the freshwater rearing PBF for juvenile CCV steelhead.

2.5.2.2.3 Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults

Sacramento River winter-run Chinook PBFs:

- Adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles
- Access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River
- Access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean

CV spring-run Chinook and CCV steelhead PBFs:

- Freshwater Migration Corridors

For the purposes of this analysis, freshwater migration corridors for the salmonids addressed in thisbiological opinionrefers to those migratory corridors linking estuarine habitat in the Delta and spawning habitat in upstream spawning reaches. Critical habitat designated within the action area that contains freshwater migratory habitat for all three salmonid species is confined to the mainstem Sacramento River. Freshwater migratory habitat for CCV steelhead also includes the Lower American River and the portion of the lower San Joaquin River located within the Delta. Effects to critical habitat within the Delta are discussed in the context of estuarine PBFs in Section 2.5.2.2.4.

The impacts to juvenile rearing habitat in the vicinity of the NDD as described in Section 2.5.2.2.2 are likely to result in some degradation to migratory PBFs for juvenile life stages in that area for all three salmonid species. Increased predation risk, risk of impingement, loss of habitat complexity, and reduced river flows are all stressors that may reduce juvenile survival during outmigration, thus degrading PBFs related to migratory behavior. The revised PA provides for unlimited pulse protections at the NDD during the primary migration period for juvenile winter- and spring-run Chinook salmon which will reduce the impact to migratory PBFs for these species. There will likely be benefits to migrating juvenile steelhead from these pulse protections as well.

Additionally, physical and acoustic disturbance, and sedimentation may degrade migratory habitat utilized by CCV steelhead in this area. Spawning adults migrating through the mainstem Sacramento River are likely to encounter physical disturbance from barge operations year-round during the period of barge operations which may impede upstream migration, degrading these PBFs for all three species. Adult CCV steelhead may also encounter construction-related acoustic and physical disturbances during in-water work windows, further degrading the migratory corridor PBF for this species. Freshwater migratory corridors also occur for CCV steelhead within the action area in the Lower American River and San Joaquin River. Degradation to the migratory corridor PBF for this species as a result of the PA is not expected to occur in the Lower American River.

In the portion of the San Joaquin within the Delta, migratory habitat for juveniles will likely not be impacted by construction or operation of the NDD due to being outside the footprint of the effects of NDD activities, nor by construction activities in the vicinity of the HOR gate site due to timing of in-water work windows. However, diversion at the existing CVP and SWP export facilities in the south Delta are expected to cause changes in hydrodynamic conditions that are likely to result in some degradation to the migratory PBF for juvenile CCV steelhead in the south Delta. The extent to which export-related changes in hydrodynamic conditions may degrade the migratory PBF for adult CCV steelhead in the south Delta is uncertain. Migratory habitat for adults in the south Delta will likely be impacted by construction activities in the vicinity of the HOR gate site as they may migrate upstream in the San Joaquin River during the proposed in-water work window. Construction-related effects that are anticipated to occur at this site include hydroacoustic impacts, other physical impacts due to pile driving, increased sedimentation and turbidity, and contaminant exposure. Adverse effects resulting from construction activity in this area are described in further detail in the analysis of effects of the PA to species (Section 2.5.1).

2.5.2.2.4 Estuarine Habitat for Rearing and Migration

Sacramento River winter-run Chinook PBFs:

- Habitat areas and adequate prey that are not contaminated
- Riparian habitat that provides for successful juvenile development and survival
- Access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River
- Access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean

CV spring-run Chinook and CCV steelhead PBFs:

- Estuarine areas

For the purposes of this analysis, estuarine habitat within the action area is considered to be the legal Delta, as well as waterways between the legal Delta and the Golden Gate Bridge. Although the NDD sites are within the legal Delta boundary, effects to critical habitat (i.e., rearing and migration) pertaining to those components of the PA are discussed in Sections 2.5.2.2.2 and 2.5.2.2.3. There are some differences in the exact delineation of critical habitat for the listed salmonids species that are important to note here as it relates to the impacts to estuarine critical habitat within the Delta. Within the legal Delta, critical habitat occurs for spring-run Chinook in northern portions of the Delta including various tidal sloughs upstream to Knight's Landing on the Sacramento River. The downstream boundary of designated critical habitat terminates at Sherman Island. For winter-run, designated critical habitat includes waterways downstream of Sherman Island to the Golden Gate Bridge. Upstream of Sherman Island, only the mainstem Sacramento River is designated critical habitat within the legal Delta upstream to Knight's Landing. For CCV steelhead, Sacramento and San Joaquin Delta hydrologic units are designated critical habitat.

This PBF for winter-run Chinook salmon could be affected by the operation of the SMSCG, with the gates potentially delaying upstream-migrating adult winter-run Chinook salmon that have entered Montezuma Slough and are seeking to exit the slough at its eastward end. Adult winter-run that do not continue upstream past the SMSCG are expected to return downstream by backtracking through Montezuma Slough to Suisun Bay, and they will likely find the alternative upstream route to their natal Central Valley streams through Suisun and Honker Bays (National Marine Fisheries Service 2009: 435). The tidally-operated gates are also expected to influence water currents and tidal circulation periodically during the 10 to 20 days of annual operation, which could also delay juvenile winter-run migration. However, these changes in water flow will be limited to the flood portion of the tidal cycle and will generally be limited to a few days during each periodic operational episode. Overall, the short-term changes to tidal flow patterns in Montezuma Slough due to operation of the SMSCG are expected to cause a minor impact to this PBF for both migrating juveniles and adults of winter-run Chinook salmon (National Marine Fisheries Service 2009: 437). The timing of SMSCG operations does not impact CCV steelhead or spring-run Chinook salmon migration.

Minimal loss of riparian habitat is anticipated to occur at barge landing sites located within the Delta. The footprint of construction at these sites is not yet determined; however, associated removal of vegetation is expected to result in relatively minor impacts to these PBFs. Estuarine PBFs of all three species may be degraded due to physical disturbance and risk of propeller entrainment as barge operations are carried out in the Delta. Additionally, estuarine PBFs for all three species are expected to be degraded in the vicinity of the NDD sites due to risk of impingement.

Construction and maintenance activities are likely to cause sedimentation events which may directly impact CCV steelhead rearing and/or migrating near barge landing and HOR construction sites in the Delta. Influx of suspended sediment is likely to degrade estuarine PBFs related to rearing and migration. Additionally, impacts to benthic substrate may also impact availability of prey. These added stressors will likely cause some degradation to estuarine PBFs.

Changes to in-Delta flow are projected to result in routing changes to juveniles of each salmonid species. Entry into the interior Delta is expected to increase under the PA in the months of October, November, June, and sometimes March. Travel time through the Delta is expected to increase for smolts outmigrating from the Sacramento River past the NDD; however, travel times for CCV steelhead outmigrating from the San Joaquin are expected to decrease. Increased travel times in the Delta will likely increase risk of predation during outmigration, degrading these PBFs. Unlimited pulse protections at the NDD as part of the revised PA will reduce the degradation of these PBFs relative to smolt outmigration travel time, routing and survival during the primary migration period for winter-run and spring-run Chinook salmon, which will also apply to a portion of the juvenile steelhead migration period. Ongoing diversion at the existing CVP and SWP export facilities in the south Delta are expected to cause changes in hydrodynamic conditions that are likely to result in some degradation to the estuarine PBFs in the south Delta for juvenile CCV steelhead that are used for rearing and migration. The estuarine area PBF for adult CCV steelhead will likely be impacted by construction activities in the vicinity of the HOR gate site as they may migrate upstream in the San Joaquin River during the proposed in-water work window. Construction-related effects that are anticipated to occur at this site include hydroacoustic impacts, other physical impacts due to pile driving, increased sedimentation and turbidity, and contaminant exposure. Adverse effects resulting from construction activity in the area are described in further detail in the analysis of effects to species from the PA (Section 2.5.1).

Estuarine PBFs for later life stages will also be degraded due to the presence of barge traffic in the Delta. Migratory components of estuarine habitat may be impacted due to physical disturbances along migratory routes through the Delta that connect marine habitat in the Pacific Ocean to upstream spawning grounds throughout the Central Valley.

The availability of rearing habitats in the north Delta is reduced under the PA because reduced flows downstream of NDD lower the water level, which reduces the inundation index of wetland and riparian benches that serve as rearing habitats (Section 5.4.1.3.2.2 of the BA Habitat Suitability). With few exceptions, the inundation index for wetland and riparian benches is lower under the PA, particularly in the mainstem Sacramento River downstream of NDD, Sutter and Steamboat Sloughs, and the Sacramento River to Rio Vista reach (Table 2-240, Section 5.4.1.3.2.2 of the BA Habitat Suitability). These benches are shallow areas along the channel margins that have relatively gentle slopes (e.g., 10:1 instead of the customary 3:1) and are designed to be wetted or flooded during certain parts of the year to provide habitat for listed species of fish and other species. Wetland benches are at lower elevations where more frequent wetting and inundation may be expected, and riparian benches occupy higher portions of the slope where inundation is restricted to high-flow events. This is unlikely to change under the revised PA due to unlimited pulse protections because reduced in-Delta flows will still occur downstream of the NDD.

Several levee improvements projects along the Sacramento River have been implemented by the USACE and others, and have included the restoration of benches intended to be inundated under specific flows during certain months to provide suitable habitat for listed species of fish. Restored benches in the north Delta could potentially be affected by the PA because of changes in water level; for example, less water in the Sacramento River below the NDD could result in riparian benches being inundated less frequently. This possibility was examined by calculating bench inundation indices for juvenile Chinook salmon (see detailed method description in Appendix 5.D of the BA, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.1.3.1, Bench Innundation). These indices range from 0 (no availability of bench habitat) to 1 (water depth on the bench is optimal for juvenile Chinook salmon all of the time). The analysis was undertaken for a number of riparian and wetland benches in five geographic locations within the north Delta, by linking bench elevation data to DSM2-HYDRO-simulated water surface elevation.

The bench inundation analysis suggests that the effects of changes in water surface elevation caused by PA operations would vary by location and bench type (Table 2-240). As noted above, wetland benches are located at lower elevation than riparian benches and are intended to be inundated much of the time; this results in relatively high bench inundation indices in all water year types, and makes them less susceptible to differences in water levels that could be caused by the NDD, as reflected by the small differences between NAA and PA in all locations and water year types. In the Sacramento River above the NDD, the wetland bench inundation indices were greater in drier than wetter years, reflecting the water depth becoming shallower and therefore moving toward the optimum for juvenile Chinook salmon (i.e., 2.2-2.5 feet; see Appendix 5.D of the BA, Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.1.3.1, Bench Innundation)).

In contrast to wetland benches, riparian benches are at higher elevations and are intended to be inundated only for portions of winter and spring months. Riparian bench inundation indices were higher in wetter years and smaller in drier years, particularly in spring (Table 2-240). Although there were some large relative differences in bench inundation indices between NAA and PA (e.g., ~40–90% lower under PA in below normal to critical years in the Sacramento River below the NDD to Sutter/Steamboat sloughs), these differences occurred in drier years when there was little expected habitat value under either PA or NAA due to little or no inundation of those areas.

The greatest losses of available riparian bench habitat under the PA, during the periods when the riparian benches would provide more than minimal habitat value, are expected to occur in wet and above normal years (assumption in the BA made based on best professional judgement, to be a bench inundation index > 0.05 – cells highlighted in red in Table 2-240). As the model results in Table 2-240 indicate, there is expected to be some relative loss of estuarine rearing habitat in the Delta under the PA in the winter and spring of wet and above normal years (percent loss >5%). In wet and above normal years, during these months, these areas may be utilized for rearing by juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead (as discussed in Section 2.5.1.2.7 Reduced in-Delta flows). Thus some degradation to estuarine PBFs related to juvenile rearing is expected to occur as a result of decreased riparian bench inundation under the PA.

Table 2-240. Mean Bench Inundation Index by Location, Bench Type, Water Year Type, and Season, for NAA and PA.

Location	Bench Type (Total Length)	Water Year Type	Winter (December-February)			Spring (March-June)		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Cache Slough	Riparian (2,950 ft)	W	0.011	0.01	-0.001 (-6%)	0.003	0.003	0.000 (-9%)
		AN	0.004	0.004	0.000 (-6%)	0.001	0.001	0.000 (-8%)
		BN	0.003	0.003	0.000 (-4%)	0	0	0.000 (-7%)
		D	0.002	0.002	0.000 (-8%)	0	0	0.000 (-6%)
		C	0.002	0.002	0.000 (-4%)	0	0	0.000 (-4%)
	Wetland (3,992 ft)	W	0.232	0.229	-0.003 (-1%)	0.189	0.186	-0.003 (-2%)
		AN	0.202	0.199	-0.003 (-2%)	0.158	0.157	-0.001 (-1%)
		BN	0.181	0.178	-0.002 (-1%)	0.135	0.134	-0.001 (-1%)
		D	0.176	0.173	-0.003 (-2%)	0.139	0.138	-0.001 (-1%)
		C	0.158	0.157	-0.002 (-1%)	0.132	0.132	0.000 (0%)
Sacramento River above NDD	Riparian (18,521 ft)	W	0.17	0.186	0.016 (9%)	0.186	0.18	-0.007 (-4%)
		AN	0.162	0.169	0.007 (4%)	0.105	0.103	-0.001 (-1%)
		BN	0.1	0.1	0.000 (0%)	0.015	0.009	-0.005 (-35%)
		D	0.111	0.112	0.000 (0%)	0.023	0.017	-0.006 (-28%)
		C	0.038	0.038	0.000 (0%)	0.004	0.003	-0.001 (-27%)
	Wetland (3,766 ft)	W	0.36	0.364	0.004 (1%)	0.398	0.412	0.014 (3%)
		AN	0.398	0.396	-0.002 (-1%)	0.471	0.47	0.000 (0%)
		BN	0.447	0.45	0.003 (1%)	0.493	0.492	-0.001 (0%)
		D	0.424	0.429	0.005 (1%)	0.489	0.489	0.000 (0%)
		C	0.475	0.466	-0.009 (-2%)	0.393	0.391	-0.002 (-1%)
Sacramento River below NDD to Sutter/Steamboat Sl.	Riparian (3,037 ft)	W	0.247	0.227	-0.020 (-8%)	0.18	0.142	-0.039 (-21%)
		AN	0.21	0.175	-0.035 (-17%)	0.084	0.064	-0.020 (-24%)
		BN	0.116	0.098	-0.018 (-15%)	0.002	0	-0.002 (-77%)
		D	0.144	0.123	-0.020 (-14%)	0.008	0.005	-0.003 (-40%)
		C	0.041	0.036	-0.004 (-11%)	0	0	0.000 (0%*)
	Wetland (3,115 ft)	W	0.318	0.331	0.013 (4%)	0.357	0.343	-0.014 (-4%)
		AN	0.319	0.322	0.003 (1%)	0.289	0.28	-0.009 (-3%)
		BN	0.281	0.276	-0.006 (-2%)	0.203	0.192	-0.011 (-5%)
		D	0.281	0.278	-0.003 (-1%)	0.212	0.199	-0.014 (-6%)
		C	0.226	0.221	-0.005 (-2%)	0.171	0.168	-0.003 (-2%)
Sacramento River from Sutter/Steamboat Sl. to Rio Vista	Riparian (1,685 ft)	W	0.257	0.219	-0.039 (-15%)	0.171	0.126	-0.045 (-26%)
		AN	0.206	0.159	-0.047 (-23%)	0.075	0.053	-0.022 (-29%)
		BN	0.118	0.092	-0.025 (-22%)	0.002	0	-0.001 (-75%)
		D	0.146	0.115	-0.031 (-21%)	0.006	0.004	-0.003 (-43%)
		C	0.044	0.036	-0.008 (-18%)	0	0	0.000 (0%**)
	Wetland (2,430 ft)	W	0.41	0.421	0.011 (3%)	0.437	0.42	-0.017 (-4%)
		AN	0.412	0.409	-0.003 (-1%)	0.362	0.35	-0.013 (-3%)
		BN	0.361	0.354	-0.007 (-2%)	0.265	0.254	-0.012 (-4%)
		D	0.365	0.36	-0.005 (-1%)	0.276	0.262	-0.014 (-5%)
		C	0.295	0.29	-0.005 (-2%)	0.23	0.226	-0.003 (-1%)
Sutter/Steamboat Sloughs	Riparian (5,235 ft)	W	0.262	0.233	-0.028 (-11%)	0.196	0.159	-0.037 (-19%)
		AN	0.22	0.186	-0.034 (-15%)	0.103	0.085	-0.018 (-17%)
		BN	0.138	0.117	-0.020 (-15%)	0.024	0.021	-0.003 (-12%)
		D	0.16	0.135	-0.025 (-16%)	0.03	0.026	-0.004 (-14%)
		C	0.066	0.059	-0.007 (-11%)	0.019	0.018	-0.001 (-4%)
	Wetland (2,670 ft)	W	0.515	0.528	0.014 (3%)	0.562	0.548	-0.014 (-2%)
		AN	0.528	0.526	-0.001 (0%)	0.499	0.486	-0.013 (-3%)
		BN	0.488	0.482	-0.006 (-1%)	0.401	0.387	-0.014 (-3%)
		D	0.487	0.483	-0.004 (-1%)	0.414	0.397	-0.017 (-4%)
		C	0.42	0.415	-0.005 (-1%)	0.356	0.352	-0.004 (-1%)

Notes: *Value was changed from -92% because absolute change was extremely small. **Value was changed from -80% because absolute change was extremely small.

Outflow from the Delta affects salinity levels in the Bay which is another important transition zone for juvenile salmonids. During winter and spring months, juveniles may leave the Delta to access brackish waters where alternative prey sources and foraging habitat become available. In the Sacramento-San Joaquin estuary, there is evidence through long term monitoring sampling of fry use of San Pablo Bay habitat as outflows increase and salinity decreases.

Analysis of San Pablo Bay salinities and fry Chinook salmon presence (2000 to 2014) indicate that when mean monthly outflow is under 20,000 cfs, fry sampling locations in San Pablo Bay always averaged over 20 ppt (Redler et al. 2016). When mean monthly Delta outflow is over 38,000 cfs, salinity in Bay sampling sites always averaged under 20 ppt. What this means in terms of fry presence is that Chinook salmon fry have not been sampled in the Bay when mean Delta outflows were under 20,000 cfs and Bay sampling sites average over 20 ppt. When mean monthly Delta outflows range between 20,000 cfs to 38,000 cfs, salinity averages between 12 ppt to 27 ppt and fry may or may not be present. When mean monthly outflows were over 38,000 cfs and salinities were under 20 ppt, Chinook salmon fry are commonly sampled in the Bay (Redler et al. 2016).

Examination of the CWF scenarios for exceedance of these mean monthly outflows could indicate the probability of salinities in the Bay being suitable for fry rearing (>38,000) or unsuitable (<20,000 cfs). In-between these flows there is variability in salinity regimes and fry presence/absence. The analysis indicates that, of the 82 year historical Calsim record, approximately 35% of years during January and March and almost half the years in February should provide suitable habitat for fry rearing in the Bay, thus facilitating expression of life history diversity. There are some small changes in exceedance of these monthly flows between the scenarios. NAA meets the minimum criteria of exceeding 20,000 cfs monthly outflow 2% and 5% more often in February and March, respectively, but 1% less in January (Table 2-241). Exceedance of a monthly flow that would likely promote fry rearing in the Bay (>38,000) is met more frequently under NAA in January and February by 1% to 2%, respectively (Table 2-241).

Table 2-241. Exceedance of 20,000 cfs and 38,000 cfs mean monthly Delta outflow during the months of January, February, and March (based on hydrology from 82 year CWF Calsim modeling). Negatives numbers in parentheses.

Exceedance of 20,000cfs monthly outflow	**NAA**	**PA**	**PA minus NAA**
Jan	53%	54%	1%
Feb	69%	67%	(2%)
Mar	59%	54%	(5%)
Exceedance of 38,000 cfs monthly outflow	**NAA**	**PA**	**PA minus NAA**
Jan	37%	35%	(2%)
Feb	49%	48%	(1%)
Mar	35%	35%	0%

This analysis indicates there would be some loss in potential for fry or immature smolts to use the Bay for rearing in some months under the PA by decreasing the average monthly outflow under 20,000 cfs thereby, increasing or maintaining salinities over 20 ppt (Table 2-241) which contributes to degradation of this PBF. Effects on Bay outflow and salinity also include slightly reducing the frequency of average monthly outflow over 38,000 cfs, which historically has been associated with fry presence in the Bay (Redler et al. 2016). While fry presence or absence in the Bay is associated with multiple factors, it is nevertheless important to recognize that outflow is a metric to detect system-wide changes in hydrology under the scenarios that could impact fry movement and rearing potential in the Bay.

2.5.2.3 Effects to sDPS Green Sturgeon Critical Habitat

sDPS green sturgeon critical habitat includes PBFs that describe features of habitat types for multiple life stages. This section is structured similarly to Section 2.5.2.2 Effects to Critical Habitat for ESA-Listed Salmonids, by habitat types associated with life stages that are present within the action area. Specific PBFs that are present in the action area are identified within each habitat type and described in the context of each life stage.

2.5.2.3.1 Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Larvae

sDPS green sturgeon PBFs:

- Substrate Type or Size
- Water Flow
- Water Quality

Spawning habitat occurs for sDPS green sturgeon in the upper reaches of the Sacramento River and is likely concentrated between the GCID upstream to the RBDD (refer to Section 2.2 Rangewide Status of the Species and Critical Habitat).

As discussed in Section 2.5.1.2, the predicted range of water temperatures in the upper Sacramento River following implementation of the PA is not expected to adversely affect critical habitat PBFs utilized by early life stages in the Sacramento River. Also, because spawning occurs in deep pools, degradation to spawning habitat PBFs is not anticipated to occur as a result of dewatering or scouring of spawning areas.

The PA does not include any in-water activity that would disturb, contaminate, remove, or otherwise degrade spawning gravel within the known primary spawning range for green sturgeon in the Sacramento River. Likewise, due to a lack of any construction activity, contaminant incursion to any component of this area is not expected. Therefore, these PBFs occurring in the Sacramento River are expected to be minimally degraded as a result of the PA.

2.5.2.3.2 Freshwater Rearing Habitat for Juveniles and Subadults

sDPS green sturgeon PBFs:

- Food Resources
- Water Flow
- Water Quality
- Sediment Quality
- Depth

The anticipated impacts to sDPS green sturgeon freshwater rearing habitat are similar to those discussed for salmonids in Section 2.5.2.2.2. Due to the complex life history and varied timing of presence throughout the action area for juveniles and subadults, construction activities are anticipated to affect critical habitat utilized by these life stages year-round during the construction period. Differences in impacts from those anticipated for salmonids are that the removal of riparian vegetation will likely impact this species less because at the juvenile and subadult life stages, they are primarily benthically oriented. Likewise, the entrainment and impingement threat to salmonids at the NDD screens is most likely not an issue for sturgeon. If debris loading becomes an issue at the screens, then juvenile sturgeon could become impinged but this is expected to be rare situation when the Sacramento River is at high flood stage. Because green sturgeon are benthically-oriented fish and juveniles are larger than juvenile salmonids, activities in the PA that may increase predation of salmonids are less of a concern for green sturgeon.

Disturbance to benthic substrate resulting from construction activities is likely to reduce benthic macroinvertebrate prey abundance for green sturgeon at the NDD sites, resulting in some degradation to these PBFs at those locations. Rearing individuals may be exposed to contaminated sediment that is re-suspended as a result of barge operations or construction activity, and sedimentation events due to construction activity at the NDD sites (see Sections 2.5.1.1.3 Contaminant Exposure and 2.5.1.1.2 Sediment Concentration and Turbidity Stress). Sturgeon are known to rear in deep pools, and the displacement of sediment during dredging activities may impact this habitat feature within NDD dredging footprints. The addition of these stressors is likely to degrade these PBFs in the vicinity of the NDD construction sites.

Based on the temperature thresholds and requirements for the early life stages of this species discussed in Section 2.5.1.2.1.4 Green Sturgeon Exposure and Risk (Increased Upstream Temperature section), the predicted range of water temperatures in the upper Sacramento River following implementation of the PA is not expected to degrade critical habitat PBFs utilized by juveniles for rearing.

Freshwater rearing areas for juveniles and subadults also occur within the lowest reaches of the American River (downstream of the SR-160 bridge), and in the lower reaches of the San Joaquin River, although little is known about potential rearing behavior for sDPS green sturgeon in the San Joaquin River. Impacts due to construction and operation of the NDD are not anticipated to degrade PBFs associated with freshwater rearing habitat in these locations. Ongoing diversions at the existing CVP and SWP export facilities in the south Delta are expected to cause changes in hydrodynamic conditions, but the extent to which export-related changes in hydrodynamic conditions may degrade PBFs associated with freshwater rearing habitat for juvenile and sub-adult green sturgeon is uncertain.

2.5.2.3.3 Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults

sDPS green sturgeon PBFs:

- Migratory Corridor
- Depth
- Sediment Quality

For the purposes of this analysis, freshwater migration corridors for sDPS green sturgeon addressed in this Opinion refer to those migratory corridors linking estuarine habitat in the Delta and spawning habitat in upstream spawning reaches in the Sacramento and Feather (that is upstream of the action area) Rivers. Critical habitat designated within the action area that contains freshwater migratory habitat for this species is confined to the mainstem Sacramento River. Since sDPS green sturgeon are only known to spawn in the Sacramento River watershed, the Lower American and San Joaquin Rivers are not considered to be migratory corridors and are therefore not included in this analysis.

The impacts to freshwater rearing habitat in the vicinity of the NDD as described in Section 2.5.2.3.2 are likely to result in some degradation to migratory PBFs for juvenile, subadult, and adult life stages in that area. Degradation of benthic habitat, exposure to sedimentation events, and risk of physical and acoustic disturbance are stressors that may reduce survival or impact behavior during migration, thus degrading PBFs related to migration. Migratory behavior may be impacted year-round as temporal patterns of migratory behavior for various lifestages of sDPS green sturgeon are highly variable.

2.5.2.3.4 Estuarine Habitat for Rearing and Migration

sDPS green sturgeon PBFs:

- Migratory Corridor
- Depth
- Sediment Quality
- Water Quality

For the purposes of this analysis, estuarine habitat within the action area is considered to be the legal Delta, as well as waterways between the legal Delta and the Golden Gate Bridge. Although the NDD sites are within the legal Delta boundary, effects to critical habitat pertaining to those components of the PA are discussed in Sections 2.5.2.3.2 and 2.5.2.3.3. For sDPS green sturgeon, the entire legal Delta is designated critical habitat as well as all waterways downstream to the Golden Gate Bridge. Estuarine habitat PBFs for juvenile, subadult, and adult life stages are expected to be degraded due to physical disturbance and risk of propeller entrainment year-round as barge operations are carried out in the Delta. Additional degradation to critical habitat is expected to result from physical and acoustic disturbance as pile driving and other construction activities are carried out at barge landing sites and at the HOR gate construction site. Deep pools, which are known to be preferred by subadults and adults, may be impacted by maintenance dredging operations or dredging operations related to construction activities at barge landings or the HOR site. Benthic food resources for these life stages will likely be reduced in Delta areas that experience heavy dredging activity as a result of long-term maintenance dredging. These disturbances will cause some degradation of these PBFs as rearing and migratory behavior for these life stages may be impacted.

Construction and maintenance activities are likely to cause sedimentation events which may directly impact estuarine habitat near barge landing and HOR construction sites in the Delta. Degradation to the estuarine habitat PBFs may result from risk of exposure to suspended sediment, which may cause physical injury or may result in contaminant exposure.

As discussed in Section 2.5.1.2.7, reduced in-Delta flow due to operations of the NDD may have an impact on estuarine habitat PBFs for sDPS green sturgeon, given that life history strategies including spawning and migration are thought to be flow-dependent. To date, this has not been scientifically explored or verified. Additionally, the extent to which juveniles may utilize wetland bench habitat is not well understood; however, under the PA the availability of potential rearing habitats in the North Delta is reduced because reduced flows downstream of NDD lower the water level, which reduces the inundation index of wetland and riparian benches that may serve as rearing habitats (Section 5.4.1.3.2.2 of the BA Habitat Suitability). With few exceptions, the inundation index for wetland and riparian benches is lower under the PA particularly in mainstem Sacramento River downstream of NDD, Sutter and Steamboat Sloughs, and the Sacramento River to Rio Vista reach (Section 5.4.1.3.2.2 of the BA Habitat Suitability). Ongoing diversions at the CVP and SWP export facilities in the south Delta are expected to cause changes in hydrodynamic conditions, but the extent to which export-related changes in hydrodynamic conditions may degrade PBFs associated with estuarine habitat for rearing and migration of all life stages of green sturgeon.

2.5.2.4 Summary of Effects to Critical Habitat for Each Species

Critical habitat impacts are summarized in this section for each species. Conclusions for the overall impacts to designated critical habitat for each species are scaled from 'minimal' to 'moderate' to 'high'.

2.5.2.4.1 Sacramento River Winter-Run Chinook

Negative effects to winter-run critical habitat will likely be concentrated to upstream reaches and Delta rearing and migratory corridors. Projected decreases in both spawning and fry and juvenile rearing WUA will cause a medium-level magnitude of degradation to spawning and rearing habitat PBFs. Overall, the monthly temperature modeling results, exceedance plots and biological tools all indicate that thermal impacts on the PBFs of winter-run Chinook salmon critical habitat that relate to spawning will largely be the same with implementation of either the NAA or PA operations. Adverse thermal effects on these PBFs from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in Section 2.7 Integration and Synthesis, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in substantial degradation to spawning PBFs in critically dry years. The revised PA (Appendix A2) however, includes a recommitment to expanding the available habitat for spawning adults, incubation of eggs, and rearing for fry, specifically, in Battle Creek and above Shasta Dam, into the McCloud River. In addition, the revised PA includes 80 acres of expanded rearing habitat through restoration in the upper Sacramento River between Keswick Dam and RBDD and 1,800 acres of tidal rearing habitat restoration in the Delta. Although these additional habitat restoration activities will have short-term impacts to habitat from ground and in-water disturbance the restoration is expected to begin improving these PBFs before proposed action operations commence and improve this PBF for all listed salmonids in the long-term.

Some degradation to rearing and migratory habitat in both the mainstem Sacramento River and Delta are anticipated to occur as a result of barge traffic in the area, which will occur year-round during the period of barge operations and is expected to result in physical disturbance, exposure to re-suspended contaminated sediment, and risk of propeller entrainment. Loss of habitat complexity at the NDD sites will also likely degrade migratory PBFs for juveniles, as this will increase the risk of predation and impingement within the NDD structural footprint. The PA describes the incorporation of refugia along the NDD screens that may provide additional minimization to screen impingement and associated predation risk. Phased testing and operation of the three NDD intakes will ensure that the screens are functioning to NMFS screening criteria.

The in-Delta flow analysis concludes that there will be adverse effects to Sacramento River winter-run Chinook critical habitat in the Delta including impacts to rearing and migratory habitats in this area. Also, availability of rearing habitats in the North Delta is likely to be reduced under the PA because reduced flows downstream of NDD lower the water level, which reduces the inundation index of wetland and riparian benches that serve as rearing habitats. These conclusions indicate that there will be degradation to the estuarine habitat PBFs for this species. Under the PA, greater frequency of routing into the interior Delta is anticipated due to reduced in-Delta flows, which is expected to degrade migratory PBFs for the juvenile life stage. However, the revised PA unlimited pulse protections will reduce the impact to juvenile migration routing and travel time to some degree.

Taking into account the project impacts to each PBF, as well as the revised PA habitat improvements, the Sacramento River winter-run Chinook salmon critical habitat will likely be impacted to a moderate level by the PA. Commitments to adaptive management (as described in Appendix A2) will ensure impacts are minimized.

2.5.2.4.2 CV Spring-Run Chinook Salmon

Negative effects to spring-run critical habitat are expected to be concentrated at the NDD intake sites due to construction activity and barge traffic at that location. Projected decreases in both spawning and fry and juvenile rearing WUA will cause a low-level magnitude of degradation to spawning and rearing habitat PBFs. Overall, the monthly temperature modeling results, exceedance plots and biological tools all indicate that thermal impacts on the PBFs of spring-run Chinook salmon critical habitat that relate to spawning will largely be the same with implementation of either the NAA or PA operations. Adverse thermal effects on these PBFs from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in the Integration and Synthesis section, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in substantial degradation to spawning PBFs in critically dry years. The revised PA (Appendix A2), however, includes a recommitment to expanding the available habitat for spawning adults, incubation of eggs, and rearing for fry, specifically, in Battle Creek and above Shasta Dam, into the McCloud River. In addition, the revised PA includes 80 acres of expanded rearing habitat through restoration in the upper Sacramento River between Keswick Dam and RBDD and 1,800 acres of tidal rearing habitat restoration in the Delta. Although the target species for these efforts is winter-run Chinook salmon, spring-run Chinook salmon will likely benefit from this expanded habitat. Additionally, habitat restoration activities are expected to have short-term impacts to habitat from ground and in-water disturbance; however, the restoration is expected to begin improving these PBFs before proposed action operations commence and improve this PBF for all listed salmonids in the long-term.

At the NDD sites, barge operations are anticipated year-round during the period of barge operations and this is expected to result in physical disturbance, exposure to re-suspended contaminated sediment, and risk of propeller entrainment. Similar impacts are anticipated to occur within juvenile CV spring-run rearing and migratory habitat at barge landing sites in the Delta. Loss of habitat complexity at the NDD sites will likely degrade migratory PBFs for juveniles, as this will increase the risk of predation within the NDD structural footprint. The PA describes the incorporation of refugia along the NDD screens that may provide additional minimization to screen impingement and associated predation risk. Phased testing and operation of the three NDD intakes will ensure that the screens are functioning to NMFS screening criteria.

The in-Delta flow analysis concludes that there will be adverse effects to CV spring-run Chinook critical habitat in the Delta including impacts to rearing and migratory habitat in this area. Also, availability of rearing habitats in the North Delta is likely to be reduced under the PA because reduced flows downstream of NDD lower the water level, which reduces the inundation index of wetland and riparian benches that serve as rearing habitats. These conclusions indicate that there will be some degradation to the estuarine habitat PBFs for this species. Under the PA, greater frequency of routing into the interior Delta is anticipated, as well as increased Delta travel times, resulting in further degradation to migratory and estuarine habitat PBFs. However, the revised PA unlimited pulse protections will reduce the impact to juvenile migration routing and travel time to some degree.

Taking into account the project impacts to each PBF, as well as the revised PA habitat improvements, the Central Valley spring-run Chinook salmon critical habitat will likely be impacted to a moderate level by the PA, which will be further ensured through adaptive management (as described in Appendix A2).

2.5.2.4.3 CCV Steelhead

Overall, the monthly temperature modeling results, exceedance plots and biological tools all indicate that thermal impacts on the PBFs of CCV steelhead critical habitat that relate to spawning will largely be the same with implementation of either the NAA or PA operations. Adverse thermal effects on these PBFs from changes to upstream operations as a result of the PA are not expected. However, for purposes of the analysis in the Integration and Synthesis section, the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in substantial degradation to spawning PBFs in critically dry years. The revised PA (Appendix A2), however, includes a recommitment to expanding the available habitat for spawning adults, incubation of eggs, and rearing for fry, specifically in Battle Creek and above Shasta Dam, into the McCloud River. In addition, the revised PA includes 80 acres of expanded rearing habitat through restoration in the upper Sacramento River between Keswick Dam and RBDD and 1,800 acres of tidal rearing habitat restoration in the Delta. Although the target species for these efforts is winter-run Chinook salmon, steelhead will likely benefit from this expanded habitat. Additionally, habitat restoration activities are expected to have short-term impacts to habitat from ground and in-water disturbance; however, the restoration is expected to begin improving these PBFs before proposed action operations commence and improve these PBF for all listed salmonids in the long-term. Projected decreases in both spawning and fry and juvenile rearing WUA will cause a low-level magnitude of degradation to spawning and rearing habitat PBFs. Construction-related effects to critical habitat for this species will be more extensive than for winter-run or spring-run Chinook salmon as juvenile CCV steelhead are expected to be present in the action area during scheduled construction in-water work windows. Juveniles are typically present from November through June (peaking in February and March), and adults may begin their upstream migration through the action area as early as June, extending through March. Physical disturbances to rearing and migration PBFs resulting from construction activities include: barge operations and other construction activity at the NDD sites; barge landing sites; and the HOR construction site. Also, sedimentation events and contaminants sourced from re-suspended sediment as a result of construction-related disturbance to benthic substrates will impact rearing and migration PBFs. Overall, rearing and migration habitat for CCV steelhead is expected to be degraded as a result of construction-related effects from the PA because some juveniles will be using critical habitat at the above named construction sites during scheduled in-water work windows. Loss of habitat complexity within the NDD footprint due to permanent disturbance of riparian habitat is expected to degrade the migratory PBFs for CCV steelhead. The PA describes the incorporation of refugia along the NDD screens that may provide additional minimization to screen impingement and associated predation risk. Phased testing and operation of the three NDD intakes will ensure that the screens are functioning to NMFS screening criteria. The in-Delta flow analysis concludes that there will be adverse effects to CCV steelhead critical habitat in the Delta due to NDD operations including impacts to rearing and migratory habitats in this area. However, the revised PA unlimited pulse protections at the NDD will reduce the impact to juvenile migration routing and travel time through the Delta to some degree. Diversions at the existing CVP and SWP export facilities in the south Delta are expected to cause changes in hydrodynamic conditions that are likely to result in some degradation to PBFs associated with estuarine habitat, freshwater rearing and freshwater migratory corridors for juvenile CCV steelhead in the south Delta.

Also, availability of rearing habitats in the north Delta is likely to be reduced under the PA because reduced flows downstream of NDD lower the water level, which reduces the inundation index of wetland and riparian benches that serve as rearing habitats. These conclusions indicate that there will be some degradation to the estuarine habitat PBFs for this species. Additionally, the in-Delta flow analysis concluded that some routing into the interior Delta may occur for outmigrating juveniles, suggesting that there will be degradation to the migratory PBFs for CCV steelhead.

Taking into account the project impacts to each PBF, as well as the revised PA habitat improvements, the California Central Valley steelhead critical habitat will likely be impacted to a moderate level by the PA, and adaptive management (as described in Appendix A2) will support this conclusion.

2.5.2.4.4 sDPS Green Sturgeon

The analysis of upstream temperature and flow effects to sDPS green sturgeon critical habitat indicate that PBFs utilized by early life stages will not be degraded as a result of the PA. Negative impacts to sDPS green sturgeon critical habit will primarily occur from the following: disturbances to benthic substrate due to barge operation and other construction activities, acoustic disturbances resulting from pile-driving activity, and physical disturbance and risk of propeller entrainment due to barge operations. Juvenile, subadult, and adult green sturgeon rely heavily on benthic food resources. Localized disturbance to benthic macroinvertebrate communities is anticipated at NDD sites, barge landing sites, and at the HOR construction site. Like CCV steelhead, various life stages of sDPS green sturgeon are expected to be present during in-water construction work windows, so some degradation to PBFs pertaining to rearing and migration in the Delta is anticipated due to construction-related impacts. In-Delta flow reductions due to NDD operations and hydrodynamics changes in the south Delta due to ongoing diversions at the existing CVP and SWP export facilities may impact estuarine PBFs for green sturgeon as the availability and/or functionality of benthic habitat utilized by sDPS green sturgeon in the Delta may be impacted by altered hydrologic cues or decreased inundation of wetland benches. The extent to which the designated critical habitat in the Delta for sDPS green sturgeon will be diminished as a result of in-Delta flow reductions or hydrodynamic changes in the south Delta is currently not well understood.

Taking into account the project impacts to each PBF, sDPS green sturgeon critical habitat will be moderately impacted by the PA.

2.6 Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02).Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-Federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline *vs.* cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in the environmental baseline (Section2.4).

2.6.1 Unscreened Water Diversions

Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the California Central Valley. Thousands of small and medium-size water diversions exist along the Sacramento River, San Joaquin River, their tributaries, and the Delta, and many of them remain unscreened. Depending on the size, location, and season of operation, these unscreened diversions entrain and kill many life stages of aquatic species, including juvenile listed anadromous species (Mussenet al. 2013, Mussen et al.2014). For example, as of 1997, 98.5 percent of the 3,356 diversions included in a Central Valley database were either unscreened or screened insufficiently to prevent fish entrainment (Herren and Kawasaki 2001).Most of the 370 water diversions operating in Suisun Marsh are unscreened(Herren and Kawasaki 2001).

2.6.2 Agricultural Practices

Agricultural practices may negatively affect riparian and wetland habitats through upland modifications that lead to increased siltation or reductions in water flow in stream channels flowing into the action area, including the Sacramento River and Delta. Grazing activities from dairy and cattle operations can degrade or reduce suitable critical habitat for listed salmonids by increasing erosion and sedimentation, as well as introducing nitrogen, ammonia, and other nutrients into the watershed, which then flow into receiving waters. Stormwater and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may disrupt various physiological mechanisms and may negatively affect reproductive success and survival rates of listed anadromous fish(Scott and Sloman 2004).

2.6.3 Increased Urbanization

According to the Delta Protection Commission's Economic Sustainability Plan, the population within the Legal Delta experienced a 56 percent increase from 1990 to 2010, while California as a whole experienced a 25 percent increase over that time period (Delta Protection Commission 2012).Growth projections through 2050 indicate that all counties overlapping the Delta are projected to grow at a faster rate than the state as a whole. Details on recent and forecasted population growth in Delta counties are provided in Table 5.7-1 and 5.7-2 of the Biological Assessment (USBR 2016).

Increases in urbanization and housing developments can impact habitat by altering watershed characteristics, and changing both water use and stormwater runoff patterns. Increased growth will place additional burdens on resource allocations, including natural gas, electricity, and water, as well as on infrastructure such as wastewater sanitation plants, roads and highways, and public utilities. Some of these actions, particularly those which are situated away from waterbodies, will not require Federal permits, and thus will not undergo review through the ESA section 7 consultation process with NMFS.

Increased urbanization also is expected to result in increased recreational activities in the region.

Among the activities expected to increase in volume and frequency is recreational boating.

Boating activities typically result in increased wave action and propeller wash in waterways. This potentially will degrade riparian and wetland habitat by eroding channel banks and mid-channel islands, thereby causing an increase in siltation and turbidity. Wakes and propeller wash also churn up benthic sediments thereby potentially resuspending contaminated sediments and degrading areas of submerged vegetation. This, in turn, would reduce habitat quality for the invertebrate forage base required for the survival of juvenile salmonids and green sturgeon moving through the system. Increased recreational boat operation is anticipated to result in more contamination from the operation of gasoline and diesel powered engines on watercraft entering the associated water bodies.

2.6.4 Wastewater Treatment Plants

Two wastewater treatment plants (one located on the Sacramento River near Freeport and the other on the San Joaquin River near Stockton) have received special attention because of their discharge of ammonia. The Sacramento Regional Wastewater Treatment Plan (SRWTP), in order to comply with Order no. R5-2013-0124 of the Central Valley Regional Water Quality Control Board (CVRWQCB), has begun implementing compliance measures to reduce ammonia discharges. Construction of treatment facilities for three of the major projects required for ammonia and nitrate reduction was initiated in March 2015 (Sacramento Regional County Sanitation District 2015). Order no. R5-2013-0124, which was modified on October 4, 2013, by the CVRWQCB, imposed new interim and final effluent limitations, which must be met by May 11, 2021 (CVRWQCB 2013). By May 11, 2021, the SRWTP must reach a final effluent limit of 2.0 milligrams per liter (mg/L) per day from April to October, and 3.3 mg/L per day from November to March (CVRWQCB 2013). However, the treatment plant is currently releasing several tons of ammonia in the Sacramento River each day.

EPA published revised national recommended ambient water quality criteria for the protection of aquatic life from the toxic effects of ammonia in 2013. However, few studies have been conducted to assess the effects of ammonia on Chinook salmon, steelhead, or sturgeon. Studies of ammonia effects on various fish species have shown numerous effects including membrane transport deficiencies, increases in energy consumption, immune system impairments, gill lamellae fusions deformities, liver hydropic degenerations, glomerular nephritis, and nervous and muscular system effects leading to mortality(Connon et al.2011). Additionally, a study of coho salmon and rainbow trout exposed to ammonia showed a decrease in swimming performance due to metabolic challenges and depolarization of white muscle (Wickset al.2002).

2.6.5 Changes in Location, Volume, Timing, and Method of Delivery for Non-Central Valley Project and Non-State Water Project Diversions

Changes in location, volume, timing, and method of delivery for non-Central Valley Project and non-State Water Project diversions not previously included in the Section 7 Effects Analysis of the 2008 biological assessment for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project may be fully or partially implemented without Federal consultation. While the details of implementation are not certain, changes may be expected to occur due to:

- Implementation of the California Sustainable Groundwater Management Act that requires development and implementation of Groundwater Sustainability Plans;
- Implementation of the California Senate Bill X7-7 provisions which require the state to achieve a 20% reduction in urban per capita water use by December 31, 2020;
- Implementation of the California 2009 Delta Reform Act (implementation of portions of the Delta Reform Act also is part of the California Water Action Plan);
- Implementation of the California Water Action Plan released by Governor Jerry Brown in January 2014, specifically, for provisions of the plan that would not necessarily require separate environmental documentation and consultation for related Federal actions.

NMFS does not have information on the specific impacts from these programs to listed fish species or critical habitat at this time; thus, NMFS cannot determine the specific impacts of these programs. NMFS expects that habitat restoration activities under the California Water Action Plan would have short-term effects (sedimentation, turbidity, acoustic noise, temporary habitat disturbance) similar to effects discussed in this biological opinion for similar habitat restoration activities (see Section 2.5.1 Effects to Species and Section 2.5.2 Effects to Critical Habitat). In general, NMFS expects that implementation of these programs will improve habitat conditions for listed fish into the future through the increased availability of instream flows and Delta habitat restoration.

2.6.6 Activities within the San Francisco Bay

Given current baseline conditions and trends, NMFS does not expect to see significant improvement in habitat conditions in the near future due to existing land and water development in San Francisco Bay. In the long term, climate change may produce temperature and precipitation changes that may adversely affect listed anadromous salmonids and green sturgeon habitat in the action area. Freshwater rearing and migratory habitat are most at risk to climate change. However, productivity in the San Francisco Bay is likely to change based on changes in freshwater flows, nutrient cycling, and sediment amounts (Scaviaet al. 2002). This may result in altered trophic level interactions, introduction or survival of invasive species, emergence of harmful algal blooms, changes in timing of ecological events, all of which may cause decreases (or increases) in abundance of green sturgeon and salmonids as well as of their predators and competitors.

2.6.7 Activities within the Nearshore Pacific Ocean

Future tribal, state, and local government actions will likely be in the form of legislation, administrative rules, policy initiatives, or fishing permits. Activities are primarily those conducted under state, and tribal management. These actions may include changes in ocean policy and increases and decreases in the types of activities that currently occur, including changes in the types of fishing activities, resource extraction, or designation of marine protected areas, any of which could impact listed species or their habitat. Government actions are subject to political, legislative and fiscal uncertainties. These realities, added to the geographic scope, which encompasses several government entities exercising various authorities, and the changing economies of the region, make analysis of cumulative effects speculative.

A Final Recovery Plan for Southern Resident killer whales was published in 2008 (NMFS 2008).Although state, tribal and local governments have developed plans and initiatives to benefit marine fish species, ESA-listed salmonids, green sturgeon, and Southern Residents, they must be applied and sustained in a comprehensive way before NMFS can consider them “reasonably certain to occur” in its analysis of cumulative effects.

Private activities are primarily associated with commercial and sport fisheries, construction, and marine pollution. These potential factors are ongoing and expected to continue in the future, and the level of their impact is uncertain. For these reasons, it is not possible to predict beyond what is included in the subsections pertaining to cumulative effects above, whether future non-Federal actions will lead to an increase or decrease in prey available to Southern Resident, or have other effects on their survival and recovery.

2.6.8 Other Activities

Other future, non-Federal actions within the action area that are likely to occur and may adversely affect Chinook, steelhead, and green sturgeon and their critical habitat include: the dumping of domestic and industrial garbage that decreases water quality; oil and gas development and production that may affect aquatic habitat and may introduce pollutants into the water; and state or local levee maintenance that may also destroy or adversely affect habitat and interfere with natural, long term habitat-maintaining processes.

Power plant cooling system operations can also affect aquatic habitat. Contra Costa Power Plant, which was owned and operated by NRG Delta, LLC, was retired in 2013 and replaced with the new natural gas power plant, Marsh Landing Generating Station. The Pittsburg Generating Station (PGS) remains in operation and consisted of seven once-through cooling systems, four of which have been retired, one of which is in the process of being retired, and two of which remain in operation. The once-through cooling system intake process can cause the impingement and entrainment of marine animals, kill organisms from all levels of the food chain, and disrupt the normal processes of the ecosystem. Additionally, the plant can discharge heated water that can reach temperatures as high as 100°F into the action area. This sudden influx of hot water can adversely affect the ecosystem and the animals living in it (San Francisco Baykeeper 2010).

On May 4, 2010, the SWRCB adopted a Statewide Policy on the Use of Coastal and Estuarine Water for Power Plant Cooling under Resolution No. 2010–0020, which required existing cooling water intake structures to reflect the best technology available for minimizing adverse environmental impacts (SWRCB 2010). The PGS was required to submit an implementation plan to comply with this policy by December 31, 2017. The PGS chose to comply by retrofitting two of the existing units and retiring one unit. The retrofit and retirement of these units is underway(GenOn Delta LLC 2011).

2.7 Integration and Synthesis

The Integration and Synthesis section is the final step in NMFS' assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (described in section 2.5) to the Environmental Baseline (section 2.4) and the Cumulative Effects (section 2.6), taking into account the Rangewide Status of the Species and Critical Habitat (section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated critical habitat for the conservation of the species. The Analytical Approach (section 2.1) describes the analyses and tools used to complete our assessments.

This section is organized by species to integrate and synthesize first the effects to the species survival and recovery and second the effects to that species' critical habitat. Species with multiple populations are organized by diversity groups and the river basin of origin either Sacramento or San Joaquin. The information for the survival and recovery analysis is organized further and presented in the following stepwise order: (1) Status of the Species and Environmental Baseline; (2) Summary of Proposed Action Effects to Individuals; (3) Risk to the Population; and (4) Risk to the ESU/DPS. This same general order of summarizing status and effect is used to present the critical habitat analysis using the steps: (1) Status of Critical Habitat and Environmental Baseline; (2) Summary of Proposed Action Effects on Physical or Biological Features of Critical Habitat; and (3) Impact to the Critical Habitat at the designation level.

In the Effects of the Proposed Action (section 2.5) NMFS deconstructs the action, identifies the proposed action activities and the relevant stressors affected, and details the results of the exposure, response, and risk for individuals of each species of ESA-listed fish or mammal, as well as the physical or biological features of designated critical habitat from effects of those stressors. Critical to this approach is an analysis of the full effects of future water operations modified and attributed to the PA such that the "effects of the action" include the direct and indirect effects of the proposed action and of interrelated or interdependent activities "that will be added to the environmental baseline" (50 CFR 402.02). As described in the Analytical Approach (section 2.1), given the timeline of the PA and because it includes an on-going action (i.e., the future ongoing delivery of water), we analyze the entire suite of proposed action effects (both construction- and operations-related) along with environmental baseline conditions in the future, which captures anticipated effects of non-proposed action processes and activities. As presented in the project description of the BA, the proposed action includes Delta operations of the CVP/SWP in the future after construction of the new north Delta intakes. These future operations include modifications to some operations outlined in the 2008 USFWS and 2009 NMFS biological opinions on the CVP/SWP (i.e., CVP/SWP operations in the Delta); however, not all CVP/SWP operations are included in the CWF proposed action (i.e., CVP/SWP operations outside of the Delta). The facilities and operations included and not included in the proposed action are identified in Chapter 1 of the BA. Specifically, upstream operational criteria of CVP/SWP facilities at Trinity, Shasta/Keswick, Folsom, Oroville, New Melones, and Friant reservoirs are not included in the proposed action, and effects of operations of these facilities are considered part of the environmental baseline for this analysis to the extent those effects occur in the action area. However, the effects of the action are considered in the context of environmental baseline conditions, including effects of CVP/SWP operations outside the Delta.

For each stressor, NMFS determines the relative direction of effect described as likely to have an adverse effect, no adverse effect, or a beneficial effect. The direction of effect is further assessed by a qualitative assessment of the risk to individuals of a species as affecting a relative proportion of the population (e.g., small, medium, or large proportion). In this Integration and Synthesis section, NMFS compiles and summarizes the stressors and their responses based on the effects analysis for each population of fish, by species, while following their life cycle in the freshwater environment. For each response, NMFS assigns a relative magnitude of effect (high, medium, or low), which is a qualitative assessment of the likelihood of a fitness consequence occurring, i.e., the associated risk. Such a qualitative assessment allows for incorporation of some aspects of uncertainty by acknowledging the inherent complexities of water and environmental management in the Delta (Luoma et. al. 2015). The categories used to assign magnitude of effect mirror those from NMFS (2009) and are defined as follows:

- High: Lethal effect due to stressor that has a broad effect on the population at significant frequency.
- Medium: Effect between high and low definitions.
- Low: Generally sublethal effect, or lethal effect on a very small percentage of one population at a very infrequent interval.

NMFS then determines the relative weight of evidence (high, medium, or low) for each effect based on the best available scientific information. The stressor effect, as identified by a particular analytical method, is categorized based on the characteristics of the analytical method, as outlined in NMFS (2009), with modifications to include statistical power of analytical methods. In assigning weight of evidence for each effect, NMFS also considers the variable and dynamic nature of the Delta ecosystem, such that the weight attributed to a particular line of evidence is commensurate with the Delta's inherent complexity. Weights are defined as:

- High: Supported by multiple scientific and technical publications, especially if conducted on the species within the area of effect, based on quantitative data, and/or using modeled results; high power in interpretation of analytical results.
- Medium: Evidence between high and low definitions.
- Low: One study, or unpublished data, or scientific hypotheses that have been articulated but not tested; low power in interpretation of analytical results.

High magnitude of effect coupled with high weight of evidence for that effect indicates a greater likelihood of a fitness consequence, whereas a high magnitude of effect with a low weight of evidence provides lower certainty of a fitness consequence. The fitness consequences by life history stage are considered in context of the status of the species and environmental baseline to evaluate the effect of the action at the population scale. The evaluation of the effects of the action is made in the context of the VSP parameters of abundance, productivity, spatial structure, and diversity.

Cumulative Effects

The Cumulative Effects section (section 2.6) of the biological opinion describes future state, tribal, local, or private actions that are reasonably certain to occur in the action area. For this biological opinion, these include unscreened water diversions and the point and non-point source chemical contaminant discharges related to agricultural and urban land use. These actions typically result in habitat fragmentation and degradation of habitats that incrementally reduces the carrying capacity of the rearing and migratory corridors found within the action area. Cumulative effects also include the implementation of changes in state law and the California Water Action Plan as outlined in Section 2.6 Cumulative Effects, which could change the location, volume, timing, and method of delivery for non-Central Valley Project and non-State Water Project diversions not previously included in the Section 7 Effects Analysis of the 2008 biological assessment for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project (Reclamation 2008) which may be fully or partially executed without Federal consultation. The effect of these actions, while uncertain, are expected to provide greater oversight of water use and associated water quality which would improve conditions for aquatic species in the action area.

Revisions to the Proposed Action and Ongoing Adaptive Management

As chronicled in section 1.2 Consultation History and described in the introduction of the Effects of the Action (section 2.5), considerable effort was put into addressing uncertainty related to the extent of potentially significant adverse effects to salmonids as identified in the Initial Draft Biological Opinion for the CWF (dated January 21, 2017). These discussions resulted in a final revised PA that was received by NMFS on June 2, 2017, and is contained in Appendix A2 of this Opinion. NMFS has supplemented the effects analysis in the Initial Draft Biological Opinion to reflect the components of the revisions to the PA as described in Appendix A2 of this Opinion Based on NMFS' analysis, the revisions to the PA would encompass and limit a range of potential adverse effects of the PA in a way that is reasonably certain to occur.

2.7.1 Sacramento River Winter-run Chinook Salmon

- First listed as threatened (August 4, 1989, 54 FR 32085).
- Reclassified as endangered (January 4, 1994, 59 FR 440), reaffirmed as endangered (June 28, 2005, 70 FR 37160).

The Sacramento River winter-run Chinook salmon ESU historically occurred in only one diversity group (basalt and porous lava) within the Central Valley and currently consists of a single population that is supplemented with hatchery production. Detailed information regarding the federally listed ESU of Sacramento River winter-run Chinook salmon life history and status, critical habitat status description and designation history, and VSP parameters can be found in Appendix B Rangewide Status of the Species and Critical Habitat of this Opinion.

2.7.1.1 Status of the Species and Environmental Baseline

The status of the species and environmental baseline for Sacramento River winter-run Chinook salmon have been described in sections 2.2 and 2.4, respectively. Critical to the integration and synthesis of effects are the VSP parameters of abundance, productivity, spatial structure, and diversity. Because these parameters are consistent with the “reproduction, numbers, or distribution” criteria found within the regulatory definition of jeopardy (50 CFR 402.02), the VSP parameters are used as surrogates for the jeopardy criteria. These VSP parameters are used to establish the reference condition of the population in the status of the species and environmental baseline and are used to assess the risk to the population and the risk to the ESU.

Winter-run Chinook Salmon Abundance:

Population estimates for Sacramento River winter-run Chinook salmon (i.e., the derived metric of abundance) have been made since 1970 based on counts of returning adults entering hatcheries and migrating past dams, carcasses, live fish, and redds (via ground and aerial surveys) (California Department of Fish and Wildlife 2016). Previous estimates of the winter-run Chinook salmon population have been as high as 120,000 fish in the 1960s but have declined to fewer than 200 fish in the 1990s (National Marine Fisheries Service 2011c). From 2007 to 2013, the population averaged 2,486 adults with a low of 827 in 2011. The current low level of abundance is likely due to a combination of factors that affect the status of the species and, in most cases, are part of the environmental baseline. These factors include poor ocean productivity (Lindley et al. 2009a), drought conditions from 2007-2009, low in-river survival (National Marine Fisheries Service 2011c), and extreme drought conditions in 2012-2016 (National Marine Fisheries Service 2016c). In 2014 and 2015, the population was estimated at 3,015 and 3,440 adults, respectively, slightly greater than the 2007–2013 average, but less than the peak (17,296) for the last 10 years. The population estimate decreased to 1,546 in 2016 (California Department of Fish and Wildlife 2016).

Winter-run Chinook Salmon Productivity:

Sacramento River winter-run Chinook salmon ESU productivity was positive from 1989-2006, and adult escapement and juvenile production had been increasing annually until 2007 when productivity became negative with declining escapement estimates. From 2013 to 2015, the winter-run Chinook salmon cohort replacement rate returned to a positive rate, possibly due to favorable in-river conditions in 2011 and 2012 (wet and below normal water years, respectively) which increased juvenile survival to the ocean. Although the growth rate for the winter-run Chinook salmon population is positive, it exhibits the typical variability found in most endangered species populations. Coupled with an environmental baseline of a single population dependent upon cold-water releases from Shasta Reservoir, the ESU remains vulnerable to periods of prolonged drought (National Marine Fisheries Service 2016).

Productivity, as measured by the number of juveniles entering the Delta (i.e., the juvenile production estimate (JPE)), has declined in recent years from a high of 3.8 million in 2007 to 124,521 in 2015. Since water year 2012, California has experienced five consecutive years of below-average rainfall and snowpack, resulting in significant adverse effects to juvenile winter-run Chinook salmon cohorts. Due to insufficient inflow and cold water pool in Shasta Reservoir and competing water demands in 2014 and 2015, Sacramento River water temperatures increased to sub-lethal and lethal levels. These conditions contributed to very low egg-to-fry survival of juvenile winter-run Chinook salmon estimated to pass RBDD in brood years 2014

(5.9%) and 2015 (4.2%), well below the 18-year average (23.6% survival) (Martin et al. 2001; NMFS 2016; Poytress et al. 2014, 2015; Poytress 2016). NMFS Southwest Fisheries Science Center found that, in 2014 and 2015, temperature dependent mortality alone resulted in a loss of approximately 77% and 85% of the population, respectively (Martin et al. 2016).

The natural production of winter-run Chinook salmon is supplemented by the conservation program at LSNFH, which produces approximately 176,348 juveniles per year (2001–2010 average), compared to the estimated natural production of 4.7 million juveniles per year based on the 2002–2010 average (Poytress and Carrillo 2011). Hatchery production therefore represents approximately 3%-4% of the total in-river juvenile production in a typical year. In 2014, the third year of drought increased water temperatures in the upper Sacramento River (NMFS 2016). Due to the anticipated reduced in-river survival caused by the higher temperatures, hatchery production from LSNFH was tripled (i.e., 612,056 juveniles released). This increase represented 55% of the total juvenile production compared to in-river production for that year (i.e., 502,506 fry production at RBDD) (NMFS 2015). Drought conditions persisted in 2015, and hatchery production was increased again to 420,000 juveniles or 51% of the total juvenile production estimated at RBDD (NMFS 2016).

Winter-run Chinook Salmon Spatial Structure:

The distribution of winter-run Chinook salmon spawning and initial rearing was historically limited to only one diversity group within the Central Valley – the basalt and porous lava diversity group (Lindley 2007). This group consisted of individuals from the upper Sacramento River (upstream of Shasta Dam), the McCloud River, the Pitt River, and Battle Creek, where springs provide cold water throughout the summer, allowing for spawning, egg incubation, and rearing during the mid-summer period (Yoshiyama et al. 1998). The construction of Shasta Dam in 1943 blocked access to all of these waters except Battle Creek, which currently has its own impediments to upstream migration (i.e., a number of small hydroelectric dams situated upstream of the Coleman National Fish Hatchery weir). Approximately 299 miles of former tributary spawning habitat above Shasta Dam is inaccessible to winter-run Chinook salmon. Yoshiyama et al. (2001) estimate that, in 1938, the upper Sacramento River had a "potential spawning capacity" of approximately 14,000 redds equal to 28,000 spawners. Since 2001, the majority of winter-run Chinook salmon redds have been constructed in the first ten miles downstream of Keswick Dam. Most components of the winter-run Chinook salmon life history (e.g., spawning, incubation, freshwater rearing) have been compromised by the construction of Shasta Dam.

The Recovery Plan (NMFS 2014) criteria for delisting winter-run Chinook salmon includes a spatial structure component identifying the need for a total of three viable populations within the basalt and porous lava diversity group. Limited spatial structure remains the greatest risk to extinction for winter-run Chinook salmon because the ESU is comprised of only one population that spawns below Keswick Dam. This remnant and remaining population cannot access 95 percent of the historical spawning habitat, and relies on being artificially maintained by spawning gravel augmentation, hatchery supplementation, and regulation of the finite cold water pool behind Shasta Dam to reduce water temperatures in the Sacramento River (National Marine Fisheries Service 2016a). Section 2.4.4.7 Restoration Actions from NMFS 2009 RPA Opinion on the Long-term operations of CVP/SWP BiOp identifies several actions from the NMFS 2009 BiOp RPA that are expected to improve the spatial structure and abundance for winter-run Chinook salmon before operations of the NDD conveyance facilities commence:

- RPA Action I.7: Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass (Improve Yolo Bypass Adult Fish Passage)
- RPA Action I.6.1: Restoration of Floodplain Rearing Habitat (Increase Juvenile Salmonid Access to Yolo Bypass, and Increase Duration and Frequency of Yolo Bypass Floodplain Inundation)
- RPA Action NF 4: Implementation of Pilot Reintroduction Program (Implementation of Pilot Reintroduction Program above Shasta Dam)
- RPA Action IV.1.3: Consider Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta, and Reduce Exposure to CVP and SWP Export Facilities (Including Georgiana Slough Non-Physical Barrier)
- RPA Action I.2.6: Restore Battle Creek for Winter-Run, Spring-Run, and CV Steelhead (Complete Battle Creek Salmon and Steelhead Restoration Project)

Reclamation and DWR have re-committed to these actions as part of the revisions to the PA (Appendix A2).

Winter-run Chinook Salmon Diversity:

The current winter-run Chinook salmon population is the result of the introgression of several stocks (e.g., spring-run and fall-run Chinook salmon) that occurred with the construction of Shasta and Keswick dams which blocked access to the upper watershed and did not allow spatial separation of the different runs (Good et al. 2005b). Lindley et al. (2007b) recommended reclassifying the winter-run Chinook salmon population extinction risk from low to moderate if the proportion of hatchery origin fish from the LSNFH exceeds 15 percent due to the impacts of hatchery fish over multiple generations of spawners. Since 2005, the percentage of hatchery winter-run Chinook salmon recovered in the Sacramento River has been greater than 15 in four years: 2005, 2012, 2014, and 2015. The average over the last 12 years (covering approximately four generations) is 13%; the most recent generation had 20% hatchery influence, qualifying the population as a moderate risk of extinction (NMFS 2016c). Although there is a concern for exceeding 15 percent hatchery origin, LSNFH is considered an “Integrated-Recovery” supplementation program because of its use of best management practices. Propagation at LNSFH is managed to be genetically integrated with the natural population. Winter-run Chinook salmon produced at the LSNFH are also intended to return as adults to the upper Sacramento River, spawn in the wild, and become reproductively and genetically assimilated into the natural spawning population.

Winter-run Chinook Salmon ESU Viability Summary:

Several criteria qualify the winter-run Chinook salmon population for being at moderate risk of extinction, though only one criteria is required. Because a single population spawns below Keswick Dam, the winter-run Chinook salmon ESU is at high risk of extinction in the long-term according to criteria in Lindley et al. (2007b). Recent trends in those criteria are:

(1) continued low abundance;

(2) a negative growth rate over 6 years (2006–2012), which is two complete generations;

(3) a significant rate of decline since 2006;

(4) increased hatchery influence on the population; and

(5) increased risk of catastrophe from oil spills, wild fires, or extended drought (i.e., realization of effects of climate change).

The most recent 5-year status review (National Marine Fisheries Service 2016c) on winter-run Chinook salmon concludes that the extinction risk of this ESU has increased since the last status review largely due to extreme drought and poor ocean conditions.

2.7.1.2 Summary of Proposed Action Effects

Detailed descriptions regarding the exposure, response, and risk of winter-run Chinook salmon to stressors associated with the proposed action are presented in section 2.5, Effects of the Action. The proposed action-related effects to winter-run Chinook salmon are separated into those related to construction and those related to operations and permanent structures. Also included with the assessment of operations is an assessment of the Section 2.5.1.3 Ancillary Delta Facilities, which were originally covered by the 2009 NMFS CVP/SWP opinion but are now part of the PA. The distinction between construction and operations is based on differences in expected duration of effect; effects of construction activities are generally expected to occur over a finite period while effects of operations and permanent structures and ancillary Delta facilities, are considered ongoing. Furthermore, the majority of construction-related effects are minimized by the timing of construction activities and proposed in-water work windows which are scheduled for times of year when winter-run Chinook salmon presence is low or unlikely. Work window timing and the expected duration of in-water construction activities (up to 8 years) are detailed in section 2.5.1.1, Construction Effects, Table 2-9. Site-specific effects of PA elements that will be covered programmatically are not included in this summary of effects, because these elements are at various stages of development, and at this time are lacking sufficient information regarding the potential site-specific effects to individual winter-run Chinook salmon. These Programmatic Activities (section 2.5.1.4) are instead considered later, in section 2.7.1.3 (Assess Risk to the Population) where the overall effects and/or benefits they provide are analyzed in the assessment of risk to the population and species. The construction-related effects on winter-run Chinook salmon, including the overall effect of the PA with the environmental baseline and cumulative effects, are summarized in Table 2-242:

Table 2-242. Integration and synthesis of construction related effects with the environmental baseline and cumulative effects, on winter-run Chinook salmon.

Section Number	Stressor	Life Stage (Location)	Life Stage Timing (Work Window Intersection)	Individual Response and Rationale of Effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of Overall Effect (PA + Baseline + Cumulative Effects (CE))
2.5.1.1.1.1	Pile Driving (Acoustic)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.); Adults: Nov. - June (<4% below RBDD in June)	Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed.	Low - Expected acute effect limited to a very small proportion of the population.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Low - Expected acute effect limited to a very small proportion of the population, baseline, and CE add “periodic” pile driving (section 2.4.4.6).
2.5.1.1.1.2	Barge Traffic (Acoustic)	Juvenile rearing and emigration; Adult immigration (Delta)	Juveniles: Oct. - April (<2% in Oct, modified routing Nov – May); Adults: Nov. - June (modified routing Nov - May)	Reduced feeding/foraging behavior due to increased stress, distraction (foraging success) and prey masking.	Low - Generally sublethal effect, expected to be imposed on a very small proportion of the population.	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration, and extent of barge operations.	Reduced growth	Low to Medium - Generally a sublethal effect, expected on a very small proportion of the population; however, baseline adds that portions of the action area “experience heavy commercial and recreational vessel traffic” (section 2.4.4.5).
2.5.1.1.2.1	Pile Driving (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.); Adults: Nov. – June (rare)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect, expected to be imposed on a very small proportion of the population.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect, but expected to be imposed on a very small proportion of the population baseline and CE add “periodic” pile driving (section 2.4.4.6).
2.5.1.1.2.2	Barge Traffic (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	Juveniles: Oct. - April (<2% in October, modified routing Nov – May); Adults: Nov. - June (modified	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in turbidity.	Low - Generally sublethal effect, expected to be imposed on a very small proportion of the population.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding timing,	Reduced growth	Low to Medium - Generally a sublethal effect, expected on a very small proportion of the population; however, baseline and CE adds that portions

			routing Nov - May)			duration and extent of barge operations.		of the action area "experience heavy commercial and recreational vessel traffic" (section 2.4.4.5).
2.5.1.1.2.3	Geotechnical Analysis (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.); Adults: Nov. – June (rare)	No response, as turbidity associated with geotechnical analysis is likely imperceptible.	NA	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	NA	NA (Geotechnical analysis is not included in the Environmental Baseline section 2.4).
2.5.1.1.2.4	Dredging (Sediment Concentration) + Facility Maintenance (2.5.1.2.9.1)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.); Adults: Nov. – June (rare)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a very small proportion of the population.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Behavioral modification (not a measure of fitness)	Low to Medium - Generally sublethal effect limited to a very small proportion of the population. The baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale" (section 2.4.4.4).
2.5.1.1.3.1	Pile Driving (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.); Adults: Nov. - June (<4% below RBDD in June)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes.	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low to Medium - Generally sublethal effect limited to a very small proportion of the population; however, the baseline adds "documented high levels of contaminants" in the action area (section 2.4.4.1).

2.5.1.1.3.2	Barge Traffic (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (Delta)	Juveniles: Oct. - April (<2% in October, modified routing Nov – May); Adults: Nov. - June (modified routing Nov - May)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes.	Low - Generally sublethal effect expected to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is somewhat unpredictable owing to uncertainty regarding timing, duration and extent of barge operations as well as sediment composition.	Reduced growth, Reduced reproductive success	Low to Medium - Generally sublethal effect limited to a very small proportion of the population; however, the baseline adds “documented high levels of contaminants” in the action area (section 2.4.4.1).
2.5.1.1.3.3	Geotechnical Analysis (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.) Adults: Nov. - June (<4% below RBDD in June)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes.	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low to Medium- Generally sublethal effect limited to a very small proportion of the population, however, the baseline adds “documented high levels of contaminants” in the action area (section 2.4.4.1).
2.5.1.1.3.4	Dredging (Contaminant Exposure) + Facility Maintenance (2.5.1.2.9.1)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.); Adults: Nov. - June (<4% below RBDD in June)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes.	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low - Generally sublethal effect limited to a very small proportion of the population. The baseline adds “periodic” dredging projects in the Action Area, that are of “varying scope and scale” (section 2.4.4.4).
2.5.1.1.4.1	Clearing and Grubbing (Increased Temperature) + Facility	Juvenile rearing and emigration; Adult immigration (Delta)	Juveniles: Oct. - April (no work window); Adults: Nov. - June (no work window)	No response, as temperature changes associated with project removal of riparian vegetation would be imperceptible.	NA	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to uncertainty	NA	Low – “Due to levee construction, and shoreline development, [which involves the removal of riparian vegetation], estuarine

	Maintenance (2.5.1.2.9.2)					regarding the extent of thermal change.		habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the action area is improving this condition (section 2.4.2.3).
2.5.1.1.5.1	Pile Driving (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.); Adults: Nov. - June (<4% below RBDD in June)	Increasing feeding success rate as anthropogenic waves may inject prey species into the water column or expose benthic infauna.	Low - Minor or short-term effect that impacts a small proportion of the population.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	Increased growth (Beneficial)	Low - Minor or short-term effect that impacts a small proportion of the population and the baseline and CE add "periodic" pile driving (section 2.4.4.6).
2.5.1.1.5.2	Barge Traffic (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	Juveniles: Oct. - April (<2% in October, modified routing Nov – May); Adults: Nov. - June (modified routing Nov - May)	Increasing feeding success rate as anthropogenic waves may inject prey species into the water column or expose benthic infauna.	Low – A minor effect that impacts a very small proportion of the population.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to timing, duration and extent of barge operations as well as the extent of prey availability.	Increased growth (Beneficial)	Low – A minor effect that impacts a small proportion of the population; however, the baseline adds that portions of the action area "experience heavy commercial and recreational vessel traffic" (section 2.4.4.5).
2.5.1.1.5.3	Geotechnical analysis (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.); Adults: Nov. - June (<4% below RBDD in June)	No response, as changes in prey abundance and availability associated with geotechnical analysis is likely imperceptible.	NA	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	NA	NA
2.5.1.1.5.4	Dredging (Reduced Prey) + Facility	Juvenile rearing and emigration;	Juvenile: Oct. - April (<2% expected in	Reduced prey availability, decreasing feeding success caused	Low - Generally sublethal effect limited to a very	Medium - Understanding is High but nature of outcome	Reduced growth	Low - Generally sublethal effect limited to a very small

	Maintenance (2.5.1.2.9.2)	Adult immigration (Delta)	Oct.); Adults: Nov. - June (<4% below RBDD in June)	by the removal of benthic sediments and infauna (prey base).	small proportion of the population.	is somewhat unpredictable because of uncertainty regarding sediment/prey composition.		proportion of the population. The baseline adds "periodic" dredging projects in the action area, that are of "varying scope and scale" (section 2.4.4.4).
2.5.1.1.5.5	Clearing and Grubbing (Reduced Prey) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Adult immigration (Delta)	Juveniles: Oct. - April (no work window); Adults: Nov. - June (no work window)	Reduced prey availability, decreasing feeding success caused by the removal of riparian flora and associated fauna.	Low - Generally sublethal effect limited to a very small proportion of the population.	High - multiple scientific and technical publications.	Reduced growth	Medium - Generally sublethal effect limited to a very small proportion of the population. The baseline diminishes available prey because "Due to levee construction, and shoreline development, [which involves the removal of riparian vegetation], estuarine habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the action area is improving this condition (section 2.4.2.3).
2.5.1.1.6.1	Pile Driving (Increased Predation)	Juvenile rearing and emigration	Juvenile: Oct. - April (<2% expected in Oct.)	Increased mortality (predation) caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance. Adults not likely to be affected.	Low to Medium - Acute effect limited to a very small proportion of the population.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Medium - Expected acute effect limited to a very small proportion of the population, baseline and CE add "periodic" pile driving (section 2.4.4.6)
2.5.1.1.6.2	Barge Traffic (Increased Predation)	Juvenile rearing and emigration	Juveniles: Oct. - April (<2% in October,	Increased mortality (predation) caused by anthropogenic noise masking acoustic	Low - Acute effect to a very small proportion of the population	Medium - There are a few publications regarding the effects	Reduced survival	Low to Medium - Acute effect, expected on a very small proportion of the

			modified routing Nov – May)	predator cues, compromising predator avoidance. Adults not likely to be affected.	(modified timing and routing greatly reduces potential exposure).	of sound on predator-prey interactions.		population, however baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)
2.5.1.1.6.3	Interim in-water structures (Increased Predation)	Juvenile rearing and emigration	Juveniles: Oct. - April (no work window)	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish. Adults not likely to be affected.	Low - Acute effect limited to a very small proportion of the population.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium – An acute effect limited to a very small proportion of the population. Added to a baseline of diminished habitat complexity when "due to levee construction, [and] shoreline development, […] estuarine habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the action area is improving this condition (section 2.4.2.3).
2.5.1.1.6.4	Clearing and Grubbing (Increased Predation) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration	Juveniles: Oct. - April (no work window)	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish. Adults not likely to be affected.	Low - Expected acute effect limited to a small proportion of juveniles.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium – An acute effect limited to a very small proportion of the population. Added to a baseline of diminished habitat complexity when "levee construction involves the removal of riparian vegetation, resulting in reduced habitat complexity and shading, making juveniles more

								susceptible to predation." Some restoration work in the action area is improving this condition (section 2.4.2.3).
2.5.1.1.7.1	Pile Driving (Physical Impacts to Fish)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.); Adults: Nov. - June (<4% below RBDD in June)	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile driving-induced sound creates a temporary barrier to migration.	Low - Expected sublethal effect limited to a very small proportion of the population	High – Multiple technical publications including quantitative modeling results.	Reduced growth, Reduced reproductive success (adults)	Low – Expected sublethal effect limited to a very small proportion of the population. The baseline and CE add "periodic" pile driving effects (section 2.4.4.6).
2.5.1.1.7.2	Dredging entrainment (Physical Impacts to Fish) + Facility Maintenance (2.5.1.2.10)	Juvenile rearing and emigration (Delta)	Juvenile: Oct. - April (<2% expected in Oct.)	Mortality from entrainment into dredge cutterhead. Adults not likely to be affected.	Low – Expected acute effect limited to a very small proportion of the population.	High – There are multiple scientific and technical publications	Reduced survival	Low to Medium - Acute effect limited to a very small proportion of the population. The baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale." (section 2.4.4.4)
2.5.1.1.7.3	Propeller entrainment (Physical Impacts to Fish)	Juvenile rearing and emigration; Adult immigration (Delta)	Juveniles: Oct. - April (<2% in October, modified routing Nov – May); Adults: Nov. - June (modified routing Nov - May)	Injury and mortality from entrainment into the propellers of passing barges.	Low - Acute effect to a very small proportion of the population (modified timing and routing greatly reduces potential exposure).	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration and extent of barge operations.	Reduced survival	Low to Medium - Acute effect, expected on a very small proportion of the population, however baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic" (Section 2.4.4.5).
2.5.1.1.7.4	Dewatering (Physical Impacts to	Juvenile rearing and emigration;	Juvenile: Oct. - April (<2% expected in Oct.)	Injury and mortality from dewatering and handling during rescue	Low - Acute effect limited to a very	High – There are multiple scientific and technical publications	Reduced survival	Low – Acute effect limited to a small proportion of the

	Fish) + Facility Maintenance (2.5.1.2.10)	Adult immigration (Delta)		operations. Adults not likely to be affected.	small proportion of a population		population (Dewatering is not included in the Environmental Baseline Section 2.4).

Post-construction operational effects of the action on winter-run Chinook salmon along with the environmental baseline and cumulative effects are summarized in Table 2-243. Because a more certain characterization of the effects of operations will depend on a number of design criteria and real-time factors, this Opinion analyzes a range of effects depending on the expected use of these criteria and factors. The expectation remains, however, that certain aspects of this effects analysis will be reevaluated through proposed research, monitoring and adaptive management (section 2.5.1.4, Programmatic Activities). This expectation is confirmed in Chapter 7 of the BA (Effects Determination), which provides, "the RTO and adaptive management and monitoring provisions included in the PA provide additional opportunities to refine the operating criteria and make adjustments to CVP/SWP Delta operations to minimize the risks of incidental take while maximizing water supply." In this Opinion, NMFS' assessment of operational effects relies on the best scientific and commercial data available (section 2.5.1.2 Operations Effects and section 2.5.1.3 Ancillary Delta Facilities) with the understanding that the specifics of operations and design criteria will be refined within the bounds of the RTO and adaptive management and monitoring programs.

Table 2-243. Integration and synthesis of post-construction, operational effects with the environmental baseline and cumulative effects, on winter-run Chinook salmon.

Section Number	Stressor	Life Stage (Location)	Life Stage Timing	Individual Response and Rationale of effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of Overall Effect (PA + Baseline + Cumulative Effects)
2.5.1.2.1	Operations (Increased Upstream Temperature)	Spawning Adults, Egg incubation, Fry rearing (upstream of RBDD)	Spawning : mid-April - mid-August; Egg and Fry: April - October	Prespawn mortality, and egg mortality caused by increased temperatures, and daily fluctuation of temperatures.	Low or No effect - Effects of the action are not substantially different from the NAA.	High: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. Uncertain - Modeling results based on downscaled monthly data.	Reduced survival, Reduced reproductive success	High - Temperature effects place a high magnitude stress on the species and accounts for a large amount of mortality. From the baseline: “freshwater spawning sites for these species has been degraded within the action area due to high water temperatures, redd dewatering, and loss of spawning gravel recruitment in reaches below Keswick Dam” (section 2.4.2.3, and section 2.4.4.1.1). These effects may be minimized by real-time operational management.
2.5.1.2.2	Operations (Redd Dewatering)	Egg incubation, Fry rearing (upstream of RBDD)	Egg and Fry: April - October	Redd dewatering; loss of a portion or all eggs in redd	Low - Expected acute population effect on a small proportion of the population, although there are only marginal differences between the PA and the NAA.	High: Supported by multiple scientific and technical publications and modeling results.	Reduced survival	Medium - Expected acute population effect on a small proportion of the population. (section 2.4.2.3, see also section 2.5.1.2.2)
2.5.1.2.3	Operations (Redd Scour)	Egg incubation, Fry rearing (upstream of RBDD)	Egg and Fry: April - October	Scour of redds not expected to occur	NA - Effects of the action are not substantially different from the NAA.	High: Supported by multiple scientific and technical publications.	NA	Low – Expected acute affect in very rare cases (less than 1% of months) (section 2.4.4.1.1, see also section 2.5.1.2.3)
2.5.1.2.4	Operations (Stranding)	Fry rearing (upstream of RBDD)	Fry: July - October	Mortality either directly through desiccation or	Low or Uncertain - Effects of the	High: Supported by multiple scientific and technical	Reduced survival	Medium - Expected acute population effect on a small proportion of the population.

				indirectly through predation or reduced water quality.	action are not substantially different from the NAA.	publications including recent and historic observations.		
2.5.1.2.5	Operations (Impingement and Entrainment)	Juvenile migration and rearing (NDD)	Juvenile migration and rearing: October - April	Mortality from contact with fish screen, and indirectly predation; sublethal effects from injury (e.g. loss of scales, disorientation)	Medium - Expected sustained population effect. Expected annual entrainment would be <0.1%, and combined injury and mortality from impingement would be <9.0%. The proportion of the population exposed is expected to be reduced by the commitment to UPP and phased testing to ensure the fish screens meet NMFS criteria.	Medium - Understanding is High but nature of outcome is somewhat unpredictable due to uncertainty of exposure.	Reduced survival	Medium - Expected sustained population effect. For all three intakes combined expected annual entrainment would be <0.1%, and combined injury and mortality from impingement would be <9.0%. The proportion of the population exposed is expected to be reduced by the commitment to UPP and phased testing to ensure the fish screens meet NMFS criteria.
2.5.1.2.6.1	Permanent In-water Structures (Increased Predation)	Juvenile migration and rearing (NDD)	Juvenile migration and rearing: October - April	Mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish. Uncertainty regarding design and criteria of mitigating refugia	Medium - Expected sustained population effect on a large moderate proportion of the population.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium – Effect limited to a moderate proportion of the population. Added to a baseline of diminished habitat complexity when “due to levee construction, [and] shoreline development, […] estuarine habitat in the Delta is significantly degraded from its historical condition.” Some restoration work in the Action Area is improving this condition (Section 2.4.2.3).

				and predator cover areas.				
2.5.1.2.7.1	NDD Operations (Travel Time)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: October - April	Mortality caused by increased migration times, with increases in predator exposure.	Medium - Expected sustained population effect on a large proportion of the population.	High - There are a number of publications regarding the relationship between flow, river velocity, and Delta survival and travel time in the North Delta; conclusions supported by modeling results.	Reduced survival	High - Expected sustained population effect on a large proportion of the population.
2.5.1.2.7.2	NDD Operations (Outmigration routing)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: October - April	Mortality caused by routing into interior Delta routes with lower survival.	Medium - Expected sustained population effect on a medium proportion of the population.	High - There are a number of publications regarding the relative survival in various North Delta and Central Delta migratory routes; conclusions supported by modeling results.	Reduced survival	Medium - Expected sustained population effect on a medium proportion of the population.
2.5.1.2.7.3	Operations (Altered South Delta hydro-dynamics due to South Delta exports and HOB operations)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: October - April	Mortality or decreases in condition due to migratory delays due to altered hydrodynamics and loss of migratory cues. Delays increase exposure to sources of mortality and morbidity (predation, poor water quality, contaminants, etc.)	Medium - Expected sustained population effect on a medium proportion of the population.	Medium to High – Delta hydrodynamics well studied. Effects of Delta hydrodynamics on salmonids more uncertain.	Reduced survival, reduced growth	High - Expected sustained population effect on a medium proportion of the population.

2.5.1.2.7.3.1	CVP/SWP Operations (Entrainment and loss at South Delta export facilities)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: October - April	Loss is approximately 35% of entrained fish at the CVP's Tracy Fish Collection Facility, and 84% at the SWP's Skinner Delta Fish Protective Facility.	Low - Expected sustained population effect on a small proportion of the population.	High – Numerous studies have evaluated screening efficiency, predation, and overall salvage operations survival	Reduced survival	Low - Expected sustained population effect on a small proportion of the population.
2.5.1.3.1.1	Suisun Marsh Salinity Control Gates	Juvenile rearing and emigration; Adult immigration (Suisun Marsh)	Juveniles: Year-round; Adults: Year-round	Limited effect to juveniles; sublethal, behavioral effect to adults, migration delay and changes to routing.	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population.	Medium – Delta hydrodynamics well studied. Effects of Delta hydrodynamics on salmonid migration more uncertain.	Reduced reproductive success	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.1.2	Roaring River Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Mortality caused by entrainment into pumps distributing water to Suisun Marsh.	None – Fish screens of adequate size and approach velocities slow enough to exclude juveniles from entrainment.	Medium – Fish/Screen interactions well studied. Observations at this location limited.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.1.3	Morrow Island Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Mortality caused by entrainment into culverts diverting from Goodyear Slough, and draining into Grizzly Bay or Suisun Slough.	None – Entrainment of juveniles unlikely because of location of intakes and probable size of fish.	Low to Medium – Inference based on understanding of fish life history. Observations at this location limited, but include entrainment of fall-run Chinook salmon.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.

2.5.1.3.1.4	Goodyear Slough Outfall	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Passive entrainment into Suisun Marsh, possible improvement to water quality and available foraging habitat.	None or Low – Entrainment of juveniles unlikely because of location of intakes and probable size of fish.	Low – Inference based on understanding of fish life history. No observations at this location.	Improved growth	None or Low – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.2	North Bay Aqueduct	Juvenile rearing and emigration; (Delta)	Juveniles: Year-round	Injury and mortality caused by entrainment into pumps or impingement in screens at North Bay Aqueduct, Barker Slough Intake.	None or Low – Entrainment or impingement of juveniles unlikely because of location of intakes, efficacy of fish screens and probable size of fish.	Low to Medium – Inference based on understanding of fish life history. Observations at this location limited.	Reduced survival	None or Low – Insignificant effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.3	Contra Costa Canal Rock Slough Intake	Juvenile rearing and emigration; (Delta)	Juveniles: Year-round	Injury and mortality caused by entrainment into pumps or impingement in screens at Contra Costa Canal Rock Slough Intake.	None or Low – Entrainment or impingement of juveniles unlikely because of location of intakes, and probable effectiveness of fish screens.	Low to Medium – Inference based on understanding of fish life history. Continued testing of fish screen and vegetation removal expected until at least 2018.	Reduced survival	None or Low – Insignificant effect pending resolution of fish screen sweeping efficiency. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.

2.7.1.3 Assess Risk to the Population

NMFS applies the VSP concept as an approach to evaluate the population viability of Sacramento River winter-run Chinook salmon with the proposed action and to determine the extinction risk of the ESU. Viability of the population and extinction risk of the ESU relate to the likelihood of both the survival and recovery of the ESU. In this section, we evaluate the effects of the action using the VSP parameters of abundance, productivity, spatial structure, and diversity. NMFS considers these specific parameters because they are predictors of extinction risk and reflect general biological and ecological processes that are critical to the growth and survival of salmon (McElhany et al. 2000b). As described in section 2.5 Effects of the Action, the proposed action will impose conditions in the Sacramento River and Delta that will either directly or indirectly affect winter-run Chinook salmon in a number of ways that are expected to reduce the fitness of individuals. Based on the change in fitness of individuals, while considering the effects and/or benefits provided by the programmatic activities and the minimization aspects of the revised PA, NMFS assesses whether the collective changes, including the environmental baseline and cumulative effects, are expected to constitute a change in the VSP parameters and thereby affect the winter-run Chinook salmon population.

Winter-run Chinook Salmon Abundance:

The three key attributes of the abundance VSP parameter require that the relative size of a spawning population be large enough to: 1) have a high probability of surviving environmental variability; 2) allow compensatory process to provide resilience from environmental and anthropogenic disturbance; and 3) maintain its genetic diversity (McElhany et al. 2000b). In 2007, Lindley et al. identify the census population size ($N > 2{,}500$) or effective population size ($N_e > 500$) as one of four criterion needed to assess a salmonid population's risk of extinction. NMFS uses changes in the adult population as the measure against which any potential reduction in the VSP abundance parameter is assessed. Changes in juvenile abundance are also considered; however, because juveniles are not yet part of the spawning population (i.e., the effective population), the effects of the action on juvenile winter-run Chinook salmon are instead considered in the assessment of the productivity VSP parameter. Winter-run Chinook salmon population estimates from 2007 to 2013 average 2,486 adults with estimates of adult escapement in 2014 and 2015 being 3,015 and 3,440 adults respectively. Given this baseline condition of the adult population, which is at or about the threshold for a moderate risk of extinction based on the abundance VSP parameter, small changes in abundance could shift the extinction risk to the species regardless of the condition of the other criterion.

NMFS expects the proposed action will have a number of short-term construction-related impacts to the species, only one of which possess the potential to reduce the abundance parameter of a VSP. Given the proposed work window and migration timing of adult winter-run Chinook salmon, construction-related effects are expected to impact very small numbers of returning adults. Typically, by the end of May, fewer than 4% of returning adult winter-run Chinook salmon will have yet to pass RBDD (200 river miles north of the Delta) (Hallock and Fisher 1985). Therefore, it is likely that only a few individual winter-run Chinook salmon would be found in the Delta by June 15, the start of the revised work window. Furthermore, the majority of construction-related effects would likely cause changes in behavior and not direct mortality which would affect abundance. One notable exception is the effect of pile driving-induced noise. As explained in section 2.5.1.1.1.1 Acoustics; pile driving-induced noise would affect winter-run Chinook salmon in a manner that could harm or even result in mortality. Although there is a potential for winter-run Chinook salmon mortality to be caused by pile-driving, or one of the several other construction-related effects that will result in reduced survival, this potential is greatly limited by the proposed work windows; however, it is not eliminated entirely. Each year, a few individual adult winter-run Chinook salmon are expected to be killed by any one of the construction activities. Because construction is expected to occur for up to 8 years, the loss of even a few adults on an annual basis is expected to marginally reduce the abundance VSP parameter of winter-run Chinook salmon.

The SWFSC WRLCM described in Appendix H: WRLCM Documentation, is used in this Opinion to determine the effect of the post-construction operation with the PA as compared to the NAA. The WRLCM is used as a means of comparison between the NAA and PA because relative comparisons are more robust than the absolute predictions from the model. Moreover, the model is not used to determine an actual abundance as any attempt to identify the outputs of the model as equating to actual fish in the Sacramento River would be incorrect. Because predictions are not calibrated to produce forecasts of actual abundance, results are viewed as the relative performance of the two actions (i.e., the NAA and the PA). One of the outputs of the model is a description of the relative effect of the PA on abundance, and while the model also provides an assessment of population growth, that assessment is described in the description of changes to the productivity VSP parameter. For all six scenarios analyzed with the model, the effect of the PA on abundance was more negative relative to NAA. Under no scenario is abundance greater in the PA relative to the NAA at the end of the 82-year time series, meaning that operations with the PA are expected to result in decreased abundance of the winter-run Chinook salmon population. The effect of a decrease in abundance when added to the population's baseline condition of abundance would maintain the current risk of extinction based solely on the abundance VSP parameter.

However, these results of WRLCM do not incorporate the additional project commitments in the revised PA that are expected to improve results from those described for the PA scenario. An analysis of a new WRLCM scenario was completed to evaluate PA fish routing elements and revised PA habitat restoration. Although the exact benefits from these actions cannot be captured within the model due to uncertainty of representation of these elements within the model structure, the results of this scenario indicated an improvement to the reduced cohort replacement rate described in the analysis of the PA scenario. Furthermore the commitment to preventing an increase in north Delta reverse flows was not modeled with the WRLCM. The Perry Survival Model was used to evaluate the unlimited pulse protection revision to the PA and showed that the impact to juvenile through-Delta survival is much less under these protections. RMA modeling showed that tidal Delta habitat restoration at the level proposed in the revised PA should be able to influence the tidal prism enough to prevent the exacerbation of reverse flows from the NDD operations.

Also included in the revised PA is a renewed commitment to winter-run Chinook salmon reintroduction to the Sacramento River above Shasta Dam and Battle Creek, which would increase abundance of this ESU. It is NMFS' expectation that the benefits gained from these new commitments will reduce the impacts to abundance from the PA (beyond what the WRLCM is capable of representing at this time in the model's development) and possibly even improve abundance of the species over time.

Winter-run Chinook Salmon Productivity:

The key attributes of the productivity VSP parameter represent a population's ability to reproduce itself, survival of early life stages, and the influence of hatchery produced spawners on the population. Winter-run Chinook salmon productivity, as measured by the number of juveniles entering the Delta, is estimated each year as the juvenile production estimate (JPE). From 2010 to 2015 (i.e., two generations) natural winter-run Chinook salmon productivity has averaged 8.0 million viable eggs, 1.36 million egg to fry at RBDD, and 408,249 JPE. Egg-to-fry survival of juvenile winter-run Chinook salmon estimated to pass RBDD in brood years 2014 (5.9%) and 2015 (4.2%) are well below the 18-year average (23.6% survival) (Martin et al. 2001; NMFS 2016; Poytress et al. 2014, 2015; Poytress 2016). Such low survival further depresses the natural population and artificially raises the proportion of the population that is hatchery origin. Hatchery production from 2010 - 2015 averaged 288,289 (hatchery release at RBDD) and 105,761 (hatchery entry to the Delta). With the increased hatchery production in 2014 and 2015, which was implemented as part of the drought response, hatchery influence over the last six years ranges from 18% to 21%. According to the Lindley et al. (2007) viability criterion, the current baseline condition of hatchery influence for two generations qualified winter-run Chinook salmon as a moderate risk of extinction regardless of the condition of the other viability criterion. Given the current status of the population at a moderate risk of extinction based on productivity, actions that would appreciably reduce the natural component of the population or directly or artificially increase the proportion of hatchery fish in the population are considered to reduce the productivity parameter of the VSP.

The productivity of winter-run Chinook salmon is expected to be reduced by the PA both through a reduction in pre-spawn fitness of adults as well as through injury and mortality experienced by rearing and outmigrating juveniles. Because of the construction in-water work windows, all but a few returning adult winter-run Chinook salmon will avoid most of the construction-related effects. The expected increase in Delta barge traffic associated with construction and described in sections 2.5.1.1.1.2 Acoustics, 2.5.1.1.2.2 Sediment Concentration, and 2.5.1.1.3.2 Contaminant Exposure, has been modified in routing and timing to reduce the impact to species; however, the stressor imposes a year-round effect in some areas of the Delta. Considering that these areas of increased barge traffic are outside of the natural migration pathways of returning adults, the vast majority will not be exposed to increased vessel noise, sediment concentration, or contaminants. For the few individual salmon that are exposed, this activity will not result in direct mortality to adult winter-run Chinook salmon. It will instead result in a reduced level of fitness that is likely to have a minor effect that is not expected to appreciably reduce the productivity VSP of the winter-run Chinook salmon population.

The effects of the action are expected to have a more significant impact on juvenile production as out migrating and rearing juveniles will be exposed to a number of stressors related to construction and operations of the PA. Although only a small proportion of winter-run Chinook salmon juveniles (2%) are expected to be present at construction locations during the times of year when construction is taking place, those individuals will be exposed to injury and possibly death caused by a number of construction-related actions such as pile driving and dredging. However, these effects would not be experienced by hatchery-produced winter-run Chinook salmon because hatchery fish are typically released in February, outside the proposed in-water work windows in the Delta (generally June – October, varying with location). Because of the deliberate and late release of hatchery production fish outside of the in-water work windows, construction would have a small but disproportionate effect on the natural production of winter-run Chinook salmon, with the potential to further increase hatchery influence.

A small proportion of the juvenile population would be exposed to increased barge traffic in some areas of the Delta. Because of the final proposed routing and timing of construction-related barge traffic, NMFS expects that only those juveniles entrained into the central Delta through either the DCC or Georgiana Slough would be exposed to effects of barge traffic. Unlike adult winter-run Chinook salmon, which will be exposed to increased vessel noise, sediment concentration, and contaminants, juveniles will also be exposed to propeller entrainment. The combined effect of these stressors is expected to increase exposure to predators, reduce the fitness of individual fish, and even result in mortality. The direct and indirect loss of juvenile fish caused by construction-related effects is expected to result in a small reduction of juvenile abundance which would diminish the productivity VSP parameter of the winter-run Chinook salmon population.

Post-construction operations of the PA will also affect the productivity VSP parameter of winter-run Chinook salmon. Specifically, out-migrating juveniles will be exposed to fish screen interactions (entrainment and impingement) at the NDD and reduced in-Delta flows that will result in the reduced survival of juveniles and a corresponding reduction in juvenile production.

Section 2.5.1.2.5 Impingement and Entrainment quantifies the interactions of migrating juvenile winter-run Chinook salmon with fish screens at the NDD identifying an expected combined incident rate of <9.0% for injury and mortality. However, the operational phasing commitment described in the PA will be used to demonstrate compliance with the then-current NMFS and CDFW screening design and operating criteria. The PA states that, "The fish and wildlife agencies (i.e., USFWS, NMFS, and CDFW) retain responsibility for determination of the operational criteria and constraints (i.e. which pumping stations are operated and at what pumping rate) during testing." Therefore, the extent of effect is limited to a smaller proportion of what would be expected in the PA until design and operation of the screens is sufficiently tested. The NDD screens will be designed to meet NMFS screening criteria and incorporate (as yet determined) predator refugia, which NMFS expects will minimize screen impingement and associated predation. The PA provision that the NDD screen intakes will begin operating in a phased manner with testing to ensure they are functioning as expected will ensure impacts are minimized. In addition, the revised PA commitments to habitat restoration including 80 acres in the upper Sacramento River , and 1,800 acres of restoration in the Delta, that will ultimately improve overall juvenile winter-run Chinook salmon survival; and the commitment to the revised Adaptive Management Plan includes research to assess and mitigate Sacramento River basin predation (Appendix A2, Adaptive Management Program). It is the expectation that these habitat restoration areas will be functioning and improving winter-run Chinook salmon productivity before the PA operations commence. The incident rate at the NDD screens is expected to be further reduced by the revised real-time operations for the NDD that have unlimited pulse protections, such that during periods of high fish migration diversions will be reduced to limit exposure. Under the PA without consideration of the revised PA, juvenile survival was reduced during the core migratory months ranging from 0.5% to 12% (median). With the revised PA (unlimited pulse protections) median survival reductions are improved with a range from 0.7% to 3%.

As explained in section 2.5.1.2.7 Reduced In-Delta Flows, the relationship between through-Delta travel time, migration route, and flow is such that the reduction in Delta flows caused by operations under the proposed action would have an associated reduction in juvenile survival. Perry's 2017 flow-survival model described in section 2.5.1.2.7.5.2 Perry 2017 Flow-Survival Model (Travel Time), simplifies the relationship between flows, travel time, and smolt survival, showing that with the PA in at least 75% of years, winter-run Chinook salmon migration travel time is increased for all months during the entire migration period. Increased travel times will negatively impact juveniles by increasing predator encounters, increasing tidal excursion in transition reaches of the lower Sacramento River, increasing entrainment into lower survival routes of the central Delta, and reducing turbidity, which likely benefits predators.

Although the reduction in downstream flows caused by the NDDs as analyzed for the PA scenario without consideration of the revisions to the PA will have an adverse effect on migrating juvenile winter-run, the commitments made by Reclamation and DWR in the revised PA; including the revised real-time operations for the NDDs and the restoration of Delta habitat, are expected to lessen the impact. With the revised PA (unlimited pulse protections), median survival reductions are improved with a range from 0.7% to 3% as compared to the original PA where juvenile survival was reduced during the core migratory months ranging from 0.5% to 12% (median). RMA modeling showed that tidal Delta habitat restoration at the level proposed in the revised PA should be able to influence the tidal prism enough to prevent the exacerbation of reverse flows from the NDD operations. Also included in the revised PA is a renewed commitment to winter-run Chinook salmon reintroduction to the Sacramento River above Shasta Dam and Battle Creek, which would increase productivity of this ESU. Habitat expansion through reintroduction and restoration is expected to begin improving productivity by the time PA operations commence and continue to improve productivity over the long-term.

The Delta analysis results reported above are supported by the SWFSC WRLCM analyses which is presented in section 2.5.1.2.7.5.2 Sacramento River Winter-run Chinook Salmon Life Cycle Model. In this life cycle model the cohort replacement rate is a key metric used to understand the attributes of the productivity VSP parameter, as it is the ability of a population to replace itself. In the six scenario runs used for the analyses, the PA always has a lower mean and median CRR than the NAA. The relative difference in productivity between the alternatives means that operations with the PA would reduce the productivity parameter of a winter-run Chinook salmon VSP compared to the NAA. While the differences between the CCRs of the PA and NAA are relatively small, the LCM indicates that with the PA the population is more susceptible to environmental perturbations such as drought and that it is unable to replace itself. This contrasts with the NAA population, which was able to recover. In the final review of the WRLCM results, based on commitments and changes made in the revised PA, the difference in the CRR between the revised PA and the NAA improved by about 1%, from approximately an 8% reduction to approximately a 7% reduction. Furthermore, it is NMFS' expectation that the benefits gained from the changes to operations and the new commitments to habitat restoration will reduce the impacts to productivity from the PA (beyond what the WRLCM is capable of representing at this time in the model's development) and possibly even improve the productivity of the population over time.

Overall, the effects of operations as modeled for the PA without consideration of the explicit commitments made in the revised PA, would significantly reduce the production VSP parameter of winter-run Chinook salmon. However, the following commitments and criteria, described in the revised PA are expected to limit the impact of operations such that they would affect a small reduction to the production VSP parameter of winter-run Chinook salmon. Specifically:

- The revised real-time operations for the NDD which include 1) unlimited pulse protections, 2) increased allowable diversions (relative to previous PA) during high flow events with a required minimum bypass flow, and 3) initial fish-based transitional criteria and post-pulse pumping protections based on conditions in CDFW's draft permit under California Fish and Game Code section 2081 (BA section 3.3.3.1.1 Pulse-Protection). These initial real-time operational criteria are expected to be further refined based on monitoring and science gathered prior to operations of the NDD and during the phased operational testing period.

- As part of a larger commitment to habitat restoration, the revised PA includes 1,800 acres of tidal restoration in the Delta to function as juvenile rearing habitat. This coupled with the 9,000 acres of habitat restoration proposed under existing conditions may be enough to address reverse flows, but in order to reduce uncertainty that those acreages are enough, an additional commitment was made to restore in Delta habitat for the express purpose to "sufficiently address potential undesirable hydrodynamic effects of the NDD operations" (BA section 3.4.3.1.2). The Revised PA states that "DWR and Reclamation also commit to providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations," thereby implementing the earlier commitment to avoid and minimize this adverse effect.

- Assurance that existing DCC gate closures adhere to the expectations of the criteria stated in the NMFS 2009 biological opinion. Specifically, DCC closure for downstream flood control will be based on Sacramento River flow at Freeport, upstream of the north Delta diversion facilities (BA Table 3.3-1).

The revised PA also includes an Adaptive Management Program, accompanying Agreement for Implementation of an Adaptive Management Program for Project Operations, and an Implementation Schedule for the Adaptive Management Program, that together provide a means to incrementally reduce the uncertainty related to the impact of operations. These commitments support a conclusion that any reduction in the productivity VSP parameter of the population caused by the overall effects of operations will be minimal.

Winter-run Chinook Salmon Spatial Structure:

The spatial structure parameter of a VSP is determined by the availability, diversity, and utilization of properly functioning habitats and the connections between such habitats. Winter-run Chinook salmon are primarily limited in spatial structure as they are confined to only one population in the Sacramento River that spawns below Keswick Dam. Given the paucity of habitat available to winter-run Chinook salmon in the baseline, there could be considerable impact to the spatial structure parameter of if it is further reduced through impacts to spawning, rearing and migratory habitats. A significant part of the revised PA, however, is the re-commitment to key non-operational RPA actions in the NMFS 2009 BiOp, which include: the restoration of floodplain rearing habitat (increase juvenile salmonid access to Yolo Bypass, and increase duration and frequency of Yolo Bypass floodplain inundation), the implementation of pilot reintroduction program above Shasta Dam, consideration of engineering solutions to further reduce diversion of emigrating juvenile salmonids to the interior and southern Delta such as a non-physical barrier at Georgiana Slough, and reduce exposure to CVP and SWP export facilities, and the restoration of Battle Creek for winter-run, spring-run, and CV steelhead; the combined effect of which are expected to benefit the spatial structure VSP parameter of winter-run Chinook salmon.

In section 2.5.1.2.1 Increased Upstream Temperature, the effects of temperatures with the PA are analyzed relative to the NAA (representing conditions under a continuation of the current environmental baseline) and found not to be significantly different. However, the overall temperature effects of both the PA and the NAA are so considerable (24% temperature-related mortality), that the spatial structure VSP parameter is limited by conditions in the environmental baseline. As described in section 2.4 Environmental Baseline, suitable spawning, incubation and rearing conditions in the upper Sacramento River are maintained by the Bureau of Reclamation through the release of cold water from Shasta and Keswick dams during the summer months. Through the NMFS 2009 biological opinion on the CVP/SWP, Reclamation has created and implemented improved Shasta Reservoir storage plans and year-round Keswick Dam release schedules and procedures to ensure cold water for spawning and rearing (National Marine Fisheries Service 2016e) that are expected to improve the environmental baseline conditions.

As described in section 2.5.1.2 Operation Effects, for the analysis of the PA as initially proposed in the BA, the spatial structure VSP parameter of winter-run Chinook salmon would be further impacted in a number of ways, including, but not limited to: (1) decreasing flows and increasing travel time through the north Delta due to NDD operations; (2) creating conditions favorable for predators as juveniles migrate downstream through the installation of permanent in water structures, diminishing the available habitat patches; and (3) further altering the natural hydrograph of the Delta and its tributaries which limits access to habitats. To address these specific impacts, the revised PA incorporates a number of commitments that are expected to benefit the spatial structure VSP parameter of winter-run Chinook salmon, such as: (1) the revised real-time operations for the NDD (BA section 3.3.3.1.1 Pulse-Protection), (2) the commitment to the revised Adaptive Management Plan which includes research to assess and mitigate Sacramento River basin predation (Appendix A2, Adaptive Management Program), and (3) as part of a larger commitment to habitat restoration, the revised PA includes 1,800 acres of tidal restoration in the Delta to function as juvenile rearing habitat. This coupled with the 9,000 acres of habitat restoration proposed under existing conditions may be enough to address reverse flows. However, in order to reduce uncertainty that those acreages are enough, an additional commitment was made to “sufficiently address potential undesirable hydrodynamic effects of the NDD operations” (BA section 3.4.3.1.2) by “providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations.”

As described in section 2.5.1.2.7 Reduced In-Delta Flows, operations with the PA will also reduce reverse flows in the south Delta which will reduce travel time for migrating fish in that area. These results are supported by the modeling which shows average winter-run Chinook salmon loss at the south Delta water export facilities as 53% lower for the PA than the NAA in all water year types. While the reduced reverse flows in the south Delta represent an improvement compared to current conditions, the PA includes the continued operations of the existing facilities in the south Delta. Therefore, while the negative effects of operations of the facilities in the south Delta will be reduced under the PA in relation to the NAA, there will still be negative effects of operations of the south Delta facilities under the PA. Considering the negative impacts of operations, in the context of the recommitments in the revised PA to key, non-operational actions of the RPA in the NMFS 2009 biological opinion on the coordinated operations of the CVP/SWP, which significantly expands the spatial structure of the species through reintroduction to Battle Creek and Sacramento River above Shasta Dam, the PA should improve the spatial structure VSP parameter of winter-run Chinook salmon population. Furthermore the commitments and criteria described in the revised PA, particularly the commitments to: 1) revised real-time operations for the NDD; 2) restoration in Delta habitat to address hydrodynamic effects of the NDD operations and 3) assurances regarding DCC criteria, are expected to limit the impact of NDD operations and support a conclusion that they would not reduce habitat connectivity and the spatial structure VSP parameter of winter-run Chinook salmon population.

Winter-run Chinook Salmon Diversity:

The three key attributes of the diversity VSP parameter are 1) variation in traits such as run timing, age structure, size, fecundity, morphology, behavior and genetic characteristics; 2) resilient gene flow among populations that is limited; and 3) maintenance of ecological variation (McElhany et al. 2000b). The diversity of winter-run Chinook salmon continues to be limited as a result of the proposed action which constrains the timing of migrations and alters ecological variability.

In section 2.5.1.2.1 Increased Upstream Temperature, the effects of temperatures with the PA are analyzed relative to the NAA (representing conditions under a continuation of the current environmental baseline) and found not to be significantly different. However, the overall temperature related mortality (24% on average, and much higher during drought) of both the PA and the NAA are considerable. The effects of the proposed action when added to the environmental baseline result in a diversity VSP parameter that is limited by the temperature impacts occurring during an important period of egg incubation. As described in section 2.4 Environmental Baseline, suitable spawning, incubation and rearing conditions in the upper Sacramento River are maintained by the Bureau of Reclamation through the release of cold water from Shasta and Keswick dams during the summer months. Through the NMFS 2009 biological opinion on the CVP/SWP, Reclamation has created and implemented improved Shasta Reservoir storage plans and year-round Keswick Dam release schedules and procedures to ensure cold water for spawning and rearing (National Marine Fisheries Service 2016e) that are expected to improve the environmental baseline conditions.

As described in section 2.5.1.2.7 Reduced In-Delta Flows, the NDD bypass rules are designed to protect the majority of juvenile winter-run Chinook salmon migrants, but these rules do not offer the same level of protection to all migrating fish. According to the Perry 2017 flow-survival model, juvenile migrants in October and November are offered the least protection; median increases in travel times of 1.2 to 1.3 days are expected to increase the predation risk of outmigrating smolts. This in turn can potentially affect early winter-run Chinook salmon outmigrants, which are an important component of the population diversity. And while the magnitude of channel velocity reductions in April under the bypass rules of the PA are not as large as in earlier months, the reductions for proposed action operations range from 5 to 10 percent for the north Delta and would have associated increases in travel times for juvenile winter-run Chinook salmon. Having a diverse range of run-timing allows for greater resiliency of this species as a whole because it minimizes the risk of entering the ocean at a point of unfavorable conditions when productivity often varies considerably within a season. The converse is also true; the timing of winter-run Chinook salmon ocean entry is constricted by the proposed action to a narrower range of months, decreasing the probability that smolts will enter an ocean environment with conditions favorable for growth and survival. Reducing the diversity of migration timings and the temporal distribution of ocean entry would increase the risk of extinction of the winter-run Chinook salmon population. However, the analysis of NDD operations does not reflect the commitment in the revised PA to unlimited pulse protection during periods of fish presence. With this added commitment, there is reasonable assurance that the breadth of diversity represented by migration timing will be protected since all migrations would receive an equal level of protection, and that the diversity VSP parameter will not be affected.

Diversity is also affected by the continuing effects of entrainment into the south Delta and entrainment in the south Delta CVP/SWP facilities under the PA. Although conditions are somewhat improved under the PA, juvenile winter-run Chinook salmon migrating through the Delta at times when reverse flows are occurring will be subject to entrainment and reduced survival. And while the flows in the south Delta with the PA represent an improvement compared to current conditions, there will still be negative effects of operations of the South Delta facilities under the PA. The differences in annual entrainment among the run timing scenarios discussed in section 2.5.1.2.7.2.2 Salmonid Smolt routing into the interior Delta suggests that daily entrainment probabilities vary seasonally, thereby affecting annual entrainment differentially for the alternative run timings (early, uniform or late). Depending on the run timing and the proportion of the migrating population that is impacted, entrainment into the south Delta and the localized conditions therein will impact the diversity VSP parameter of the population because those run timings that remain in the mainstem Sacramento River will experience a higher level of survival compared to those entrained. The overall in entrainment into the central Delta under the PA for all three run timings was < 2 percent difference between all the mean annual entrainment probabilities, meaning that the level of effect is small and not likely to impact the diversity parameter of the VSP.

2.7.1.4 Assess the Risk to ESU/DPS

Because winter-run Chinook salmon is composed of a single population, the risks to the population described in the previous section largely represent the risks to the ESU, aside from describing the benefits additional populations would provide to all VSP parameters. As stated in Appendix B Rangewide Status of the Species and Critical Habitat, the winter-run Chinook salmon ESU would continue to be at a high risk of extinction over the long-term because it is experiencing: (1) continued low abundance; (2) a negative growth rate over 6 years (2006–2012), which is two complete generations; (3) a significant rate of decline since 2006; (4) increased hatchery influence on the population; and (5) increased risk of catastrophe from oil spills, wild fires, or extended drought. Analysis of the effects of the action indicate that the proposed action maintains the conditions of the factors that contribute to the species extinction risk but does not increase that risk. The species' baseline stress regime described in section 2.4 Environmental Baseline with the integration of the cumulative effects, described in section 2.6 Cumulative Effects, provides a reference for how the winter-run Chinook salmon population will respond to these additional stressors throughout the species' life cycle every year for the duration of the proposed action. In addition, effects of the action, status, environmental baseline, and cumulative effects are expected to be impacted by climate change. The modeling in the BA characterizes a 2030 scenario of climate conditions, water demands, and build-out based on the CMIP3 consensus projection and an estimated sea level rise, such that the effect of climate change is implicit in the modeling (as anticipated for 2030). Beyond 2030, NMFS expects that climate conditions will follow a similar trajectory of higher temperatures and shifted precipitation type timing, which would amplify any adverse effects of the proposed action after 2030.

As described in section 2.5 Effects of the Action on Species and summarized in the VSP analysis, the construction elements of the PA are not expected to appreciably reduce the viability of the population of winter-run Chinook salmon. Likewise, post-construction operation with the PA is not expected to appreciably reduce the viability of the population of winter-run Chinook salmon.
However, these conclusions are based on commitments in the PA and revised PA as explained in the VSP analysis, including that final NDD design and operation will be established based on significant testing, refinement, and adaptive management. Based on our analysis, NMFS concludes the proposed action is not expected to appreciably reduce the likelihood of both the survival and recovery of the Sacramento River winter-run Chinook salmon ESU.

Table 2-244. Reasoning and decision-making steps for analyzing the effects of the proposed action on winter-run. Bold type identifies the conclusion at each step of decision-making. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and not likely/likely to jeopardize (NLJ/LJ).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment. Available Evidence: The PA will produce multiple stressors that will adversely affect winter-run including, but not limited to: acoustic effects, sediment concentration and contaminant effects, increased predation, impingement and entrainment, and effects related to reduced Delta flows.	True	End
		False	**Go to B**
B	Listed individuals are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action. Available Evidence: A very small proportion of winter-run will be exposed to construction related activities which occur during the construction work-window, but a medium proportion of the population will be exposed to year-round construction-related effects and the effects of operations.	True	NLAA
		False	**Go to C**
C		True	NLAA

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Listed individuals are not likely to respond upon being exposed to one or more of the stressors produced by the proposed action. Available Evidence: Multiple stressors, including but not limited to those associated with pile driving, barge traffic, dredging and operations, will rise to a level of effect that will engender a response from exposed individuals.	**False**	**Go to D**
D	Any responses are not likely to constitute "take" or reduce the fitness of the individuals that have been exposed. Available Evidence: Multiple stressors, including but not limited to those associated with pile driving, barge traffic, dredging and operations, are expected to result in a reduction of overall fitness of individuals and which could rise to the level of "take."	True	NLAA
		False	**Go to E**
E	Any reductions in individual fitness are not likely to reduce the viability of the populations those individuals represent. Available Evidence: The overall reduction in fitness of individuals caused by the PA is expected to reduce some of the parameters describing a viable salmonid population; however, none of those reductions would constitute a reduction in viability of the population or an increase in extinction risk for the species.	**True**	**NLJ**
		False	Go to F
F	Any reductions in the viability of the exposed populations are not likely to reduce the viability of the species. Available Evidence: NA	True	NLJ
		False	LJ

2.7.2 Sacramento River Winter-run Chinook Salmon Critical Habitat

- Designated critical habitat for Sacramento River winter-run Chinook salmon (June 16, 1993, 58 FR 33212)

2.7.2.1 Status of Critical Habitat and Environmental Baseline

As described in section 2.2.1.2 Appendix B Rangewide Status of the Species and Critical Habitat, designated critical habitat for Sacramento River winter-run Chinook salmon includes the bottom and water of the waterways and adjacent riparian zones of the Sacramento River from Keswick Dam to Chipps Island, as well as all waters from Chipps Island westward to and including the San Francisco Bay north of the San Francisco-Oakland Bay Bridge to the Golden Gate Bridge. Winter-run Chinook salmon critical habitat is composed of seven PBFs that are shared among many life stage specific habitats. All of the PBFs are considered necessary habitat features that provide for successful spawning, incubation, rearing, and migration. Therefore, NMFS evaluates the effect of the PA in terms of its effect on habitats for spawning adults, incubating eggs, and rearing fry; freshwater rearing habitat for juveniles; freshwater migratory corridors; and estuarine habitat for rearing and migration.

As described in Section 2.4.1.2 Status of Sacramento River Winter-run Chinook Critical Habitat in the Action Area, the status of critical habitat in the environmental baseline has many PBFs that are impaired, to the extent of limiting high quality habitat. For example, the critical habitat currently includes a number of features that reduce the quality of migratory corridors for juveniles including passage impediments, altered Delta flows, and a lack of floodplain habitat. In addition, current water operations can limit the spatial extent of cooler-water habitat downstream of Shasta Dam, which reduces the available habitat for spawning and egg incubation (based on water temperature suitability). Although the current conditions of winter-run Chinook salmon critical habitat are significantly degraded, the remaining habitat for spawning and egg incubation, migratory corridors, and rearing is considered to have high intrinsic value for the conservation of the species.

2.7.2.2 Summary of Proposed Action Effects on Critical Habitat

Detailed descriptions regarding the impacts to designated critical habitat for winter-run Chinook salmon caused by stressors associated with the proposed action are presented in section 2.5.2 Effects of the Action to Critical Habitat. The proposed action-related effects to winter-run Chinook salmon critical habitat have been further separated by life stage-specific habitat type and assessed by the effects on the PBFs found therein. The effects to winter-run Chinook salmon critical habitat are summarized in Table 2-245.

Table 2-245. Integration and synthesis of effects on winter-run Chinook salmon critical habitat.

Section Number	Action Component	Location of Effect	Physical and Biological Features Affected	Response and Rationale of Effect	Magnitude	Weight of Evidence	Probable Change in PBF Supporting the Life History Needs of the Species
2.5.2.2.1	Upstream Temperatures, (section 2.5.1.2.1); Redd Dewatering, (section 2.5.1.2.2); and Redd Scour (section 2.5.1.2.3).	Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry: Upper Sacramento River (Keswick Dam to RBDD)	- Availability of clean gravel for spawning substrate; - Adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles; - Water temperatures between 42.5–57.5°F (5.8–14.1°C) for successful spawning, egg incubation, and fry development; - Habitat areas and adequate prey that are not contaminated.	Temperatures in spawning/incubation habitats are such that the capacity of the habitat to develop temperature-related PBFs remains limited. Flow changes causing increased redd dewatering particularly in June; little response/effect related to redd scour. No change expected in the availability of spawning substrate and prey.	Low – flow fluctuations (redd dewatering) and limited temperature capacity diminish or maintain a degraded function of these PBFs although there are only marginal differences between the PA and the NAA.	Medium – Multiple peer reviewed sources and quantitative modeling support conclusions. Modeling is somewhat limited by the coarse resolution of data (monthly time scale).	- Reduction in the quantity of river flows will result in redd dewatering. - Limited temperature quality with water temperatures exceeding 57.5°F. - No change expected in the quantity or quality of spawning substrate and prey.
2.5.2.2.2	Clearing and Grubbing, (section 2.5.1.1.4.1); Barge Propeller Injury and Entrainment, (section 2.5.1.1.7.3); Screen Impingement and Entrainment North Delta Intakes (section 2.5.1.2.5); and Contaminant Exposure (section 2.5.1.1.3).	Freshwater Rearing Habitat for Juveniles: Lower Sacramento River and Delta (RBDD to NDD)	- Habitat areas and adequate prey that are not contaminated; - Riparian habitat that provides for successful juvenile development and survival.	Degradation to PBFs is anticipated as a result of physical disturbance; increased predation risk; sedimentation; risk of impingement; and loss of habitat complexity caused by the PA. However, mitigation measures and the relative scale of disturbances are such that the effect of contaminant, and clearing and grubbing disturbances is expected to be minimal.	Medium – the quality of riparian habitat in the immediate vicinity of the NDD will be diminished; this will also constitute a reduction in the quantity of habitat (WUA) during the early months of the migration period for certain year types.	Medium – Multiple peer reviewed sources support conclusions.	- Riparian habitats will have a reduced quality, limiting successful juvenile development and survival, - No change expected in the quantity and quality of prey.

2.5.2.2.3	Construction Effects, (section 2.5.1.1); Barge Propeller Injury and Entrainment, (section 2.5.1.1.7.3); Permanent In-water Structures (section 2.5.1.2.6.1) and Reduced In-Delta Flows (section 2.5.1.2.7).	Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults: Sacramento River, Delta, and SF Bay (Keswick Dam to GG Bridge)	- Adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles; - Access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River; - Access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean	Permanent in-water structures will create habitat that favors predator species such that predation risk/pressure will be increased; access downstream for migrating juveniles will be reduced. Likewise, reduced in-Delta flows caused by the NDD will directly impact the downstream transport of juveniles. Most construction-related activities will be mitigated by the work window and are not expected to limit the access of migrating adult and juvenile winter-run.	Medium– Reduced in-Delta flows will be impacted for juvenile migration and construction-related impacts to both upstream and downstream migration access are expected to be moderate.	High – Multiple peer reviewed sources and quantitative modeling support conclusions.	Reduced flows downstream of the NDDs will decrease quantity of river flows for the downstream transport of juveniles; however, the quantity and quality of access upstream to spawning areas, and downstream to the Pacific Ocean will be maintained.
2.5.2.2.4	Clearing and Grubbing, (section 2.5.1.1.4.1); Barge Propeller Injury and Entrainment, (section 2.5.1.1.7.3); Screen Impingement and Entrainment North Delta Intakes (section 2.5.1.2.5); Sediment Concentration (section 2.5.1.1.2) and Reduced In-Delta Flows (section 2.5.1.2.7).	Estuarine Habitat for Rearing and Migration: the Delta and SF Bay (NDD to GG Bridge)	- Habitat areas and adequate prey that are not contaminated - Riparian habitat that provides for successful juvenile development and survival - Access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River - Access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean	Degradation to PBFs is anticipated as a result of physical disturbance; increased predation risk; sedimentation; risk of impingement; and a reduced occurrence of riparian inundation caused by the PA. However, mitigation measures and the relative scale of disturbances, are such that the effect of sediment concentration, and clearing and grubbing disturbances is expected to be minimal.	Medium – The quality of riparian habitat downstream of the NDD will be diminished and the reduction in access to riparian habitats (bench inundation) would constitute a reduction in the quantity of habitat.	High – Multiple peer reviewed sources and quantitative modeling support conclusions.	Riparian habitats will have a reduced quality, limiting successful juvenile development and survival, The quantity and quality of access upstream to spawning areas, and downstream to the Pacific Ocean will be maintained, and No change expected in the quantity and quality of prey.

Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry

Under the proposed action, NMFS does not expect an appreciable reduction in the PBFs of winter-run Chinook salmon critical habitat, specifically for adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles and water temperatures between 42.5–57.5°F (5.8–14.1°C) for successful spawning, egg incubation, and fry development. However, when the PA effects are added to the effects of the environmental baseline and cumulative effects, there are frequent rates of temperature exceedance, flow changes, and changes in the frequency of redd dewatering. These differences are based on model results provided in the BA that are projected to occur in certain months and certain water year types (see Section 2.5.1.2 Operations Effects). For current water operations, potential spawning habitat is already reduced by temperature control to the small area downstream of Keswick Dam; therefore, even modest reductions in the PBFs will diminish habitat for spawning adults, incubation of eggs, and rearing for fry. The revised PA includes a recommitment to expanding the available habitat for spawning adults, incubation of eggs, and rearing for fry, specifically in Battle Creek and above Shasta dam, into the McCloud River, which will increase the quantity and quality of this PBF.

Freshwater Rearing Habitat for Juveniles

With the proposed action, construction-related effects are expected to cause some intermittent and minor impacts to the PBFs of winter-run critical habitat, specifically with regards to habitat areas and adequate prey that are not contaminated and riparian habitat that provides for successful juvenile development and survival. As a result of the construction aspects of the proposed action, freshwater rearing habitat for juveniles will be degraded by the effective removal of 20.1 acres of tidal perennial habitat and 1.02 linear miles of channel margin habitat; installation of interim structures and corresponding reduction of habitat complexity at the NDD sites; and an increase in construction-related disturbances which reduce the habitat’s capacity for successful juvenile development and survival.

The acreage of critical habitat loss for each structure, including areas located in designated critical habitat that could be affected by placement of permanent in-water structures, and the temporary areas of loss (i.e., areas that will only be affected during construction activities) were calculated and will be sufficiently offset for through channel margin and tidal perennial habitat creation/restoration in the appropriate areas (see Appendix A2 Proposed Action). In addition, the revised PA includes 80 acres of expanded rearing habitat on the Sacramento River upstream of Red Bluff Diversion Dam, and 1,800 acres of tidal habitat restoration in the Delta. Given the relative scale of permanent loss compared to the total abundance of adequate habitat in the immediate area and the level of habitat mitigation/compensation proposed as part of the PA at this time, it is likely that the resultant reduction of habitat, habitat complexity, and increase in disturbances will lead to a temporary degradation of these PBFs that will not extend beyond the construction period.

The impact of increased predation at the temporary in-water structures proposed in the PA has the potential to impact freshwater rearing habitat for juvenile winter-run Chinook salmon by reducing that habitat’s ability to provide for successful juvenile development and survival to a minor degree.

As a result of the NDD operation and because of the sustained, year-round risk of predation associated with permanent in-water structures as well as the effects of impingement at the NDD screens, the PBFs of freshwater rearing habitat at those locations are reduced. Specifically, the direct juvenile mortality caused by the NDD screens results in diminishing the function of riparian habitat that provides for successful juvenile development and survival. The NDD screens will be designed to meet NMFS screening criteria and incorporate (as yet determined) predator refugia, which NMFS expects will minimize screen impingement and associated predation. The PA provision that the NDD screen intakes will begin operating in a phased manner with testing to ensure they are functioning as expected will ensure minimal impacts to this PBF. In addition, the revised PA commitments to habitat restoration, including 80 acres of expanded habitat upstream of Red Bluff Diversion Dam, and 1,800 acres of tidal habitat restoration in the Delta, will improve overall juvenile winter-run Chinook salmon survival; and the commitment to the revised Adaptive Management Plan includes research to assess and control Sacramento River basin predation (Appendix A2, Adaptive Management Program) which will improve the habitat PBF related to successful juvenile development and survival.

Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults

Construction and operation of the NDD are expected to cause a moderate reduction in the quality of PBFs of the migratory corridor habitat for winter-run. Increased predation risk, risk of impingement, and loss of habitat complexity are all stressors that are likely to reduce juvenile survival during outmigration, thus degrading the PBF described by access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean. The effect of these stressors is described by the results of the WRLCM which show the survival of outmigrating smolts originating from the Lower River is reduced in the PA compared to the NAA. For smolts originating in the Delta, the WRLCM shows the opposite; survival is increased for the PA compared to the NAA. However, considering a much larger proportion of fry rear in the Lower River compared to the Delta, and that differences in survival between the PA and the NAA are larger in the Lower River, the overall effect of the PA is to reduce juvenile winter-run survival and to impede access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean. This reduction in survival is expected to be minimized because the commitment to unlimited pulse protections included in the revised PA will reduce the exposure of juveniles to the reduced flows.

Spawning adults migrating through the mainstem Sacramento River will also encounter physical disturbance from barge operations during the construction period, which may impede upstream migration, degrading the PBF characterized by access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River. These effects have been reduced by the additional restrictions placed on barge operations by the revised PA, such that the PBF characterized by access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River will experience only a minor reduction.

Estuarine Habitat for Rearing and Migration

Construction activities of the proposed action are expected to cause some intermittent and minor impacts to the PBFs of estuarine habitat for rearing and migration of winter-run Chinook salmon. Minimal loss of riparian habitat is anticipated to occur at barge landing sites located within the Delta. The footprint of construction at these sites is not yet finalized; however, associated removal of vegetation is expected to result in relatively minor impacts to the riparian habitat that provides for successful juvenile development and survival. Riparian and estuarine PBFs will experience minor degradation due to physical disturbance and risk of propeller entrainment year-round as barge operations are carried out in the Delta. However, given the temporary nature of the disturbance, coupled with the BMPs proposed as part of the PA, it is unlikely that the resultant disturbances will lead to a significant degradation of these PBFs.

Changes to in-Delta flow caused by operation of the NDD are projected to result in increased travel time for juvenile winter-run Chinook salmon, increased entry into the lower quality interior Delta corridors, and reduced survival of winter-run juveniles. Access to the riparian habitat that provides for successful juvenile development and survival will be reduced for the PA relative to the NAA because lower flows downstream of the NDD reduce the inundation of the existing wetland and riparian benches that provide rearing habitats. The riparian bench inundation index below the NDD is shown to decrease for all water year types with the PA. Entry into the interior Delta is also expected to increase for the PA, which increases juvenile winter-run susceptibility to predation and poor water quality. This in turn will reduce the successful development and survival of juveniles, limiting the access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean.

Overall, the effects of operations on flow as modeled for the PA without consideration of the explicit commitments made in the revised PA would reduce access to the riparian habitat that provides for successful juvenile development and survival and will limit access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean. However, the following commitments and criteria, described in the revised PA are expected to reduce the impact of operations such that the effect on estuarine habitat for rearing and migration would result in only a moderate reduction in the quality and quantity of PBFs. Specifically:

- The revised real-time operations for the NDD which include 1) unlimited pulse protections, 2) increased allowable diversions (relative to previous PA) during high flow events with a required minimum bypass flow, and 3) initial fish-based transitional criteria and post-pulse pumping protections based on conditions in CDFW’s draft permit under California Fish and Game Code section 2081 (BA section 3.3.3.1.1 Pulse-Protection). These initial real-time operational criteria are expected to maintain flows during fish presence such that flows will be adequate to provide access to riparian habitats and migration downstream.

- As part of a larger commitment to habitat restoration, the revised PA includes 1,800 acres of tidal restoration in the Delta to function as juvenile rearing habitat. This coupled with the 9,000 acres of habitat restoration proposed under existing conditions may be enough to address reverse flows, but in order to reduce uncertainty that those acreages are enough, an additional commitment was made to restore in Delta habitat for the express purpose to “sufficiently address potential undesirable hydrodynamic effects of the NDD operations” (BA section 3.4.3.1.2). The Revised PA states that “DWR and Reclamation also commit to providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations,” thereby implementing the earlier commitment to avoid and minimize this adverse effect.

- Assurance that existing DCC gate closures adhere to the expectations of the criteria stated in the NMFS 2009 biological opinion. Specifically, DCC closure for downstream flood control will be based on Sacramento River flow at Freeport, upstream of the north Delta diversion facilities (BA Table 3.3-1 in Appendix A1). This particular operational criteria will maintain flows in the mainstem Sacramento River to ensure that flows are adequate to provide migration downstream.

With these explicit commitments made in the revised PA, NMFS expects that the PBFs of riparian habitat that provides for successful juvenile development and survival, and access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean will experience moderate reductions in quantity and quality.

2.7.2.3 Impact to the Critical Habitat of the Species at the Designation Level

As described in section 2.2 and Appendix B Rangewide Status of the Species and Critical Habitat and Section 2.4.1.2 Status of Sacramento River Winter-run Chinook Critical Habitat in the Action Area, many of the PBFs of winter-run are currently degraded. The effects of future state, tribal, local, or private actions, described in section 2.6 Cumulative Effects, will offer little improvement to the PBFs, which will most likely maintain their degraded state. As a result of implementing the PA, the value of critical habitat for the conservation of the species, with respect to some of the PBFs, will be reduced in some areas. However, the condition of other PBFs will be increased or maintained in their current state with implementation of the PA, and none of the reductions to the value of critical habitat are expected to result in an appreciable diminishment of the overall value of the critical habitat for the conservation of the species. Based on our analysis, NMFS concludes that the proposed action will not appreciably diminish the value of critical habitat for the conservation of Sacramento River winter-run Chinook salmon.

Table 2-246. Reasoning and decision-making steps for analyzing the effects of the proposed action on winter-run critical habitat. Bold type identifies the conclusion at each step of decision-making. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and destruction or adverse modification of critical habitat (D/AD MOD).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment.	True	End
	Available Evidence: The PA will produce multiple stressors that will adversely affect the environment including, but not limited to: acoustic effects, sediment concentration and contaminant effects, increased predation, impingement and entrainment, and effects related to altered flows and temperatures.	**False**	**Go to B**
B		True	NLAA

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Areas of designated critical habitat are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action. Available Evidence: Areas of winter-run designated critical habitat will be exposed to multiple stressors produced by the PA, including PBFs such as: Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry; Freshwater Rearing Habitat for Juveniles; Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults; and Estuarine Habitat for Rearing and Migration.	**False**	**Go to C**
C	The quantity or quality of any physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to be reduced upon being exposed to one or more of the stressors produced by the proposed action. Available Evidence: In multiple instances the PA reduces the quantity and quality of the PBFs of winter-run critical habitat, or in some cases limits the capacity of the critical habitat to develop those features. For example, although the revised PA provides a number of mitigation measures that will limit the extent of impact, altered flows downstream of the NDD will reduce the extent and frequency of riparian bench inundation which will reduce the quantity of riparian habitat that provides for successful juvenile development and survival; reduced in-Delta flows will increase the time needed for juvenile migration which reduces the quality of adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles; and the effects of the PA when added to the effects of the environmental baseline and cumulative effects will also limit the capacity of upstream habitats to develop water temperatures between 42.5–57.5°F (5.8–14.1°C) for successful spawning, egg incubation, and fry development.	True	NLAA
		False	**Go to D**
D		True	NLAA

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Any reductions in the quantity or quality of one or more physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to reduce the value of critical habitat for the conservation of the species in the exposed area. Available Evidence: The reductions in quantity and quality of PBFs, as well as the reductions in the capacity of the critical habitat to develop these features over time, although small, are expected to reduce the value of the habitat for the conservation of the species in some areas. Particularly with regard to the Freshwater Rearing Habitat for Juveniles and the Estuarine Habitat for Rearing and Migration, the PA is expected to reduce flow-related PBFs and further impair the waterways of the Delta in their abilities to function as rearing and migratory corridors.	**False**	**Go to E**
E	Any reductions in the value of critical habitat for the conservation of the species in the exposed area of critical habitat are not likely to appreciably diminish the overall value of critical habitat for the conservation of the species. Available Evidence: The value of critical habitat for the conservation of the species, with respect to some of the PBFs, will be reduced in some areas. However, the condition of other PBFs will be increased or maintained in their current state with implementation of the PA, and none of the reductions to the value of critical habitat are expected to result in an appreciable diminishment of the overall value of the critical habitat for the conservation of the species. Thus, the overall value of the critical habitat for the conservation of the species at the designation level is not expected to be appreciably diminished.	**True**	**No D/AD MOD**
		False	D/AD MOD

2.7.3 Central Valley Spring-run Chinook Salmon

- First listed as threatened (September 16, 1999, 64 FR 50394), reaffirmed as threatened (June 28, 2005, 70 FR 37160).
- Experimental non-essential population designated (December 31, 2013, 78 FR 79622).

Detailed information regarding the federally listed ESU of Central Valley spring-run Chinook salmon status, ESU life history, and VSP parameters can be found in Appendix B Rangewide Status of the Species and Critical Habitat. The following section is a summary.

2.7.3.1 Status of the Species and Environmental Baseline

The status of the species and critical habitat, as well as the environmental baseline, have been described in sections 2.2 and 2.4, respectively. Critical to the integration and synthesis of effects are the VSP parameters of abundance, productivity, spatial structure, and diversity. Because these parameters are consistent with the “reproduction, numbers, or distribution” criteria found within the regulatory definition of jeopardy (50 CFR 402.02) the VSP parameters are used as surrogates for “reproduction, numbers, or distribution.” These VSP parameters are used in each of the status reviews for listed species performed by NMFS, the most recent of which was completed in 2016. Status trends from that review are summarized in Table 2-247 (National Marine Fisheries Service 2016a), and the VSP parameters specific to CV spring-run Chinook salmon may be estimated from the status trends. These VSP parameters are used to establish the reference condition of the population in the status of the species and environmental baseline and are used to assess the risk to the population and the risk to the ESU.

Table 2-247. Viability metrics for Central Valley spring-run Chinook salmon ESU populations. Total population size (N) is estimated as the sum of estimated run sizes over the most recent three years for Core 1 populations (bold) and Core 2 populations. The mean population size ($\hat{S}$) is the average of the estimated run sizes for the most recent 3 years (2012 to 2014). Population growth/decline rate (10 year trend) is estimated from the slope of log-transformed estimated run size. The catastrophic metric (recent decline) is the largest year-to-year decline in total population size (N) over the most recent 10 such ratios.

Population	N	$\hat{S}$	10-year trend (95% CI)	Recent Decline (%)
Antelope Creek	8.0	2.7	-0.375 (-0.706, -0.045)	87.8
Battle Creek	1836	612	0.176 (0.033, 0.319)	9.0
Big Chico Creek	0.0	0.0	-0.358 (-0.880, 0.165)	60.7
Butte Creek	20169	6723	0.353 (-0.061, 0.768)	15.7
Clear Creek	822	274	0.010 (-0.311, 0.330)	63.3
Cottonwood Creek	4	1.3	-0.343 (-0.672, -0.013)	87.5
Deer Creek	2272	757.3	-0.089 (-0.337, 0.159)	83.8
Feather River Fish Hatchery	10808	3602.7	0.082 (-0.015, 0.179)	17.1
Mill Creek	2091.0	697.0	-0.049 (-0.183, 0.086)	58.0
Sacramento River[a]	-	-	-	-
Yuba River	6515	2170.7	0.67 (-0.138, 0.272)	9.0

[a] Beginning in 2009, estimates of spawning escapement of Upper Sacramento River spring chinook were no longer monitored. Historically, this estimate was derived by the total Red Bluff Diversion Dam (RBDD) counts minus the spring run numbers in the upper Sacramento tributaries. Beginning in 2009, RBDD gates were partially operated in the up position and in 2012 they were entirely removed and thus spring run estimates no longer available.

Spring-run Chinook Salmon Abundance:

Historically, spring-run Chinook salmon were the second-most abundant salmon run in the Central Valley and one of the largest on the west coast (California Department of Fish and Game 1990), with runs as large as 600,000 fish between the late 1880s and 1940s (California Department of Fish and Game 1998). The best population trend indicators for current abundance estimates for the CV spring-run Chinook salmon ESU as a whole are the Sacramento River tributary populations in Mill, Deer, and Butte creeks because these streams contain the majority of the abundance and are currently the only independent populations within the ESU. Escapement numbers have been dominated by Butte Creek returns, which averaged more than 7,000 fish from 1995 to 2005, but then declined from 2006 through 2011, averaging just more than 3,000 fish. During this same period, adult returns on Mill and Deer creeks averaged more than 2,000 total fish and just more than 1,000 total fish, respectively. Declines in abundance from 2005 to 2016 placed the populations in higher extinction risk category. The next several years are anticipated to remain quite low as the effects of the 2012-2015 drought are fully realized (National Marine Fisheries Service 2016b).

Spring-run Chinook Salmon Productivity:

From 1993 to 2007, the 5-year moving average of the tributary population (Mill, Deer and Butte creeks) CRR remained greater than 1.0 but then declined to a low of 0.47 in years 2007 through 2011. The productivity of the Feather River and Yuba River populations and contribution to the spring-run Chinook salmon ESU currently is unknown, but the FRFH currently produces 2,000,000 juveniles each year. The CRR for the 2012 combined tributary population was 3.84 and 8.68 in 2013, due to increases in abundance for most populations. Although 2014 returns were lower than the previous two years, the CRR was still positive (1.85). However, 2015 returns were very low, with a CRR of 0.14 when using Butte Creek snorkel survey numbers the lowest on record. Using the Butte Creek carcass surveys, the 2015 CRR for just Butte Creek was only 0.02.

Spring-run Chinook Salmon Spatial Structure:

Of the estimated 18 or 19 independent populations of CV spring-run Chinook salmon historically, only three independent populations currently exist (Mill, Deer, and Butte creeks tributaries to the upper Sacramento River) and they all represent only the northern Sierra Nevada diversity group. Additionally, smaller populations are currently persisting in Antelope and Big Chico creeks and the Feather and Yuba rivers in the northern Sierra Nevada diversity group (California Department of Fish and Game 1998). Almost all historical populations in the basalt and porous lava diversity group and the southern Sierra Nevada diversity group have been extirpated, though Battle Creek in the basalt and porous lava diversity group has had a small persistent population since 1995, and the upper Sacramento River may have a small persisting population spawning in the mainstem-river as well. The northwestern California diversity group did not historically contain independent populations and currently contains two small persisting populations, in Clear Creek and Beegum Creek (tributary to Cottonwood Creek), that have likely been dependent on the northern Sierra Nevada diversity group populations for their continued existence. Construction of low elevation dams in the foothills of the Sierras on the San Joaquin, Mokelumne, Stanislaus, Tuolumne, and Merced rivers, has been thought to have extirpated CV spring-run Chinook salmon from these watersheds of the San Joaquin River, as well as on the American River of the Sacramento River basin. However, observations in the last decade suggest that perhaps spring-running populations may currently occur in the Stanislaus and Tuolumne rivers (Franks 2014a).

With only one of four diversity groups currently containing viable independent populations, the spatial structure of CV spring-run Chinook salmon is severely reduced. Butte Creek spring-run Chinook salmon adult returns are currently utilizing all available habitat in the creek; and it is unknown if individuals have opportunistically migrated to other systems. The persistent populations in Clear Creek and Battle Creek, with habitat restoration projects completed and more underway, are anticipated to add to the spatial structure of the CV spring-run Chinook salmon ESU if they can reach viable status in the basalt and porous lava and northwestern California diversity group areas. Section 2.4.4.7 Restoration Actions from NMFS 2009 RPA Opinion on the Long-term operations of CVP/SWP BiOp identifies several actions from the NMFS 2009 BiOp RPA that are expected to improve the spatial structure for CV spring-run Chinook salmon before operations of the NDD conveyance facilities commence:

- RPA Action I.7: Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass (Improve Yolo Bypass Adult Fish Passage)
- RPA Action I.6.1: Restoration of Floodplain Rearing Habitat (Increase Juvenile Salmonid Access to Yolo Bypass, and Increase Duration and Frequency of Yolo Bypass Floodplain Inundation)
- RPA Action NF 4: Implementation of Pilot Reintroduction Program (Implementation of Pilot Reintroduction Program above Shasta Dam)
- RPA Action IV.1.3: Consider Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta, and Reduce Exposure to CVP and SWP Export Facilities (Including Georgiana Slough Non-Physical Barrier)
- RPA Action I.2.6: Restore Battle Creek for Winter-Run, Spring-Run, and CV Steelhead (Complete Battle Creek Salmon and Steelhead Restoration Project)

Reclamation and DWR have re-committed to these actions as part of the revisions to the PA (Appendix A2).

Even with the improvements provided by the RPA recommitments, the spatial structure of the spring-run Chinook salmon ESU would still be lacking due to the extirpation of all San Joaquin River basin spring-run Chinook salmon populations. Although, recent information suggests that perhaps a self-sustaining population of spring-run Chinook salmon is occurring in some of the San Joaquin River tributaries, most notably the Stanislaus and the Tuolumne rivers, the southern Sierra Nevada diversity group is still without any viable populations. A final rule was published to designate a nonessential experimental population of CV spring-run Chinook salmon in the San Joaquin River from Friant Dam downstream to its confluence with the Merced River to allow reintroduction of the species below Friant Dam as part of the San Joaquin River Restoration Program (SJRRP) (78 FR 79622, December 31, 2013). Pursuant to ESA section 10(j), with limited exceptions, each member of an experimental population shall be treated as a threatened species. The rule includes protective regulations under ESA section 4(d) that provide specific exceptions to prohibitions for taking CV spring-run Chinook salmon within the experimental population area, and in specific instances elsewhere. The first release of CV spring-run Chinook salmon juveniles into the San Joaquin River occurred in April 2014. A second release occurred in 2015, and future releases are planned to continue annually during the spring. The 2016 release will include the first generation of spring-run Chinook salmon reared entirely in the San Joaquin River in over 60 years. The nonessential experimental population's contribution to the viability of the CV spring-run Chinook salmon ESU will be determined in future status assessments.

Lindley et al. (2007a) described a general criteria for "representation and redundancy" of spatial structure, which was for each diversity group to have at least two viable populations. More specific recovery criteria for the spatial structure of each diversity group have been laid out in the NMFS Central Valley Salmon and Steelhead Recovery Plan (National Marine Fisheries Service 2014b). According to the criteria, one viable population in the Northwestern California diversity group, two viable populations in the basalt and porous lava diversity group, four viable populations in the northern Sierra Nevada diversity group, and two viable populations in the southern Sierra Nevada diversity group, in addition to maintaining dependent populations, are needed for recovery. It is clear that further efforts will need to involve more than restoration of currently accessible watersheds to make the ESU viable. The NMFS Central Valley Salmon and Steelhead Recovery Plan calls for reestablishing populations into historical habitats currently blocked by large dams, such as the reintroduction of a population upstream of Shasta Dam, and to facilitate passage of fish upstream of Englebright Dam on the Yuba River (National Marine Fisheries Service 2014b).

Spring-run Chinook salmon Diversity:

Currently, spring-run diversity, both genetic and behavioral, is critical to success in a changing environment. Salmonids express variation in a suite of traits, such as anadromy, morphology, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, and physiology and molecular genetic characteristics (including rate of gene-flow among populations). Criteria for the diversity parameter are that human-caused factors should not alter variation of traits. The more diverse these traits (or the more these traits are not restricted), the more adaptable a population is, and the more likely that individuals, and therefore the species, would survive and reproduce in the face of environmental variation (McElhany et al. 2000a). However, when this diversity is reduced due to loss of entire life history strategies or to loss of habitat used by fish exhibiting variation in life history traits, the species is in all probability less able to survive and reproduce given environmental variation.

The CV spring-run Chinook salmon ESU is comprised of two known genetic complexes. Analysis of natural and hatchery spring-run Chinook salmon stocks in the Central Valley indicates that the northern Sierra Nevada diversity group spring-run Chinook salmon populations in Mill, Deer, and Butte creeks retain genetic integrity as opposed to the genetic integrity of the Feather River population, which has been somewhat compromised. The Feather River spring-run Chinook salmon have introgressed with the Feather River fall-run Chinook salmon (Garza et al. 2008), and it appears that the Yuba River spring-run Chinook salmon population may have been impacted by FRFH fish straying into the Yuba River (and likely introgression with wild Yuba River fall-run has occurred)(pers. Comm. Bratovich to Sprague email 5/16/17). Additionally, the diversity of the spring-run Chinook salmon ESU has been further reduced with the loss of the majority, if not all, of the San Joaquin River basin spring-run Chinook salmon populations. Efforts underway, such as the San Joaquin River Restoration Project to reintroduce a spring-run population below Friant Dam, are needed to improve the diversity of CV spring-run Chinook salmon (NMFS 2016a).

Spring-run ESU Viability Summary:

Overall, because the populations in Butte, Deer and Mill creeks are the best trend indicators for ESU viability, we can evaluate risk of extinction based on VSP parameters in these watersheds. Lindley et al. (2007a) indicated that the spring-run Chinook salmon populations in the Central Valley had a low risk of extinction in Butte and Deer creeks, according to their population viability analysis (PVA) model and other population viability criteria (i.e., population size, population decline, catastrophic events, and hatchery influence, which correlate with VSP parameters abundance, productivity, spatial structure, and diversity). The Mill Creek population of spring-run Chinook salmon was at moderate extinction risk according to the PVA model, but appeared to satisfy the other viability criteria for low-risk status. However, the CV spring-run Chinook salmon ESU failed to meet the “representation and redundancy rule” since there are only demonstrably viable populations in one diversity group (northern Sierra Nevada) out of the three diversity groups that historically contained them, or out of the four diversity groups as described in the NMFS Central Valley Salmon and Steelhead Recovery Plan. Over the long term, these three remaining populations are considered to be vulnerable to catastrophic events, such as volcanic eruptions from Mount Lassen or large forest fires due to the close proximity of their headwaters to each other. Drought is also considered to pose a significant threat to the viability of the spring-run Chinook salmon populations in these three watersheds due to their close proximity to each other. One large event could eliminate all three populations.

Until 2012, the status of CV spring-run Chinook salmon ESU had deteriorated on balance since the 2005 status review and the Lindley et al. (2007a) assessment, with two of the three extant independent populations (Deer and Mill creeks) of spring-run Chinook salmon slipping from low or moderate extinction risk to high extinction risk. Additionally, Butte Creek remained at low risk, although it was on the verge of moving towards high risk, due to rate of population decline. In contrast, spring-run Chinook salmon in Battle and Clear creeks had increased in abundance since 1998, reaching levels of abundance that place these populations at moderate extinction risk. Both of these populations have likely increased at least in part due to extensive habitat restoration. The Southwest Fisheries Science Center concluded in their viability report that the status of CV spring-run Chinook salmon ESU has probably deteriorated since the 2005 status review and that its extinction risk has increased (Williams et al. 2011). The degradation in status of the three formerly low- or moderate-risk independent populations is cause for concern.

The viability assessment of CV spring-run Chinook salmon conducted during NMFS’ 2010 status review (National Marine Fisheries Service 2011b), found that the biological status of the ESU had worsened since the previous status review (2005) and recommend that its status be reassessed in two to three years as opposed to waiting another five years, if the decreasing trend continued and the ESU did not respond positively to improvements in environmental conditions and management actions. In 2012 and 2013, most tributary populations increased in returning adults, averaging over 13,000. However, 2014 returns were lower again, just over 5,000 fish, indicating the ESU remains highly fluctuating. The most recent status review was conducted in 2015 (National Marine Fisheries Service 2016e), which looked at promising increasing populations in 2012-2014. However, in 2015, returns were extremely low (1,488), with additional pre-spawn mortality, where escapement reached record lows. Because the effects of the 2012-2015 drought have not been fully realized, we anticipate at least several more years of very low returns, which may reach severe rates of decline (National Marine Fisheries Service 2016b).

In summary, the extinction risk for the CV spring-run Chinook salmon ESU remains at moderate risk of extinction (National Marine Fisheries Service 2016b). Based on the severity of the drought and the low escapements as well as increased pre-spawn mortality in Butte, Mill, and Deer creeks in 2015, there is concern that these CV spring-run Chinook salmon strongholds will deteriorate into high extinction risk in the coming years based on the population size or rate of decline criteria (National Marine Fisheries Service 2016b).

2.7.3.2 Summary of Proposed Action Effects

Detailed descriptions regarding the exposure, response, and risk of spring-run to stressors associated with the proposed action are presented in section 2.5 Effects of the Action. The proposed action-related effects to spring-run are separated between construction-related and those that are related to operations and permanent structures. Also included with the assessment of operations is an assessment of the 2.5.1.3 Ancillary Delta Facilities which were originally covered by the 2009 NMFS CVP/SWP opinion but are now part of the PA. The distinction between construction and operations was made based on differences in expected duration of effect where effects of construction activities are generally expected to occur over a finite period while operations-related effects and the effects of permanent structures and ancillary Delta facilities, are considered ongoing. Furthermore, the majority of construction-related effects are minimized by proposed in-water work-windows and the timing of construction activities which would occur when spring-run presence is low or unlikely. Work window timing, which for the North Delta extends from June 15 to October 31, and the expected duration of construction activities, up to 8 years, are detailed in section 2.5.1.1, Construction Effects, Table 2-9. Site-specific effects of PA elements that will be covered programmatically are not included in this summary of effects, because these elements are at various stages of development and at this time are lacking sufficient information regarding the potential site-specific effects to individual CV spring-run Chinook salmon. These Programmatic Activities (section 2.5.1.4) are instead considered later, in section 2.7.3.3 (Assess Risk to the Population), where the overall effects and/or benefits they provide are analyzed in the assessment of risk to the population and species. The construction-related effects on spring-run Chinook salmon, including the overall effect of the PA with the environmental baseline and cumulative effects, are summarized in Table 2-248 below.

Table-248. Integration and synthesis of construction related effects with the environmental baseline and cumulative effects, on spring-run Chinook salmon.

Section Number	Stressor	Life Stage (Location)	Life Stage Timing	Individual Response and Rationale	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of overall Effect (PA + Baseline + Cumulative Effects)	Diversity Groups and Populations Affected
2.5.1.1.1.1	Pile Driving (Acoustic)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Mid-Nov. – Mid-June (<1%); Adults: Jan. – May	Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed.	Low - Expected acute effect to a very small proportion of juveniles.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Low - Expected acute effect to a very small proportion of juveniles. The baseline and CE add “periodic” pile driving (Section 2.4.4.6).	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Feb. – June; Adults: Jan. – March	Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed.	None to Low - Expected acute effect to a marginal proportion of juveniles.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Low – Considering the addition of the baseline and CE which add “periodic” pile driving (Section 2.4.4.6) there is an acute effect expected to a marginal proportion of juveniles.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
		Adult immigration (HOR gate)	Juvenile: April – May; Adults: Jan. – May	Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed.	None to Low - Expected acute effect to a small proportion of yearling smolts.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Low – Considering the addition of the baseline and CE which add “periodic” pile driving (Section 2.4.4.6) there is an acute effect expected to a small proportion of yearling smolts.	(Southern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration	Juvenile: Nov. – May; Adults: Jan. – June	Injury or mortality caused by anthropogenic noise-induced barotrauma	None to, Low - Expected acute effect to a marginal	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Low - Expected acute effect to a very small proportion of the population attributed to the baseline and CE which add “periodic”	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada,

		(barge landings)		which may be instantaneous or delayed.	proportion of juveniles.			pile driving (Section 2.4.4.6).	and Southern Sierra Nevada
2.5.1.1.1.2	Barge Traffic (Acoustic)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan. – March; (modified routing Nov – May)	Reduced feeding/foraging behavior due to increased stress, distraction (foraging success) and prey masking.	Low - Generally a sublethal effect is expected to be imposed on a small proportion of the spring-run juveniles (modified from original effects analysis).	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration and extent of barge operations.	Reduced growth and reduced survival	Medium - Generally a sublethal effect is expected to be imposed on a small proportion of the spring-run juveniles; however, baseline adds that portions of the action area "experience heavy commercial and recreational vessel traffic" (Section 2.4.4.5).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.2.1	Pile Driving (Sediment Concentration)	Juvenile rearing and emigration (NDD)	Juvenile: Nov. – June (<2%);	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally a sublethal effect is expected to be imposed on a small proportion of the spring-run juveniles.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally a sublethal effect is expected to be imposed on a small proportion of the spring-run juveniles, baseline and CE add "periodic" pile driving (Section 2.4.4.6).	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration (CCF, HOR gate, and barge landing locations)	Juvenile: Nov. – May; Adults: Jan. – June	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in	None to Low – Expected sublethal effect limited to a marginal proportion	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth; reduced reproductive success	Low – Expected sublethal effect limited to a marginal proportion of juvenile spring-run.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

				localized turbidity.	of juvenile spring-run.				
2.5.1.1.2.2	Barge Traffic (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan. – March, (modified routing Nov – May)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in turbidity.	Low - Generally sublethal effect expected to be imposed on a small proportion of spring-run population (modified from original effects analysis)	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding timing, duration and extent of barge operations.	Reduced growth; reduced reproductiv e success	Medium - Generally sublethal effect expected to be imposed on a small proportion of spring-run; however, baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic" (Section 2.4.4.5).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.2.3	Geotechnical Analysis (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan. – March	No response, as turbidity associated with geotechnical analysis is likely imperceptible.	None	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	NA	NA (Geotechnical analysis is not included in the Environmental Baseline Section 2.4)	NA
2.5.1.1.2.4	Dredging (Sediment Concentration) + Facility Maintenance (2.5.1.2.9.1)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – June (June, <2%); Adults: Jan – March	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity. Adult	Low - Generally sublethal effect limited to a small proportion of juveniles.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low to Medium - Generally sublethal effect limited to a small proportion of the population. The baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale" (section 2.4.4.4).	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada

			steelhead are not expected to be affected.					
	Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Feb. – June; Adults: Jan. –March.	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	None to Low - Generally sublethal effect limited to a small proportion of juveniles.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect limited to a small proportion of juveniles attributed to the baseline, which adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale" (section 2.4.4.4).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
	Smolt emigration (HOR gate)	Juvenile (SJR): Nov. – May (yearlings Oct.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a small proportion juvenile spring-run emigrating from the San Joaquin basin.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect limited to a small proportion juvenile spring-run emigrating from the San Joaquin basin.	Southern Sierra Nevada
	Juvenile rearing and emigration; Adult immigration (barge landings)	Juvenile: Nov. – June; Adults: Jan – March	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	None	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect limited to a small proportion of juveniles attributed to the baseline, which adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale" (section 2.4.4.4).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

2.5.1.1.3.1	Pile Driving (Contaminant Exposure)	Juvenile rearing and emigration (NDD)	Juvenile: Nov. – June (<2%);	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally a sublethal effect limited to a small proportion of juvenile spring-run.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductive success	Medium - Generally a sublethal effect limited to a small proportion of juvenile spring-run; however, the baseline adds “documented high levels of contaminants” in the action area (section 2.4.4.1).	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Nov. – May; Adults: Jan. – June	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	None to Low - Generally sublethal effect limited to a small proportion of spring-run.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of spring-run attributable to the baseline, which adds “documented high levels of contaminants” in the action area (section 2.4.4.1).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
		Smolt emigration (HOR gate)	Juvenile (SJR): Nov. – May, Yearlings: Oct.	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance),	Low - Generally sublethal effect limited to a small	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty	Reduced growth	Low - Generally sublethal effect limited to a small proportion of juvenile spring-run emigrating from the San Joaquin basin. The	Southern Sierra Nevada

				physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	proportion of juvenile spring-run emigrating from the San Joaquin basin.	regarding extent of sediment resuspension.		baseline adds “documented high levels of contaminants” in the action area (section 2.4.4.1).	
		Juvenile rearing and emigration; Adult immigration (barge landings)	Juvenile: Nov. – June; Adults: Jan – March	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	None	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect limited to a small proportion of spring-run attributable to the baseline which adds “documented high levels of contaminants” in the action area (section 2.4.4.1).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.3.2	Barge Traffic (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan – March; (modified routing Nov – May)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development),	Low - Generally sublethal effect limited to a small proportion of spring-run.	Low - Understanding is Medium but nature of outcome is somewhat unpredictable owing to uncertainty regarding timing, duration and extent of barge operations as well as sediment composition.	Reduced growth; reduced reproductiv e success	Medium - Generally sublethal effect limited to a small proportion of the population; however, the baseline adds “documented high levels of contaminants” in the action area (section 2.4.4.1).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

				biochemical (e.g., blood enzyme and ion levels), and histological changes					
2.5.1.1.3.3	Geotechnical Analysis (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan – March	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a very small proportion of spring-run.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductive success	Low - Generally sublethal effect limited to a very small proportion of the population. Geotechnical analysis is not included in the Environmental Baseline, such that the baseline is not expected to contribute to the "overall effect" of the stressor (section 2.4).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.3.4	Dredging (Contaminant Exposure) + Facility Maintenance (2.5.1.2.9.1)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – June (June, <2%); Adults: Jan – June (June)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of spring-run.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of spring-run. The baseline adds "periodic" dredging projects in the action area, that are of "varying scope and scale" (section 2.4.4.4).	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada

	Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Nov. – May (Nov.); Adults: Jan. –June.	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally a sublethal effect limited to a small proportion of juvenile spring-run.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductiv e success	Low - Generally a sublethal effect limited to a small proportion of juvenile spring-run. The baseline adds “periodic” dredging projects in the action area, that are of “varying scope and scale” (section 2.4.4.4)a	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
	Smolt emigration (HOR gate)	Juvenile (SJR): Nov. – May Yearlings: Oct.	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	None to Low - Generally a sublethal effect limited to a small proportion of juvenile spring-run emigrating from the San Joaquin basin.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth	Low - Generally a sublethal effect limited to a small proportion of juvenile spring-run emigrating from the San Joaquin basin attributable to the baseline which adds “periodic” dredging projects in the action area, that are of “varying scope and scale” (section 2.4.4.4).	Southern Sierra Nevada
	Juvenile rearing and emigration; Adult immigration	Juvenile: Nov. – June; Adults: Jan – March	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance),	None	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment	Reduced growth	Low - Generally a sublethal effect limited to a small proportion of juvenile spring-run. The baseline adds “periodic” dredging projects in the	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada,

		(barge landings)		physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes		composition and extent of exposure.		action area, that are of "varying scope and scale" (section 2.4.4.4).	and Southern Sierra Nevada
2.5.1.1.4.1	Clearing and Grubbing (Increased Temperature) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan – June	No response, as temperature changes associated with removal of riparian vegetation would be imperceptible.	None	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to uncertainty regarding the extent of thermal change.	NA	Low – "Due to levee construction, and shoreline development, [which involves the removal of riparian vegetation], estuarine habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the action area is improving this condition (section 2.4.2.3).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.5.1	Pile Driving (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan. – June	Increasing feeding success rate as anthropogenic waves may inject prey species into the water column or expose benthic infauna.	Low - Minor or short-term beneficial effect that impacts a small proportion the population.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	Increased growth	Low - Minor or short-term beneficial effect that impacts a small proportion of the population based on the baseline and CE which add "periodic" pile driving (Section 2.4.4.6).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.5.2	Barge Traffic (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan. – June, (modified	Increasing feeding success rate as anthropogenic waves may inject prey	Low - Minor or short-term beneficial effect that impacts a	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing	Increased growth	Low – A minor effect that impacts a small proportion of the population; however, the baseline adds that portions of the action	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada,

			routing Nov – May)	species into the water column or expose benthic infauna.	small proportion of the population.	to uncertainty related to timing, duration and extent of barge operations as well as the extent of prey availability.		area "experience heavy commercial and recreational vessel traffic" (section 2.4.4.5).	and Southern Sierra Nevada
2.5.1.1.5.3	Geotechnical analysis (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan. – June	No response, as changes in prey abundance and availability associated with geotechnical analysis is likely imperceptible.	None	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	NA	NA (Geotechnical analysis is not included in the Environmental Baseline Section 2.4)	NA
2.5.1.1.5.4	Dredging (Reduced Prey) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan. – June	Reduced prey availability, decreasing feeding success caused by the removal of benthic sediments and infauna (prey base).	Low - Generally sublethal effect limited to a very small proportion of the population.	Medium - Understanding is High but nature of outcome is somewhat unpredictable because of uncertainty regarding sediment/prey composition.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population. The baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale" (section 2.4.4.4).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.5.5	Clearing and Grubbing (Reduced Prey) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan. – June	Reduced prey availability, decreasing feeding success caused by the removal of riparian flora and associated fauna.	Low - Generally sublethal effect limited to a very small proportion of the population.	High - multiple scientific and technical publications,	Reduced growth	Medium - Generally sublethal effect limited to a very small proportion of the population. The baseline diminishes available prey because "Due to levee construction, and shoreline development, [which involves the removal of riparian vegetation], estuarine habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

								action area is improving this condition (section 2.4.2.3).	
2.5.1.1.6.1	Pile Driving (Increased Predation)	Juvenile rearing and emigration (NDD)	Juvenile: Nov. – June (June, <1%);	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Low – An acute effect limited to a very small proportion of the juvenile population.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Low - Expected acute effect limited to a very small proportion of the population, to which the baseline and CE add “periodic” pile driving (Section 2.4.4.6).	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Nov. – June	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	None to Low - Acute effect limited to a very small proportion of the juvenile population.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Low - Acute effect limited to a very small proportion of the juvenile population to which the baseline and CE add “periodic” pile driving (section 2.4.4.6).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
		Juvenile emigration (HOR gate)	Juvenile (SJR): Nov. – May Yearlings: Oct.	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	None	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Low - Acute effect limited to a very small proportion of the juvenile population to which the baseline and CE add “periodic” pile driving (Section 2.4.4.6).	Southern Sierra Nevada

		Juvenile rearing and emigration (barge landings)	Juvenile: Nov. – May;	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	None	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Low - Acute effect limited to a very small proportion of the juvenile population to which the baseline and CE add "periodic" pile driving (Section 2.4.4.6 of the Baseline).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.6.2	Barge Traffic (Increased Predation)	Juvenile rearing and emigration (Delta)	Juvenile: Nov. – June, (modified routing Nov – May)	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Low - Acute effect to a small proportion of the population.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Medium - Acute effect, expected on a small proportion of the population, however baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic" (Section 2.4.4.5).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.6.3	Interim in-water structures (Increased Predation)	Juvenile rearing and emigration (Delta)	Juvenile: Nov. – June	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Low – An acute effect on a small proportion of the juvenile population.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium – An acute effect limited to a very small proportion of the population. Added to a baseline of diminished habitat complexity when "due to levee construction, [and] shoreline development, […] estuarine habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the action area is improving this condition (section 2.4.2.3).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

2.5.1.1.6.4	Clearing and Grubbing (Increased Predation) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration (Delta)	Juvenile: Nov. – June	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Low - Expected acute effect limited to a small proportion of juvenile spring-run.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium – An acute effect limited to a very small proportion of the population. Added to a baseline of diminished habitat complexity when “levee construction involves the removal of riparian vegetation, resulting in reduced habitat complexity and shading, making juveniles more susceptible to predation.” Some restoration work in the action area is improving this condition (section 2.4.2.3).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.7.1	Pile Driving (Physical Impacts to Fish)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – June (June, <1%);	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile driving-induced sound creates a temporary barrier to migration.	Low - Generally sublethal effect limited to a small proportion of spring-run.	High – Multiple technical publications including quantitative modeling results.	Reduced growth	Low - Generally sublethal effect limited to a small proportion of spring-run. The baseline and CE add “periodic” pile driving effects (section 2.4.4.6)	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Nov. – May; Adults: Jan. – June	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile	None	High – Multiple technical publications including quantitative modeling results.	Reduced growth	Low- The baseline and CE add “periodic” pile driving effects (section 2.4.4.6) that are expected to be sublethal and limited to a small proportion of spring-run.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

				driving-induced sound creates a temporary barrier to migration.					
		Juvenile rearing and emigration; (HOR gate)	Juvenile: Nov. – May Yearlings: Oct.	Sublethal, behavioral response. Displacement or delayed emigrations as pile driving-induced sound creates a temporary barrier to migration.	Low - Generally sublethal effect limited to a very small proportion of San Joaquin origin spring-run.	High – Multiple technical publications including quantitative modeling results.	Reduced growth;	Low - Generally sublethal effect limited to a very small proportion of San Joaquin origin spring-run. The baseline and CE add “periodic” pile driving effects (section 2.4.4.6).	Southern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration (barge landings)	Juvenile: Nov. – June; Adults: Jan – March	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile driving-induced sound creates a temporary barrier to migration.	None	High – Multiple technical publications including quantitative modeling results.	Reduced growth;	Low- The baseline and CE add “periodic” pile driving effects (section 2.4.4.6) that are expected to be sublethal and limited to a small proportion of spring-run.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.7.2	Dredging entrainment (Physical Impacts to Fish) + Facility Maintenance (2.5.1.2.10)	Juvenile rearing and emigration (Delta)	Juvenile: Nov. – May Adult: Jan. - June	Mortality from entrainment into dredge cutterhead. Adult fish will not be affected.	None to Low - Expected acute effect limited to a very small proportion of juvenile spring-run.	High – There are multiple scientific and technical publications	Reduced survival	Low - The baseline and CE add “periodic” pile driving effects (section 2.4.4.6) which are expected to be acute but limited to a very small proportion of juvenile spring-run.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

2.5.1.1.7.3	Propeller entrainment (Physical Impacts to Fish)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – June; Adults: Jan. – June, (modified routing Nov – May)	Injury and mortality from entrainment into the propellers of passing barges.	Low - Acute effect to a very small proportion of the population.	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration and extent of barge operations.	Reduced survival	Medium - Acute effect, expected on a small proportion of the population; however, baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic" (section 2.4.4.5).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.7.4	Dewatering (Physical Impacts to Fish) + Facility Maintenance (2.5.1.2.10)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – June (June, <2%); Adults: Jan. – March	Injury and mortality from dewatering and handling during rescue operations. Adult fish are not expected to be affected.	Low - Acute effect limited to a very small proportion of juvenile spring-run	High – There are multiple scientific and technical publications	Reduced survival	Low – Acute effect limited to a small proportion of the population (Dewatering is not included in the Environmental Baseline Section 2.4).	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
		Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Dec. – June (rare, <1%); Adults: Jan. –March.	Injury and mortality from dewatering and handling during rescue operations. Adult fish are not expected to be affected.	Low - Generally acute lethal effect limited to a very small proportion of juvenile spring-run.	High – There are multiple scientific and technical publications	Reduced survival	Low - Generally acute lethal effect limited to a very small proportion of juvenile spring-run (Dewatering is not included in the Environmental Baseline Section 2.4).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
		Juvenile emigration (HOR gate)	Juvenile: Nov. – May Yearlings: Oct.	Injury and mortality from dewatering and handling during rescue operations.	Low - Generally acute lethal effect limited to a very small proportion of juvenile spring-run.	High – There are multiple scientific and technical publications	Reduced survival	Low - Generally acute lethal effect limited to a very small proportion of juvenile spring-run (Dewatering is not included in the Environmental Baseline Section 2.4).	Southern Sierra Nevada

Post-construction operational effects of the action on spring-run are summarized in Table 2-249. Because a more certain characterization of the effects of operations will depend on a number of design criteria and real-time factors, this Opinion analyzes a range of effects depending on the expected use of these criteria and factors. The expectation remains, however, that certain aspects of this effects analysis will be reevaluated through proposed research, monitoring, and adaptive management. This expectation is confirmed in Chapter 7 of the BA Effects Determination where, “the RTO and adaptive management and monitoring provisions included in the PA provide additional opportunities to refine the operating criteria and make adjustments to CVP/SWP Delta operations to minimize the risks of incidental take while maximizing water supply.” In this Opinion, NMFS’ assessment of operational effects relies on the best scientific and commercial data available (section 2.5.1.2 Operations Effects and section 2.5.1.3 Ancillary Delta Facilities) with the understanding that the specifics of operations and facility design criteria will be refined within the bounds of the RTO and adaptive management and monitoring programs.

Table 2-249. Integration and synthesis of post-construction, operational effects with the environmental baseline and cumulative effects, on spring-run Chinook salmon.

Section Number	Stressor	Life Stage (Location)	Life Stage Timing	Response and Rationale of effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of Overall Effect (PA + Baseline + Cumulative Effects)	Diversity Groups and Populations Affected
2.5.1.2.1	Operations (Increased Upstream Temperature)	Spawning Adults, Egg incubation, and alevin emergence (Sacramento River upstream of RBDD)	August - December	Prespawn mortality, and egg mortality caused by increased temperatures, and daily fluctuation of temperatures.	Low - Aside from a few months during certain water year-types, where water operations may increase or decrease survival, there is no discernable difference between the effects of operations under the PA relative to the NAA.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival, Reduced reproductive success	High – Temperature effects place a high magnitude stress on the species and accounts for a large amount of mortality. (These effects may be minimized by real-time operational management)	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
		Fry and Juvenile rearing, and outmigration (Sacramento River Keswick Dam to Knights Landing)	Year-round	Mortality caused by increased temperatures, and daily fluctuation of temperatures.	Low - Aside from a few months during certain water year-types, where water operations may decrease survival, the overall thermal impacts on the steelhead fry and juvenile rearing and outmigration life stage will largely be the same with implementation of either the NAA or PA operations.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However, there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival	Medium – Depending on the model used to examine effects, temperature may place a high magnitude stress on the species and account for a significant amount of mortality. (These effects may be minimized by real-time operational management)	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
		Adult immigration and holding, (Sacramento River)	March – September	Prespawn mortality of eggs caused by increased temperatures, and	Low - Impacts on the spring-run Chinook salmon adult immigration and holding life stage will largely be the	Medium: Supported by multiple scientific and technical publications, including quantitative data, and	Reduced reproductive success	Medium – The PA with the environmental baseline and CE is likely to result in adverse effects,	Basalt and Porous Lava, Northwestern California, and Northern

				daily fluctuation of temperatures.	same with implementation of either the NAA or PA operations	modeled results. However, there is uncertainty with the modeling results which are based on downscaled monthly data.		particularly in drier water years.	Sierra Nevada,
2.5.1.2.2	Operations (Redd Dewatering)	Egg incubation, Fry rearing (Sacramento River upstream of RBDD)	August - December	Redd dewatering; loss of a portion, or all eggs in a redd	Low – Dewatering impacts on spring-run Chinook salmon eggs and alevins will be similar with implementation of either the NAA or PA operations, with differences varying between 8% to -5%	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However, there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival	Medium – Dewatering of redds places a medium magnitude stress on the species and can account for a large amount of mortality. Depending on the year-type, the PA with the baseline and CE may account for 2% - 32% of redds dewatered.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
2.5.1.2.3	Operations (Redd Scour)	Egg incubation, Fry rearing (Sacramento River)	August - December	Mortality either directly as high flows displace or disrupt redds or flows may increase fine sediment infiltration and indirectly decrease egg survival.	Low - Redd scour under the PA will be similar to the NAA, and is not expected to adversely affect spring-run Chinook salmon eggs, except in rare cases	Medium: Supported by multiple scientific and technical publications. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival	Low - Redd scour under either the PA or the NAA is uncommon, only occurring in less than 3% of months.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
2.5.1.2.4	Operations (Stranding)	Fry rearing (Sacramento River)	Year-round	Mortality either directly through desiccation or indirectly through predation or reduced water quality.	None	High: Supported by multiple scientific and technical publications including recent and historic observations.	Reduced survival	Low – The PA, with the baseline and CE, will result in an acute effect on a small proportion of the population.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,

2.5.1.2.5	Operations (Impingement and Entrainment)	Juvenile migration and rearing (NDD)	December - May	Mortality from contact with fish screen, and indirectly predation; sublethal effects from injury (e.g. loss of scales, disorientation).	Medium - Expected sustained population effect. For all three intakes combined expected annual entrainment would be <0.1%, and combined injury and mortality from impingement would be <9.0%. The proportion of the population exposed is expected to be reduced by the commitment to UPP and phased testing to ensure the fish screens meet NMFS criteria.	Medium - Understanding is High but nature of outcome is somewhat unpredictable due to uncertainty of exposure.	Reduced survival	Medium - Expected sustained population effect. For all three intakes combined expected annual entrainment would be <0.1%, and combined injury and mortality from impingement would be <9.0%. The proportion of the population exposed is expected to be reduced by the commitment to UPP and phased testing to ensure the fish screens meet NMFS criteria.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
2.5.1.2.6.1	Permanent In-water Structures (Increased Predation)	Juvenile migration and rearing (NDD; HOR gate)	December - May	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Medium - Expected sustained population effect on a moderate proportion of the population.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium - Effect limited to a moderate proportion of the population. Added to a baseline of diminished habitat complexity when "levee construction involves the removal of riparian vegetation, resulting in reduced habitat complexity and shading, making juveniles more susceptible to predation." Some restoration work in the Action Area is improving the baseline	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,

								2.4.2.3)	
2.5.1.2.7	NDD Operations (Travel Time)	Juvenile migration and rearing (Delta)	December - May	Mortality caused by increased migration times, with increases in predator exposure.	Medium - Expected sustained population effect on a large proportion of the population.	High - There are a number of publications regarding the relationship between flow, river velocity, and Delta survival and travel time in the North Delta; conclusions supported by modeling results.	Reduced survival	High - Expected sustained population effect on a large proportion of the population.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
2.5.1.2.7.2	NDD Operations (Outmigratio n routing)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: December - May	Mortality caused by routing into interior Delta routes with lower survival.	Medium - Expected sustained population effect on a medium proportion of the population.	High - There are a number of publications regarding the relative survival in various North Delta and Central Delta migratory routes; conclusions supported by modeling results.	Reduced survival	Medium - Expected sustained population effect on a medium proportion of the population.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
2.5.1.2.7.3	Operations (Altered South Delta hydro-dynamics due to South Delta exports)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: December - May	Mortality or decreases in condition due to migratory delays due to altered hydrodynamics and loss of migratory cues. Delays increase exposure to sources of mortality and morbidity (predation, poor	Medium - Expected sustained population effect on a medium proportion of the population.	Medium to High – Delta hydrodynamics well studied. Effects of Delta hydrodynamics on salmonids more uncertain.	Reduced survival, reduced growth	High - Expected sustained population effect on a medium proportion of the population.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

				water quality, contaminants, *etc.*)					
	Operations (Altered South Delta hydro-dynamics due to HOR gate operations)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: December - May	Decreases in migratory delays due to altered hydrodynamics.	Low - Expected sustained population effect on a small proportion of the population.	Medium – Delta hydrodynamics well studied. Effects of San Joaquin hydrodynamics dependent on integrated HOR gate operations and upstream operations.	Increased survival	Medium - Expected sustained population effect on a small proportion of the population.	Southern Sierra Nevada
2.5.1.2.7.3.1	CVP/SWP Operations (Entrainment and loss at South Delta export facilities)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: December - May	Loss is approximately 35% of entrained fish at the CVP's Tracy Fish Collection Facility, and 84% at the SWP's Skinner Delta Fish Protective Facility.	Low - Expected sustained population effect on a small proportion of the population.	High – Numerous studies have evaluated screening efficiency, predation, and overall salvage operations survival	Reduced survival	Low - Expected sustained population effect on a small proportion of the population.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.3.1.1	Suisun Marsh Salinity Control Gates	Juvenile rearing and emigration; Adult immigratio n (Suisun Marsh)	Juveniles: Year-round; Adults: Year-round	Limited effect to juveniles; sublethal, behavioral effect to adults, migration delay and changes to routing.	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population.	Medium – Delta hydrodynamics well studied. Effects of Delta hydrodynamics on salmonid migration more uncertain.	Reduced reproductive success	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

2.5.1.3.1.2	Roaring River Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Mortality caused by entrainment into pumps distributing water to Suisun Marsh.	None – Fish screens of adequate size and approach velocities slow enough to exclude juveniles from entrainment.	Medium – Fish/Screen interactions well studied. Observations at this location limited.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.3.1.3	Morrow Island Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Mortality caused by entrainment into culverts diverting from Goodyear Slough, and draining into Grizzly Bay or Suisun Slough.	None – Entrainment of juveniles unlikely because of location of intakes and probable size of fish.	Low to Medium – Inference based on understanding of fish life history. Observations at this location limited, but include entrainment of fall-run Chinook salmon.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.3.1.4	Goodyear Slough Outfall	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Passive entrainment into Suisun Marsh, possible improvement to water quality and available foraging habitat.	None or Low – Entrainment of juveniles unlikely because of location of intakes and probable size of fish.	Low – Inference based on understanding of fish life history. No observations at this location.	Improved growth	None or Low – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

2.5.1.3.2	North Bay Aqueduct	Juvenile rearing and emigration; (Delta)	Juveniles: Year-round	Injury and mortality caused by entrainment into pumps or impingement in screens at North Bay Aqueduct, Barker Slough Intake.	None or Low – Entrainment or impingement of juveniles unlikely because of location of intakes, efficacy of fish screens and probable size of fish.	Low to Medium – Inference based on understanding of fish life history. Observations at this location limited.	Reduced survival	None or Low – Insignificant effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada
2.5.1.3.3	Contra Costa Canal Rock Slough Intake	Juvenile rearing and emigration; (Delta)	Juveniles: Year-round	Injury and mortality caused by entrainment into pumps or impingement in screens at Contra Costa Canal Rock Slough Intake.	None or Low – Entrainment or impingement of juveniles unlikely because of location of intakes, and probable effectiveness of fish screens.	Low to Medium – Inference based on understanding of fish life history. Continued testing of fish screen and vegetation removal expected until at least 2018.	Reduced survival	None or Low – Insignificant effect pending resolution of fish screen sweeping efficiency. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

2.7.3.3 Assess Risk to the Population

As identified in the analytical approach, the use of the VSP concept identifies guidelines describing a viable ESU, where the viability of an ESU depends on the number of populations within the ESU, their individual status, their spatial arrangement with respect to each other and to sources of potential catastrophes, and diversity of the populations and their habitat (Lindley et al. 2007). NMFS applies the VSP concept as an approach to evaluate the population viability of with the proposed action and the extinction risk of the ESU. Viability of the population and extinction risk of the ESU relate to the survival and recovery of the ESU. In section 2.5 Effects of the Action the effects to individuals from different populations are not differentiated because many of the effects associated with the proposed action are experienced at locations where individual populations or diversity groups come together and are typically experienced equally among the individuals originating from a particular basin. Based on the change in fitness of individuals, while considering the effects and/or benefits provided by the programmatic activities and the minimization aspects of the revised PA, NMFS assesses whether the collective changes, including the environmental baseline and cumulative effects, are expected to constitute a change in the VSP parameters and thereby affect the spring-run Chinook salmon population.

The Sacramento River basin origin spring-run Chinook salmon belong to one of three diversity groups, including the basalt and porous lava, northwestern California, and northern Sierra Nevada diversity groups. While the southern Sierra Nevada diversity group is made up of spring-run whose origin are in the streams tributary to the San Joaquin River, as well as the San Joaquin River itself. These diversity groups reflect the historic distribution of the spring-run species and each is considered essential for the recovery of the species. The impacts to the diversity and spatial structure provided by the individual populations and their diversity groups are evaluated during the ESU risk assessment. Here, when the VSP approach is applied, the change in fitness described in section 2.5 Effects of the Action for individuals of the species is assessed as whether these changes with consideration of the assurances provided by the programmatic activities, when added to the environmental baseline and cumulative effects (described in sections 2.4 and 2.6, respectively), are expected to constitute a change in the VSP parameters applied to populations of a particular diversity group(s) which comprise a river basin of origin.

Sacramento River Basin Spring-run

Collectively the three diversity groups which make up the Sacramento River Basin origin spring-run Chinook salmon, once held 15 historic independent populations. Currently only one of these populations (Butte Creek) is considered recovered, independent and viable. For spring-run Chinook salmon, individuals of Sacramento River basin populations are analyzed as a single unit because of the shared point of entry to the north Delta, where the effects of the action will be experienced equally among these populations.

Spring-run Abundance

As described by McElhany et al. (2000b), the three key attributes of the abundance VSP parameter are that a population be: 1) large enough to have a high probability of surviving environmental variability, 2) large enough that compensatory process may provide resilience from environmental and anthropogenic disturbance, and 3) large enough to maintain its genetic diversity. This parameter has been further refined by Lindley et al. (2007) where a census population size (N > 2,500) is identified as one of four criterion needed for a salmonid population to be considered at a low risk of extinction. Here we use changes in the adult population relative to that population size criterion as the measure against which any potential reduction in the VSP abundance parameter is assessed. Changes to juvenile abundance are also considered; however, they are reflected in the assessment of the productivity VSP parameter.

Based on the 2016 status review of spring-run, the 2012 – 2014 estimates of the populations originating in the Sacramento River basin include the Core 1 populations (those with a known ability to support viable populations) and the Core 2 populations (those with the potential to support viable populations) are described in Table 2-250.

Table 2-250. Sacramento River Basin spring-run population size, classification and diversity group. Total population size (N) is estimated as the sum of estimated run sizes over the most recent three years (2012 – 2014) for Core 1 populations (bold) and Core 2 populations. The population growth/decline rate (10 year trend) is estimated from the slope of log-transformed estimated run size.

Population	N	Population growth rate (95% CI)	Classification	Diversity Group
Battle Creek	1836	0.176 (0.033, 0.319)	Core 1	Basalt and Porous Lava
Sacramento River	-	-	Core 2	
Clear Creek	822	0.010 (-0.311, 0.330)	Core 1	Northwestern California
Cottonwood Creek	4	-0.343 (-0.672, -0.013)	Core 2	
Antelope Creek	8	-0.375 (-0.706, -0.045)	Core 2	Northern Sierra Nevada
Big Chico Creek	0	-0.358 (-0.880, 0.165)	Core 2	
Butte Creek	20169	0.353 (-0.061, 0.768)	Core 1	
Deer Creek	2272	-0.089 (-0.337, 0.159)	Core 1	
Feather River Fish Hatchery	10808	0.082 (-0.015, 0.179)	Core 2	
Mill Creek	2091	-0.049 (-0.183, 0.086)	Core 1	
Yuba River	6515	0.67 (-0.138, 0.272)	Core 2	

NMFS expects the proposed action will have a number of short-term construction-related impacts to the species; however, given the proposed work windows and migration timing of adult spring-run, construction-related effects would only be expected to impact very small numbers of returning adults. By June, only a few individual spring-run would be found in the Delta and have the potential to be exposed to construction related effects. Furthermore, the majority of the construction-related effects would likely cause changes in behavior and not direct mortality affecting abundance. One notable exception, regarding the severity of the construction-related effects, is the effect of pile-driving induced noise. As explained in section 2.5.1.1.1.1 Acoustics, pile-driving induced noise would affect some spring-run in a manner that could rise to the level of harm or even result in mortality. Although the potential for spring-run mortality to be caused by pile-driving, or one of the several other construction-related effects that will result in reduced survival, is greatly limited by the proposed work windows, it is not eliminated entirely. Regardless of the construction-related stressor the proportion of the population exposed will be the same, such that each year a few individual adult spring-run would be expected to be killed by construction activities. This level of impact is not expected to appreciably reduce the VSP abundance parameter for the Core 1 populations of spring-run Chinook salmon populations of the Sacramento River basin. However, given the small size of some of the Core 2 populations, and the relative sensitivity of those populations to the loss of even a few individuals on an annual basis; the abundance VSP parameter of the Core 2, spring-run Chinook salmon populations of the Sacramento River basin could be reduced by the construction-related impacts of the PA.

The SWFSC WRLCM described in Appendix G: WRLCM Description, was used in this Opinion to determine the effect on winter-run of the post-construction operation under the PA as compared to the NAA. Although there is no analogous life cycle model for spring-run, many of the trends described by the WRLCM would be expected to be the same for spring-run given similarities between winter-run and spring-run in the overlap of life histories and habitats. Moreover, the model was not used to determine actual winter-run abundance as any attempt to identify the outputs of the model as equating to actual fish in the Sacramento River would be incorrect. Because predictions are not calibrated to produce forecasts of actual abundance, results are viewed as the relative performance of the two actions (i.e., the NAA and the PA), which are relevant not only to winter-run but to similar species as well. One of the outputs of the model is a description of the relative effect of the PA on abundance, and while the model also provides an assessment of population growth, that assessment is described in the description of changes to the productivity VSP parameter. Under all six scenarios analyzed in the model, the effect of the PA on winter-run abundance was more negative relative to NAA. Under no scenario would abundance be greater in the PA relative to the NAA at the end of the 82-year time series, meaning that operations under the proposed action would negatively impact the abundance of winter-run Chinook salmon. Based on these model results, similar trends would be expected for spring-run originating in the streams tributary to the Sacramento River basin. The effect of a decrease in abundance when added to the Sacramento River basin populations' baseline condition of abundance would maintain the current risk of extinction for Core 1 populations based solely on the abundance VSP parameter. Likewise, for Core 2 populations the effect of a decrease in abundance when added to those populations' baseline condition of abundance would maintain the current risk of extinction based on the abundance VSP parameter, which is already high.

However, these results of WRLCM do not incorporate the additional project commitments in the revised PA that are expected to improve results from those described for the PA scenario. An analysis of a new WRLCM scenario was completed to evaluate PA fish routing elements and revised PA habitat restoration. Although the exact benefits from these actions cannot be captured within the model due to uncertainty of representation of these elements within the model structure, the results of this scenario indicated a reduction to the reduced cohort replacement rate described in the analysis of the PA scenario. Furthermore the commitment to preventing an increase in north Delta reverse flows was not modeled with the WRLCM. The Perry Survival Model was used to evaluate the unlimited pulse protection revision to the PA and showed that the impact to juvenile through-Delta survival is much less under these protections. RMA modeling showed that tidal Delta habitat restoration at the level proposed in the revised PA should be able to influence the tidal prism enough to prevent the exacerbation of reverse flows from the NDD operations.

Also included in the revised PA is a renewed commitment to winter-run Chinook salmon reintroduction to the Sacramento River above Shasta Dam and Battle Creek, which will likely also include reintroduction of spring-run and would increase abundance of this ESU. It is NMFS' expectation that the benefits gained from these new commitments will reduce the impacts to abundance from the PA (beyond what the WRLCM is capable of representing at this time in the model's development) and possibly even improve abundance of the species over time.

Spring-run Chinook Salmon Productivity

The key attributes of the productivity VSP parameter deal with a populations ability to reproduce itself, survival of early life-stages, and the influence of hatchery produced spawners on the population. Based on these attributes, two common metrics that may be used to assess the productivity VSP parameter are the population growth rate (or decline) and the proportion of spawners of hatchery origin (hatchery influence). These metrics have been further refined by Lindley et al. 2007 to where the population growth rate (10 year trend estimated from the slope of log-transformed estimated run size), must not show a decline and where hatchery influence must be 'Low' (<10% hatchery influence for 2 generations, or <5% for 3 generations) in order for a salmonid population to be considered at a low risk of extinction. Currently, for all Core 1 populations of spring-run originating in the streams tributary to the Sacramento River basin, the population growth rate is positive, or shows no apparent decline (growth rate at or near zero). However, while the hatchery influence in the Feather River and Yuba River populations is unknown, the FRFH currently produces 2,000,000 juveniles each year which likely has a high rate of influence on these Core 2 populations. Using the metrics of population growth rate and hatchery influence, actions that would appreciably reduce the natural component of the population, or that would directly or artificially increase the proportion of hatchery fish in the population, are considered to reduce the productivity parameter of the VSP.

The productivity of Sacramento River basin-origin spring-run would be reduced by the proposed action both through a reduction in pre-spawn fitness of adults as well as through injury and mortality experienced by rearing and out-migrating juveniles. For adults, the construction in-water work windows will protect all but a few returning adult spring-run from the vast majority of the construction-related effects. Likewise, the timing and routing of construction-related Delta barge traffic described in sections 2.5.1.1.1.2 Acoustics; 2.5.1.1.2.2 Sediment Concentration; and 2.5.1.1.3.2 Contaminant Exposure; is such that exposure is expected to be low. However, some portions of the Delta and adult spring-run migration routes will experience a significant increase in barge traffic which will be a year round stressor that has the potential to expose the entire adult population to increased vessel noise, sediment concentration, and contaminants. Although it is unlikely that this activity will result in direct mortality to adult spring-run, it will result in a reduced level of fitness that will affect productivity.

Like adults, juvenile spring-run are expected to experience a reduced level of impact related to the construction portion of the proposed action because of the proposed work-window. Only a small proportion of spring-run juveniles (about 1%) are expected to be present during the construction in-water work window, when those individuals will be exposed to possible injury and death caused by construction-related actions such as pile driving. A more significant effect related to construction is expected to be caused by increased barge traffic in the Delta, which has the potential to expose a larger proportion of the juvenile population. Although the timing and routing of construction-related Delta barge traffic has been modified to reduce the level of exposure, certain sections of the Delta that are part of the spring-run migration corridor would still be exposed to increased barge traffic. And, while adult spring-run exposure is limited to increased vessel noise, sediment concentration and contaminants, juveniles will also be exposed to propeller entrainment and increased exposure to predators; the combined effects of which would reduce the fitness of individual fish or result in mortality. For fish emigrating from the Sacramento River basin, expected exposure to increased barge traffic is limited to those fish entrained into the central Delta such that the associated effects would not be expected to significantly reduce the productivity VSP parameter for most of these populations. However, for some Core 1 populations of spring-run, whose population growth rate is at or near zero (e.g. Clear Creek and Mill Creek), the loss of juvenile fish caused by construction-related effects of the PA could be enough to reduce a populations growth rate to a point of decline.

Post-construction operations under the proposed action are also likely to affect the productivity VSP parameter of spring-run. Specifically, out-migrating juveniles will be exposed to fish screen interactions (entrainment and impingement) at the NDD and reduced in-Delta flows that will result in the reduced survival of juveniles. Section 2.5.1.2.5 Impingement and Entrainment quantified the interactions of migrating juvenile spring-run with fish screens at the NDD which are expected to result in a combined incident rate of <9.0% for injury and mortality. Year after year the effects of impingement, if realized, will significantly reduce the productivity VSP parameter of spring-run Chinook salmon populations originating from the Sacramento River basin. However, the operational phasing commitment described in the PA will be used to demonstrate compliance with the then-current NMFS and CDFW screening design and operating criteria. The PA states that, "The fish and wildlife agencies (i.e. USFWS, NMFS, and CDFW) retain responsibility for determination of the operational criteria and constraints (i.e., which pumping stations are operated and at what pumping rate) during testing." Therefore, the extent of effect is limited to a smaller proportion of what would be expected in the PA until design and operation of the screens is sufficiently tested. The NDD screens will be designed to meet NMFS screening criteria and incorporate (as yet determined) predator refugia, which NMFS expects will minimize screen impingement and associated predation. The PA provision that the NDD screen intakes will begin operating in a phased manner with testing to ensure they are functioning as expected will ensure impacts are minimized. In addition, the revised PA commitments to habitat restoration including 80 acres in the upper Sacramento River and 1,800 acres of restoration in the Delta, that will ultimately improve overall juvenile winter-run Chinook salmon survival; and the commitment to the revised Adaptive Management Plan includes research to assess and mitigate Sacramento River basin predation (Appendix A2, Adaptive Management Program). It is the expectation that these habitat restoration areas will be functioning and improving winter-run Chinook salmon productivity before the PA operations commence. The incident rate at the NDD screens is expected to be further reduced by the revised real-time operations for the NDD that have unlimited pulse protections, such that during periods of high fish migration diversions will be reduced to limit exposure. Under the PA without consideration of the revised PA, juvenile survival was reduced during the core migratory months ranging from 0.5% to 12% (median). With the revised PA (unlimited pulse protections) median survival reductions are improved with a range from 0.7% to 3%.

As explained in section 2.5.1.2.7 Reduced In-Delta Flows, the relationship between through Delta travel time, migration route, and flow is such that the reduction in Delta flows caused by operations under the proposed action would have an associated reduction in juvenile survival. Perry's 2017 flow-survival model described in section 2.5.1.2.7.3.2 Perry 2017 Flow-Survival Model, simplifies the relationship between flows, travel time and smolt survival, showing that under the PA in at least 75% of years, Chinook salmon migration travel time is increased for all months during the entire migration period. Overall increased travel times will negatively impact juveniles by increasing predator encounters, increasing tidal excursion in transition reaches of the lower Sacramento River, increasing entrainment into the lower survival routes of the central Delta and reducing turbidities which likely benefits predators. This in turn results in a reduction in median survival for the months of March, April, and May, during peak juvenile spring-run emigration, of 1.6%, 0.5%, and 0.8%.

Although the reduction in downstream flows caused by the NDDs as analyzed for the PA scenario without consideration of the revisions to the PA will have an adverse effect on migrating juvenile spring-run, the commitments made by Reclamation and DWR in the revised PA are expected to limit the impact of operations such that they would affect a small reduction to the production VSP parameter of spring-run Chinook salmon. Specifically, the relevant commitments are to the revised real-time operations for the NDD, the commitment to restore in Delta habitat to address potential undesirable hydrodynamic effects of the NDD operations, and the revised DCC criteria. The revised PA also includes an Adaptive Management Program, accompanying Agreement for Implementation of an Adaptive Management Program for Project Operations, and an Implementation Schedule for the Adaptive Management Program that together provide the means to incrementally reduce the uncertainty related to the impact of operations. The commitments made in the revised PA are described in detail in Section 2.7.1.3 Assess Risk to the Population: Winter-run Chinook salmon Productivity. These commitments support a conclusion that operations will be refined and managed so as to not diminish the productivity VSP parameter to a level that would affect Sacramento River basin populations.

Spring-run Spatial Structure:

The spatial structure parameter of a VSP reflects how abundance is distributed among available or potential available habitats. The attributes of the spatial structure parameter describe the availability, diversity, and utilization of properly functioning habitats and the connections between such habitats. The spatial structure of spring-run populations in the Sacramento River basin are limited mostly because of a loss of historical spawning habitat and the degradation of remaining habitat such that of the estimated 15 historic populations of CV spring-run Chinook salmon, only three independent populations currently exist (Mill, Deer, and Butte creeks tributaries to the upper Sacramento River); and that, of those three, only 1 (Butte Creek) is considered at low risk of extinction. Given the limited habitat available in the baseline, there could be considerable impact to the spatial structure parameter of the VSP if it is further reduced. A significant part of the revised PA, however, is the re-commitment to key non-operational RPA actions in the NMFS 2009 BiOp, which include: the restoration of floodplain rearing habitat (increase juvenile salmonid access to Yolo Bypass, and increase duration and frequency of Yolo Bypass floodplain inundation), the implementation of pilot reintroduction program above Shasta Dam, consideration of engineering solutions to further reduce diversion of emigrating juvenile salmonids to the interior and southern Delta, and reduce exposure to CVP and SWP export facilities, and the restoration of Battle Creek for winter-run, spring-run, and CV steelhead; the combined effect of which are expected to benefit the spatial structure VSP parameter of CV spring-run Chinook salmon.

As described in section 2.5.1.1 Construction Effects, most of the construction-related impacts of the PA would not result in further habitat fragmentation or diminish the species ability to move between habitats. Some stressors, such as physical impacts to fish from activities like pile driving are expected to cause displacement or delayed migrations for some Sacramento River basin populations; however, this effect would be very small and not likely to have an appreciable effect on the population. In section 2.5.1.2.1 Increased Upstream Temperature, the effects of temperatures under the PA were analyzed relative to the NAA (conditions under a continuation of the current baseline) and found not to be significantly different from each other. However, both the PA and the NAA showed considerable temperature-related effects, such that the proposed action, when added to the environmental baseline, results in continued limits to the appropriate exchange of spawners and limits to the expansion of a population into underused habitat.

As described in section 2.5.1.2 Operation Effects, under the PA the spatial structure VSP parameter of spring-run would be further impacted in a number of ways, including, but not limited to: (1) decreasing flows and increasing travel time through the north Delta due to NDD operations; (2) creating conditions favorable for predators as juveniles migrate downstream through the installation of permanent in water structures, diminishing the available habitat patches; and (3) further altering the natural hydrograph of the Delta and its tributaries which limits access to habitats. To address these specific impacts, the revised PA incorporates a number of commitments that are expected to benefit the spatial structure VSP parameter of CV spring-run Chinook salmon, such as: (1) the revised real-time operations for the NDD (BA section 3.3.3.1.1 Pulse-Protection), (2) the commitment to the revised Adaptive Management Plan which includes research to assess and mitigate Sacramento River basin predation (Appendix A2, Adaptive Management Program), and (3) as part of a larger commitment to habitat restoration, the revised PA includes 1,800 acres of tidal restoration in the Delta to function as juvenile rearing habitat. This coupled with the 9,000 acres of habitat restoration proposed under existing conditions may be enough to address reverse flows. However, in order to reduce uncertainty that those acreages are enough, an additional commitment was made to “sufficiently address potential undesirable hydrodynamic effects of the NDD operations” (BA section 3.4.3.1.2) by “providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations.”

As described in section 2.5.1.2.7 Reduced In-Delta Flows, operations under the PA would also reduce reverse flows in the south Delta which reduces travel time for migrating fish therein. These results are supported by the modeling which shows average spring-run loss at the south Delta water export facilities would be 69% lower under the PA than the NAA in all water year types. And while the reduced reverse flows in the south Delta represents an improvement over current conditions, the PA includes operations of the existing facilities in the south Delta, which will still result in some negative effects. Considering the negative impacts of operations, in the context of the commitments in the revised PA to key, non-operational actions of the RPA in the NMFS 2009 biological opinion on the coordinated operations of the CVP/SWP, which significantly expands the spatial structure of the species, the PA is expected to maintain the population's current spatial structure. Furthermore the commitments and criteria described in the revised PA, particularly the commitments to revised real-time operations for the NDD, the commitment to restore in Delta habitat to address hydrodynamic effects of the NDD operations and the revised DCC criteria, are expected to limit the impact of NDD operations and support a conclusion that they would not reduce habitat connectivity in the Delta so that the spatial structure VSP parameter of CV spring-run Chinook salmon populations would not be reduced.

Spring-run Chinook Salmon Diversity:

The diversity VSP parameter comprises the three key attributes of: 1) variation in traits such as run timing, age structure, size, fecundity, morphology, behavior and genetic characteristics, 2) resilient gene flow among populations that is limited, and 3) maintenance of ecological variation (McElhany et al. 2000b). The diversity of spring-run populations in the Sacramento River basin continues to be limited as a result of the proposed action which constrains the timing of migrations and alters ecological variability.

As described in section 2.5.1.2.7 Reduced In-Delta Flows, the NDD bypass rules are designed to protect the majority of juvenile winter-run and spring-run migrants but these rules do not offer the same level of protection to all migrating fish. According to the Perry 2017 flow-survival model early migrants, those juvenile spring-run emigrating in November, are offered the least protection with median increases to travel times of 1.2 to 1.3 days. The increased travel time for outmigrating smolts is expected to have a corresponding increase in predation risk. And while the magnitude of channel velocity reductions under the bypass rules of the PA during the end of juvenile migration, in April, are not as large as in earlier months, the reductions for proposed action operations range from 5 to 10 percent for the north Delta and would have associated increases in travel times for juvenile spring-run Chinook salmon. Having a diverse range of run-timing allows for greater resiliency of this species as a whole because it minimizes the risk of entering the ocean at a point of unfavorable conditions where productivity often varies considerably within a season. The converse is true as well, whereas the timing of spring-run ocean entry is constricted by the proposed action to a narrow range of months, the probability that smolts will enter an ocean environment with favorable conditions for growth and survival decreases. However, the analysis of NDD operations does not reflect the commitment in the revised PA to unlimited pulse protection during periods of fish presence. With this added commitment, there is reasonable assurance that the breadth of diversity represented by migration timing will be protected since all migrations would receive an equal level of protection, and that the diversity VSP parameter will not be affected.

For Sacramento River basin origin spring-run populations, diversity is affected by the continuing effects of entrainment into the south Delta and entrainment in the south Delta CVP/SWP facilities. Although the PA is expected to improve conditions in the south Delta, where modeling shows average spring-run loss at the south Delta water export facilities would be 69% lower under the PA than the NAA in all water year types, there remains a negative impact under the PA. The differences in annual entrainment among the run timing scenarios discussed in section 2.5.1.2.7.2.2 Salmonid Smolt routing into the interior Delta suggests that daily entrainment probabilities vary seasonally, thereby affecting annual entrainment differentially for the alternative run timings (early, uniform or late). Depending on the run timing and the proportion of the migrating population that is impacted, entrainment into the south Delta and the localized conditions therein will impact the diversity VSP parameter of a population because those run timings that remain in the mainstem Sacramento River will experience a higher level of survival compared to those entrained. The overall entrainment into the central Delta with the PA for all 3 run timings was <2% difference between the means of all three annual entrainment probabilities, meaning that the level of effect is small and not likely to have significant impact on the diversity parameter of the VSP.

San Joaquin River Basin Spring-run Chinook Salmon

All San Joaquin River basin origin spring-run salmon belong to a single diversity group, the Southern Sierra Nevada diversity group, which was once made up of 4 historic populations that are now extant. Anecdotal observations suggests that a self-sustaining population of spring-run Chinook salmon is occurring in some of the San Joaquin River tributaries, most notably the Stanislaus and the Tuolumne rivers (Franks 2014a). In addition, a nonessential experimental population of CV spring-run Chinook salmon was designated under ESA section 10(j) in the San Joaquin River from Friant Dam downstream to its confluence with the Merced River to allow for reintroduction of the species as part of the San Joaquin River Restoration Program (SJRRP) (78 FR 79622, December 31, 2013). This reintroduction is also a key part of the recovery strategy for spring-run where the objective is to establish and maintain two populations in the Southern Sierra Diversity Group at low risk of extinction. Considering that the current nonessential experimental population and any future population in the San Joaquin River basin would enter the Delta at a different location, compared to the populations of the Sacramento River basin, the effects of the proposed action on these populations are examined separate from those effects on populations of the Sacramento River basin.

Spring-run Abundance

There are no abundance estimates for spring-run populations in the San Joaquin River basin; however, there have been reports of adult “spring-running” Chinook salmon returning to San Joaquin River tributaries, February through June (NMFS 2016b), indicating that a population (or populations) do(es) exist. Additionally, in 2014, implementation of the spring-run Chinook salmon reintroduction plan into the San Joaquin River began and these reintroduced fish have been designated as a nonessential experimental population under ESA section 10(j) when within the defined boundary in the San Joaquin River (78 FR 79622, December 31, 2013). However, without a discrete estimate of abundance assessing the abundance VSP parameter for the San Joaquin River basin population(s) is limited to a qualitative assessment of whether conditions under the PA, when added to the environmental baseline and cumulative effects, would be expected to maintain, reduce or increase abundance.

NMFS expects the proposed action will have a number of short-term construction-related impacts to population(s) of the San Joaquin River basin; however, given the proposed work window and migration timing of adult spring-run, construction-related effects would only be expected to impact very small numbers of returning adults. By June 15, the start of the revised work window, only a few individual spring-run would be found in the Delta and have the potential to be exposed to construction related effects. Furthermore most construction-related effects would likely cause changes in behavior and not mortality which would affect abundance.

One notable exception regarding the potential severity of the construction-related effects is the effect of pile-driving induced noise. As explained in section 2.5.1.1.1.1 Acoustics, pile-driving induced noise would affect some spring-run in a manner that could rise to the level of harm or even result in mortality. However, impacts to the abundance VSP parameter are unlikely as the potential for spring-run mortality to be caused by pile-driving operations, or one of the several other construction-related effects that will result in reduced survival, is greatly limited by the proposed work windows, in which impact pile-driving at the HOR Gate and CCF will be restricted to start after July 1 (CCF) or August 1 (HOR Gate), when spring-run presence is very unlikely.

The abundance of San Joaquin River basin-origin spring-run may be affected by the construction-related Delta barge traffic described in sections 2.5.1.1.1.2 Acoustics; 2.5.1.1.2.2 Sediment Concentration; and 2.5.1.1.3.2 Contaminant Exposure. The timing and routing of construction-related Delta barge traffic is such that San Joaquin River basin spring-run will experience a significant increase in effects related to barge traffic which will be a year-round stressor that will expose the entire adult population to increased vessel noise, sediment concentration, and contaminants. This activity is unlikely to result in direct mortality to adult spring-run, but rather it will result in a reduced level of fitness caused by delayed or disrupted migrations that in turn could affect reproductive success of individuals and thereby reduce the effective population size. Overall, however, the PA is expected to maintain abundance and not appreciably reduce the VSP parameter of the spring-run population(s) in the San Joaquin River basin.

Spring-run Productivity

Information regarding the productivity of San Joaquin River basin population(s) of spring-run is absent given that there are no identified, extant, naturally produced populations and there are no estimates of population growth or decline. And, like the assessment of the abundance VSP parameter, without a discrete estimate of productivity, assessing the productivity VSP parameter for the San Joaquin River basin population(s) is limited to a qualitative assessment of whether conditions under the PA, when added to the environmental baseline and cumulative effects, would appreciably reduce the natural component of the population, or directly or artificially increase the proportion of hatchery fish in a population.

The productivity VSP parameter of San Joaquin River basin-origin spring-run may be reduced by the proposed action as rearing and out-migrating juveniles will be exposed to a number of stressors related to construction and operations the effect of which can result in injury or mortality. Since only a few individual spring-run juveniles would be expected to be present in the Delta during the construction work window and because the San Joaquin River Restoration Program releases are made in March (outside of the work window) juvenile spring-run would avoid the majority of construction related impacts. However, barge traffic in the San Joaquin River related to construction is expected to be year-round such that it will expose the entire juvenile population to increased vessel noise, sediment concentration, and contaminants. And unlike adult spring-run, whose response will be limited to behavioral changes, juveniles will also be exposed to propeller entrainment which will result in direct mortality and increased exposure to predators. The direct and indirect loss of juvenile fish caused by the increased barge traffic would be expressed as a reduction of juvenile production at the population level.

Post-construction operations under the proposed action are also likely to affect the production VSP parameter of spring-run. However, unlike the spring-run populations in the Sacramento River Basin, out-migrating juveniles belonging to populations originating in the San Joaquin River basin will not be exposed to fish screen interactions (entrainment and impingement) at the NDD and will experience a relative increase in Delta flows that will result in increased survival of juveniles when compared to current conditions. As explained in section 2.5.1.2.7 Reduced In-Delta Flows, the relationship between through Delta travel time, migration route, and flow is such that the reduction in north Delta flows caused by operation of the NDD under the proposed action would have an associated reduction in juvenile survival for juveniles emigrating from the Sacramento River basin. And while flows in the north Delta will be reduced, flows in the central Delta are mostly unchanged, and for flows in the south Delta, there will be a net increase so that there would also be a relative increase in survival for juveniles emigrating from the San Joaquin River basin. The PA, however, will include the operations of the existing facilities in the south Delta, which will still result in some negative effects due to altered hydrologic conditions and entrainment at the south Delta export facilities. Overall the effects of operations will increase the productivity VSP parameter of spring-run Chinook salmon populations originating from the San Joaquin River basin relative to current conditions. The revised PA also provides an Adaptive Management Program, accompanying Agreement for Implementation of an Adaptive Management Program for Project Operations, and an Implementation Schedule for the Adaptive Management Program, that together enable a means to incrementally reduce the uncertainty related to the impact of operations and support a conclusion that operations will be refined and managed so as to not diminish the productivity VSP parameter of the San Joaquin River basin populations.

Spring-run Spatial Structure

Because the attributes of the spatial structure VSP parameter describe the availability, diversity, and utilization of properly functioning habitats, this VSP parameter reflects how species abundance is distributed among available or potential habitats and the connections between such habitats. As described in section 2.5.1.1 Construction Effects, most of the construction-related impacts of the proposed action would not result in further habitat fragmentation or diminish a population's ability to move between habitats. Some stressors, such as physical impacts to fish from activities like pile driving are expected to cause displacement or delayed migrations for some Sacramento River basin populations; however, for San Joaquin River basin populations, the proposed work window is sufficient to protect the vast majority of migrating fish, such that any effect would be very small and not likely to have an impact on the population. Again, the exception will be increased barge traffic, the timing and routing of which will disproportionately impact spring-run populations in the San Joaquin River basin. Migrating fish will be subject to increased vessel noise, sediment concentration, and contaminants for the duration of construction, the effects of which will result in a reduced level of fitness caused by delayed or disrupted migrations that in turn will negatively affect the spatial structure VSP parameter.

Operation of the NDD and HOR under the proposed action, described in section 2.5.1.2 Operation Effects, will also impact the spatial structure VSP parameter of spring-run but it will do so in a way that is expected to benefit populations in the San Joaquin River basin. As described in section 2.5.1.2.7 Reduced In-Delta Flows, operations under the proposed action would reduce reverse flows in the south Delta which would reduce travel time for migrating fish therein. In the San Joaquin River, velocities for the PA are often substantially greater in most months, typically by at least 15% and up to 54%, mainly due to the presence of the HOR in the PA. These results are supported by the modeling which shows average spring-run loss at the south Delta water export facilities would be 69% lower under the PA than the NAA in all water year types. Since the PA will include the operations of the existing facilities in the south Delta, there will still be some negative effects from these operations. The proposed action is expected to diminish the spatial structure VSP parameter in the short-term as construction-related barge traffic is likely to disrupt or delay spring-run migrations in the San Joaquin River basin. However, the long-term effect of the proposed action, specifically the operation of the HOR, when added to the environmental baseline and cumulative effects that include the establishment of a San Joaquin River population of CV spring-run Chinook salmon as part of the SJRRP, will maintain or even increase the San Joaquin River basin population's current spatial structure by sustaining access to habitat with the potential to increase habitat connectivity, quantity and quality relative to current conditions.

Spring-run Diversity

The three key attributes of the diversity VSP parameter are: 1) variation in traits such as run timing, age structure, size, fecundity, morphology, behavior and genetic characteristics, 2) resilient gene flow among populations that is limited, and 3) maintenance of ecological variation (McElhany et al. 2000b). Currently the diversity of spring-run populations in the San Joaquin River basin is greatly limited as there are no independent and viable populations in the San Joaquin River basin, and the non-essential experimental population that is being introduced as part of the SJRRP is wholly dependent on hatchery supplementation which constrains the initial and future variability of that population.

Operation of the NDD and HOR under the proposed action, as described in section 2.5.1.2 Operation Effects, will impact the diversity VSP parameter of spring-run populations originating in the Sacramento River basin because the reduced flows caused by the NDD will disproportionately impact those spring-run that begin their migrations in November and December. The same effect is not expected to be experienced by spring-run populations originating in the San Joaquin River basin, because in the south Delta operations under the proposed action would reduce reverse flows which would reduce travel time for migrating fish therein. Having a diverse range of run-timing allows for greater resiliency of this species as a whole because it minimizes the risk of entering the ocean at a point of unfavorable conditions where productivity often varies considerably within a season. In the San Joaquin River, the analysis based on the SalSim Juvenile Delta Module survival function suggested that the PA would likely have a positive effect on San Joaquin River spring-run Chinook salmon in the Delta but this effect is not expected to disproportionately affect any one segment of a San Joaquin River basin population such that any life history diversity would be lost. Overall, the proposed action is not expected to diminish the diversity VSP parameter as spring-run migrations avoid most construction-related effects and the operation of the HOR will not constrain and may even increase the window of successful migration timing for San Joaquin River basin populations.

2.7.3.4 Assess the Risk to ESU/DPS

In assessing the risk posed by the proposed action to the ESU of spring-run, NMFS determines if changes in population viability are likely to be sufficient to reduce the viability of the species those populations comprise. In this assessment, we use the species' status (established in the status of the species and Appendix B Rangewide Status of the Species and Critical Habitat which is a reflection of the environmental baseline as our point of reference. Currently the extinction risk for the CV spring-run Chinook salmon ESU is at moderate risk of extinction (National Marine Fisheries Service 2016b). And, based on the severity of the drought and the low escapements as well as increased pre-spawn mortality in Butte, Mill, and Deer creeks in 2015, there is concern that CV spring-run Chinook salmon will deteriorate into high extinction risk in the coming years based on the population size or rate of decline criteria. Given this reference, and based on our knowledge of the population structure of the species, NMFS considers the consequences of any change in extinction risk to one or more of those populations and if that change would reduce appreciably the likelihood of both the survival and recovery of the species.

Using the ESU-Level Recovery Criteria identified in the spring-run 5-year status review, (National Marine Fisheries Service 2016b) the combined risk to individual populations are evaluated to determine the risk to the ESU as a whole. These recovery criteria for spring-run are distributed by diversity group such that recovery will be achieved by establishing:

- One population in the Northwestern California Diversity Group at low risk of extinction,
- Two populations in the Basalt and Porous Lava Diversity Group at low risk of extinction,
- Four populations in the Northern Sierra Diversity Group at low risk of extinction,
- Two populations in the Southern Sierra Diversity Group at low risk of extinction, and
- Maintain multiple populations at moderate risk of extinction

With regard to the recovery of the species, the action must not increase the extinction risk of current spring-run populations so as to preclude establishing at least eight populations at a low risk of extinction distributed throughout the Central Valley, as well as additional populations at a moderate risk of extinction.

For populations of the Sacramento River basin, those of the Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada diversity groups; the VSP analysis shows that the construction elements of the PA are not expected to appreciably reduce the viability of any of the Core 1 populations. Likewise, the VSP analysis shows that the construction elements of the proposed action are not expected to appreciably reduce the viability of the populations of the Southern Sierra Nevada diversity group. With regard to post-construction operation of the NDD, it is likely that Sacramento River basin spring-run Core 2 populations would remain at a high risk of extinction, given their small size and relative sensitivity to stressors. And, although there is considerable uncertainty regarding the effects of operations in the south Delta, the effect on the viability of the spring-run populations of the San Joaquin Basin is such that it would not reduce and may support the viability of the populations therein. These conclusions are based on commitments in the PA and the revised PA as explained in the VSP analysis, including that final NDD design and operation will be established based on significant testing, refinement, and adaptive management. Based on our analysis, NMFS concludes that, although the PA would reduce some of the viability parameters for Core 2 populations in the Sacramento River basin which are all currently at a high risk of extinction, it is not likely to increase the extinction risk of those populations or any other populations, which would otherwise lead to an increase in the risk of extinction for the species. Therefore, NMFS concludes the proposed action is not expected to appreciably reduce the likelihood of both the survival and recovery of the CV spring-run Chinook salmon ESU.

Table 2-251. Reasoning and decision-making steps for analyzing the effects of the proposed action on spring-run. Bold type indicates the conclusion made at each step of the decision-making process. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and not likely/likely to jeopardize (NLJ/LJ).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment. Available Evidence: The PA will produce multiple stressors that will adversely affect spring-run including, but not limited to: acoustic effects, sediment concentration and contaminant effects, increased predation, impingement and entrainment, and effects related to reduced Delta flows.	True	End
		False	**Go to B**
B	Listed individuals are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action. Available Evidence: A few individual spring-run will be exposed to construction related activities which occur during the construction work-window, but a much larger proportion of the population will be exposed to year-round construction-related effects (e.g. temporary structures, barge traffic) and the effects of operations.	True	NLAA
		False	**Go to C**
C	Listed individuals are not likely to respond upon being exposed to one or more of the stressors produced by the proposed action. Available Evidence: Multiple stressors, including but not limited to those associated with pile driving, barge traffic, screen impingement and entrainment, and operations, will rise to a level of effect that will engender a response from exposed individuals.	True	NLAA
		False	**Go to D**
D	Any responses are not likely to constitute "take" or reduce the fitness of the individuals that have been exposed. Available Evidence: Multiple stressors, including but not limited to those associated with pile driving, barge traffic, screen impingement and entrainment, and operations, are expected to result in a reduction of overall fitness of individuals and which could rise to the level of "take."	True	NLAA
		False	**Go to E**
E		True	NLJ

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Any reductions in individual fitness are not likely to reduce the viability of the populations those individuals represent. Available Evidence: The overall reduction in fitness of individuals caused by the proposed action is expected to reduce a number of the VSP parameters describing a viable salmonid population. For the Core 1 populations of the Sacramento River basin, and the populations of the San Joaquin River basin, these reductions are expected to be small and/or mitigated by RTO, adaptive management and the commitment to habitat restoration, all of which are outlined in the revised PA. Core 2 populations in the Sacramento River basin are all currently at a high risk of extinction such that reductions in the VSP parameters for these populations will likely reduce the viability of those populations and maintain their high risk of extinction.	**False**	**Go to F**
F	Any reductions in the viability of the exposed populations are not likely to reduce the viability of the species. Available Evidence: The spring-run ESU is composed of Sacramento River Basin populations and San Joaquin River Basin populations and, while elements of the PA are expected to reduce the viability parameters for some of those populations, the PA provides standards and commitments that are reasonably certain to occur to support a conclusion that the proposed action is not likely to reduce the viability of the listed species.	**True**	**NLJ**
		False	LJ

2.7.4 Central Valley Spring-Run Chinook Salmon Critical Habitat

- Designated critical habitat (September 2, 2005, 70 FR 52488)

2.7.4.1 Status of Critical Habitat and Environmental Baseline

As described in section 2.2.1.2 (and at length in Appendix A Rangewide Status of the Species and Critical Habitat), the geographic extent of designated critical habitat for Central Valley spring-run Chinook salmon includes stream reaches of the Feather, Yuba, and American rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks, and the Sacramento River, as well as portions of the northern Delta. Spring-run critical habitat is composed of four physical or biological features that include freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine habitat. NMFS has evaluated the effect of the PA in terms of its effect on habitats for spawning adults, incubating eggs, and rearing fry; freshwater rearing habitat for juveniles; freshwater migratory corridors; and, estuarine habitat for rearing and migration.

As described in Section 2.4.1.2 Status of Central Valley Spring-run Chinook Critical Habitat in the Action Area, the status of critical habitat in the environmental baseline has many of its PBFs impaired, such that it provides limited high quality habitat. For example, there are presently a number of features that lessen the quality of migratory corridors for juveniles including: passage impediments, altered flows in the Delta, and a lack of floodplain habitat. However, even in the degraded state, the available habitat has a high value for the conservation of the species because its function directly affects the spawning success, access to migratory corridors, and rearing potential of the species.

2.7.4.2 Summary of Proposed Action Effects

Detailed descriptions regarding the impacts to designated critical habitat for spring-run caused by stressors associated with the proposed action are presented in section 2.5.2, Effects of the Action to Critical Habitat. The proposed action-related effects to spring-run critical habitat have been further separated by life-stage specific habitat type and assessed by the effects on the PBFs found therein. Much like the effects to the species, the effects to spring-run critical habitat are summarized in Table 2-252:

Table 2-252. Integration and synthesis of effects on spring-run critical habitat.

Section Number	Action Component	Location of Effect	Physical and Biological Features Affected	Response and Rationale of Effect	Magnitude	Weight of Evidence	Probable Change in PBF Supporting the Life History Needs of the Species
2.5.2.2.1	Upstream Temperatures, (section 2.5.1.2.1); Redd Dewatering, (section 2.5.1.2.2); and Redd Scour (section 2.5.1.2.3).	Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry:	- Freshwater spawning sites with sufficient water quantity and quality conditions and substrate supporting spawning, incubation, and larval development.	Temperatures in spawning/incubation habitats are such that the capacity of the habitat to develop temperature quality related to the PBF remains limited. Flow changes cause increased redd dewatering particularly in June; little response/effect is expected related to redd scour. No change expected in the availability of spawning substrate and prey.	Low – flow fluctuations (redd dewatering) and limited temperature capacity, maintain a degraded function of these PBFs although there are only marginal differences between the PA and the NAA.	Medium – Multiple peer reviewed sources and quantitative modeling support conclusions. Modeling is somewhat limited by the coarse resolution of data (monthly time scale).	- Reductions or limitations to potential improvement in the quantity (available flows) and quality (water temperatures) of the PBF.
2.5.2.2.2	Clearing and Grubbing, (section 2.5.1.1.4.1); Barge Propeller Injury and Entrainment, (section 2.5.1.1.7.3); Screen Impingement and Entrainment North Delta Intakes (section 2.5.1.2.5); and Contaminant Exposure (section 2.5.1.1.3).	Freshwater Rearing Habitat for Juveniles:	- Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions that support juvenile growth and mobility; water quality and forage supporting juvenile salmonid development; and natural cover such as shade, submerged and overhanging large woody material, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.	Degradation to PBFs is anticipated as a result of physical disturbance; increased predation risk; sedimentation; risk of impingement; and loss of habitat complexity caused by the PA. However, mitigation measures and the relative scale of disturbances are such that the effect of contaminant, and clearing and grubbing disturbances is expected to be minimal.	Medium – the quality of riparian habitat in the immediate vicinity of the NDD will be diminished; this will also constitute a reduction in the quantity of habitat (WUA) during the migration period for certain year types.	Medium – Multiple peer reviewed sources support conclusions.	- Reduction in the quality of available habitat that would otherwise support growth mobility and development. - Reduction in the quantity of floodplain connectivity (WUA).

2.5.2.2.3	Construction Effects, (section 2.5.1.1); Barge Propeller Injury and Entrainment, (section 2.5.1.1.7.3); Permanent In-water Structures (section 2.5.1.2.6.1) and Reduced In-Delta Flows (section 2.5.1.2.7).	Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults:	- Freshwater migration corridors free of obstruction and excess predation with water quantity and quality conditions and natural cover such as submerged and overhanging large woody objects, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.	Permanent in-water structures will create habitat that favors predator species such that predation risk/pressure will be increased, which will reduce access downstream for migrating juveniles. Likewise, reduced in-Delta flows caused by the NDD will directly impact the downstream transport of juveniles. Most construction-related activities will be mitigated by the work window such that they are not expected to limit the access of migrating adult and juvenile spring-run.	Medium – Reduced in-Delta flows will remain adequate for juvenile transport and construction-related reductions to both upstream and downstream access are expected to be minimal.	High – Multiple peer reviewed sources and quantitative modeling support conclusions.	- Reduction in quality of available habitat that should otherwise be free of obstruction and excess predation.

2.5.2.2.4	Clearing and Grubbing, (section 2.5.1.1.4.1); Barge Propeller Injury and Entrainment, (section 2.5.1.1.7.3); Screen Impingement and Entrainment North Delta Intakes (section 2.5.1.2.5); Sediment Concentration (section 2.5.1.1.2) and Reduced In-Delta Flows (section 2.5.1.2.7).	Estuarine Habitat for Rearing and Migration:	- Estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and salt water; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.	Degradation to PBFs is anticipated as a result of physical disturbance; increased predation risk; sedimentation; risk of impingement; and a reduced occurrence of riparian inundation caused by the PA. However, mitigation measures and the relative scale of disturbances are such that the effect of sediment concentration, and clearing and grubbing disturbances is expected to be minimal.	Medium – The quality of riparian habitat downstream of the NDD will be diminished and the reduction in access to riparian habitats (bench inundation) would constitute a reduction in the quantity of habitat.	High – Multiple peer reviewed sources and quantitative modeling support conclusions.	- Reduction in the quality (increased predation risk, loss of habitat complexity) and quantity (reduced bench inundation) of available habitat.

Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry

With the PA, NMFS expects that there would be an appreciable reduction in the PBFs of spring-run critical habitat, specifically for sufficient water quantity and quality conditions and substrate to support spawning, incubation, and larval development. There is some uncertainty associated with the effect of the PA in the temperature analyses included in Section 2.5.1.2 where a temperature threshold analysis, SALMOD model analysis, and the SWFSC's egg mortality model analysis, all suggest that implementation of the PA, when added to the effects of the environmental baseline, would have adverse effects to spawning habitat in the Sacramento River utilized by CV spring-run Chinook salmon. These results indicate that in the current environmental baseline, potential spawning habitat is already reduced by current water operations and temperature control efforts. In the Sacramento River, where spawning is restricted to the small area below Keswick Dam, even modest reductions in water quantity and quality will diminish habitat for spawning adults, incubation of eggs, and rearing for fry. The revised PA includes a recommitment to expanding the available habitat for spawning adults, incubation of eggs, and rearing for fry, specifically in Battle Creek and above Shasta dam, into the McCloud River, which will increase the quantity and quality of this PBF.

Freshwater Rearing Habitat for Juveniles

Construction related effects of the proposed action are expected to cause some intermittent and minor impacts to the PBFs of spring-run critical habitat, specifically with regard to water quantity and floodplain connectivity adequate enough to form and maintain physical habitat conditions that support juvenile growth and mobility; water quality and forage sufficient to support juvenile salmonid development; and available natural cover necessary for successful juvenile development and survival. As a result of the construction aspects of the proposed action, freshwater rearing habitat for juveniles will be degraded by the effective removal of 20.1 acres of tidal perennial habitat and 1.02 linear miles of channel margin habitat; installation of interim structures and corresponding reduction of habitat complexity at the NDD sites; and an increase in construction-related disturbances which reduce the habitat's capacity for successful juvenile development and survival.

The acreage of critical habitat loss for each structure, including areas located in designated critical habitat that could be affected by placement of permanent in-water structures, and the temporary areas of loss (i.e., areas that will only be affected during construction activities) were calculated and will be sufficiently offset for through channel margin and tidal perennial habitat creation/restoration in the appropriate areas (see Appendix A2 Proposed Action). In addition, the revised PA includes 80 acres of expanded habitat upstream of Red Bluff Diversion Dam, and 1,800 acres of tidal habitat restoration in the Delta. Given the relative scale of permanent loss compared to the total abundance of adequate habitat in the immediate area and the level of habitat mitigation/compensation proposed as part of the PA at this time, it is likely that the resultant reduction of habitat, habitat complexity, and increase in disturbances will lead to a temporary degradation of these PBFs that will not extend beyond the construction period. In addition, the impact of increased predation at the temporary structures proposed under the PA has the potential to further impact freshwater rearing habitat for juvenile spring-run Chinook salmon.

As a result of the operation of the NDD under the PA and because of the sustained, year-round risk of predation associated with permanent in-water structures as well as the effects of impingement at the NDD screens, the PBF of freshwater rearing habitat at those locations is reduced. Specifically, the direct juvenile mortality caused by the NDD screens results in riparian habitat that is diminished in its capacity to promote juvenile growth, mobility and development. Differences between the PA and NAA in rearing WUA were examined, and rearing WUA of the PA was found to generally match rearing WUA of the NAA for all water year types but, in some instances, WUA was decreased under the PA relative to the NAA, such that the water quantity and floodplain connectivity is reduced during certain year-types and months during spring-run Chinook salmon juvenile rearing. To mitigate this loss, there are significant commitments to habitat restoration including 80 acres of expanded habitat upstream of Red Bluff Diversion Dam, and 1,800 acres of tidal habitat restoration in the Delta that will ultimately improve Delta survival and the commitment to the revised Adaptive Management Plan, includes research to assess and mitigate Sacramento River basin predation (Appendix A2, Adaptive Management Program) which will improve the freshwater rearing habitat PBF for juveniles.

Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults

Construction and operation of the NDD are expected to reduce the PBFs of the migratory corridor habitat for spring-run. Increased predation risk, risk of impingement, and loss of habitat complexity are all stressors that are likely to reduce juvenile survival during outmigration, thus degrading the PBF of migration corridors free of obstruction and excess predation with water quantity and quality conditions and natural cover. Some of the effect of these stressors on spring-run critical habitat may be inferred by the results of the WRLCM which show the survival of outmigrating winter-run smolts originating from the Lower River is reduced in the PA compared to the NAA. Conversely, for smolts originating in the Delta, the WRLCM shows opposite, where survival is increased under the PA compared to the NAA. Considering that differences in survival between the PA and the NAA are larger in the Lower River, the overall effect of the PA would be expected to reduce juvenile spring-run survival and to diminish the riparian habitat and its ability to support successful juvenile development and survival. This reduction in survival is expected to be minimized because the commitment to unlimited pulse protections included in the revised PA will reduce the exposure of juveniles to the reduced flows.

Spawning adults migrating through the mainstem Sacramento River will also encounter physical disturbance from barge operations during the construction period, which may impede upstream migration, degrading the PBF characterized by access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River. These effects have been reduced by the additional restrictions placed on barge operations by the revised PA, such that the PBF characterized by access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River will experience only a minor reduction.

Estuarine Habitat for Rearing and Migration

Construction activities under the proposed action are expected to cause some intermittent and minor impacts to the PBF of estuarine habitat. Minimal loss of riparian habitat is anticipated to occur at barge landing sites located within the Delta. The footprint of construction at these sites is not yet finalized; however, associated removal of vegetation is expected to result in relatively minor impacts to the riparian habitat that provides for successful juvenile development and survival. Riparian and estuarine PBFs will experience minor degradation due to physical disturbance and risk of propeller entrainment year-round as barge operations are carried out in the Delta. However, given the temporary nature of the disturbance, coupled with the BMPs proposed as part of the PA, it is unlikely that the resultant disturbances will lead to a significant degradation of these PBFs.

Changes to in-Delta flow caused by operation of the NDD are projected to result in increased travel time for juvenile spring-run Chinook salmon, increase entry into the lower quality interior Delta corridors, and result in reduced survival of spring-run juveniles. Access to the riparian habitat that provides for successful juvenile development and survival will be reduced under the PA relative to the NAA, because as flows downstream of the NDD are reduced the inundation of the wetland and riparian benches that serve as rearing habitats are reduced as well. The riparian bench inundation index below the NDD is shown to decrease for all water year types under the PA. Entry into the interior Delta is also expected to increase under the PA which increases juvenile spring-run susceptibility to predation and poor water quality. This in turn will reduce the successful development and survival of juveniles, limiting the access downstream.

Overall, the effects of operations on flow as modeled for the PA without consideration of the explicit commitments made in the revised PA, would degrade estuarine habitat for rearing and migration, through reductions in water quantity and quality. However, the following commitments and criteria described in the revised PA are expected to reduce the impact of operations such that the effect on estuarine habitat for rearing and migration would result in only a small reduction in the quality and quantity of the PBF. Specifically:

- The revised real-time operations for the NDD which include 1) unlimited pulse protections, 2) increased allowable diversions (relative to previous PA) during high flow events with a required minimum bypass flow, and 3) initial fish-based transitional criteria and post-pulse pumping protections based on conditions in CDFW’s draft permit under California Fish and Game Code section 2081 (BA section 3.3.3.1.1 Pulse-Protection). These initial real-time operational criteria are expected to maintain flows during fish presence such that flows will be adequate to provide access to riparian habitats and migration downstream.

- As part of a larger commitment to habitat restoration, the revised PA includes 1,800 acres of tidal restoration in the Delta to function as juvenile rearing habitat. This coupled with the 9,000 acres of habitat restoration proposed under existing conditions may be enough to address reverse flows, but in order to reduce uncertainty that those acreages are enough, an additional commitment was made to restore in Delta habitat for the express purpose to “sufficiently address potential undesirable hydrodynamic effects of the NDD operations” (BA section 3.4.3.1.2). The Revised PA states that “DWR and Reclamation also commit to providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations,” thereby implementing the earlier commitment to avoid and minimize this adverse effect.

- Assurance that existing DCC gate closures adhere to the expectations of the criteria stated in NMFS 2009 biological opinion. Specifically, DCC closure for downstream flood control will be based on Sacramento River flow at Freeport, upstream of the north Delta diversion facilities (BA Table 3.3-1). This particular operational criteria will maintain flows in the mainstem Sacramento River to ensure that there is adequate water quality, water quantity, and salinity conditions.

With these explicit commitments made in the revised PA, NMFS expects that the PBFs of estuarine habitat for rearing and migration will experience only small reductions in quantity and quality.

2.7.4.3 Impact to the Critical Habitat of the Species at the Designation Level

As described in section 2.2 and Appendix A Rangewide Status of the Species and Critical Habitat and Section 2.4.1.4 Status of Central Valley Spring-run Chinook Critical Habitat in the Action Area, many of the physical or biological features that are essential for the conservation of spring-run are currently degraded. Also the effects of future State, tribal, local, or private actions, described in section 2.6 Cumulative Effects are not likely to improve the PBFs, which will most likely remain in their degraded state. As a result of implementing the PA, the value of critical habitat for the conservation of the species, with respect to some of the PBFs, will be reduced in some areas. However, the condition of other PBFs will be increased or maintained in their current state with implementation of the PA, and none of the reductions to the value of critical habitat are expected to result in an appreciable diminishment of the overall value of the critical habitat for the conservation of the species Based on our analysis, NMFS concludes that the proposed action is not likely to appreciably diminish the value of the critical habitat for the conservation of Central Valley spring-run Chinook salmon.

Table 2-253. Reasoning and decision-making steps for analyzing the effects of the proposed action on spring-run critical habitat. Bold type identifies the conclusion at each step of decision-making. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and destruction or adverse modification of critical habitat (D/AD MOD).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment. Available Evidence: The PA will produce multiple stressors that will adversely affect the environment including, but not limited to: acoustic effects, sediment concentration and contaminant effects, increased predation, impingement and entrainment, and effects related to altered flows and temperatures.	True	End
		False	**Go to B**
B		True	NLAA

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Areas of designated critical habitat are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action. Available Evidence: Areas of spring-run designated critical habitat will be exposed to multiple stressors produced by the PA, including habitats such as: Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry; Freshwater Rearing Habitat for Juveniles; Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults; and Estuarine Habitat for Rearing and Migration.	**False**	**Go to C**
C	The quantity or quality of any physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to be reduced upon being exposed to one or more of the stressors produced by the proposed action. Available Evidence: In multiple instances the quantity and quality of the PBFs of spring-run critical habitat, or in some cases the capacity of the critical habitat to develop those features, will be reduced by the PA. For example, altered flows downstream of the NDD will reduce the extent and frequency of riparian bench inundation which will effectively reduce the quantity of natural cover such as submerged and overhanging large woody objects, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival; reduced in-Delta flows will increase the time needed for juvenile migration which reduces the quality of freshwater migration corridors free of obstruction and excess predation; and the effects of the PA when combined with the environmental baseline will limit the capacity of upstream habitats to develop freshwater spawning sites with sufficient water quantity and quality conditions and substrate supporting spawning, incubation, and larval development.	True **False**	NLAA **Go to D**
D		True	NLAA

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Any reductions in the quantity or quality of one or more physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to reduce the value of critical habitat for the conservation of the species in the exposed area. Available Evidence: The reductions in quantity and quality of PBFs, as well as the reductions in the capacity of the critical habitat to develop these features over time, is expected to reduce the value of the habitat. Particularly with regard to the Freshwater rearing sites and the Estuarine areas, the PA is expected to further impair the waterways of the Delta designated as critical habitat for spring-run in their abilities to function as rearing and migratory corridors.	**False**	**Go to E**
E	Any reductions in the value of critical habitat for the conservation of the species in the exposed area of critical habitat are not likely to appreciably diminish the overall value of critical habitat for the conservation of the species. Available Evidence: As a result of implementing the PA, the value of critical habitat for the conservation of the species, with respect to some of the PBFs, will be reduced in some areas. However, the condition of other PBFs will be increased or maintained in their current state with implementation of the PA, and none of the reductions to the value of critical habitat are expected to result in an appreciable diminishment of the overall value of the critical habitat for the conservation of the species	**True**	**No D/AD MOD**
		False	D/AD MOD

2.7.5 CCV Steelhead

- Originally listed as threatened (63 FR 13347, March 19, 1998); reaffirmed as threatened (71 FR 834, January 5, 2006).

Detailed information regarding the federally listed DPS of CCV steelhead life history, status, and VSP parameters can be found in Appendix B Rangewide Status of the Species and Critical Habitat.

2.7.5.1 Status of the Species and Environmental Baseline

The status of the species, as well as the environmental baseline, have been described at length in Sections 2.2 and 2.4, respectively. Critical to the integration and synthesis of effects are the VSP parameters of abundance, productivity, spatial structure, and diversity, which are consistent with the “reproduction, numbers, or distribution” criteria found within the regulatory definition of jeopardy (50 CFR 402.02) and are used as surrogates for “reproduction, numbers, or distribution.” These VSP parameters have been used in each of the status reviews for listed species performed by NMFS; the most recent of which was completed in 2016 (National Marine Fisheries Service 2016a). Status trends from that review are summarized in the following Table 2-254, and the VSP parameters specific to CCV steelhead may be estimated from the status trends. These VSP parameters are used to establish the reference condition of the population in the status of the species and environmental baseline and are used as the basis against which the risk to the populations and the risk to the ESU are assessed.

Table 2-254. Viability metrics for CCV steelhead populations. Total population size (N) is estimated as the sum of estimated run sizes over the most recent three years for independent populations (bold) and dependent populations. The mean population size (Ŝ) is the average of the estimated run sizes for the most recent three years. Population growth rate (or decline; 10 year trend) is estimated from the slope of log-transformed estimated run sizes. The catastrophic metric (Recent Decline) is the largest year-to-year decline in total population size (N) over the most recent 10 such ratios.

Steelhead population	N	Ŝ	10-yr trend (95% CI)	Recent decline (%)
American River[a]	472	157.3	-0.062 (-0.164, 0.039)	45.8
Clear Creek[a]	761	253.7	0.111 (-0.021, 0.244)	9.5
Coleman National Fish Hatchery	8461	2820.3	0.051 (-0.043, 0.146)	18.4
Feather River Hatchery[b]	4119	1373.0	0.061 (-0.171, 0.292)	38.3
Mokelumne River Hatchery	398	132.7	-0.051 (-0.169, 0.067)	30.5
Nimbus Hatchery	4052	1350.7	-0.155 (-0.378, 0.067)	4.5

[a] - American River and Clear Creek steelhead data are derived from redd counts. Some redds may be from non-anadromous O.mykiss or steelhead.

[b] - Feather River Hatchery numbers include repeat spawners (fish returning the hatchery multiple times in a single year). These findings based on recent tagging studies suggest hatchery return numbers are likely slightly inflated.

Steelhead Abundance

Historic CCV steelhead run sizes are difficult to estimate given the paucity of data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s the CCV steelhead run size had declined to about 40,000 adults (McEwan 2001). Hallock et al. (1961) estimated an average of 20,540 adult steelhead through the 1960s in the Sacramento River upstream of the Feather River. Steelhead counts at the Red Bluff Diversion Dam (RBDD) declined from an average of 11,187 from 1967 to 1977, to an average of approximately 2,000 through the early 1990s.

Population trend data remains extremely limited for the CCV steelhead DPS. The total populations on Battle Creek, Coleman NFH, and Feather River Hatchery have significantly increased since the 2010 assessment with all three populations showing positive population growth estimates over the last decade (Williams et al. 2016, see Table 2-254). Steelhead returns to Coleman NFH have increased over the last four years. After a low of only 790 fish in 2010, the two years prior to the 2016 status review averaged 2,895 fish. The estimate of the total population of steelhead returning to the Coleman NFH are 8461 fish with an annual average run size of 2820 fish (NMFS 2016a). Since 2003, adults returning to the hatchery have been classified as wild (unclipped) or hatchery produced (adipose fin clipped). Wild adults counted at the hatchery each year represent a small fraction of overall returns, but their numbers have remained relative steady, typically 200-300 fish each year. Numbers of wild adults have ranged from 185 to 334 in the last five years. This information indicates that hatchery produced fish comprise the majority of the steelhead adult escapement returning to Battle Creek. Starting in 2005, at NMFS' request, only wild steelhead were allowed to pass upstream of the fish weir at the Coleman NFH into the Battle Creek restoration area. Between 2012 and 2014, the total population of natural-origin adults greater than 17 inches (size threshold identified for anadromous O. mykiss at Coleman NFH) passing the weir was 510 with an average run size of 170 adults (Williams et al. 2016). The low natural origin steelhead abundance places it in the moderate extinction risk category, albeit with lower hatchery influence than the previous 2010 assessment.

The returns of steelhead to the Feather River Hatchery were very low in 2009 and 2010, with only 312 and 86 fish returning in those years (NMFS 2016a). Since then the numbers have rebounded, with a high of 1,797 in 2013, and have averaged over 1,100 fish over the last five years. Escapement at this hatchery seems to be quite variable over the years, despite the fact that stocking levels have remained fairly constant and that the vast majority of returning fish to the hatchery are of hatchery origin. In addition, recent tagging studies have shown that there are fish that re-enter the hatchery multiple times in a single season, which may slightly inflate the estimates of adult escapement back to the hatchery (NMFS 2016a).

The adult returns to the Mokelumne River Hatchery have shown a decline of approximately 5% per year over the last decade. Current estimates of the total population size returning to the hatchery are 398 fish with an average annual run of 133 fish. In the Mokelumne River, East Bay Municipal Utilities District (EBMUD) has included steelhead in their redd surveys on the Lower Mokelumne River since the 1999-2000 spawning season (NMFS 2016a). Based on data from these surveys, the overall trend suggests that redd numbers have slightly increased over the years (2000-2010). However, according to Satterthwaite et al. (2010), it is likely that a large majority of the O. mykiss spawning in the Mokelumne River are non-anadromous (or resident) fish rather than steelhead. Video recordings of steelhead moving through the fish ladder at Woodbridge

Dam indicate that 92%–96% of adult steelhead observed were hatchery steelhead, with only 3–10 natural origin steelhead returning to the Mokelumne River each year from 2010–2013. The Mokelumne River steelhead population is highly supplemented by Mokelumne River Hatchery production, and this tributary's steelhead population is considered to have a high risk of extinction based on low numbers and high hatchery influence.

The adult steelhead returns to the Nimbus Hatchery on the American River have declined on average 15.5% per year over the past decade. Current estimates of the total population of steelhead returning to the hatchery are 4,052 fish with an annual run size of 1,351 fish (NMFS 2016a). Within the American River, redd counts have shown a decline of approximately 6% a year over the past decade. Over the period from 2002-2015, the annual average redd count on the American River was 142 redds per year. However, in 2015, only 58 redds were observed, which is the lowest number ever observed for this particular survey. The estimated total population for the American River is 472 fish, based on the redd counts, with an annual run size of 157 fish.

The total steelhead population in Clear Creek has increased over the past decade at approximately 11% per year. The estimated total population size (based on redd counts) is 761 fish with an average run size of 254 fish. The average redd count over the past 10 years is 215, representing approximately 215 to 431 spawning adult female steelhead. The average redd count since 2011 is 231. The vast majority of these steelhead are wild fish, as no hatcheries are present on Clear Creek and no hatchery steelhead are stocked in this waterbody. USFWS biologist have indicated that adipose fin clipped steelhead are rarely observed during surveys on Clear Creek (NMFS 2016a).

Information on steelhead escapement in Mill Creek is now available from a video monitoring station run by CDFW at Ward Dam. Counts of adult steelhead moving upstream have been made since the 2008-09 season. Adult counts have ranged from 60 to 237, with an average of 142 over the last six years. All of these fish appear to be naturally produced (NMFS 2016a).

Escapement data for CCV steelhead in the San Joaquin River basin is spotty. However recent efforts to install weirs with video recording capability have allowed estimates of annual adult escapement to basin tributaries. The numbers of natural origin adult steelhead remains low, with a high hatchery influence, placing the populations in the San Joaquin tributaries forming the Southern Sierra Nevada diversity group at a high risk of extinction. The annual number of adult steelhead counted moving upstream through the Stanislaus River weir ranged from 1 - 17 during 2005 to 2008 and 8 - 32 during 2011 to 2014 (Williams et al. 2016). Thirteen to fifty percent of those fish were identified as hatchery fish having clipped adipose fins, placing the Stanislaus River population at a high risk of extinction based on low numbers and high hatchery influence

Steelhead Productivity

An estimated 100,000 to 300,000 naturally produced juvenile steelhead are estimated to leave the Central Valley annually, based on rough calculations from sporadic catches in trawl gear (Good et al. 2005a), compared to Nobriga and Cadrett (2001) who used adipose fin-clipped (hatchery) to unclipped (wild) steelhead smolt catch ratios in the Chipps Island trawl from 1998 through 2000 to estimate that about 400,000 to 700,000 steelhead smolts are produced naturally each year in the Central Valley. These smolts are predominantly originating from the Sacramento River basin. The Mossdale trawls, on the San Joaquin River conducted annually by CDFW and USFWS, capture steelhead smolts only in very small numbers. Those Mossdale recoveries, which represent migrants from the Stanislaus, Tuolumne, and Merced rivers, suggest that the productivity of CCV steelhead in these tributaries is very low.

Catches of steelhead at the fish collection facilities in the southern Delta are another source of information on the relative abundance of the CCV steelhead DPS, as well as the production of wild steelhead relative to hatchery steelhead (ftp.delta.dfg.ca.gov/salvage). The overall catch of steelhead has declined dramatically since the early 2000s, with an overall average of 2,705 smolts salvaged per year over the last 10 years (2004 to 2014). The percentage of wild (unclipped) fish in salvage has fluctuated, but has leveled off to an average of 36 percent since a high of 93 percent in 1999.

Steelhead Spatial Structure

About 80% of the historical spawning and rearing habitat once used by anadromous O. mykiss in the Central Valley is now upstream of impassible dams (Lindley et al. 2006). Many historical populations of CCV steelhead are entirely above impassable barriers and may persist as resident or adfluvial rainbow trout; however, they are presently not considered part of the DPS. Steelhead are well-distributed throughout the Central Valley below the major rim dams (Good et al. 2005, National Marine Fisheries Service 2016a). Most of the steelhead populations in the Central Valley have a high hatchery component, including Battle Creek (adults intercepted at the Coleman NFH weir), the American River, Feather River, and Mokelumne River.

The Recovery Plan (NMFS 2014b) criteria for delisting CCV steelhead includes a spatial structure very similar to that of spring-run Chinook salmon, with one viable population in the Northwestern California diversity group, two viable populations in the basalt and porous lava diversity group, four viable populations in the northern Sierra Nevada diversity group, and two viable populations in the southern Sierra Nevada diversity group. It is clear that further efforts will need to involve more than restoration of currently accessible watersheds to make the DPS viable. The NMFS Recovery Plan calls for reestablishing populations into historical habitats currently blocked by large dams (National Marine Fisheries Service 2014b). Section 2.4.4.7 (Restoration Actions from NMFS 2009 RPA Opinion on the Long-term operations of CVP/SWP BiOp) identifies several actions from the NMFS 2009 BiOp RPA that are expected to improve the spatial structure for CCV steelhead before operations of the NDD conveyance facilities commence:

- RPA Action I.7: Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass (Improve Yolo Bypass Adult Fish Passage)
- RPA Action I.6.1: Restoration of Floodplain Rearing Habitat (Increase Juvenile Salmonid Access to Yolo Bypass, and Increase Duration and Frequency of Yolo Bypass Floodplain Inundation)
- RPA Action NF 4: Implementation of Pilot Reintroduction Program (Implementation of Pilot Reintroduction Program above Shasta Dam). Note: this action is not specific to steelhead but the species may also benefit from fish passage activities related to reintroduction of Chinook salmon.
- RPA Action IV.1.3: Consider Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta, and Reduce Exposure to CVP and SWP Export Facilities (Including Georgiana Slough Non-Physical Barrier)

- RPA Action I.2.6: Restore Battle Creek for Winter-Run, Spring-Run, and CCV Steelhead (Complete Battle Creek Salmon and Steelhead Restoration Project)

Reclamation and DWR have re-committed to the actions as part of the revisions to the PA (Appendix A2).

Steelhead Diversity

CCV steelhead abundance and growth rates continue to decline, largely the result of a significant reduction in the amount and diversity of habitats available to these populations (Lindley et al. 2006). Evidence of these declines are supported by genetic analysis, where the mean ratio of the number of alleles to the range in allele size, calculated from a population sample of microsatellite loci, decreases when a population is reduced in size (Nielsen et al. 2003). Overall genetic diversity between Central Valley populations has also been shown to be relatively low by Garza and Pearse (2008) who analyzed the genetic relationships among CCV steelhead populations and found that fish below barriers in the Central Valley were often more closely related to below barrier fish from other watersheds than to O. mykiss above barriers in the same watershed. This pattern suggests the ancestral genetic structure is still relatively intact above barriers, but may have been altered below barriers by stock transfers. The genetic diversity of CCV steelhead is also compromised by hatchery origin fish, placing the natural population at a high risk of extinction (Lindley et al. 2007). Steelhead in the Central Valley historically consisted of both summer-run and winter-run migratory forms. Only winter-run (ocean maturing) steelhead currently are found in California Central Valley rivers and streams as summer-run have been extirpated (McEwan and Jackson 1996, Moyle 2002).

Steelhead DPS Viability Summary

All indications are that natural origin CCV steelhead abundance, and the proportion of natural origin steelhead in the DPS, has continued to decrease over the past 25 years (Good et al. 2005a, National Marine Fisheries Service 2016c); with the long-term trend remaining negative. Hatchery production and returns are dominant over natural origin steelhead, with hatchery releases (100 percent adipose fin-clipped fish since 1998) remaining relatively constant over the past decade, but the proportion of adipose fin-clipped hatchery smolts to unclipped naturally produced smolts has steadily increased over the past decade.

Using data through 2005, Lindley et al. (2007a) found that data were insufficient to determine the status of any of the naturally-spawning populations of CCV steelhead, except for those spawning in rivers adjacent to hatcheries, which were likely to be at high risk of extinction due to extensive spawning of hatchery-origin fish in natural areas. And although the widespread distribution of natural origin steelhead in the Central Valley provides the spatial structure necessary for the DPS to survive and avoid localized catastrophes, most natural origin CCV steelhead populations are very small and may lack the resiliency to persist for protracted periods if subjected to additional stressors. The genetic diversity of CCV steelhead has likely been impacted by low population sizes and high numbers of hatchery origin steelhead relative to natural origin fish.

The most recent status review of the CCV steelhead DPS (National Marine Fisheries Service 2016c) found that the status of the DPS has not changed since the 2011 status review.

2.7.5.2 Summary of Proposed Action Effects

Detailed descriptions regarding the exposure, response, and risk to individual steelhead caused by stressors associated with the proposed action are presented in section 2.5, Effects of the Action. The proposed action-related effects to CCV steelhead have been split between construction-related and those that are related to operations and permanent structures. Also included with the assessment of operations is an assessment of the Section 2.5.1.3 Ancillary Delta Facilities, which were originally covered by the 2009 NMFS CVP/SWP opinion but are now part of the PA. The distinction between construction and operations is based on differences in expected duration of effect; effects of construction activities are generally expected to occur over a finite period while effects of operations and permanent structures and ancillary Delta facilities, are considered ongoing. Furthermore, the majority of construction-related effects are minimized by the timing of construction activities and proposed in-water work windows which are scheduled for times of year when winter-run Chinook salmon presence is low or unlikely. Work window timing and the expected duration of in-water construction activities (up to 8 years) are detailed in section 2.5.1.1, Construction Effects, Table 2-9. Site-specific effects of PA elements that will be covered programmatically are not included in this summary of effects, because these elements are at various stages of development, and at this time are lacking sufficient information regarding the potential effects to individual steelhead. These Programmatic Activities (section 2.5.1.4) are instead considered later, in section 2.7.1.3 (Assess Risk to the Population), where the overall effects and/or benefits they provide are analyzed in the assessment of risk to the population and species. The construction-related effects on CCV steelhead are expected to occur over the span of up to 8 years and are summarized in Table 2.-255:

Table 2-255. Integration and synthesis of construction-related effects, with the environmental baseline and cumulative effects, on CCV steelhead.

Section Number	Stressor	Life Stage (Location)	Life Stage Timing (work window intersection)	Response and Rationale of effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of overall Effect (PA + Baseline + Cumulative Effects)	Diversity Groups and/or Populations Affected
2.5.1.1.1.1	Pile Driving (Acoustic)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – mid-June (rare, <1%); Adults: mid-June – mid-March (mid-June – mid-Sept. ~36% of Sac Basin population)	Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed.	Medium - Expected acute effect to a medium proportion of adults and a marginal proportion of juveniles.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Medium - Expected acute effect to medium proportion of adults and a marginal proportion of juveniles. The baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Dec. – June (rare, <1%); Adults: Sacramento Basin origin fish: mid-June–mid-March. San Joaquin basin origin fish Sept. – March (July – Oct.)	Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed.	Low to medium- Expected acute effect to a low to medium proportion of adult populations from both basins and a marginal proportion of juveniles.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Medium – Considering the addition of the baseline and CE which add “periodic” pile driving (Section 2.4.4.6 of the Baseline), there is an acute effect expected on a medium proportion of adult populations from both basins and a marginal proportion of juveniles.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
		Adult immigration (HOR gate)	Adults (SJR): Sept – March (Sept. – Oct.)	Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed.	Medium - Expected acute effect limited to a small proportion of adults	High – Multiple technical publications including quantitative	Reduced survival	Medium – Considering the addition of the baseline and CE which add “periodic” pile driving (Section 2.4.4.6 of the Baseline), there is an expected acute	Southern Sierra Nevada

					immigrating to the San Joaquin basin; however, size of population is very small.	modeling results.		effect limited to a small proportion of adults immigrating to the San Joaquin basin; however, size of population is very small	
		Juvenile rearing and emigration; Adult immigration (barge landings)	Juvenile: Nov. – mid-June (rare, <1-2%); Adults: June – March (July – Aug., approximately 14% of Sacramento Basin population)	Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed.	Low - Expected acute effect limited to a small proportion of adults.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Low - Expected acute effect to a small proportion of the population plus the baseline and CE which add "periodic" pile driving (Section 2.4.4.6 of the Baseline)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.1.2	Barge Traffic (Acoustic)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; Adults: June – March (year round barge traffic, but limited to specific routes and seasons.	Reduced feeding/foraging behavior due to increased stress, distraction (foraging success) and prey masking.	Low - Generally sublethal effect is expected to be imposed on a small proportion of the juvenile steelhead populations	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration and extent of barge operations.	Reduced growth; reduced reproductive success	Medium - Generally a sublethal effect is expected to be imposed on a small proportion of the steelhead juveniles; however, baseline adds that portions of the action area "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.2.1	Pile Driving (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – mid-June (rare, <1%); Adults: mid-June – mid-March (mid-June – mid-Sept.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a medium proportion of adults	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of	Reduced growth; reduced reproductive success	Low - Generally a sublethal effect limited to a medium proportion of adults and a marginal proportion of juveniles; the baseline and CE add "periodic"	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada

			and a marginal proportion of juveniles.	uncertainty regarding extent of sediment resuspension.		pile driving (Section 2.4.4.6 of the Baseline)	
Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Dec. – June (rare, <1%); Adults: mid-June –mid-March for Sacramento River basin fish, Sept through March for SJ River basin fish) (July – Oct.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a low to medium proportion of adults from both basins and a marginal proportion of juveniles.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth; reduced reproductive success	Medium - Generally sublethal effect limited to a low to medium proportion of adults from both basins and a marginal proportion of juveniles; the baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
Adult immigration (HOR gate)	Adults (SJR): Sept – March (Sept. – Oct.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a small proportion of adults immigrating to the San Joaquin basin.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of adults immigrating to the San Joaquin basin; the baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)	Southern Sierra Nevada
Juvenile rearing and emigration; Adult immigration (barge landings)	Juvenile: Nov. – mid-June (rare, <1-2%); Adults: June – March (July – Aug, approximately 14% of Sacramento	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a small proportion of adult steelhead.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding	Reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of adult steelhead; the baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

			Basin population)			extent of sediment resuspension.			
2.5.1.1.2.2	Barge Traffic (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; Adults: June – March (year round barge traffic, but limited to specific routes and seasons.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in turbidity.	Low - Generally sublethal effect expected to be imposed on a small proportion of the steelhead populations. Steelhead originating in the San Joaquin River basin will experience a higher level of exposure.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding timing, duration and extent of barge operations.	Reduced growth; reduced reproductive success	Medium - Generally sublethal effect expected to be imposed on a small proportion of steelhead; however, baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.2.3	Geotechnical Analysis (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; Adults: June – March (Aug – Oct)	No response, as turbidity associated with geotechnical analysis is likely imperceptible.	NA	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	NA	NA (Geotechnical analysis is not included in the Environmental Baseline Section 2.4)	NA
2.5.1.1.2.4	Dredging (Sediment Concentration) + Facility Maintenance (2.5.1.2.9.1)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – June (June, <1-2%); Adults: June – March (June – Oct.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized	Low - Generally sublethal effect limited to a small	Medium – A few scientific publications and nature of outcome is somewhat	Reduced growth	Low - to Medium - Generally sublethal effect limited to a small proportion of the population. The baseline adds	Basalt and Porous Lava, Northwestern California, and Northern

		turbidity. Adult steelhead are not expected to be affected.	proportion of juveniles.	unpredictable because of uncertainty regarding extent of sediment resuspension.		"periodic" dredging projects in the Action Area, that are of "varying scope and scale." (section 2.4.4.4)	Sierra Nevada
Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Dec. – June (rare, <1%); Adults: Sacramento Basin origin fish: mid-June–mid-March. San Joaquin basin origin fish Sept. – March (July – Nov.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a medium proportion of adult steelhead with an increased exposure for the San Joaquin basin origin steelhead.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced reproductive success in exposed adults	Low - Generally sublethal effect limited to a medium proportion of adult steelhead with an increased exposure for the San Joaquin basin origin steelhead; the baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale." (section 2.4.4.4)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
Adult immigration (HOR gate)	Adults (SJR): Sept – March (Sept. – Oct.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a small proportion of adult steelhead immigrating to the San Joaquin basin.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced reproductive success	Low - Generally sublethal effect limited to a small proportion adult steelhead immigrating to the San Joaquin basin.	Southern Sierra Nevada
Juvenile rearing and emigration; Adult immigration	Juvenile: Nov. – mid-June (rare, <1-2%); Adults: June – March (Aug. – Oct.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by	Low - Generally sublethal effect limited to a very small	Medium – A few scientific publications and nature of outcome is somewhat	Reduced growth; reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of steelhead populations, to which the baseline adds "periodic"	Basalt and Porous Lava, Northwestern California, Northern Sierra

		(barge landings)		increases in localized turbidity.	proportion steelhead populations.	unpredictable because of uncertainty regarding extent of sediment resuspension.		dredging projects in the Action Area, that are of "varying scope and scale." (section 2.4.4.4)	Nevada, and Southern Sierra Nevada
2.5.1.1.3.1	Pile Driving (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – mid-June (rare, <1%); Adults: mid-June – mid-March (mid-June – mid-Sept., ~36% of Sac Basin population migrates during work window)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of steelhead.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductiv e success	Medium - Generally a sublethal effect limited to a small proportion of steelhead; however, the baseline adds "documented high levels of contaminants" in the Action Area. (section 2.4.4.1)	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Dec. – June (rare, <1%); Adults: Sacramento Basin origin fish: mid-June–mid-March. San Joaquin basin origin fish Sept. – March (July – Oct.).)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of steelhead, particularly for the San Joaquin basin population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductiv e success	Low - Generally sublethal effect limited to a small proportion of steelhead, particularly for the San Joaquin basin segment. The baseline also adds "documented high levels of contaminants" in the Action Area. (section 2.4.4.1)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
		Adult immigration (HOR gate)	Adults (SJR): Sept – March (Sept. – Oct.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and	Low - Generally sublethal effect limited to a small proportion	Low - Understanding is Medium but nature of outcome is unpredictable owing to	Reduced reproductiv e success	Low - Generally sublethal effect limited to a small proportion of steelhead adults immigrating to the San Joaquin basin. The baseline adds	Southern Sierra Nevada

				development), biochemical (e.g., blood enzyme and ion levels), and histological changes	of steelhead adults immigrating to the San Joaquin basin.	uncertainty regarding sediment composition and extent of exposure.		"documented high levels of contaminants" in the Action Area. (section 2.4.4.1)	
		Juvenile rearing and emigration; Adult immigration (barge landings)	Juvenile: Nov. – mid-June (rare, <1-2%); Adults: June – March (July – Aug.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of steelhead.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductiv e success	Low - Generally sublethal effect limited to a small proportion of steelhead, to which the baseline adds "documented high levels of contaminants" in the Action Area. (section 2.4.4.1)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.3.2	Barge Traffic (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; Adults: June – March (year round barge traffic, but limited to specific routes and seasons.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of steelhead.	Low - Understanding is Medium but nature of outcome is somewhat unpredictable owing to uncertainty regarding timing, duration and extent of barge operations as well as sediment composition.	Reduced growth; reduced reproductiv e success	Low to Medium - Generally sublethal effect limited to a small proportion of the population; however, the baseline adds "documented high levels of contaminants" in the Action Area. (Section 2.4.4.1) and where portions of the action area will "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.3.3	Geotechnical Analysis (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; Adults: June – March (August – October)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth,	Low - Generally sublethal effect limited to a small	Low - Understanding is Medium but nature of outcome is unpredictable	Reduced growth; reduced reproductiv e success	Low - Generally sublethal effect limited to a small proportion of the population. Geotechnical analysis is not included in the	Basalt and Porous Lava, Northwestern California, Northern Sierra

				reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	proportion of steelhead.	owing to uncertainty regarding sediment composition and extent of exposure.		Environmental Baseline, such that the baseline is not expected to contribute to the "overall effect" of the stressor (Section 2.4)	Nevada, and Southern Sierra Nevada
2.5.1.1.3.4	Dredging (Contaminant Exposure) + Facility Maintenance (2.5.1.2.9.1)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – June (June, <1-2%); Adults: June – March (June – Oct., overlap with ~83% of annual adult spawning migration into Sacramento Basin)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of steelhead.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductiv e success	Low - Generally sublethal effect limited to a small proportion of steelhead. The baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale." (section 2.4.4.4)	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
		Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Dec. – June (rare, <1%); Adults: Sacramento Basin origin fish: mid-June–mid-March. San Joaquin basin origin fish Sept. – March (July – Nov.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of steelhead, with an increased exposure for the San Joaquin basin population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductiv e success	Low - Generally a sublethal effect limited to a small proportion of steelhead, with an increased exposure for the San Joaquin basin population. The baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale." (section 2.4.4.4)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
		Adult immigration (HOR gate)	Adults (SJR): Sept – March (Sept. – Oct.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and	Low - Generally sublethal effect limited to a small proportion	Low - Understanding is Medium but nature of outcome is unpredictable owing to	Reduced reproductiv e success	Low - Generally a sublethal effect limited to a small proportion of adult steelhead immigrating to the San Joaquin basin. The baseline adds	Southern Sierra Nevada

				development), biochemical (e.g., blood enzyme and ion levels), and histological changes	of adult steelhead immigrating to the San Joaquin basin.	uncertainty regarding sediment composition and extent of exposure.		"periodic" dredging projects in the Action Area, that are of "varying scope and scale." (section 2.4.4.4)	
		Juvenile rearing and emigration; Adult immigration (barge landings)	Juvenile: Nov. – mid-June (rare, <1-2%); Adults: June – March (Aug. – Oct.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect to a large proportion of adult steelhead and a marginal proportion of juveniles.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced reproductiv e success	Low to medium - Generally a sublethal effect to a large proportion of adult steelhead and a marginal proportion of juveniles. The baseline also adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale." (section 2.4.4.4)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.4.1	Clearing and Grubbing (Increased Temperature) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; Adults: June – March (year round)	No response, as temperature changes associated with removal of riparian vegetation is likely imperceptible.	NA	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to uncertainty regarding the extent of thermal change.	NA	Low – "Due to levee construction, and shoreline development, [which involves the removal of riparian vegetation], estuarine habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the Action Area is improving this condition. (Section 2.4.2.3)	NA
2.5.1.1.5.1	Pile Driving (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; Adults: June – March (mid-June – Oct – Delta wide)	Increasing feeding success rate as anthropogenic produced sound waves may inject prey species into the water column or expose benthic infauna.	Low - Minor or short-term effect that impacts a small proportion of the	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable	Increased growth	Low - Minor or short-term beneficial effect that impacts a small proportion of the Sacramento River and San Joaquin River basin steelhead populations, the	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern

					Sacramento River and San Joaquin River basin steelhead populations.	owing to uncertainty related to extent of prey availability.		baseline and CE add "periodic" pile driving (Section 2.4.4.6 of the Baseline).	Sierra Nevada
2.5.1.1.5.2	Barge Traffic (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; Adults: June – March (year-round)	Increasing feeding success rate as vessel wakes may inject prey species into the water column or expose benthic infauna. Increased suspended sediment may smother epibenthic and burrowing invertebrates, reducing forage base.	Low – A minor effect that impacts a small proportion of the population. Potentially mixed effects to forage species populations.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to timing, duration and extent of barge operations as well as the extent of prey availability.	Increased growth	Low – A minor effect that impacts a small proportion of the population with mixed effects to forage species populations. The relative level of effect is increased by the baseline which adds that portions of the action area "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.5.3	Geotechnical analysis (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (+Delta)	Juvenile: Nov. – mid-June; Adults: June – March (August – October)	No response, as changes in prey abundance and availability associated with geotechnical analysis is likely imperceptible.	NA	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	NA	NA (Geotechnical analysis is not included in the Environmental Baseline Section 2.4)	NA
2.5.1.1.5.4	Dredging (Reduced Prey)	Juvenile rearing and emigration; Adult	Juvenile: Nov. – mid-June; Adults: June – March (June –	Reduced prey availability, decreasing feeding success caused by the removal of benthic	Low - Generally sublethal effect limited to a	Medium - Understanding is High but nature of outcome is	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population. The	Basalt and Porous Lava, Northwestern California, Northern

		immigration (Delta)	Nov Delta wide)	sediments and infauna (prey base).	very small proportion of the population.	somewhat unpredictable because of uncertainty regarding sediment/prey composition.		baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale." (section 2.4.4.4)	Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.5.5	Clearing and Grubbing (Reduced Prey) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; Adults: June – March	Reduced prey availability, decreasing feeding success caused by the removal of riparian flora and associated fauna.	Low - Generally sublethal effect limited to a very small proportion of the population.	High - multiple scientific and technical publications,	Reduced growth	Medium - Generally sublethal effect limited to a very small proportion of the population. The baseline diminishes available prey because "Due to levee construction, and shoreline development, [which involves the removal of riparian vegetation], estuarine habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the Action Area is improving this condition. (Section 2.4.2.3)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.6.1	Pile Driving (Increased Predation)	Juvenile rearing and emigration; (NDD)	Juvenile: Nov. – mid-June (rare, <1%); (mid-June – mid-Sept.)	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Low - Acute effect limited to a very small proportion of the juvenile population.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Low - Expected acute effect limited to a very small proportion of the juvenile population, to which the baseline and CE add "periodic" pile driving (Section 2.4.4.6 of the Baseline)	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
		Juvenile rearing and emigration; (CCF)	Juvenile: Nov. – mid-June (rare, <1%);	Increased mortality (predation) of juveniles caused by anthropogenic noise	Low - Acute effect limited to a very small	Medium - There are a few publications	Reduced survival	Low - Acute effect limited to a very small proportion of the juvenile population to	Basalt and Porous Lava, Northwestern California,

				masking acoustic predator cues, compromising predator avoidance.	proportion of the juvenile population	regarding the effects of sound on predator-prey interactions.		which the baseline and CE add "periodic" pile driving (Section 2.4.4.6 of the Baseline).	Northern Sierra Nevada, and Southern Sierra Nevada
		Adult immigration (HOR gate)	Adults (SJR): Sept – March (Sept. – Oct.)	No anticipated effect or response from returning adults.	NA	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	NA	NA	NA
		Juvenile rearing and emigration; (barge landings)	Juvenile: Nov. – mid-June (rare, <1-2%);	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Low - Expected acute effect limited to a small proportion of juvenile steelhead.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Low - Acute effect limited to a small proportion of the juvenile population to which the baseline and CE add "periodic" pile driving (Section 2.4.4.6 of the Baseline).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.6.2	Barge Traffic (Increased Predation)	Juvenile rearing and emigration (Delta)	Juvenile: Nov. – mid-June (year round barge traffic, but limited to specific routes and seasons.)	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	High - Acute effect to a medium proportion of the population.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	High - Acute effect, expected on a medium proportion of the population; however, baseline and CE add to the effect as portions of the action area "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.6.3	Interim in-water structures (Increased Predation)	Juvenile rearing and emigration (Delta)	Juvenile: Nov. – mid-June (year-round)	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer	Medium - Acute effect limited to a small proportion	Medium – There are few publications regarding the relationship	Reduced survival	Medium – An acute effect limited to a small proportion of the juvenile population. Added to a baseline of	Basalt and Porous Lava, Northwestern California, Northern

				no refugia for small fish.	of the juvenile population.	between predation and reduced habitat complexity.		diminished habitat complexity when "due to levee construction, [and] shoreline development, […] estuarine habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the Action Area is improving this condition. (Section 2.4.2.3)	Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.6.4	Clearing and Grubbing (Increased Predation)	Juvenile rearing and emigration (Delta)	Juvenile: Nov. – mid-June (year-round)	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Low - Expected acute effect limited to a small proportion of juvenile steelhead.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium – An acute effect limited to a small proportion of juvenile steelhead. Added to a baseline of diminished habitat complexity with "levee construction involves the removal of riparian vegetation, resulting in reduced habitat complexity and shading, making juveniles more susceptible to predation." Some restoration work in the Action Area is improving this condition. (Section 2.4.2.3)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.7.1	Pile Driving (Physical Impacts to Fish)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – mid-June (rare, <1%); Adults: mid-June – mid-March (mid-June – mid-Sept., overlaps	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile driving-induced sound creates	Low - Generally sublethal effect limited to a small proportion of steelhead.	High – Multiple technical publications including quantitative modeling results.	Reduced growth (juveniles); reduced reproductiv e success (adults)	Low - Generally sublethal effect limited to a small proportion of steelhead. The baseline and CE add "periodic" pile driving effects (Section 2.4.4.6 of the Baseline).	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada

		with ~36% of annual adult migration to Sacramento River basin)	a temporary barrier to migration.					
	Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Dec. – June (rare, <1%); Adults: Sacramento Basin origin fish: mid-June–mid-March. San Joaquin basin origin fish Sept. – March (July – Nov.)	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile driving-induced sound creates a temporary barrier to migration.	Low - Generally sublethal effect limited to a very small proportion of steelhead.	High – Multiple technical publications including quantitative modeling results.	Reduced growth (juveniles); reduced reproductive success (adults)	Low- The baseline and CE add “periodic” pile driving effects (Section 2.4.4.6 of the Baseline) that are expected to be sublethal and limited to a very small proportion of steelhead.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
	Juvenile rearing and emigration; Adult immigration (HOR gate)	Juvenile: Dec. – June (rare, <1-2%); Adults (SJR): Sept – March (Sept. – Oct.)	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile driving-induced sound creates a temporary barrier to migration.	Low - Generally sublethal effect limited to a very small proportion of steelhead.	High – Multiple technical publications including quantitative modeling results.	Reduced reproductive success	Low - Generally sublethal effect limited to a very small proportion of San Joaquin origin steelhead. The baseline and CE add “periodic” pile driving effects (Section 2.4.4.6 of the Baseline).	Southern Sierra Nevada
	Juvenile rearing and emigration; Adult immigration (barge landings)	Juvenile: Nov. – mid-June (rare, <1-2%); Adults: June – March (July – Aug.)	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile driving-induced sound creates a temporary barrier to migration.	Low - Generally sublethal effect limited to a small proportion of juvenile steelhead and a larger proportion	High – Multiple technical publications including quantitative modeling results.	Reduced growth (juveniles); reduced reproductive success (adults)	Low- The baseline and CE add “periodic” pile driving effects (Section 2.4.4.6 of the Baseline) that are expected to be sublethal and limited to a small proportion of juvenile steelhead and a larger proportion of adult steelhead.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

					of adult steelhead.				
2.5.1.1.7.2	Dredging entrainment (Physical Impacts to Fish) + Facility Maintenance (2.5.1.2.10)	Juvenile rearing and emigration (Delta)	Juvenile: Nov. – mid-June (June – Nov.)	Mortality from entrainment into dredge cutterhead. Adult fish are will not be affected.	Low - Expected acute effect limited to a very small proportion of juvenile steelhead.	High – There are multiple scientific and technical publications	Reduced survival	Low - The baseline and CE add "periodic" pile driving effects (Section 2.4.4.6 of the Baseline) which are expected to be acute but limited to a very small proportion of juvenile steelhead.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.7.3	Propeller entrainment (Physical Impacts to Fish)	Juvenile rearing and emigration; Adult immigration (Delta)	Juvenile: Nov. – mid-June; (year-round barge traffic) Adults: June – March (year-round barge traffic)	Injury and mortality from entrainment into the propellers of passing barges.	Medium - Expected acute and sustained effect on a small proportion of steelhead.	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration, and extent of barge operations.	Reduced survival	Medium - Acute effect, expected on a small proportion of the population, to which the baseline and CE add that portions of the action area "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.1.7.4	Dewatering (Physical Impacts to Fish) + Facility Maintenance (2.5.1.2.10)	Juvenile rearing and emigration; Adult immigration (NDD)	Juvenile: Nov. – June (June, <1-2%); Adults: June – March (June – Oct.)	Injury and mortality from dewatering and handling during rescue operations. Adult fish are not expected to be affected.	Low - Generally acute lethal effect limited to a very small proportion of juvenile steelhead.	High – There are multiple scientific and technical publications	Reduced survival	Low – Acute effect limited to a very small proportion of the population. (Dewatering is not included in the Environmental Baseline Section 2.4)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
		Juvenile rearing and emigration; Adult immigration (CCF)	Juvenile: Dec. – June (rare, <1%); Adults: July – March. (July – Nov.)	Injury and mortality from dewatering and handling during rescue operations. Adult fish are not expected to be affected.	Low - Generally acute lethal effect limited to a very small proportion	High – There are multiple scientific and technical publications	Reduced survival	Low - Generally acute lethal effect limited to a very small proportion of juvenile steelhead. (Dewatering is not included in the Environmental Baseline Section 2.4)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern

				of juvenile steelhead.				Sierra Nevada
	Adult immigration (HOR gate)	Adults (SJR): Sept – March (Sept. – Oct.)	Adult fish are not expected to be affected.	NA	High – There are multiple scientific and technical publications	NA	NA (Dewatering is not included in the Environmental Baseline Section 2.4)	Southern Sierra Nevada

Post-construction operational effects of the action on steelhead along with the environmental baseline and cumulative effects are summarized in Table 2-256. Understanding of the effects of operations is still being developed and will depend on a number of design criteria and real-time factors. This Opinion analyzes a range of effects depending on the expected use of these criteria and factors. The expectation remains, however, that certain aspects of this effects analysis will be reevaluated through proposed research, monitoring and adaptive management. This expectation is confirmed in Chapter 7 of the BA Effects Determination where, “the RTO and adaptive management and monitoring provisions included in the PA provide additional opportunities to refine the operating criteria and make adjustments to CVP/SWP Delta operations to minimize the risks of incidental take while maximizing water supply.” In this Opinion NMFS’ assessment of operational effects relies on the best scientific and commercial data available (section 2.5.1.2 Operations Effects and section 2.5.1.3 Ancillary Delta Facilities) and with the understanding that the specifics of operations and facility design criteria will be refined within the bounds of the RTO and adaptive management and monitoring programs.

Table 2-256. Integration and synthesis of post-construction, operational effects, with the environmental baseline and cumulative effects on CCV steelhead.

Section Number	Stressor	Life Stage (Location)	Life Stage Timing	Individual Response and Rationale	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of Overall Effect (PA + Baseline + Cumulative Effects)	Diversity Groups and/or Populations Affected
2.5.1.2.1	Operations (Increased Upstream Temperature)	Spawning Adults, Egg incubation, and alevin emergence (Assumed: Sacramento River upstream of RBDD)	November - April	Prespawn mortality, and egg mortality caused by increased temperatures, and daily fluctuation of temperatures.	Low – Temperature effects of the PA relative to the NAA are such that the level of effect is difficult to distinguish.	High: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival, Reduced reproductive success	High – Temperature effects place a high magnitude stress on the species at this life stage accounting for a large amount of mortality. From the baseline: “freshwater spawning sites for these species has been degraded within the action area due to high water temperatures, redd dewatering, and loss of spawning gravel recruitment in reaches below Keswick Dam” (section 2.4.2.3, and section 2.4.4.1.1). These effects may be minimized by real-time operational management.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada
		Kelt Emigration (Sacramento River upstream of the Delta)	February - May	Sub-optimal growth caused by increased temperatures, and daily fluctuation of temperatures.	NA - Little effect associated with temperatures during the February to May time period throughout which	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is	NA	NA - Little effect associated with temperatures during the February to May time period throughout which temperature thresholds are not exceeded.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada

			temperature thresholds are not exceeded	uncertainty with the modeling results which are based on downscaled monthly data.			
Juvenile rearing (Sacramento River, Keswick Dam to RBDD)	Year round	Sub-optimal growth and impaired smoltification caused by increased temperatures, and daily fluctuation of temperatures.	Low –Subtle trend towards slightly higher water temperatures in drier years in late summer and early fall under the PA	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced growth	Low – For most of the year, temperatures place a low magnitude stress on the species at this life stage accounting for sublethal effects to the species. However, the effect of the PA relative to the NAA is such that the level of effect is difficult to distinguish.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada
Smolt Emigration (Sacramento River, Keswick Dam to RBDD)	November - June	Sub-optimal growth, impaired smoltification , and delayed or advanced migration caused by increased temperatures, and daily fluctuation of temperatures.	NA –PA does not differ substantially from NAA during peak periods of smolt emigration.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	NA	NA – no effect associated with temperatures during the smolt emigration period as the limited exceedances that would occur (April, May and June) do so outside the peak period of steelhead migration downstream (January through March).	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada
Adult immigration and holding, (Sacramento River, Keswick Dam to RBDD)	August – March (Immigration); September - November (Holding)	Delayed immigration and prespawn mortality of eggs caused by increased temperatures, and daily	Low – Modeling indicates that PA has slightly more days above critical temperature thresholds for adult holding in August and	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is	Reduced reproductive success	Medium– Temperatures place a medium magnitude stress on the species at this life stage that can cause lethal and sub-lethal effects. However the effect of the PA relative to the NAA is	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada

		fluctuation of temperatures.	September of critically dry years.	uncertainty with the modeling results which are based on downscaled monthly data.		such that the level of effect is difficult to distinguish	
Spawning Adults, Egg incubation, and alevin emergence (American River)	November - April	Prespawn mortality, reduced fitness of eggs and egg mortality caused by increased temperatures, and daily fluctuation of temperatures.	Low –PA does not differ substantially from NAA during peak periods of December through May spawning, egg incubation, and alevin development.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival, Reduced reproductive success	High – Elevated temperatures under baseline conditions place a high magnitude stress on the species causing reduced fitness and mortality of eggs. However the effect of the PA relative to the NAA is such that the level of effect is difficult to distinguish	Northern Sierra
Kelt Emigration (American River)	February - May	Sub-optimal growth caused by increased temperatures, and daily fluctuation of temperatures.	Low – The PA does not differ substantially from the NAA during the February through April period of Kelt emigration and is only slightly higher in temperature in May during critical water year types.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However, there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced growth	Low – Sublethal effect associated with elevated temperatures isolated to the month of May in some year types. However, the effect of the PA relative to the NAA is such that the level of effect is difficult to distinguish over the future baseline.	Northern Sierra
Juvenile rearing, (American River)	Year round	Sub-optimal growth and impaired smoltification caused by increased temperatures, and daily	Low- The PA does not differ substantially from the NAA in mean monthly water temperatures. Minimal	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results.	Reduced growth	Medium – Temperatures place a medium magnitude stress on the species at this life stage accounting for sublethal effects to the species. However the	Northern Sierra

				fluctuation of temperatures.	differences in the percentage of days that exceed temperature thresholds for rearing.	However there is uncertainty with the modeling results which are based on downscaled monthly data.		effect of the PA relative to the NAA is such that the level of effect is difficult to distinguish	
		Smolt Emigration (American River)	December - June	Sub-optimal growth, impaired smoltification, and delayed or advanced migration caused by increased temperatures, and daily fluctuation of temperatures.	NA – Minimal differences between mean monthly water temperatures for the PA and NAA scenarios. Minimal differences in the exceedances of temperature thresholds for smolt emigration (January through March) between PA and NAA scenarios	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	NA	NA - no effect associated with temperatures during the smolt emigration period as the limited exceedances that would occur (April, May and June) do so outside the peak period of steelhead migration downstream (January through March).	Northern Sierra
		Adult immigration and holding, (American River)	October – April (Immigration); October - November (Holding)	Delayed immigration and prespawn mortality and reduced fitness of eggs caused by increased temperatures, and daily fluctuation of temperatures.	Low- Minimal differences in mean monthly water temperatures with PA trending to slightly higher water temperatures in some months and water year types.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced reproductive success	Medium– Temperatures place a medium magnitude stress on the species at this life stage that can cause lethal and sub-lethal effects. However, the effect of the PA relative to the NAA is such that the level of effect is difficult to distinguish	Northern Sierra
2.5.1.2.2	Operations (Redd Dewatering)	Egg incubation, and alevin emergence (Assumed:	November - April	Redd dewatering; loss of a portion, or all	NA – Modeling indicates that PA would rarely have more redd dewatering than	Medium: Supported by multiple scientific and technical publications,	Reduced survival	Medium –- Expected acute population effect on a small proportion of the population.	Basalt and Porous Lava, Northwestern California, Northern

		Sacramento River upstream of RBDD)		eggs in a redd.	the NAA scenario over the range of conditions modeled.	including quantitative data, and modeled results. However, there is uncertainty with the modeling results which are based on downscaled monthly data.		(section 2.4.2.3, see also section 2.5.1.2.2)	Sierra Nevada
		Egg incubation, Fry rearing (American River)	December - May	Redd dewatering; loss of a portion, or all eggs in a redd.	Low-Modeling indicates small increases in the percentage of flow reductions that could cause redd dewatering under the PA in most years.	Low: Supported by scientific and technical publications, however quantitative data, and modeled results are lacking. There is also uncertainty with the available modeling results which are based on downscaled monthly data.	Reduced survival	Medium –Expected acute population effect on a small proportion of the population. (section 2.4.2.3, see also section 2.5.1.2.2)	Northern Sierra
2.5.1.2.3	Operations (Redd Scour)	Egg incubation, and alevin emergence (Assumed: Sacramento River upstream of RBDD)	November - April	Mortality either directly as high flows displace or disrupt redds or flows may increase fine sediment infiltration and indirectly decrease egg survival.	Low-Modeling indicates small increases in the percentage of flows exceeding threshold for redd scour at Red Bluff (1%) under the PA.	Medium: Supported by multiple scientific and technical publications. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival	Low – Expected acute affect in very rare cases (less than 1% of months) (section 2.4.4.1.1, see also section 2.5.1.2.3)	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada
		Egg incubation, Fry rearing (American River)	December - May	Mortality either directly as high flows displace or disrupt redds	Low- Modeling indicates small increases in the percentage of flows exceeding threshold for	Medium: Supported by multiple scientific and technical publications. However there is	Reduced survival	Low – Expected acute affect in very rare cases (less than 1% of months) (section 2.4.4.1.1, see also section 2.5.1.2.3)	Northern Sierra

				or flows may increase fine sediment infiltration and indirectly decrease egg survival.	redd scour on the American River in some months and water year types.	uncertainty with the modeling results which are based on downscaled monthly data.			
2.5.1.2.4	Operations (Stranding)	Juvenile rearing and Adult holding (Sacramento and American Rivers)	Year round	Mortality either directly through desiccation or indirectly through predation or reduced water quality.	Low-Modeling indicates lower flows in some months and water year types under the PA; however, modeling cannot determine rate of flow decreases that are germane to stranding risks.	High: Supported by multiple scientific and technical publications including recent and historic observations.	Reduced survival	Medium - Expected acute effect on a small proportion of the population; however, the effect of the PA relative to the NAA is such that the level of effect is difficult to distinguish	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada
2.5.1.2.5	Operations (Impingement and Entrainment)	Smolt emigration (NDD)	November - June	Mortality from contact with fish screen, and indirectly predation; sublethal effects from injury (e.g. loss of scales, disorientation).	Medium – Available information suggests that screens could have substantial localized effects. For all three intakes combined expected annual entrainment would be <0.1%, and combined injury and mortality from impingement would be <9.0%. The proportion of the population exposed is expected to be	Medium - Understanding is High but nature of outcome is somewhat unpredictable due to uncertainty of exposure. For all three intakes combined expected annual entrainment would be <0.1%, and combined injury and mortality from impingement would be <9.0%.The proportion of the population exposed is expected to be reduced by the commitment to UPP and phased testing	Reduced survival	Medium - Expected sustained population effect. For all three intakes combined expected annual entrainment would be <0.1%, and combined injury and mortality from impingement would be <9.0%. The proportion of the population exposed is expected to be reduced by the commitment to UPP and phased testing to ensure the fish screens meet NMFS criteria.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada

					reduced by the commitment to UPP and phased testing to ensure the fish screens meet NMFS criteria.	to ensure the fish screens meet NMFS criteria.			
2.5.1.2.6.1	Permanent In-water Structures (Increased Predation)	Smolt emigration (NDD)	November - June	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Medium - Expected sustained population effect on a moderate proportion of the population.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium - Effect limited to a moderate proportion of the population.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada and Southern Sierra
2.5.1.2.7	NDD Operations (Travel Time)	Juvenile migration and rearing (Delta)	November - June	Mortality caused by increased migration times, with increases in predator exposure.	Medium - Expected sustained population effect on a large proportion of the population. Real-time operations are expected to reduce this effect.	High - There are a number of publications regarding the relationship between flow, river velocity, and Delta survival and travel time in the North Delta; conclusions supported by modeling results.	Reduced survival	High - Expected sustained population effect on a large proportion of the population. CWF NDD Real-time operations are expected to reduce this effect.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,
2.5.1.2.7.2	NDD Operations (Outmigration routing)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: November - June	Mortality caused by routing into interior Delta routes with lower survival.	Medium - Expected sustained population effect on a medium proportion of the population. Real-time operations are expected to	High - There are a number of publications regarding the relative survival in various North Delta and Central Delta migratory routes; conclusions supported by modeling results.	Reduced survival	Medium - Expected sustained population effect on a medium proportion of the population. CWF NDD Real-time operations are expected to reduce this effect.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,

					reduce this effect.				
2.5.1.2.7.3	Operations (Altered South Delta hydro-dynamics due to South Delta exports)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: December - June	Mortality or decreases in condition due to migratory delays due to altered hydrodynamics and loss of migratory cues. Delays increase exposure to sources of mortality and morbidity (predation, poor water quality, contaminants, etc.)	Medium - Expected sustained population effect on a medium proportion of the population.	Medium to High – Delta hydrodynamics well studied. Effects of Delta hydrodynamics on salmonids more uncertain.	Reduced survival, reduced growth	High - Expected sustained population effect on a medium proportion of the population.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
	Operations (Altered South Delta hydro-dynamics due to HOR gate operations)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: December - June	Decreases in migratory delays due to altered hydrodynamics.	Low - Expected sustained population effect on a small proportion of the population.	Medium – Delta hydrodynamics well studied. Effects of San Joaquin hydrodynamics dependent on integrated HOR gate operations and upstream operations.	Increased survival	Medium - Expected sustained population effect on a small proportion of the population.	Southern Sierra Nevada

2.5.1.2.7.3.1	CVP/SWP Operations (Entrainment and loss at South Delta export facilities)	Juvenile migration and rearing (Delta)	Juvenile migration and rearing: December - June	Loss is approximately 35% of entrained fish at the CVP's Tracy Fish Collection Facility, and 84% at the SWP's Skinner Delta Fish Protective Facility.	Low - Expected sustained population effect on a small proportion of the population.	High – Numerous studies have evaluated screening efficiency, predation, and overall salvage operations survival	Reduced survival	Low - Expected sustained population effect on a small proportion of the population.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.3.1.1	Suisun Marsh Salinity Control Gates	Juvenile rearing and emigration; Adult immigration (Suisun Marsh)	Juveniles: Year-round; Adults: Year-round	Limited effect to juveniles; sublethal, behavioral effect to adults, migration delay and changes to routing.	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population.	Medium – Delta hydrodynamics well studied. Effects of Delta hydrodynamics on salmonid migration more uncertain.	Reduced reproductive success	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.3.1.2	Roaring River Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Mortality caused by entrainment into pumps distributing water to Suisun Marsh.	None – Fish screens of adequate size and approach velocities slow enough to exclude juveniles from entrainment.	Medium – Fish/Screen interactions well studied. Observations at this location limited.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

2.5.1.3.1.3	Morrow Island Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Mortality caused by entrainment into culverts diverting from Goodyear Slough, and draining into Grizzly Bay or Suisun Slough.	None – Entrainment of juveniles unlikely because of location of intakes and probable size of fish.	Low to Medium – Inference based on understanding of fish life history. Observations at this location limited, but include entrainment of fall-run Chinook salmon.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.3.1.4	Goodyear Slough Outfall	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Passive entrainment into Suisun Marsh, possible improvement to water quality and available foraging habitat.	None or Low – Entrainment of juveniles unlikely because of location of intakes and probable size of fish.	Low – Inference based on understanding of fish life history. No observations at this location.	Improved growth	None or Low – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada
2.5.1.3.2	North Bay Aqueduct	Juvenile rearing and emigration; (Delta)	Juveniles: Year-round	Injury and mortality caused by entrainment into pumps or impingement in screens at North Bay Aqueduct, Barker Slough Intake.	None or Low – Entrainment or impingement of juveniles unlikely because of location of intakes, efficacy of fish screens and probable size of fish.	Low to Medium – Inference based on understanding of fish life history. Observations at this location limited.	Reduced survival	None or Low – Insignificant effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada,

2.5.1.3.3	Contra Costa Canal Rock Slough Intake	Juvenile rearing and emigration; (Delta)	Juveniles: Year-round	Injury and mortality caused by entrainment into pumps or impingement in screens at Contra Costa Canal Rock Slough Intake.	None or Low – Entrainment or impingement of juveniles unlikely because of location of intakes, and probable effectiveness of fish screens.	Low to Medium – Inference based on understanding of fish life history. Continued testing of fish screen and vegetation removal expected until at least 2018.	Reduced survival	None or Low – Insignificant effect pending resolution of fish screen sweeping efficiency. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.	Basalt and Porous Lava, Northwestern California, Northern Sierra Nevada, and Southern Sierra Nevada

2.7.5.3 Assess Risk to the Diversity Group Populations

As identified in section 2.1 Analytical Approach, the use of the VSP concept identifies guidelines describing a viable ESU/DPS, where the viability of an ESU or DPS depends on the number of populations within the ESU or DPS, their individual status, their spatial arrangement with respect to each other and to sources of potential catastrophes, and diversity of the populations and their habitat (Lindley et al. 2007). NMFS applies the VSP concept as an approach to evaluate the population viability of with the proposed action and the extinction risk of the ESU or DPS. As described in section 2.5 Effects of the Action, the PA will impose conditions in the Sacramento River and Delta that will either directly or indirectly affect CCV steelhead in a number of ways that would be expected to reduce the fitness of these individuals. Based on the change in fitness of these individuals it is assessed whether collectively these changes constitute a change in the VSP parameters and thereby affect the overall CCV steelhead population. Furthermore, in the effects analysis (section 2.5 Effects of the Action) the effects to individuals within a given diversity group population are not differentiated because many of the effects associated with the proposed action are experienced at locations where individual populations or diversity groups (e.g., Basalt and Porous Lava, Northwestern California, etc.) come together and are typically experienced equally among the individuals of populations originating from a particular basin. For steelhead, individuals of Sacramento River basin populations are analyzed as a single unit, and effects are separately analyzed for San Joaquin River basin steelhead with available information regarding their presence and timing. Ultimately, the impacts to the diversity and spatial structure provided by the individual populations are evaluated here, when the VSP approach is applied. Based on the change in fitness of individuals, while considering the effects and/or benefits provided by the programmatic activities and the minimization aspects of the revised PA, NMFS assesses whether the collective changes, including the environmental baseline and cumulative effects, are expected to constitute a change in the VSP parameters and thereby affect the steelhead DPS.

Sacramento River Basin Steelhead

Collectively the three diversity groups which make up the Sacramento River Basin origin steelhead once held 26 historic populations. Currently, information regarding the condition of Sacramento River basin populations of steelhead is limited and adult steelhead escapement to the Central Valley is likely to be only a few thousand fish each year. With the vast majority of fish returning to the Sacramento River basin tributaries, most of these fish will be of hatchery origin, and only a small percentage will be derived from natural origins (see Appendix B Rangewide Status of the Species and Critical Habitat).

Steelhead Abundance

As described by McElhany et al. (2000b) the three key attributes of the abundance VSP parameter are that a population be: 1) large enough to have a high probability of surviving environmental variability, 2) large enough that compensatory process may provide resilience from environmental and anthropogenic disturbance, and 3) large enough to maintain its genetic diversity. Lindley et al. (2007) identified the effective population size or the census population size, as suitable criteria for assessing the abundance VSP parameter which is then needed to assess the level of risk of extinction for a salmonid population. Here we use changes in the number of adults and changes to individuals' ability to contribute offspring to the population (i.e. the effective population) as measures for any change in the abundance VSP parameter. More specifically, if the probable change in fitness attributed to the effects of a stressor would result in 'reduced survival' or 'reduced reproductive success' (identified in Table 2-255) for a significant proportion of adults, that would be considered a reduction of the abundance VSP parameter of affected populations. Changes to the juvenile population are also considered; however, they are reflected in the assessment of the productivity VSP parameter. Because juveniles do not immediately contribute to the population and are not considered part of the effective population, changes to juvenile fitness is not represented in the assessment of the abundance VSP parameter.

NMFS expects that the PA will have multiple construction-related impacts which may reduce the abundance VSP parameter of Sacramento River basin populations of steelhead. Given the proposed in-water work windows for construction related actions generally extend from June through October and the timing of adult steelhead migration into the basins of the Sacramento River, construction-related effects would be expected to impact large numbers of returning adults. NMFS expects that approximately 83% of the Sacramento River basin fish will move through the Delta during the in-water work window of June through October each year of construction. Presence of juvenile life stages, including smolts, in the Delta are not expected to overlap with the in-water work windows proposed for the PA to any great degree (less than 1-2% of the juvenile population).

Most of the construction-related effects are projected to have a low magnitude of impact to exposed CCV steelhead individuals such that they are unlikely to result in mortality or substantial injury. However, there are certain construction activities that are projected to have medium or high levels of impacts upon exposed steelhead (see Table 2-255). The construction-related impact that will affect the largest proportion of the CCV steelhead population is the driving of sheet piles and foundation pilings for the three NDD intakes on the Sacramento River (Section 2.5.1.1.1.1 Acoustics). Based on the current proposed action description, the temporal exposure of migrating adult steelhead to impact pile driving at the NDD intakes location is mid-June to mid-September, with some flexibility for work window extensions if sound attenuation efforts are successful. However, even this work-window will affect approximately 36% of the annual spawning population moving upriver into the Sacramento River basin each year for the duration of the NDD construction schedule (2022 through 2026: 5 years). A proportion of the fish exposed to impact pile driving noise will suffer lethal injuries due to barotrauma, either immediately or delayed in time following exposure, each construction season which will result in a reduction in the abundance VSP parameter for steelhead populations in the Sacramento River basin. The remainder of the fish exposed to the acoustic noise stressor will incur effects ranging from sub-lethal injuries that may eventually heal to behavioral modifications and elevated stress levels. These effects are likely to reduce the fitness and eventual spawning success of exposed adults which if sufficient to diminish the reproductive success of individuals would constitute a reduction in the effective population size of Sacramento River basin origin steelhead. Pile driving actions at the other construction locations (CCF, HOR Gate, and barge landings) are expected to expose fewer adult steelhead from the Sacramento River basin, such that the actual number of fish lost to the effects of pile driving at these locations is expected to be small by comparison and should not demonstrably diminish the abundance of populations belonging to these diversity groups.

NMFS also assessed the impacts of post-constructional operational impacts in Table 2-256 in the upper Sacramento River below Keswick Dam, the American River below Nimbus Dam, and within the Delta related to the PA. With regard to the upstream operations, effects were determined by comparing modeling outputs for the PA and NAA scenarios using the models described in Section 2.5.1.2 of the Effects Analysis. Differences between the PA and NAA were considered significant if the differences were greater than 5%. Overall, water temperatures in the Sacramento and American rivers showed no significant differences between the PA and NAA scenarios. However, modeled water temperatures as reflected by the environmental baseline (predicted temperatures under current operations, NAA, with climate change) indicate that water temperatures in certain months may reach levels that adversely impact steelhead adults immigrating into the Sacramento and American rivers during critically dry years. This modeling indicates that, when the effects of the proposed action are added to the environmental baseline, there is a potential for reduced abundance during the late summer and early fall for adult steelhead immigrating into and holding in the spawning areas due to exposure to the water temperatures exceeding the critical threshold. These elevated temperatures are expected to negatively affect adult abundance by increasing morbidity and mortality of less fit fish.

Steelhead Productivity

The key attributes of the productivity VSP parameter deal with a population's ability to reproduce itself, survival of early life-stages, and the influence of hatchery produced spawners on the population. Based on these attributes, two common metrics used to assess the productivity VSP parameter are the population growth rate (or decline) and the proportion of spawners of hatchery origin (hatchery influence). These metrics have been further refined by Lindley et. al. (2007) to where the population growth rate (10 year trend estimated from the slope of log-transformed estimated run size) must not show a decline and where hatchery influence must be 'Low' (<10% hatchery influence for 2 generations, or <5% for 3 generations) in order for a salmonid population to be considered at a low risk of extinction. Currently data are lacking for calculation of population growth rates, although some inferences can be made from redd count trends; in Clear Creek the 10-year trend is a positive 11%, and in the American River the 10-year trend has been a decline of 6% (NMFS 2016c). And in both cases data are derived from redd counts where distinguishing between anadromous and non-anadromous O.mykiss redds is difficult. Furthermore hatchery influence on steelhead populations and the species as a whole, as measured by the proportion of Chipps Island midwater trawl catch has risen, exceeding 90% in some years and reaching a high of 95% in 2010 (Williams et al 2011). Given the limitations of using the metrics of population growth rate and hatchery influence to assess changes in steelhead populations' productivity VSP parameter, here we examine actions that would appreciably reduce the natural component of the juvenile population, and actions that would directly or artificially increase the proportion of hatchery fish in the population.

NMFS expects the productivity of Sacramento River basin-origin steelhead populations would be reduced by the PA through injury and mortality experienced by rearing and out-migrating juveniles. The PA will have multiple construction-related impacts which may reduce the productivity VSP parameter of Sacramento River basin populations. However, given the proposed in-water work windows for construction related actions that generally extend from June through October, presence of juvenile life stages, including smolts, in the Delta are not expected to overlap with the in-water work windows proposed for the PA to any great degree (less than 1-2% of the juvenile population). The work-window is such that exposure to those construction-related activities that are contained within that period are so limited that associated effects are not expected to reduce the productivity VSP parameter of steelhead populations originating from the Sacramento River basin. Other actions associated with the construction elements of the PA, but that are not limited by a work-window, and that are expected to have impacts on the productivity of CCV steelhead diversity groups include: (1) the effects of barge traffic on vulnerability to predation and the vulnerability to propeller entrainment; and (2) elevated predation associated with interim structures associated with the construction phase of the PA. Since these elements of the project will be present year round in the Delta, they will affect the juvenile life stages of the CCV steelhead and all three diversity groups of the Sacramento River basin of CCV steelhead.

The timing and routing of construction-related Delta barge traffic has been modified to reduce the level of exposure to listed fish, including that experienced by juvenile steelhead migrating through the Delta, such that the majority of adverse effects are avoided. However, certain sections of the Delta, that are part of the steelhead migration corridor, would still be exposed to year-round, increased barge traffic. In those areas, juveniles will also be exposed to propeller entrainment and increased predation; the combined effects of which would result in mortality or reduce the fitness of individual fish. Loss of multiple individual fish over each year, coupled with consecutive years of barge operations, is expected to decrease overall steelhead productivity.

Interim structures related to construction in the Delta, primarily associated with the NDD intakes, will affect the three diversity groups associated with the Sacramento River basin. These interim structure effects will last from mid-2022 to early 2029 for the NDD intakes (approximately 6.5 years), and each year the cofferdams are in place during the multi-year construction phase of the PA. Emigrating steelhead smolts from the Sacramento River basin will be at risk to predators associated with these altered nearshore habitats. This individual annual loss will be compounded by the cumulative multi-year loss, reducing both annual juvenile abundance and eventual productivity of steelhead populations from the Sacramento River basin.

Post-construction operations under the PA are also likely to affect the productivity VSP parameter of steelhead populations from the Sacramento River basin. Although modeled, upstream water temperatures in the Sacramento and American rivers showed no significant differences between the PA and NAA scenarios, water temperatures attributed to the environmental baseline (predicted temperatures under current operations, NAA, with climate change), indicate that water temperatures in certain months may reach levels that adversely impact steelhead eggs, alevin, and juvenile rearing in the Sacramento River basin. Under baseline conditions, water temperatures in the Sacramento River would reduce productivity by reducing the number of eggs and alevins surviving to the fry stage, a condition perpetuated by the PA operations scenario. In the American River, below Nimbus dam, excessive temperatures attributable to the baseline strongly indicate that eggs still in the gravel or laid in April and May will have the potential for substantially reduced viability and a high proportion of mortality or embryo abnormalities which will affect their future survival and fitness. Temperature modeling also indicates that there is a potential for reduced productivity during the late summer and early fall for rearing steelhead in the Sacramento River basin during critically dry water year types.

Effects of post-construction operations also likely to affect the productivity VSP parameter of steelhead populations from the Sacramento River basin include fish screen interactions (entrainment and impingement) at the NDDs and reduced in-Delta flows that will result in the reduced survival of juveniles. Section 2.5.1.2.5 Impingement and Entrainment quantified the interactions of migrating juvenile steelhead with fish screens at the NDD which are expected to result in an incident rate of 3.75 percent for injury, and 7.05 percent for mortality. Overall the effects of operations will, if realized, significantly reduce the productivity VSP parameter of steelhead populations originating from the Sacramento River basin. However, the operational phasing commitment described in the PA will be used to demonstrate compliance with the then-current NMFS and CDFW screening design and operating criteria. The PA states that, "The fish and wildlife agencies (i.e., USFWS, NMFS, and CDFW) retain responsibility for determination of the operational criteria and constraints (i.e., which pumping stations are operated and at what pumping rate) during testing." Therefore, the extent of effect is limited to a smaller proportion of what would be expected in the PA until design and operation of the screens is sufficiently tested. The NDD screens will be designed to meet NMFS screening criteria and incorporate (as yet determined) predator refugia, which NMFS expects will minimize screen impingement and associated predation. The PA provision that the NDD screen intakes will begin operating in a phased manner with testing to ensure they are functioning as expected will ensure impacts are minimized. The incident rate at the NDD screens is expected to be further reduced by the revised real-time operations for the North Delta Diversions that have unlimited pulse protections, such that during periods of high fish migration diversions will be reduced to limit exposure. Under the PA without consideration of the revised PA, juvenile Chinook salmon survival was reduced during the core migratory months ranging from 0.5% to 12% (median). With the revised PA (unlimited pulse protections) median survival reductions are improved with a range from 0.7% to 3%. These reductions in impact to survival would be expected to occur with juvenile steelhead that are migrating at the same time as winter- and spring-run Chinook salmon.

As explained in section 2.5.1.2.7 Reduced In-Delta Flows, the relationship between through Delta travel time, migration route, and flow is such that the reduction in Delta flows caused by operations under the PA would have an associated reduction in juvenile survival. Since the studies and the associated survivals models are based on Chinook salmon, only a generalized association can be made with steelhead smolts which are typically larger and have somewhat different behaviors associated with their downstream migration as smolts (Chapman et al 2013). Perry's 2017 flow-survival model, described in section 2.5.1.2.7.3.2 Perry 2017 Flow-Survival Model, simplifies the relationship between flows, travel time and Chinook smolt survival, showing that under the PA in at least 75% of years, Chinook salmon migration travel time is increased for all months during the entire migration period. Overall increased travel times will negatively impact juveniles by increasing predator encounters, increasing tidal excursion in transition reaches of the lower Sacramento River, increasing entrainment into the lower survival routes of the central Delta and reducing turbidities which likely benefits predators. Given that both the DPM and Perry 2017 models showed decreased survival for winter-run smolts under the PA, it would be reasonable to conclude that steelhead smolts emigrating through the Delta at the same time and under the same conditions assumed for the PA would also have reduced survival under the PA scenario compared to the NAA scenario, although the magnitude of the decreased survival is uncertain due to the differences between Chinook salmon and steelhead. Interpretation of the results of the models is further limited because the models were analyzed without consideration of the revisions to the PA. Although NMFS still expects the PA will have an adverse effect on migrating juvenile steelhead, the commitments made by Reclamation and DWR in the revised PA are expected to limit the impact of operations such that they would affect a small reduction to the production VSP parameter of CCV steelhead. Specifically, the commitment to the revised real-time operations for the NDD, the commitment to restore in Delta habitat to address potential undesirable hydrodynamic effects of the NDD operations, and the revised DCC criteria are expected to reduce the level of impact of operations. The revised PA also includes an Adaptive Management Program, accompanying Agreement for Implementation of an Adaptive Management Program for Project Operations, and an Implementation Schedule for the Adaptive Management Program that together provide the means to incrementally reduce the uncertainty related to the impact of operations. These commitments support a conclusion that any reduction in the productivity VSP parameter of Sacramento River basin populations of CCV steelhead caused by the overall effects of operations will be minimal. Specifics of the revised PA are discussed in section 2.7.1.3 Assess Risk to the Population: Winter-run Chinook Salmon Productivity.

Steelhead Spatial Structure

The spatial structure parameter of a VSP reflects how abundance is distributed among available or potential habitats. The attributes of the spatial structure parameter describe the availability, diversity, and utilization of properly functioning habitats and the connections between such habitats. The spatial structure of steelhead populations in the Sacramento River basin are significantly limited as about 80% of the historical spawning and rearing habitat once used by anadromous O. mykiss in the Central Valley is now upstream of impassible dams (Lindley et al. 2006). Given the limited habitat available in the baseline, there could be considerable impact to the spatial structure parameter of the VSP if it is further reduced. A significant part of the revised PA, however, is the re-commitment to key non-operational RPA actions in the NMFS 2009 BiOp, which include: the restoration of floodplain rearing habitat (increase juvenile salmonid access to Yolo Bypass, and increase duration and frequency of Yolo Bypass floodplain inundation), the implementation of pilot reintroduction program above Shasta Dam, consideration of engineering solutions to further reduce diversion of emigrating juvenile salmonids to the interior and southern Delta, and reduce exposure to CVP and SWP export facilities, and the restoration of Battle Creek for winter-run, spring-run, and CV steelhead; the combined effect of which are expected to benefit the spatial structure VSP parameter of Sacramento River basin populations of salmonids.

As described in section 2.5.1.1 Construction Effects, and given the level of exposure to steelhead to the construction-related impacts, the PA could result in further limiting the species ability to move between habitats. Some stressors, such as physical impacts to fish from activities such as pile driving are expected to cause displacement or delayed migrations for a large portion of the Sacramento River basin populations. Based on the current project description, the temporal exposure of migrating adult steelhead to impact pile driving at the NDD location is mid-June to mid-September, with some flexibility for work window extensions if sound attenuation efforts are successful. However, even this work-window will affect approximately 36% of the annual adult spawning population moving upriver into the Sacramento River basin each year for the duration of the NDD construction schedule.

In section 2.5.1.2.1 Increased Upstream Temperature, the effects of temperatures under the PA were analyzed relative to the NAA (conditions under a continuation of the current baseline) and found not to be significantly different from each other. However, both the PA and the NAA showed water temperatures above the critical threshold from August through October. This modeling indicates that there is a potential for temperatures to limit the movement of adults during the late summer and early fall for steelhead immigrating into and holding in the

Sacramento River during critically dry water year types. These temperature-related effects are such that the PA, when added to the environmental baseline, will result in continued limits to the appropriate exchange of spawners and limits to the expansion of a population into underused habitat.

As described in section 2.5.1.2 Operation Effects, under the PA the spatial structure VSP parameter of steelhead would be further impacted in much the same way that other salmonids would be, including, but not limited to: (1) decreasing flows and increasing travel time through the north Delta due to NDD operations; (2) creating conditions favorable for predators as juveniles migrate downstream through the installation of permanent in water structures, diminishing the available habitat patches; and (3) further altering the natural hydrograph of the Delta and its tributaries which limits access to habitats. To address these specific impacts, the revised PA incorporates a number of commitments that are expected to benefit the spatial structure VSP parameter of CCV steelhead, such as: (1) the revised real-time operations for the NDD (BA section 3.3.3.1.1 Pulse-Protection), (2) the commitment to the revised Adaptive Management Plan which includes research to assess and mitigate Sacramento River basin predation (Appendix A2, Adaptive Management Program), and (3) as part of a larger commitment to habitat restoration, the revised PA includes 1,800 acres of tidal restoration in the Delta to function as juvenile rearing habitat. This coupled with the 9,000 acres of habitat restoration proposed under existing conditions may be enough to address reverse flows. However, in order to reduce uncertainty that those acreages are enough, an additional commitment was made to “sufficiently address potential undesirable hydrodynamic effects of the NDD operations” (BA section 3.4.3.1.2) by “providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations.”

As described in section 2.5.1.2.7 Reduced In-Delta Flows, operations with the PA would provide a benefit, as it would also reduce the reverse flows in the south Delta which would reduce travel time for migrating fish therein. Evidence of this beneficial effect is described by the modeling which shows average steelhead loss at the south Delta water export facilities would be 41% lower under the PA than the NAA in all water year types. Overall, the PA is expected to maintain and possibly increase the population’s current spatial structure by incorporating the non-operational actions of the RPA in the NMFS 2009 biological opinion on the coordinated operations of the CVP/SWP, which significantly expands access to adequate habitat and increases habitat connectivity, quantity and quality, which reduce the current moderate risk of extinction for the steelhead populations of the Sacramento River basin. Furthermore, the commitments and criteria described in the revised PA, particularly the commitments to revised real-time operations for the NDD, the commitment to restore in Delta habitat to address hydrodynamic effects of the NDD operations and the revised DCC criteria are expected to limit the impact of NDD operations and support a conclusion that they would not reduce habitat connectivity in the Delta so that the spatial structure VSP parameter of CCV steelhead populations would not be reduced by operations.

Steelhead Diversity

The diversity VSP parameter comprises the three key attributes of: 1) variation in traits such as run timing, age structure, size, fecundity, morphology, behavior and genetic characteristics, 2) resilient gene flow among populations that is limited, and 3) maintenance of ecological variation

(McElhany et al. 2000b). O. mykiss have long been recognized as having one of the most complex and diverse life histories among all the salmonids. Populations may be entirely anadromous, partly anadromous, or entirely resident, and levels of anadromy can vary by age and sex. One of the difficulties in assessing any steelhead data in the Central Valley is the possibility that some individuals may actually be resident fish, as it is nearly impossible to visually distinguish the two life history forms when they are juveniles (NMFS 2016c). Considering the breadth of diversity in steelhead life history, assessing changes to the diversity VSP parameter of a particular population is done by examining the effects of the PA that would change the natural diversity of a population or disproportionately favor a particular trait or behavior. The diversity of steelhead populations in the Sacramento River basin continues to be limited as a result of the PA which constrains the timing of migrations and alters ecological variability.

Post-construction operations under the PA are likely to affect the diversity VSP parameter of steelhead populations from the Sacramento River basin. Although modeled, upstream water temperatures in the Sacramento and American rivers showed no significant differences between the PA and NAA scenarios on the smoltification of steelhead. Water temperatures attributed to the environmental baseline indicate that water temperatures in certain months may reach levels that would impair the smoltification process of steelhead in the Sacramento River basin. This would have the effect of selecting one life history over the other with the potential to reduce the diversity VSP parameter of the population by artificially limiting the life history strategies available to future cohorts. As described in section 2.5.1.2.7 Reduced In-Delta Flows, the NDD bypass rules are designed to protect the majority of juvenile winter-run and spring-run Chinook salmon migrants but these rules do not offer the same level of protection to all migrating fish such as steelhead. And since the studies and the associated survivals models used to develop the NDD bypass rules are based on Chinook salmon, only a generalized association can be made with steelhead smolts which are typically larger and have somewhat different behaviors associated with their downstream migration. According to the Perry 2017 flow-survival model, early migrants, those juvenile Chinook emigrating in November, are offered the least protection with median increases to travel times of 1.2 to 1.3 days. The increased travel time for outmigrating smolts is expected to have a corresponding increase in predation risk. A diverse range of run-timing allows for greater resiliency of this species as a whole because it minimizes the risk of entering the ocean at a point of unfavorable conditions where productivity often varies considerably within a season. The converse is true as well, whereas the timing of steelhead ocean entry is constricted by the PA to a narrow range of months, the probability that smolts will enter an ocean environment with favorable conditions for growth and survival decreases. Reducing the diversity of migration timings and the temporal distribution of ocean entry would increase the risk of extinction of the steelhead populations. However, the analysis of NDD operations does not reflect the commitment in the revised PA to unlimited pulse protection during periods of fish presence. With this added commitment, there is reasonable assurance that the breadth of diversity represented by migration timing will be protected since all migrations would receive an equal level of protection based on monitoring so that the diversity VSP parameter will not be affected.

For Sacramento River basin origin steelhead populations, diversity is also affected by the continuing effects of entrainment into the south Delta and entrainment in the south Delta CVP/SWP facilities. Although the PA is expected to improve conditions in the south Delta, where modeling shows average steelhead loss at the south Delta water export facilities would be

41% lower under the PA than the NAA in all water year types, there remains a negative impact under the PA. The differences in annual entrainment among the run timing scenarios discussed in section 2.5.1.2.7.2.2 Salmonid Smolt routing into the interior Delta suggests that daily entrainment probabilities vary seasonally, thereby affecting annual entrainment differentially for the alternative run timings (early, uniform or late). Depending on the run timing and the proportion of the migrating population that is impacted, entrainment into the south Delta and the localized conditions therein will impact the diversity VSP parameter of a population because those run timings that remain in the mainstem Sacramento River will experience a higher level of survival compared to those entrained. The overall entrainment into the central Delta with the PA for all 3 run timings was <2% difference between the means of all three annual entrainment probabilities, meaning that the level of effect is small and not likely to impact the diversity parameter of the VSP.

San Joaquin River Basin Steelhead

All San Joaquin River basin origin steelhead belong to the Southern Sierra Nevada diversity group, which was once made up of 5 historic populations of steelhead but is now constrained to 4 remnant populations of uncertain condition (NMFS 2014). At the current time, it is expected that only a few dozen to a few hundred adult steelhead will return each year to the San Joaquin River basin and its tributaries. Like the Sacramento River basin, the majority of these fish are likely to be of hatchery origin, and since there are no steelhead hatcheries in the San Joaquin River basin south of the Delta, any hatchery fish in these southern tributaries will be strays from other hatcheries in the Central Valley. The only steelhead hatchery located on a tributary to the San Joaquin River is the Mokelumne River Fish Hatchery; however, the population supported by this hatchery (Mokelumne River, below Camanche Dam) is considered part of the Northern Sierra diversity group.

Steelhead Abundance

Without a discrete estimate of abundance, assessing the abundance VSP parameter for the San Joaquin River basin population(s) is limited to a qualitative assessment of whether conditions under the PA, when added to the environmental baseline and cumulative effects, would be expected to maintain, reduce or increase abundance. Specifically, changes in the number of adults and changes to individuals' ability to contribute offspring to the population (i.e., the effective population) are used here as measures for any change in the abundance VSP parameter. If the probable change in fitness attributed to the effects of a stressor would results in 'reduced survival' or 'reduced reproductive success' (identified in Table 2-255) for a significant proportion of adults, that would be considered a reduction of the abundance VSP parameter of affected populations.

NMFS expects the PA will have a number of short-term construction-related impacts to steelhead population(s) of the San Joaquin River basin. Given the proposed work window and migration timing of adult steelhead, construction-related effects would be expected to impact significant number of returning steelhead adults. However, a smaller fraction of the fish destined for the San Joaquin River basin would be exposed to construction-related effects due to their later migration window. The most significant stressor, regarding the potential severity of the construction-related effects, is the effect of pile-driving induced noise. As explained in section 2.5.1.1.1.1 Acoustics, pile-driving induced noise would affect some steelhead in a manner that would rise to the level of harm or even result in mortality.

It is expected that any fish from the Southern Sierra Diversity Group will not be affected by pile driving at the NDD locations; thus, there will be little to no affect to those populations' abundance related to this component of the proposed action. The pile driving actions at the other construction locations (CCF, HOR Gate, and barge landings) are expected to expose adult steelhead from San Joaquin River basin to the negative effects of acoustic noise due to the spatial and temporal distributions of the those actions. Pile driving required for the construction of the HOR gate will occur during the in-water work window from August 1 to October 31 which occurs prior to the peak of upstream migration of steelhead into the San Joaquin River basin (November through January), but is expected to result in the exposure of some early arriving fish in September and October. Likewise, adult steelhead from the Southern Sierra diversity group are more likely to use the waterways in the South Delta surrounding the CCF inlet for migratory movements than fish from the Sacramento River basin, as they lead to the San Joaquin River watershed. The presence of Southern Sierra Diversity Group fish will increase from September through October, as the peak of migration approaches (November through January). For the pile driving associated with construction of the barge landings, most adult fish are anticipated to follow the main stem San Joaquin River route to reach the San Joaquin River basin tributaries rather than follow the alternative migratory routes through the Old River and Middle River channels where the barge landing sites are distributed. Thus, few adult steelhead are anticipated to be exposed to the pile driving at the barge landing locations due to spatial and temporal separation from the main migratory route and main migratory period used by adult steelhead from the Southern Sierra Diversity Group.

NMFS expects that few steelhead will be present during the construction period, but those that are will be at high risk of injury or death if they move past any of the pile driving activities, particularly the HOR gate construction site because of its relatively narrow channel. Even though the risk to the Southern Sierra Diversity Group is reduced due to the timing of the in-water work window, the extremely small size of the population in the basin amplifies the risk to the group's abundance with the loss of only a few individual adult fish.

The abundance of San Joaquin River basin-origin steelhead is also expected to be affected by the construction-related Delta barge traffic described in sections 2.5.1.1.1.2 Acoustics; 2.5.1.1.2.2 Sediment Concentration; and 2.5.1.1.3.2 Contaminant Exposure. The timing and routing of construction-related Delta barge traffic is such that San Joaquin River basin steelhead will experience an increase in effects related to barge traffic which will be a year-round stressor in the San Joaquin River that will expose the entire adult population to increased vessel noise, sediment concentration, and contaminants; particularly during the period from November 1 through February 28 (peak adult migration), when the routes that barge traffic can follow are limited to the San Joaquin River main stem from the Port of Stockton to Bouldin Island. Although this activity is unlikely to result in direct mortality to adult steelhead, it will result in a reduced level of fitness caused by delayed or disrupted migrations that in turn could affect the effective population size. Overall, the PA is expected to diminish the abundance VSP parameter of the steelhead population(s) in the San Joaquin River basin.

Steelhead Productivity

Like the assessment of the abundance VSP parameter, without a discrete estimate of production assessing the productivity VSP parameter for the San Joaquin River basin population(s) is limited to a qualitative assessment of whether conditions under the PA, when added to the environmental baseline and cumulative effects, would appreciably reduce the natural component of the population, or directly or artificially increase the proportion of hatchery fish in a population. The productivity VSP parameter of San Joaquin River basin-origin steelhead may be reduced by the proposed action as rearing and out-migrating juveniles will be exposed to a number of stressors related to construction and operations the effect of which can result in injury or mortality. Presence of juvenile life stages, including smolts, in the Delta are not expected to overlap with the in-water work windows proposed for the PA to any great degree (less than 1-2% of the juvenile population) such that only a few individual steelhead juveniles would be expected to be exposed to construction-related effects

Barge traffic in the San Joaquin River related to construction will expose the juvenile population to increased vessel noise, sediment concentration, and contaminants. And unlike adult steelhead, whose response will be limited to behavioral changes, juveniles will also be exposed to propeller entrainment which will result in direct mortality and increased exposure to predators. During the period of March 1 through May 31, barge traffic is restricted to the San Joaquin River reach between the Port of Stockton and Bouldin Island, but the frequency of trips is reduced, and limited to barge traffic that is absolutely essential to move heavy and oversized equipment that cannot be moved by surface means such as trucks or rail. This is the period of time when the majority of wild San Joaquin River fish will be moving out of this basin into the Delta. While the overlap of the downstream steelhead migratory route and the route of barge traffic is substantial between the Port of Stockton and Bouldin Island, the effects are reduced by the decrease in the number of barge trips, as well as the dimensions of this waterway, which is wider and deeper than other potential barge routes and provides areas in which emigrating fish can find refuge from the barges. However, loss of multiple individual fish over each year, coupled with consecutive years of barge operations, decreases juvenile steelhead abundance which would be expressed as a reduction of juvenile production at the population level.

Construction of the HOR gate is expected to take two years. The HOR gate will be constructed in two phases using cofferdams to isolate and dewater half the channel during the first phase and the other half during the second phase (see Section 2.5.1.1.6.3). The interim structure is expected to affect steelhead belonging to the Southern Sierra Diversity Group which originate in the San Joaquin River basin upstream of the Delta. The short duration of the construction schedule (2 years) helps to reduce the impacts to juvenile steelhead abundance, but the magnitude of impact is enhanced disproportionately by the very small population size of this diversity group. Each fish lost to predation due to the presence of the interim structure has more relative impact because the size of the annual emigrating population is very small. Presence of the interim HOR Gate cofferdams will decrease juvenile abundance which constitutes a reduction in juvenile production at the population level.

Post-construction operations with the PA are also likely to affect the production VSP parameter of San Joaquin River basin steelhead. However, unlike the steelhead populations in the Sacramento River Basin, out-migrating juveniles belonging to populations originating in the San Joaquin River basin will not be exposed to fish screen interactions (entrainment and impingement) at the NDD and will experience a relative increase in Delta flows that will result in increased survival of juveniles. As explained in section 2.5.1.2.7 Reduced In-Delta Flows, the relationship between through Delta travel time, migration route, and flow is such that the reduction in north Delta flows caused by operation of the NDD under the proposed action would have an associated reduction in juvenile survival for juveniles emigrating from the Sacramento River basin. And while flows in the north Delta will be reduced, flows in the central Delta are mostly unchanged, and for flows in the south Delta, there will be a net increase so that there would also be an expected increase in survival for juveniles emigrating from the San Joaquin River basin. The PA, however, will include operations of the existing facilities in the south Delta, which will still result in some negative effects. Overall the effects of operations will increase the productivity VSP parameter of steelhead populations originating from the San Joaquin River basin. The revised PA also provides an Adaptive Management Program, accompanying Agreement for Implementation of an Adaptive Management Program for Project Operations, and an Implementation Schedule for the Adaptive Management Program, that together enable a means to incrementally reduce the uncertainty related to the impact of operations and thereby support a conclusion that any reduction in the productivity VSP parameter of the population caused by the overall effects of operations will be minimal.

Steelhead Spatial Structure

Attributes of the spatial structure VSP parameter describe the availability, diversity, and utilization of properly functioning habitats, and an assessments of this VSP parameter reflects how species abundance is distributed among available or potential habitats and the connections between such habitats. Stressors attributed to the PA that would increase or further limit access to available habitats would be expected to affect the spatial structure VSP parameter.

As described in section 2.5.1.1 Construction Effects, most of the construction-related impacts of the PA would not result in further habitat fragmentation or diminish a population's ability to move between habitats. Some stressors, such as physical impacts to fish from activities like pile driving, are expected to cause displacement or delayed migrations for some Sacramento River basin populations; however, for San Joaquin River basin populations, the proposed work window is sufficient to protect the vast majority of migrating fish, such that any effect would be very small and not likely to have an impact on the population. A minor exception will be increased barge traffic, the timing and routing of which will disproportionately impact steelhead populations in the San Joaquin River basin. Migrating fish will be subject to increased vessel noise, sediment concentration, and contaminants at varying levels but for the duration of construction. The expected effects of displacement or delayed migrations caused by San Joaquin barge traffic will result in a reduced level of fitness that in turn will negatively affect the spatial structure VSP parameter.

Operation of the NDD and HOR gate with the PA, described in section 2.5.1.2 Operation Effects, will also impact the spatial structure VSP parameter of steelhead, but it will do so in a way that is expected to benefit populations in the San Joaquin River basin. As described in section 2.5.1.2.7 Reduced In-Delta Flows, operations under the proposed action would reduce reverse flows in the south Delta which would reduce travel time for migrating fish therein. In the San Joaquin River, velocities for the PA are often substantially greater in most months, by at least 15% and up to 54%, mainly due to the presence of the HOR in the PA. These results are supported by the modeling which shows average spring-run loss at the south Delta water export facilities would be 41% lower under the PA than the NAA in all water year types. Since the PA will include the operations of the existing facilities in the south Delta, there will still be negative effects, although reduced, from operations of the facilities in the south Delta under the PA. The PA is expected diminish the spatial structure VSP parameter in the short-term as construction-related barge traffic is likely to disrupt or delay steelhead migrations in the San Joaquin River basin. However, the long-term effect of the proposed action, specifically with the operation of the HOR gate, will maintain or even increase the San Joaquin River basin population's current spatial structure by sustaining access to adequate habitat with the potential to increase habitat connectivity, quantity and quality over the baseline.

Steelhead Diversity

The diversity VSP parameter comprises the three key attributes of: 1) variation in traits such as run timing, age structure, size, fecundity, morphology, behavior and genetic characteristics, 2) resilient gene flow among populations that is limited, and 3) maintenance of ecological variation (McElhany et al. 2000b). O. mykiss populations may be entirely anadromous, partly anadromous, or entirely resident, and levels of anadromy can vary by age and sex. One of the difficulties in assessing any steelhead data in the Central Valley is the possibility that some individuals may actually be resident fish, as it is nearly impossible to visually distinguish the two life history forms when they are juveniles (NMFS 2016c). Considering the breadth of diversity in steelhead life history, assessing changes to the diversity VSP parameter of a particular population is done by examining the effects of the PA that would change the natural diversity of a population or disproportionately favor a particular trait or behavior.

Operation of the NDD and HOR under the proposed action, described in section 2.5.1.2 Operation Effects, will impact the diversity VSP parameter of steelhead populations originating in the Sacramento River basin because the reduced flows caused by the NDD will disproportionately impact those steelhead that begin their migrations in November and December. The same effect is not expected to be experienced by steelhead from populations originating in the San Joaquin River basin, because operations with the PA would reduce reverse flows in the south Delta which would reduce travel time for migrating fish therein. In the San Joaquin River, the analysis based on the SalSim Juvenile Delta Module survival function suggested that the PA would likely have a positive effect on San Joaquin River spring-run Chinook salmon in the Delta, and since these studies are based on Chinook salmon, only a generalized association can be made with regard to steelhead smolts. Nevertheless, a positive effect is expected although it is not expected to disproportionately affect any one segment of a San Joaquin River basin population such that any life history diversity would be lost. In summary, the PA is not expected to diminish the diversity VSP parameter as steelhead juvenile migrations avoid most construction-related effects and the operation of the HOR will not constrain and may even increase the window of successful migration timing for San Joaquin River basin populations.

2.7.5.4 Assess the Risk to ESU/DPS

To assess the risk posed by the PA to the DPS of CCV steelhead, when combined with the status of the species, environmental baseline, and cumulative effects, NMFS determines if changes in population viability, based on changes in the VSP parameters of that population, are likely to be sufficient to reduce the viability of the species. In this assessment, we use the species' status, based on the current condition of the VSP parameters, (established in the status of the species and Appendix B—Rangewide Status of the Species and Critical Habitat) as our point of reference for the effects of the environmental baseline. Currently the CCV steelhead DPS is at moderate risk of extinction (National Marine Fisheries Service 2016b). However, there is considerable uncertainty with regard to the magnitude of that risk, due in large part to the general lack of information and uncertainty regarding the status of many of its populations. Given this uncertain point of reference, but based on our knowledge of the population structure of the species, NMFS considers the consequences of a relative change in extinction risk to one or more of those populations and if that change would reduce appreciably the likelihood of both the survival and recovery of the species. Using the ESU/DPS-Level Recovery Criteria identified in the steelhead 5-year status review (National Marine Fisheries Service 2016b), the combined risk to individual populations are evaluated to determine the risk to the DPS as a whole. With regard to the likelihood of recovery of the species, the action must not increase the extinction risk of current steelhead populations so as to preclude establishing at least eight populations at a low risk of extinction distributed throughout the Central Valley, as well as establishing additional populations at a moderate risk of extinction.

The VSP analysis shows that the construction elements of the PA are expected to appreciably reduce the abundance VSP parameter for steelhead populations of the Sacramento River basin, those of the Basalt and Porous Lava, Northwestern California, and Northern Sierra Nevada diversity groups. Likewise, the VSP analysis shows that the construction elements of the PA are expected to maintain the current condition of the productivity, spatial structure, and diversity VSP parameters; it is unlikely that those parameters would be significantly reduced beyond their currently degraded state in the Sacramento River basin. Within the San Joaquin River basin, steelhead populations of the Southern Sierra Nevada diversity group are not expected to experience a significant reduction in the abundance, spatial structure, and diversity VSP parameters related to construction elements of the PA. However, construction elements of the PA are expected to appreciably reduce the productivity VSP parameter of steelhead populations in the San Joaquin River basin. With regard to the impact of post-construction operations, although there is uncertainty regarding the design and operation of the NDD, it is likely that the productivity VSP parameter of Sacramento River basin steelhead populations would be reduced. And, although there is also uncertainty regarding the effects of operations in the south Delta, the effect on the viability of the steelhead populations of the San Joaquin Basin is such that it would not reduce, and may support, the viability of the populations therein.

These conclusions are based on commitments in the PA and revisions to the PA as explained in the VSP analysis, including that final operation will be established based on significant testing, refinement, and adaptive management. Based on our analysis, NMFS concludes that the steelhead DPS is composed of Sacramento River Basin populations and San Joaquin River Basin populations and, while elements of the PA are expected to reduce the viability parameters for some of those populations, the PA provides standards and commitments that are reasonably certain to occur to support a conclusion that the proposed action is not likely to reduce the viability of the species. Therefore, NMFS concludes the proposed action is not expected to appreciably reduce the likelihood of both the survival and recovery of the CCV steelhead DPS.

Table 2-257. Reasoning and decision-making steps for analyzing the effects of the proposed action on steelhead. Bold type identifies the conclusion at each step of decision-making. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and not likely/likely to jeopardize (NLJ/LJ).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment.	True	End

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Available Evidence: The PA will produce multiple stressors that will adversely affect steelhead including, but not limited to: acoustic effects, sediment concentration and contaminant effects, increased predation, impingement and entrainment, and effects related to reduced Delta flows.	**False**	**Go to B**
B	Listed individuals are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action.	True	NLAA
	Available Evidence: A large number of adult steelhead will be exposed to construction related activities which occur during the construction work-window, and a significant proportion of the juvenile population will be exposed to year-round construction-related effects (e.g., temporary structures, barge traffic) as well as the effects of operations.	**False**	**Go to C**
C	Listed individuals are not likely to respond upon being exposed to one or more of the stressors produced by the proposed action.	True	NLAA
	Available Evidence: Multiple stressors, including but not limited to those associated with pile driving, barge traffic, screen impingement and entrainment, and operations, will rise to a level of effect that will engender a response from exposed individuals.	**False**	**Go to D**
D	Any responses are not likely to constitute "take" or reduce the fitness of the individuals that have been exposed.	True	NLAA
	Available Evidence: Multiple stressors, including but not limited to those associated with pile driving, barge traffic, screen impingement and entrainment, and operations, are expected to result in a reduction of overall fitness of individuals and which could rise to the level of "take."	**False**	**Go to E**
E	Any reductions in individual fitness are not likely to reduce the viability of the populations those individuals represent.	True	NLJ
	Available Evidence: The overall reduction in fitness of individuals caused by the proposed action, has been shown to reduce a number of the parameters describing a viable salmonid population, such that reductions in these parameters will likely reduce the viability of steelhead populations.	**False**	**Go to F**
F		**True**	**NLJ**

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Any reductions in the viability of the exposed populations are not likely to reduce the viability of the species. Available Evidence: The steelhead DPS is composed of Sacramento River Basin populations and San Joaquin River Basin populations and, while elements of the PA are expected to reduce the viability parameters for some of those populations, the PA provides standards and commitments that are reasonably certain to occur to support a conclusion that the proposed action is not likely to reduce the viability of the species.	False	LJ

2.7.6 CCV Steelhead Critical Habitat

- Designated critical habitat (70 FR 52488, September 2, 2005).

2.7.6.1 Status of Critical Habitat and Environmental Baseline

As described in section 2.2.1.2 (and at length in Appendix A Rangewide Status of the Species and Critical Habitat), the geographical extent of designated critical habitat includes: the Sacramento, Feather, and Yuba rivers, and Deer, Mill, Battle, Clear, and Antelope creeks in the Sacramento River basin; the San Joaquin River, including its tributaries but excluding the mainstem San Joaquin River upstream of the Merced River confluence; and the waterways of the Delta. Steelhead critical habitat is composed of four physical or biological features that include freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine habitat. The description of these PBFs is shared with that of CV spring-run Chinook salmon such that the PA is expected to impact them in a similar way. All of those PBFs are considered necessary habitat features that provide for successful spawning, incubation, rearing, and migration. Therefore, we have evaluated the effect of the PA in terms of its effect on habitats for spawning adults, incubating eggs, and rearing fry; freshwater rearing habitat for juveniles; freshwater migratory corridors; and, estuarine habitat for rearing and migration.

As described in Section 2.4.1.6 Status of California Central Valley Steelhead Critical Habitat in the Action Area, the status of critical habitat in the environmental baseline has many of its PBFs impaired, such that it provides limited high quality habitat. For example, levee construction has degraded the value for the conservation of the species of freshwater rearing and migration habitat and estuarine areas where riparian vegetation has been removed, reducing habitat complexity, food resources, and resulting in many other ecological effects. However, even in the degraded state, the spawning habitat, migratory corridors, and rearing habitat that remain in the Sacramento River and San Joaquin River watersheds and the Delta are considered to have high intrinsic value for the conservation of the species.

2.7.6.2 Summary of Proposed Action Effects

Detailed descriptions regarding the impacts to designated critical habitat for steelhead caused by stressors associated with the PA are presented in section 2.5.2, Effects of the Action to Critical Habitat. The PA-related effects to steelhead critical habitat have been separated by life-stage specific habitat type and assessed by the effects on the PBFs found therein. Considering that the relevant PBFs for CCV steelhead critical habitat are shared with those of CV spring-run Chinook salmon, and that since the PA is expected to impact these critical habitats in a similar way; the effects described for CV spring-run Chinook salmon critical habitat, summarized in Table 2-252, are similar for CCV steelhead.

Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry

With the PA, NMFS expects an appreciable reduction in the PBFs of steelhead critical habitat, specifically for sufficient water quantity and quality conditions and substrate to support spawning, incubation, and larval development. However, There is some uncertainty associated with the effect of the PA in the temperature analyses included in Section 2.5.1.2 where a temperature threshold analysis, SALMOD model analysis, and the SWFSC's egg mortality model analysis, all suggest that implementation of the PA, when added to the effects of the environmental baseline, would have adverse effects to spawning habitat in the Sacramento River utilized by steelhead. These results indicate that in the current environmental baseline, potential spawning habitat is already reduced by current water operations and temperature control efforts. In the Sacramento River, where spawning is restricted to the small area below Keswick Dam, even modest reductions in water quantity and quality will diminish habitat for spawning adults, incubation of eggs, and rearing for fry. The revised PA includes a recommitment to expanding the available habitat for spawning adults, incubation of eggs, and rearing for fry, specifically in Battle Creek and above Shasta dam, into the McCloud River which will increase the quantity and quality of this PBF.

Freshwater Rearing Habitat for Juveniles

Construction related effects of the proposed action, are expected to cause some intermittent and minor impacts to the PBFs of steelhead critical habitat, specifically with regard water quantity and floodplain connectivity adequate enough to form and maintain physical habitat conditions that support juvenile growth and mobility; water quality and forage sufficient to support juvenile salmonid development; and available natural cover necessary for successful juvenile development and survival. As a result of the construction aspects of the proposed action, freshwater rearing habitat for juveniles will be degraded by the effective removal of 20.1 acres of tidal perennial habitat and 1.02 linear miles of channel margin habitat; installation of interim structures and corresponding reduction of habitat complexity at the NDD sites; and an increase in construction-related disturbances which reduce the habitat's capacity for successful juvenile development and survival.

The acreage of critical habitat loss for each structure, including areas located in designated critical habitat that could be affected by placement of permanent in-water structures, and the temporary areas of loss (i.e., areas that will only be affected during construction activities) were calculated and will be sufficiently offset for through channel margin and tidal perennial habitat creation/restoration in the appropriate areas (see Appendix A2 Proposed Action). These direct effects are partially mitigated by the commitment of habitat restoration acreages described in the Revised PA. These revisions include 80 acres of expanded habitat upstream of Red Bluff Diversion Dam, and 1,800 acres of restoration in the Delta. Given the relative scale of permanent loss compared to the total abundance of adequate habitat in the immediate area and the level of habitat mitigation/compensation proposed as part of the PA at this time, it is likely that the temporary degradation of these PBFs will not extend beyond the construction period. In addition, the impact of increased predation at the temporary structures proposed under the PA, has the potential to further impact freshwater rearing habitat for juvenile steelhead.

As a result of the operation of the NDD under the PA and because of the sustained, year-round risk of predation associated with permanent in-water structures as well as the effects of impingement at the NDD screens, the PBFs of freshwater rearing habitat at those locations is reduced. Specifically the direct juvenile mortality caused by the NDD screens reflects a riparian habitat that is diminished in its capacity to promote juvenile growth, mobility and development. Differences between the PA and NAA in rearing WUA were examined, and rearing WUA of the PA was found to generally match rearing habitat of the NAA for all water year-types but, in some instances, WUA was decreased under the PA relative to the NAA, such that the water quantity and floodplain connectivity is reduced during certain year-types and certain months, including during the November – June juvenile emigration period. To mitigate this loss there are significant commitments to habitat restoration including 80 acres of habitat in the upper Sacramento River and 1,800 acres of restoration in the Delta, that will ultimately improve Delta survival and the commitment to the revised Adaptive Management Plan, includes research to assess and mitigate Sacramento River basin predation (Appendix A2, Adaptive Management Program) which will improve the freshwater rearing habitat PBF for juveniles.

Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults

Construction and operation of the NDDs are expected to reduce the PBFs of the migratory corridor habitat for steelhead. Increased predation risk, risk of impingement, and loss of habitat complexity are all stressors that are likely to reduce juvenile survival during outmigration, thus degrading the PBF of migration corridors free of obstruction and excess predation with water quantity and quality conditions and natural cover. In the north Delta, it is expected that the PBF will be somewhat degraded, while in the south Delta, a relative increase in function is expected. Some of these effects on steelhead critical habitat may be inferred by the results of the WRLCM, but since this study is based on Chinook salmon, only a generalized association can be made with regard to the impacts to steelhead critical habitat. Nevertheless, results of the WRLCM show that, while the survival of outmigrating winter-run smolts originating from the lower Sacramento River is reduced in the PA compared to the NAA, for smolts originating in the Delta, the WRLCM shows the opposite, where survival is increased under the PA compared to the NAA. Considering that differences in survival between the PA and the NAA are larger in the Lower River, the overall effect of the PA would be expected to reduce juvenile steelhead survival and to marginally diminish the quantity and quality of riparian habitat and its ability to provide for successful juvenile development and survival. This reduction in survival is expected to be minimized because of the commitment to unlimited pulse protection included in the revised PA will reduce the exposure of juveniles to reduced flows. Furthermore, juveniles and spawning adults migrating through the mainstem San Joaquin River will also encounter physical disturbance from year-round barge operations during the construction period, which will impede migrations, degrading the function of the PBF which should be free of obstruction and excess predation.

Estuarine Habitat for Rearing and Migration

Construction activities under the PA are expected to cause some intermittent and minor impacts to the PBF of estuarine habitat. Minimal loss of riparian habitat is anticipated to occur at barge landing sites located within the Delta. The footprint of construction at these sites is not yet finalized; however, associated removal of vegetation is expected to result in relatively minor impacts to the riparian habitat that provides for successful juvenile development and survival. Riparian and estuarine PBFs will experience minor degradation due to physical disturbance and risk of propeller entrainment year-round as barge operations are carried out in the San Joaquin River. However, given the temporary nature of the disturbance, coupled with the BMPs proposed as part of the PA, it is unlikely that the resultant disturbances will lead to a significant degradation of these PBFs.

Changes to in-Delta flow caused by operation of the NDDs are projected to result in increased travel time for juvenile steelhead, increase entry into the lower quality interior Delta corridors, and result in reduced survival of steelhead juveniles. Access to the riparian habitat that provides for successful juvenile development and survival will be reduced under the PA relative to the NAA, because as flows downstream of the NDDs are reduced the inundation of the wetland and riparian benches that serve as rearing habitats are reduced as well. The riparian bench inundation index below the NDDs is shown to decrease for all water year types under the PA. Entry into the interior Delta is also expected to increase under the PA which increases juvenile steelhead susceptibility to predation and poor water quality. This in turn will reduce the successful development and survival of juveniles, limiting the access downstream.

Overall, the effects of operations on flow as modeled for the PA without consideration of the explicit commitments made in the revised PA would degrade estuarine habitat for rearing and migration. However, the following commitments and criteria, described in the revised PA are expected to reduce the impact of operations such that the effect on estuarine habitat for rearing and migration would result in only a moderate reduction in the quality and quantity of PBFs. Specifically:

- The revised real-time operations for the NDD which include 1) unlimited pulse protections, 2) increased allowable diversions (relative to previous PA) during high flow events with a required minimum bypass flow, and 3) initial fish-based transitional criteria and post-pulse pumping protections based on conditions in CDFW’s draft permit under California Fish and Game Code section 2081 (BA section 3.3.3.1.1 Pulse-Protection). These initial real-time operational criteria are expected to maintain flows during fish presence such that flows will be adequate to provide access to riparian habitats and migration downstream.

- As part of a larger commitment to habitat restoration, the revised PA includes 1,800 acres of tidal restoration in the Delta to function as juvenile rearing habitat. This coupled with the 9,000 acres of habitat restoration proposed under existing conditions may be enough to address reverse flows, but in order to reduce uncertainty that those acreages are enough, an additional commitment was made to restore in Delta habitat for the express purpose to “sufficiently address potential undesirable hydrodynamic effects of the NDD operations” (BA section 3.4.3.1.2). The Revised PA states that “DWR and Reclamation also commit to providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations,” thereby implementing the earlier commitment to avoid and minimize this adverse effect.

- Assurance that existing DCC gate closures adhere to the expectations of the criteria stated in the NMFS 2009 biological opinion. Specifically, DCC closure for downstream flood control will be based on Sacramento River flow at Freeport, upstream of the north Delta diversion facilities (BA Table 3.3-1 in Appendix A1). This particular operational criteria will maintain flows in the mainstem Sacramento River to ensure that flows are adequate to provide migration downstream.

With these explicit commitments made in the revised PA, NMFS expects that the PBFs of estuarine habitat for rearing and migration will experience moderate reductions in quantity and quality.

2.7.6.3 Impact to the Critical Habitat of the Species at the Designation Level

As described in section 2.2 and Appendix A (Rangewide Status of the Species and Critical Habitat), and in section 2.4 Environmental Baseline, many of the physical or biological features that are essential for the conservation of CCV steelhead are currently degraded. Also the effects of future State, tribal, local, or private actions, described in section 2.6 Cumulative Effects, are not likely to improve the PBFs, which will most likely remain in their degraded state. As a result of implementing the PA, the value of critical habitat for the conservation of the species, with respect to some of the PBFs, will be reduced in some areas. However, the condition of other PBFs will be increased or maintained in their current state with implementation of the PA, and none of the reductions to the value of critical habitat are expected to result in an appreciable diminishment of the overall value of the critical habitat for the conservation of the species. Based on the analysis of available evidence, NMFS concludes that the proposed action is not likely to appreciably diminish the value of the critical habitat for the conservation of California Central Valley steelhead.

Table 2-258. Reasoning and decision-making steps for analyzing the effects of the proposed action on steelhead critical habitat. Bold type identifies the conclusion at each step of decision-making. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and destruction or adverse modification of critical habitat (D/AD MOD).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment. Available Evidence: The PA will produce multiple stressors that will adversely affect the environment including, but not limited to: acoustic effects, sediment concentration and contaminant effects, increased predation, impingement and entrainment, and effects related to altered flows and temperatures.	True	End
		False	**Go to B**
B		True	NLAA

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Areas of designated critical habitat are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action. Available Evidence: Areas of steelhead designated critical habitat will be exposed to multiple stressors produced by the PA, including habitats such as: Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry; Freshwater Rearing Habitat for Juveniles; Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults; and Estuarine Habitat for Rearing and Migration.	**False**	**Go to C**
C	The quantity or quality of any physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to be reduced upon being exposed to one or more of the stressors produced by the proposed action. Available Evidence: In multiple instances the quantity and quality of the PBFs of steelhead critical habitat, or in some cases the capacity of the critical habitat to develop those features, will be reduced by the PA. For example, altered flows downstream of the NDD will reduce the extent and frequency of riparian bench inundation which will effectively reduce the quantity of natural cover such as submerged and overhanging large woody objects, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival; reduced in-Delta flows will increase the time needed for juvenile migration which reduces the quality of freshwater migration corridors free of obstruction and excess predation; and both the effects of the PA when combined with the environmental baseline will limit the capacity of upstream habitats to develop freshwater spawning sites with sufficient water quantity and quality conditions and substrate supporting spawning, incubation, and larval development.	True	NLAA
		False	**Go to D**
D		True	NLAA

<table>
<tr><th>Step</th><th>Apply the Available Evidence to Determine if…</th><th>True/False</th><th>Action</th></tr>
<tr><td></td><td>Any reductions in the quantity or quality of one or more physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to reduce the value of critical habitat for the conservation of the species in the exposed area.

Available Evidence: The reductions in quantity and quality of PBFs, as well as the reductions in the capacity of the critical habitat to develop these features over time, is expected to reduce the value of the habitat. Particularly with regard to the Freshwater Rearing Habitat for Juveniles and the Estuarine Habitat for Rearing and Migration, the PA is expected to further impair the waterways of the Delta designated as critical habitat for steelhead in their abilities to function as rearing and migratory corridors.</td><td>False</td><td>Go to E</td></tr>
<tr><td rowspan="2">E</td><td rowspan="2">Any reductions in the value of critical habitat for the conservation of the species in the exposed area of critical habitat are not likely to appreciably diminish the overall value of critical habitat for the conservation of the species.

Available Evidence: As a result of implementing the PA, the value of critical habitat for the conservation of the species, with respect to some of the PBFs, will be reduced in some areas. However, the condition of other PBFs will be increased or maintained in their current state with implementation of the PA, and none of the reductions to the value of critical habitat are expected to result in an appreciable diminishment of the overall value of the critical habitat for the conservation of the species.</td><td>True</td><td>No D/AD MOD</td></tr>
<tr><td>False</td><td>D/AD MOD</td></tr>
</table>

2.7.7 Green Sturgeon

- Listed as threatened April 7, 2006 (71 FR 17757)

Detailed information regarding the federally listed Southern distinct population segment (sDPS) of North American green sturgeon, life history, and status of the species can be found in Appendix B—Rangewide Status of the Species and Critical Habitat.

2.7.7.1 Status of the Species and Environmental Baseline

The status of the species and critical habitat, as well as the environmental baseline, have been described at length in Sections 2.2 and 2.4, respectively. Although the VSP concept, as described in the Analytical Approach (section 2.1), was developed for Pacific salmonids, the underlying parameters are general principles of conservation biology and can therefore be applied more broadly; here NMFS adopts the VSP parameters for analyzing sDPS green sturgeon viability.

Green Sturgeon Abundance

The ability to derive a reliable estimate of sDPS green sturgeon population abundance is particularly challenging given the sparsity of monitoring for any life stage of green sturgeon. Further complicating the effort to generate and assess specific population dynamic metrics is the lack of any consistently sustained monitoring effort which might be employed to establish a population baseline and track trends.

Historically, abundance and population trends of sDPS green sturgeon has been inferred in two ways; first by analyzing salvage numbers at the State and Federal pumping facilities, and second, by incidental catch of green sturgeon by the CDFW's white sturgeon sampling/tagging program. Both methods of estimating sDPS green sturgeon abundance are problematic as biases in the data are evident. Perhaps the most useful dataset for establishing and observing sDPS green sturgeon population trends presently available comes from spawning surveys that have been conducted utilizing Dual Frequency Identification Sonar (DIDSON) cameras in the mainstem Sacramento River since 2010. These surveys have recently been used to generate an adult sDPS green sturgeon abundance estimate of 1,990 (95% confidence interval [CI] = 1,172-2,808; Mora 2016). This estimate does not include spawning adults in the lower Feather River where green sturgeon spawning was recently confirmed, however. Mora (2016) also applied a conceptual demographic structure to the above adult population estimate and generated a subadult sDPS green sturgeon population estimate of 10,450 (95% CI = 6,155-14,745). Data and modelling from those surveys has greatly improved our understanding of adult sDPS green sturgeon abundance and may eventually provide population abundance trends with additional surveys and improvements to demographic structure models.

Green Sturgeon Productivity

The parameters of green sturgeon productivity, or population growth rate, and carrying capacity in the Sacramento River Basin are poorly understood. Larval count data from incidental bycatch in rotary screw traps seasonally near the Red Bluff and Glen Colusa Irrigation District diversions show enormous variability between years with a high count of over 30 green sturgeon per acre-feet of water volume sampled in 2016 (while in other years larval counts were an order of magnitude lower (USFWS 2016). There is some concern that the Sacramento River may have temperature regimes too cold for optimal larval growth, or for optimal hatching success in the upper regions of the river (Poytress et al. 2013). In general, sDPS green sturgeon year class strength appears to be highly variable with overall abundance dependent upon a few successful spawning events (NMFS 2010). It is unclear if the population is able to consistently replace itself or grow to greater abundance than levels currently observed. Other indicators of productivity, such as data for cohort replacement rates, do not exist for sDPS green sturgeon. The long lifespan of the species and long age to maturity makes trend detection dependent upon data sets spanning decades, something that is currently lacking. Continuation of the acoustic telemetry work initiated on the Sacramento and Feather rivers (Mora 2016, Seesholtz et al. 2015, as well as larval and juvenile studies carried out in the upper Sacramento River (Poytress et al. 2012), may eventually produce a more statistically robust analysis of productivity.

Green Sturgeon Spatial Structure

Green sturgeon (made up of both nDPS and sDPS) are known to range from Baja California to the Bering Sea along the North American continental shelf. During the late summer and early fall, subadults and non-spawning adult green sturgeon frequently can be found aggregating in estuaries along the Pacific coast (Emmett 1991, Moser and Lindley 2007). Israel et al. (2009)

found that green sturgeon within the Central Valley of California are sDPS green sturgeon. Acoustic tagging studies have additionally shown that green sturgeon found within the San Francisco Bay estuary and further inland are exclusively sDPS green sturgeon.

In waters inland from the Golden Gate Bridge in California, sDPS green sturgeon are known to range through the estuary and the Delta and upstream within the Sacramento, Feather, and Yuba rivers. In the Yuba River, green sturgeon have been documented as far upstream as Daguerre Point Dam (Bergman et al. 2011). Migration past Daguerre Point Dam is not possible for green sturgeon, although potential spawning habitat upriver does exist. The same can be said about the Feather River where green sturgeon have been observed by DWR staff as far upstream as the Fish Barrier Dam. On the Sacramento River, Keswick Dam, located at RM (river mile) 302, marks the highest point on the river accessible to green sturgeon, and it might be presumed that green sturgeon would utilize habitat to this point. However, USFWS sampled for larvae in 2012 at RM 267 and at RM 292 and no larvae were caught at these locations; habitat usage could not be confirmed any further upriver than the confluence with Ink’s Creek (RM 264), which was a confirmed spawning site in 2011 (Poytress et al. 2012). However, Heublein (2008) detected adults as far upstream as river km 451 near Cow Creek, suggesting that their spawning range may extend farther upstream than previously documented. The upstream extent of their spawning range lies somewhere below ACID (river km 480), as that dam impedes passage for green sturgeon in the Sacramento River (Heublein et al. 2008). It is uncertain, however, if green sturgeon spawning habitat exists closer to ACID, which could allow spawning to shift upstream in response to climate change effects. Adams et al. (2007) summarizes information that suggests sDPS green sturgeon may have been distributed above the locations of present-day dams on the Sacramento and Feather rivers. Mora et al. (2009) analyzed and characterized known green sturgeon habitat and used that characterization to identify historic green sturgeon habitat within the Sacramento River and San Joaquin River basins that are currently blocked by dams. This study concluded that about 9 percent of historically available habitat now blocked by impassible dams, was likely of high quality for spawning.

Mora (2016) demonstrated that green sturgeon spawning sites are concentrated into a very few locations, finding that in the Sacramento River just 3 sites accounted for over 50 percent of the green sturgeon documented in June of 2010, 2011, and 2012. This is a critical point with regards to the application of the spatial structure VSP parameter, which is largely concerned with the spawning habitat spatial structure, as well as other life history stages. A high concentration of individuals in just a few spawning sites, is more vulnerable to increased extinction risk due to stochastic events.

Green sturgeon have been documented in areas of the lower San Joaquin River; (Radtke 1966) reported catching green sturgeon in tidal portions of the San Joaquin River at the Santa Clara Shoals. Modern usage of the San Joaquin River by green sturgeon primarily occurs in tidal areas of the Delta. Anglers have reported catching green sturgeon at various locations within the San Joaquin River basin upstream of the tidally-influenced Delta, however, no photographic evidence has surfaced. Unless stronger evidence can be substantiated, it is currently believed that green sturgeon only utilize tidal portions of San Joaquin River and its tributaries.

In summary, current available information indicates that the spatial structure of sDPS green sturgeon is composed of a single, independent population, which principally spawns in the mainstem Sacramento River, and also breeds opportunistically in the Feather River and possibly even the Yuba River. Concentration of adults into a very few select spawning locations makes the species highly vulnerable to poaching and catastrophic events. The apparent extirpation from upstream spawning reaches of the San Joaquin River narrows the habitat usage by the species, leaving little buffer to impacts to the species.

Green Sturgeon Diversity

Diversity, as defined in McElhany et al. (2000), includes genetic traits such as DNA sequence variation, and other traits that are influenced by both genetics and the environment, such as ocean behavior, age at maturity, and fecundity. Variation is important to the viability of a species for several reasons. First, it allows a species to utilize a wider array of environments than they could without it. Second, diversity protects a species from short term spatial and temporal changes in the environment by increasing the likelihood that at least some individuals will have traits that allow them to persist in spite of changing environmental conditions. Third, genetic diversity provides the raw material necessary for the species to have a chance to adapt to changing environmental conditions over the long term.

While it is recognized that diversity is crucial to the viability of a species in general, it is not well understood how well sDPS green sturgeon display these diversity traits and if there is sufficient diversity to buffer against long term extinction risk. In general, a larger number of populations and number of individuals within those populations should offer increased diversity and greater chance of long term viability. The diversity of sDPS green sturgeon is probably low given current abundance estimates, and limited spatial structure. Also, because human alteration of the environment is so pervasive in the California Central Valley, basic diversity principles such as run timing and behavior are likely adversely influenced through mechanisms such as diminished springtime flow rates as water is impounded behind dams.

Green Sturgeon sDPS Viability Summary

The viability of sDPS green sturgeon is constrained by factors such as a small population size, lack of multiple populations, and concentration of spawning sites into a limited section of the river. The risk of extinction is believed to be moderate because, although threats due to habitat alteration are thought to be high and indirect evidence suggests a decline in abundance, there is much uncertainty regarding the scope of threats and the accuracy of population abundance indices (NMFS 2010). Viable status is defined as an independent population having a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year timeframe (McElhany et al. 2000). The best available scientific information does not indicate that the extinction risk facing sDPS green sturgeon is negligible over a long term (~100 year) time horizon; therefore, the sDPS is not currently viable. To support this statement, the population viability analysis (PVA) that was done for sDPS green sturgeon in relation to stranding events (Thomas et al. 2013) may provide some insight. While this PVA model made many assumptions that need to be verified as new information becomes available, it was alarming to note that over a 50-year time period the sDPS green sturgeon population declined under all scenarios where stranding events were recurrent over the lifespan of a green sturgeon.

Although the population structure of sDPS green sturgeon is still being refined, it is currently believed that only one population of sDPS green sturgeon exists. Lindley et al. (2007), in discussing winter-run Chinook salmon, stated that an ESU represented by a single population at moderate risk of extinction is at high risk of extinction over the long run. This concern applies to any DPS or ESU represented by a single population, and if this were to be applied to sDPS green sturgeon directly, it could be said that sDPS green sturgeon face a high extinction risk. However, NMFS concludes, upon weighing all available information (and lack thereof), the extinction risk is moderate (NMFS 2010). Additional information about sDPS green sturgeon is critical, especially with regards to a robust abundance estimate, habitat usage, a greater understanding of their biology, and further information about their habitat needs.

2.7.7.2 Summary of Proposed Action Effects

Detailed descriptions regarding the exposure, response, and risk of green sturgeon to stressors associated with the PA are presented in section 2.5, Effects of the Action. The proposed action-related effects to green sturgeon have been split between construction-related and those that are related to operations. The distinction was also made based on differences in expected duration of effect where effects of construction activities are generally expected to occur over a finite period while operations-related effects and the effects of permanent structures are considered ongoing. Construction-related effects on green sturgeon are summarized in Table 2-259.

Table 2-259. Integration and synthesis of construction related effects with the environmental baseline and cumulative effects on green sturgeon.

Section Number	Stressor	Life Stage (Location)	Life Stage Timing (work window intersection)	Response and Rationale of effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of Overall Effect (PA + Baseline + Cumulative Effects (CE))
2.5.1.1.1.1	Pile Driving (Acoustic)							
		Juveniles and post-spawn adults (NDD)	6/15 – 9/15	Injury or mortality caused by anthropogenic noise induced barotrauma which may be instantaneous or delayed. Reduced foraging opportunities as a result of avoidance of near shore rearing habitat.	Medium – Expected to affect a very small proportion of the population seasonally over multiple years	High – Multiple technical publications including quantitative modeling results.	Reduced survival, fitness, and/or growth.	Medium – Expected to affect a very small proportion of the population seasonally over multiple years; baseline and CE add “periodic” pile driving (section 2.4.4.6).
		Juveniles and sub-adults (CCF)	7/1 – 10/31	Injury or mortality caused by anthropogenic noise induced barotrauma which may be instantaneous or delayed.	Low – minimal exposure to a very small proportion of the population.	High – Multiple technical publications including quantitative modeling results.	Reduced survival.	Low – minimal exposure to a very small proportion of the population; baseline and CE add “periodic” pile driving (section 2.4.4.6 of the Baseline)
		Juveniles and sub-adults (HOR)	7/1 – 8/31	Injury or mortality caused by anthropogenic noise induced barotrauma which may be instantaneous or delayed. Reduced foraging opportunities as a result of avoidance	Medium – Expected to affect a very small proportion of the population seasonally over multiple years	High – Multiple technical publications including quantitative modeling results.	Reduced survival, fitness, and/or growth.	Medium – Expected to affect a very small proportion of the population seasonally over multiple years; baseline and CE add “periodic” pile driving (section 2.4.4.6).

				of near shore rearing habitat.				
		Juveniles and sub-adults (BLL)	7/1 – 8/31	Injury or mortality caused by anthropogenic noise induced barotrauma which may be instantaneous or delayed. Reduced foraging opportunities as a result of avoidance of near shore rearing habitat.	Medium – Expected to affect a very small proportion of the population seasonally over multiple years	High – Multiple technical publications including quantitative modeling results.	Reduced survival, fitness, and/or growth.	Medium – Expected to affect a very small proportion of the population seasonally over multiple years; baseline and CE add "periodic" pile driving (section 2.4.4.6).
2.5.1.1.1.2	Barge Traffic (Acoustic)	Juvenile rearing and emigration; Sub-adult foraging; Adult immigration and emigration (Delta)	6/1 – 2/28	Reduced feeding/foraging behavior due to increased stress, distraction, displacement from rearing habitat, and prey masking.	Low - Generally sublethal effect, expected to be imposed on a small proportion of the population over multiple years.	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration and extent of barge operations.	Reduced growth	Low to Medium – Generally sublethal effect, expected to be imposed on a small proportion of the population over multiple years;, however, baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic" (section 2.4.4.5).
2.5.1.1.2.1	Pile Driving (Sediment Concentration)							
		Juveniles and post-spawn adults (NDD)	6/15 – 9/15	Sublethal exposure to reduced dissolved oxygen concentrations and prey masking.	Low - Generally sublethal effect, expected to be imposed on a very small proportion of the population	Low – Effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low – Generally sublethal effect, expected to be imposed on a very small proportion of the population; baseline and CE add "periodic" pile driving (section 2.4.4.6)

		Juveniles and sub-adults (CCF)	7/1 – 10/31	Sublethal exposure to reduced dissolved oxygen concentrations and prey masking.	Low - Generally sublethal effect, expected to be imposed on a very small proportion of the population	Low – Effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low – Generally sublethal effect, expected to be imposed on a very small proportion of the population; baseline and CE add “periodic” pile driving (section 2.4.4.6).
		Juveniles and sub-adults (HOR)	7/1 – 8/31	Sublethal exposure to reduced dissolved oxygen concentrations and prey masking.	Low - Generally sublethal effect, expected to be imposed on a very small proportion of the population	Low – Effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low – Generally sublethal effect, expected to be imposed on a very small proportion of the population; baseline and CE add “periodic” pile driving (section 2.4.4.6).
		Juveniles and sub-adults (BLL)	7/1 – 8/31	Sublethal exposure to reduced dissolved oxygen concentrations and prey masking.	Low - Generally sublethal effect, expected to be imposed on a very small proportion of the population	Low – Effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low – Generally sublethal effect, expected to be imposed on a very small proportion of the population; baseline and CE add “periodic” pile driving (section 2.4.4.6 of the Baseline).
2.5.1.1.2.2	Barge Traffic (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	6/1 – 2/28	Sublethal exposure to reduced dissolved oxygen concentrations and prey masking.	Low - Generally sublethal effect, expected to be imposed on a small proportion of the population over multiple years	Low – Effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding timing, duration and extent of barge operations.	Reduced growth	Low – Generally sublethal effect, expected to be imposed on a small proportion of the population over multiple years; however, baseline and CE adds that portions of the action area “experience

								heavy commercial and recreational vessel traffic.” (Section 2.4.4.5)
2.5.1.1.2.3	Geotechnical Analysis (Sediment Concentration)	Juvenile rearing and emigration (Delta)	Year round presence	No response, as turbidity associated with geotechnical analysis is likely imperceptible.	NA	Low – Effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	NA	NA (Geotechnical analysis is not included in the Environmental Baseline Section 2.4)
2.5.1.1.2.4	Dredging (Sediment Concentration) + Facility Maintenance (2.5.1.2.9.1)							
		Juveniles and post-spawn adults (NDD)	6/15 – 10/31	Sublethal exposure to reduced dissolved oxygen concentrations and prey masking.	Low - Generally sublethal effect limited to a very small proportion of the population.	Low – effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population; baseline and CE add “periodic” dredging projects in the Action Area that are of “varying scope and scale.” (section 2.4.4.4)
		Juveniles and sub-adults (CCF)	7/1 – 10/31	Sublethal exposure to reduced dissolved oxygen concentrations and prey masking.	Low - Generally sublethal effect limited to a very small proportion of the population.	Low – effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population; baseline and CE add “periodic” dredging projects in the Action Area that are of “varying scope

								and scale." (section 2.4.4.4)
		Juveniles and sub-adults (HOR)	8/1 – 10/31	Sublethal exposure to reduced dissolved oxygen concentrations and prey masking.	Low - Generally sublethal effect limited to a very small proportion of the population.	Low – effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population; baseline and CE add "periodic" dredging projects in the Action Area that are of "varying scope and scale." (section 2.4.4.4)
		Juveniles and sub-adults (BLL)	8/1 – 10/31	Sublethal exposure to reduced dissolved oxygen concentrations and prey masking.	Low - Generally sublethal effect limited to a very small proportion of the population.	Low – effect of turbidity on sturgeon is unclear and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population; baseline and CE add "periodic" dredging projects in the Action Area that are of "varying scope and scale." (section 2.4.4.4)
2.5.1.1.3.1	Pile Driving (Contaminant Exposure)							
		Juveniles and post-spawn adults (NDD)	6/15 – 9/15	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low – Generally sublethal effect, limited to a very small proportion of the population. Baseline and CE add "periodic" pile driving (Section 2.4.4.6)

	Juveniles and sub-adults (CCF)	7/1 – 10/31	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low – Generally sublethal effect, limited to a very small proportion of the population. Baseline and CE add "periodic" pile driving (Section 2.4.4.6) in areas potentially exhibiting "documented high levels of contaminants" in the Action Area. (section 2.4.4.1)
	Juveniles and sub-adults (HOR)	7/1 – 8/31	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low – Generally sublethal effect, limited to a very small proportion of the population. Baseline and CE add "periodic" pile driving (Section 2.4.4.6) in areas potentially exhibiting "documented high levels of contaminants" in the Action Area. (section 2.4.4.1)
	Juveniles and sub-adults (BLL)	7/1 – 8/31	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low – Generally sublethal effect, limited to a very small proportion of the population. Baseline and CE add "periodic" pile driving (Section 2.4.4.6) in areas potentially

				levels), and histological changes				exhibiting "documented high levels of contaminants" in the Action Area. (section 2.4.4.1)
2.5.1.1.3.2	Barge Traffic (Contaminant Exposure)	Juvenile rearing and emigration; Sub-adult foraging; Adult immigration and emigration (Delta)	6/1 – 2/28	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect expected to affect a small proportion of the population.	Low - Understanding is Medium but nature of outcome is somewhat unpredictable owing to uncertainty regarding timing, duration and extent of barge operations as well as sediment composition.	Reduced growth, Reduced reproductive success	Low to Medium – Generally sublethal effect expected to affect a small proportion of the population; however the baseline adds that portions of the action area potentially exhibit "documented high levels of contaminants" (Section 2.4.4.1) and may additionally "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)
2.5.1.1.3.3	Geotechnical Analysis (Contaminant Exposure)	Juvenile rearing and emigration (Delta)	Year round presence	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low – Generally sublethal effect limited to a very small proportion of the population. (Geotechnical analysis is not included in the Environmental Baseline Section 2.4)
2.5.1.1.3.4	Dredging (Contaminant Exposure) + Facility Maintenance (2.5.1.2.9.1)							

	Juveniles and post-spawn adults (NDD)	6/15 – 10/31	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low - Generally sublethal effect limited to a very small proportion of the population; baseline and CE add “periodic” dredging projects in the Action Area that are of “varying scope and scale.” (section 2.4.4.4)
	Juveniles and sub-adults (CCF)	7/1 – 10/31	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low to Medium - Generally sublethal effect limited to a very small proportion of the population; however, the baseline and CE add “periodic” dredging projects in the Action Area that are of “varying scope and scale” (section 2.4.4.4) in areas that may potentially exhibit “documented high levels of contaminants” (Section 2.4.4.1)
	Juveniles and sub-adults (HOR)	8/1 – 10/31	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low to Medium - Generally sublethal effect limited to a very small proportion of the population; however, the baseline and CE add “periodic” dredging projects in the

				levels), and histological changes				Action Area that are of “varying scope and scale” (section 2.4.4.4) in areas that may potentially exhibit “documented high levels of contaminants” (Section 2.4.4.1)
		Juveniles and sub-adults (BLL)	8/1 – 10/31	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a very small proportion of the population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth, Reduced reproductive success	Low to Medium - Generally sublethal effect limited to a very small proportion of the population; however, the baseline and CE add “periodic” dredging projects in the Action Area that are of “varying scope and scale” (section 2.4.4.4) in areas that may potentially exhibit “documented high levels of contaminants” (Section 2.4.4.1)
2.5.1.1.4.1	Clearing and Grubbing (Increased Temperature) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Sub-adult foraging; Adult immigration and emigration (Delta)	Year round presence	No response, as temperature changes associated with removal of riparian vegetation are likely imperceptible.	NA	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to uncertainty regarding the extent of thermal change.	NA	NA
2.5.1.1.5.1	Pile Driving (Reduced Prey)							

		Juveniles and post-spawn adults (NDD)	6/15 – 9/15	Increasing feeding success rate as anthropogenic waves may inject prey species into the water column or expose benthic infauna.	Low - Minor or short-term effect that impacts a small proportion of the population.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	Increased growth	Low – Minor or short-term effect that impacts a small proportion of the population; baseline and CE add "periodic" pile driving (Section 2.4.4.6 of the Baseline)
		Juveniles and sub-adults (CCF)	7/1 – 10/31	Increasing feeding success rate as anthropogenic waves may inject prey species into the water column or expose benthic infauna.	Low - Minor or short-term effect that impacts a small proportion of the population.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	Increased growth	Low – Minor or short-term effect that impacts a small proportion of the population, baseline and CE add "periodic" pile driving (Section 2.4.4.6 of the Baseline)
		Juveniles and sub-adults (HOR)	7/1 – 8/31	Increasing feeding success rate as anthropogenic waves may inject prey species into the water column or expose benthic infauna.	Low - Minor or short-term effect that impacts a small proportion of the population.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	Increased growth	Low – Minor or short-term effect that impacts a small proportion of the population; baseline and CE add "periodic" pile driving (Section 2.4.4.6 of the Baseline)
		Juveniles and sub-adults (BLL)	7/1 – 8/31	Increasing feeding success rate as anthropogenic waves may inject prey species into the water column or expose benthic infauna.	Low - Minor or short-term effect that impacts a small proportion of the population.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	Increased growth	Low – Minor or short-term effect that impacts a small proportion of the population; baseline and CE add "periodic" pile driving (Section 2.4.4.6 of the Baseline)
2.5.1.1.5.2	Barge Traffic (Reduced Prey)	Juvenile rearing and	6/1 – 2/28	Increasing feeding success rate as	Low – A minor effect that	Low - There are few papers or technical	Increased growth	Low to Medium – A minor effect that

		emigration; Sub-adult foraging; Adult immigration and emigration (Delta)		anthropogenic waves may inject prey species into the water column or expose benthic infauna.	impacts a small proportion of the population.	documents to support and the nature of outcome is unpredictable owing to uncertainty related to timing, duration and extent of barge operations as well as the extent of prey availability.		impacts a small proportion of the population; however, baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)
2.5.1.1.5.3	Geotechnical analysis (Reduced Prey)	Juvenile rearing and emigration; Sub-adult foraging; Adult immigration and emigration (Delta)	Year round presence	No response, as changes in prey abundance and availability associated with geotechnical analysis are likely imperceptible.	NA	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	NA	NA (Geotechnical analysis is not included in the Environmental Baseline Section 2.4)
2.5.1.1.5.4	Dredging (Reduced Prey) + Facility Maintenance (2.5.1.2.9.2)							
		Juveniles and post-spawn adults (NDD)	6/15 – 10/31	Reduced prey availability, decreasing feeding success caused by the removal of benthic sediments and infauna (prey base).	Low - Generally sublethal effect limited to a very small proportion of the population.	Medium - Understanding is High but nature of outcome is somewhat unpredictable because of uncertainty regarding sediment/prey composition.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population; baseline and CE add "periodic" dredging projects in the Action Area that are of "varying scope and scale." (section 2.4.4.4)
		Juveniles and sub-adults (CCF)	7/1 – 10/31	Reduced prey availability, decreasing feeding success caused by the removal of	Low - Generally sublethal effect limited to a very small	Medium - Understanding is High but nature of outcome is somewhat unpredictable because	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population;

				benthic sediments and infauna (prey base).	proportion of the population.	of uncertainty regarding sediment/prey composition.		baseline and CE add "periodic" dredging projects in the Action Area that are of "varying scope and scale." (section 2.4.4.4)
		Juveniles and sub-adults (HOR)	8/1 – 10/31	Reduced prey availability, decreasing feeding success caused by the removal of benthic sediments and infauna (prey base).	Low - Generally sublethal effect limited to a very small proportion of the population.	Medium - Understanding is High but nature of outcome is somewhat unpredictable because of uncertainty regarding sediment/prey composition.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population; baseline and CE add "periodic" dredging projects in the Action Area that are of "varying scope and scale." (section 2.4.4.4)
		Juveniles and sub-adults (BLL)	8/1 – 10/31	Reduced prey availability, decreasing feeding success caused by the removal of benthic sediments and infauna (prey base).	Low - Generally sublethal effect limited to a very small proportion of the population.	Medium - Understanding is High but nature of outcome is somewhat unpredictable because of uncertainty regarding sediment/prey composition.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population; baseline and CE add "periodic" dredging projects in the Action Area that are of "varying scope and scale." (section 2.4.4.4)
2.5.1.1.5.5	Clearing and Grubbing (Reduced Prey) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Sub-adult foraging; Adult immigration and emigration (Delta)	Year round presence	No response, as changes in prey abundance and availability associated with removal of riparian vegetation are likely imperceptible.	NA	High - multiple scientific and technical publications	NA	NA
2.5.1.1.6.1	Pile Driving (Increased Predation)							

		Juvenile rearing and emigration (NDD)	6/15 – 9/15	Increased mortality (predation) caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Low - Acute effect limited to a very small proportion of the population.	Low – Rates of predation on juvenile sturgeon in the river are poorly understood and difficult to verify or quantify.	Reduced survival	Low - Acute effect limited to a very small proportion of the population; baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)
		Juvenile rearing and emigration (CCF)	7/1 – 10/31	Increased mortality (predation) caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Low - Acute effect limited to a very small proportion of the population.	Low – Rates of predation on juvenile sturgeon in the river are poorly understood and difficult to verify or quantify.	Reduced survival	Low - Acute effect limited to a very small proportion of the population; baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)
		Juvenile rearing and emigration (HOR)	7/1 – 8/31	No response as juvenile sturgeon in the vicinity of HOR will be of a sufficient size and stage of development to diminish the likelihood of being preyed upon.	NA	Low – Rates of predation on juvenile sturgeon in the river are poorly understood and difficult to verify or quantify.	NA	NA
		Juvenile rearing and emigration (BLL)	7/1 – 8/31	Increased mortality (predation) caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Low - Acute effect limited to a very small proportion of the population.	Low – Rates of predation on juvenile sturgeon in the river are poorly understood and difficult to verify or quantify.	Reduced survival	Low - Acute effect limited to a very small proportion of the population; baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)
2.5.1.1.6.2	Barge Traffic (Increased Predation)	Juvenile rearing and emigration	6/1 – 2/28	Increased mortality (predation) caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Low - Acute effect limited to a very small proportion of the population.	Low – Rates of predation on juvenile sturgeon in the river are poorly understood and difficult to verify or quantify.	Reduced survival	Low – Acute effect limited to a very small proportion of the population over multiple years; however, baseline and CE adds that

								portions of the action area “experience heavy commercial and recreational vessel traffic.” (Section 2.4.4.5)
2.5.1.1.6.3	Interim in-water structures (Increased Predation)	Juvenile rearing and emigration	Year round presence	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Low - Acute effect limited to a very small proportion of the population.	Low – Rates of predation on juvenile sturgeon in the river are poorly understood and difficult to verify or quantify.	Reduced survival	Low - Acute effect limited to a very small proportion of the population.
2.5.1.1.6.4	Clearing and Grubbing (Increased Predation) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration	Year round presence	No response, as changes in available predator refugia associated with removal of riparian vegetation is likely imperceptible.	NA	Low – Rates of predation on juvenile sturgeon in the river are poorly understood and difficult to verify or quantify.	NA	NA
2.5.1.1.7.1	Pile Driving (Physical Impacts to Fish)	Juveniles and post-spawn adults (NDD)	6/15 – 9/15	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile driving-induced sound creates a temporary barrier to migration.	Low - Expected sublethal effect limited to a very small proportion of the population	High – Multiple technical publications including quantitative modeling results.	Reduced growth, Reduced reproductive success (adults)	Low - Expected sublethal effect limited to a very small proportion of the population; baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)
		Juveniles (CCF)	7/1 – 10/31	Sublethal, behavioral response. Displacement or delayed juvenile emigrations as pile driving-induced sound creates a temporary barrier to migration.	Low - Expected sublethal effect limited to a very small proportion of the population	High – Multiple technical publications including quantitative modeling results.	Reduced growth	Low - Expected sublethal effect limited to a very small proportion of the population; baseline and CE add “periodic” pile

								driving (Section 2.4.4.6 of the Baseline)
		Juveniles (HOR)	7/1 – 8/31	Sublethal, behavioral response. Displacement or delayed juvenile emigrations as pile driving-induced sound creates a temporary barrier to migration.	Low - Expected sublethal effect limited to a very small proportion of the population	High – Multiple technical publications including quantitative modeling results.	Reduced growth	Low - Expected sublethal effect limited to a very small proportion of the population; baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)
		Juveniles (BLL)	7/1 – 8/31	Sublethal, behavioral response. Displacement or delayed juvenile emigrations as pile driving-induced sound creates a temporary barrier to migration.	Low - Expected sublethal effect limited to a very small proportion of the population	High – Multiple technical publications including quantitative modeling results.	Reduced growth	Low - Expected sublethal effect limited to a very small proportion of the population; baseline and CE add “periodic” pile driving (Section 2.4.4.6 of the Baseline)
2.5.1.1.7.2	Dredging entrainment (Physical Impacts to Fish) + Facility Maintenance (2.5.1.2.10)	Juveniles and post-spawn adults (NDD)	6/15 – 10/31	Mortality from entrainment into dredge cutterhead.	Low - Expected acute effect limited to a very small proportion of the population	High – There are multiple scientific and technical publications	Reduced survival	Low – Expected acute effect limited to a very small proportion of the population; baseline and CE add “periodic” dredging projects in the Action Area that are of “varying scope and scale.” (section 2.4.4.4)
		Juveniles and sub-adults (CCF)	7/1 – 10/31	Mortality from entrainment into dredge cutterhead.	Low - Expected acute effect limited to a very small proportion of the population	High – There are multiple scientific and technical publications	Reduced survival	Low – Expected acute effect limited to a very small proportion of the population; baseline and CE add “periodic” dredging

								projects in the Action Area that are of "varying scope and scale." (section 2.4.4.4)
		Juveniles and sub-adults (HOR)	8/1 – 10/31	Mortality from entrainment into dredge cutterhead.	Low - Expected acute effect limited to a very small proportion of the population	High – There are multiple scientific and technical publications	Reduced survival	Low – Expected acute effect limited to a very small proportion of the population; baseline and CE add "periodic" dredging projects in the Action Area that are of "varying scope and scale." (section 2.4.4.4)
		Juveniles and sub-adults (BLL)	8/1 – 10/31	Mortality from entrainment into dredge cutterhead.	Low - Expected acute effect limited to a very small proportion of the population	High – There are multiple scientific and technical publications	Reduced survival	Low – Expected acute effect limited to a very small proportion of the population; baseline and CE add "periodic" dredging projects in the Action Area that are of "varying scope and scale." (section 2.4.4.4)
2.5.1.1.7.3	Propeller entrainment (Physical Impacts to Fish)	Juvenile rearing and emigration; Sub-adult foraging; Adult immigration and emigration (Delta)	Year round presence	Injury and mortality from entrainment into the propellers of passing barges.	High - Expected acute sustained population effect across a large area.	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration and extent of barge operations and vessel traffic.	Reduced survival	High - Expected acute sustained population effect across a large area; however, baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic." (Section 2.4.4.5)

2.5.1.1.7.4	Dewatering (Physical Impacts to Fish) + Facility Maintenance (2.5.1.2.10)	Juvenile rearing and emigration; Adult immigration (Delta)	Year round presence	Injury and mortality from dewatering and handling during rescue operations.	Low - Acute effect limited to a very small proportion of the population	High – There are multiple scientific and technical publications	Reduced survival	Low – Acute effect limited to a very small proportion of the population. (Dewatering is not included in the Environmental Baseline Section 2.4)

Post-construction operational effects of the action on green sturgeon are summarized in Table 2-260. Because a more certain characterization of the effects of operations will depend on a number of design criteria and real-time factors, this Opinion analyzes a range of effects depending on the expected use of these criteria and factors. The expectation remains, however, that certain aspects of this effects analysis will be reevaluated through proposed research, monitoring, and adaptive management. This expectation is confirmed in Chapter 7 of the BA (Effects Determination), which provides, "the RTO and adaptive management and monitoring provisions included in the PA provide additional opportunities to refine the operating criteria and make adjustments to CVP/SWP Delta operations to minimize the risks of incidental take while maximizing water supply." In this Opinion, NMFS' assessment of operational effects relies on the best scientific and commercial data available (section 2.5.1.2 Operations Effects) and the understanding that the specifics of operations and facility design criteria will be refined within the bounds of the RTO and adaptive management and monitoring programs.

Table 2-260. Integration and synthesis of post-construction, operational effects with the environmental baseline and cumulative effects on green sturgeon.

Section Number	Stressor	Life Stage (Location)	Life Stage Timing	Response and Rationale of effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of Overall Effect (PA + Baseline + Cumulative Effects (CE))
2.5.1.2.1	Operations (Increased Upstream Temperature)	Juveniles and spawning or post-spawn adults.	Year round presence	No response - Upstream temperatures are already lower than the reported optimum temperatures for sturgeon.	NA	High: Supported by multiple scientific and technical publications.	NA	NA
2.5.1.2.2	Operations (Redd Dewatering)	Juveniles and spawning or post-spawn adults.	Year round presence	No response – Spawning preferences (e.g. deep pools, fast flowing water) reduce to the risk of dewatering such that it is unlikely.	NA	Medium: Supported by multiple scientific and technical publications, although there is limited information regarding exact location and distribution of spawning	NA	NA
2.5.1.2.3	Operations (Redd Scour)	Juveniles and spawning or post-spawn adults.	Year round presence	No response – Spawning preferences (e.g. deep pools, coble sediment) reduce to the risk of scour such that it is unlikely.	NA	Medium: Supported by multiple scientific and technical publications, although there is limited information regarding exact location and distribution of spawning	NA	NA
2.5.1.2.4	Operations (Stranding)	Juveniles and spawning or post-spawn adults.	Year round presence	Mortality either directly through desiccation or indirectly through reduced water quality.	Uncertain - Effects of the proposed action are difficult to distinguish from the NAA.	High: Supported by multiple scientific and technical publications including recent and historic observations.	Reduced survival	Medium - Expected acute population effect on a small proportion of the population.
2.5.1.2.5	Operations (Impingement	Juvenile migration and rearing (Delta)	Year round presence	Injury and mortality from contact and	Low - Acute effect limited to very small	Medium - Understanding is High but nature of outcome is somewhat unpredictable	Reduced survival	Low - Acute effect limited to very small proportion of the population.

	and Entrainment)			interactions with screens.	proportion of the population.	due to uncertainty of exposure.		
2.5.1.2.6.1	Permanent In-water Structures (Increased Predation)	Juvenile migration and rearing (Delta)	Year round presence	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Low - Acute effect limited to very small proportion of the population.	Low – There is little information about predation rates on juvenile sturgeon.	Reduced survival	Low – Baseline and CE are poorly understood but inclusion of effects from PA is unlikely to reflect a detectable difference above baseline.
2.5.1.2.7	Operations (Reduced In-Delta Flows)	Juvenile and spawning or post-spawn adults	Year round presence	Increased migration times and reduced availability of rearing habitat.	Uncertain - Effects of the proposed action are difficult to distinguish from the NAA.	Low – Understanding of effect is limited and extent of exposure is uncertain.	Reduced survival	Low - Acute effect limited to very small proportion of the population.
2.5.1.2.7.3.1	CVP/SWP Operations (Entrainment and loss at South Delta export facilities)	Juvenile migration and rearing (Delta)	Year round presence	Loss is approximately 35% of entrained fish at the CVP's Tracy Fish Collection Facility, and 84% at the SWP's Skinner Delta Fish Protective Facility.	Low - Expected sustained population effect on a small proportion of the population.	High – Numerous studies have evaluated screening efficiency, predation, and overall salvage operations survival	Reduced survival	Low - Expected sustained population effect on a small proportion of the population.
2.5.1.3.1.1	Suisun Marsh Salinity Control Gates	Juvenile rearing and emigration; Adult immigration (Suisun Marsh)	Year round presence	Limited effect to juveniles; sublethal, behavioral effect to adults, migration delay and changes to routing.	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population.	Medium – Delta hydrodynamics well studied. Effects of Delta hydrodynamics on salmonid migration more uncertain.	Reduced reproductive success	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.1.2	Roaring River Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Year round presence	Mortality caused by entrainment into pumps distributing water to Suisun Marsh.	None – Fish screens of adequate size and approach velocities slow enough to	Medium – Fish/Screen interactions well studied. Observations at this location limited.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.

					exclude juveniles from entrainment.			
2.5.1.3.1.3	Morrow Island Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Year round presence	Mortality caused by entrainment into culverts diverting from Goodyear Slough, and draining into Grizzly Bay or Suisun Slough.	None – Entrainment of juveniles unlikely because of location of intakes and probable size of fish.	Low to Medium – Inference based on understanding of fish life history. Observations at this location limited, but include entrainment of fall-run Chinook salmon.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.1.4	Goodyear Slough Outfall	Juvenile rearing and emigration; (Suisun Marsh)	Year round presence	Passive entrainment into Suisun Marsh, possible improvement to water quality and available foraging habitat.	None or Low – Entrainment of juveniles unlikely because of location of intakes and probable size of fish.	Low – Inference based on understanding of fish life history. No observations at this location.	Improved growth	None or Low – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.2	North Bay Aqueduct	Juvenile rearing and emigration; (Delta)	Year round presence	Injury and mortality caused by entrainment into pumps or impingement in screens at North Bay Aqueduct, Barker Slough Intake.	None or Low – Entrainment or impingement of juveniles unlikely because of location of intakes, efficacy of fish screens and probable size of fish.	Low to Medium – Inference based on understanding of fish life history. Observations at this location limited.	Reduced survival	None or Low – Insignificant effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.3	Contra Costa Canal Rock Slough Intake	Juvenile rearing and emigration; (Delta)	Juvenile s: Year-round	Injury and mortality caused by entrainment into pumps or impingement in screens at Contra	None or Low – Entrainment or impingement of juveniles unlikely because of location of	Low to Medium – Inference based on understanding of fish life history. Continued testing of fish screen and vegetation removal expected until at least 2018.	Reduced survival	None or Low – Insignificant effect pending resolution of fish screen sweeping efficiency. Effects of the baseline and CE are superseded by the

	Costa Canal Rock Slough Intake.	intakes, and probable effectiveness of fish screens.		PA such that there is no additional impact.

2.7.7.3 Assess Risk to the Population

As stated Section 2.1.3.1.2, Approach to Southern Distinct Population Segment of Green Sturgeon, NMFS believes that the concepts and viability parameters developed to addresses viable populations of salmonids in McElhany et al. (2000b) can also be applied to the sDPS of green sturgeon due to the general similarity in life cycle and freshwater/ocean use. The VSP concept is an approach to evaluate the population viability of green sturgeon under the proposed action and a way to determine the extinction risk of the DPS based on changes to the VSP parameters of abundance, productivity, spatial structure, and diversity. Viability of the population and extinction risk of the ESU relate to the likelihood of both the survival and recovery of the ESU or DPS. As described in section 2.5 Effects of the Action, the proposed action will impose conditions in the Sacramento River and Delta that will affect green sturgeon in a number of ways that are expected to reduce the fitness of these individuals. Based on the change in fitness of these individuals, NMFS assesses whether the collective changes constitute a change in the VSP parameters and whether that change will affect the sDPS of green sturgeon population.

Green Sturgeon Abundance:

As it is for salmonids, the three key attributes of the abundance VSP parameter require that the relative size of a spawning population be large enough to: 1) have a high probability of surviving environmental variability; 2) allow compensatory process to provide resilience from environmental and anthropogenic disturbance; and 3) maintain its genetic diversity (McElhany et. al. 2000b). Although, the ability to derive a reliable estimate of sDPS green sturgeon population abundance is challenging, the current, best estimate of annual abundance of sDPS adults is 1,990 (CI = 1,172-2,808; Mora, 2016). Using salmonid risk to extinction values as a guide, this abundance is below the census population size of N > 2,500 identified by Lindley et. al. (2007) that would place a population at a low risk of extinction, but is also above the population size that would be considered high risk of extinction (i.e. $N \leq 250$). To assess the effects of the PA on the abundance VSP parameter of green sturgeon, NMFS uses changes in the adult population relative to the population criteria described. More specifically, if the probable change in fitness attributed to the effects of a stressor would results in 'reduced survival' or 'reduced reproductive success' (identified in Tables 2-259 and 2-260) for a significant proportion of adults, that would be considered a reduction of the abundance VSP parameter of the population. Changes to the juvenile and sub-adult populations are also considered; however, those affects are reflected in the assessment of the productivity VSP parameter, because juveniles and sub-adults are not part of the effective population and changes to the fitness of these life stages are not considered in the assessment of the abundance VSP parameter.

NMFS expects that the proposed action will have multiple construction-related impacts which will affect the adult population of green sturgeon, but that they are unlikely to reduce the abundance VSP parameter of sDPS to a point where it would alter the extinction risk of the population. Given the proposed in-water work windows for construction-related actions generally extend from June through October, it is expected that the timing of post-spawn adult migrations would overlap temporally with construction activities.

Most of the construction-related effects are expected to have a low magnitude of impact to exposed green sturgeon individuals such that they are unlikely to result in mortality or substantial injury. However, there are certain construction activities that are projected to have medium or high levels of impacts upon exposed adults (see Table 2-259). One of the construction-related impacts that will have a significant impact to the green sturgeon population is pile driving operations in the Delta (Section 2.5.1.1.1.1 Acoustics). And although most adult and subadult sDPS green sturgeon are likely to swim away from acoustic disturbances and thereby avoid the long term exposure to sustained acoustic disturbances that would result in physical injury, a very small proportion of the population would be subject to mortality caused by anthropogenic noise induced barotrauma. The remainder of the fish exposed to the acoustic noise stressor will incur effects ranging from sub-lethal injuries that may eventually heal to behavioral modifications and elevated stress levels. Those effects are likely to reduce the fitness and eventual spawning success of exposed adults which, if sufficient to diminish the reproductive success of individuals, would constitute a reduction in the effective population size of the sDPS.

The other construction-related stressor that will have an impact on the abundance VSP parameter of the green sturgeon population is the effect of increased Delta barge traffic. The timing and routing of construction-related Delta barge traffic has been modified to reduce the level of exposure experienced by most fish in the Sacramento River. However, certain sections of the Delta, that are part of the adult sturgeon’s domain, would still be exposed to year-round, increased barge traffic. In those areas, adults will be exposed to propeller entrainment and acoustic disturbance the combined effects of which would result in mortality or reduce the fitness of individual fish. The loss of a few individual fish over each year, coupled with consecutive years of acoustic stress caused by pile driving and barge operations, will decrease the size and fitness of the adult population of green sturgeon. On their own, however, the construction-related effects of the PA are unlikely to significantly reduce the abundance VSP parameter of green sturgeon or raise the risk of extinction for the population.

Green Sturgeon Productivity:

The productivity VSP parameter for green sturgeon, is described by the key attributes of a population’s ability to reproduce itself, and the survival of early life stages. For salmonids, the productivity VSP parameter is also described by a population’s resilience to the influence of hatchery produced spawners, but since the green sturgeon sDPS is not supplemented by a hatchery, this attribute does not factor into the consideration of productivity VSP parameter. Based on the attributes remaining for green sturgeon, the common metric used to assess the productivity VSP parameter is the population growth rate (or decline). Lindley et al. (2007) further identified that the population growth rate (10 year trend estimated from the slope of log-transformed estimated run size), must not show a decline in order for a salmonid population to be considered at a low risk of extinction. If the population is experiencing a decline within last two generations to annual run size ≤ 500 spawners, or run size > 500 but declining at ≥ 10% per year, that population would be considered at high risk of extinction. Direct measurements of productivity, such as larval count data at the RBDD rotary screw traps is highly variable and because of the long lifespan of the species and long age to maturity, trend detection dependent upon these types of data sets is extremely difficult. Given the limitations of using the metric of population growth rate (based on trend estimates) to assess changes in the green sturgeon population’s productivity VSP parameter; here we examine the relative effect of actions that would impact the juvenile population. Specifically, if the probable change in fitness attributed to the effects of a stressor would results in ‘reduced survival’ or ‘reduced growth’ (identified in Tables 2-259 and 2-260) for a significant proportion (≥ 10% per year) of juveniles or sub-adults, that would be considered a reduction of the productivity VSP parameter of the population.

NMFS expects that the proposed action will have multiple construction-related impacts which will affect the abundance and fitness of juvenile and sub-adult green sturgeon, but these impacts are unlikely to affect the productivity VSP parameter of sDPS in a way that it would alter the extinction risk of the population. Most of the construction-related effects are expected to have a low magnitude of impact to exposed green sturgeon individuals such that they are unlikely to result in mortality or substantial injury. For example, the effects of dredging activities which include exposure to increased turbidities and contaminants, as well as dredge cutterhead entrainment, are expected to be of low magnitude, only affecting a small proportion of the population. In addition, the degree to which green sturgeon are adversely affected by increased turbidity concentrations are uncertain at best, regardless of the mechanisms by which sediments become suspended or re-suspended in the water column owing to the fact that green sturgeon are evolutionarily adapted for life in turbid waters. Nevertheless, zones of increased suspended sediment concentrations are likely to result in pockets of low dissolved oxygen concentrations, and may additionally affect sturgeon by masking prey species availability and reducing foraging success. A more pressing concern for green sturgeon also associated with the re-suspension of bottom substrates is the potential for exposure to contaminants, either through direct dermal contact or ingestion of prey species. It is difficult to assess the magnitude of the effect from exposure to contaminants in an attributable and quantifiable way relative to the proposed project; however, NMFS expects the likelihood of a biological response, observable at either the individual or population level, to be low.

There are certain other construction activities that are projected to have medium or high levels of impacts upon exposed juveniles (see Table 2-259). One of the construction-related impacts that will have a significant impact to the green sturgeon population is pile driving operations in the Delta (Section 2.5.1.1.1.1 Acoustics). While most adult and subadult sDPS green sturgeon should be capable of swimming away from acoustic disturbances, thereby avoiding sustained exposure, juvenile sturgeon, particularly in the vicinity of the north Delta and upper Sacramento River, will be of a size that may preclude them from avoiding acoustic disturbances that extend over a large area up and down the river and across the entire width of the channel. The impact to individual green sturgeon juveniles is somewhat reduced by work window for impact pile driving (June 15 – September 15), during which the relative abundance of juveniles (≥ 5 months) in the vicinity of the NDD is medium. NMFS expects that the acoustic effects of construction-related pile driving will adversely affect a small proportion of juveniles.

Other actions associated with the construction elements of the PA, but that are not limited by a work-window, and that are considered to have impacts on the productivity of green sturgeon include: (1) the effects of barge traffic on vulnerability to propeller entrainment and the vulnerability to predation; and (2) elevated predation associated with interim structures associated with the construction phase of the PA. Since these elements of the project will be present year round in the Delta, they will affect the juvenile and sub-adult life stages of green sturgeon. It is highly probable that entrainment into the propeller of a barge or tug would likely be fatal, particularly for adult sized sturgeon. Juvenile sturgeon may be more easily entrained into the flow field passing through a propeller, but because of their smaller size they may also pass through without being struck by the propellers blades. Even though there is a high level of overlap with barge traffic and green sturgeon distribution in the Delta, so that potential exposure to barge traffic and associated propeller entrainment would be high, the behavior of sturgeon to stay out of the upper portion of the water column reduces their actual exposure to the propellers of the shallow draft tugboats. Furthermore, the restriction that the majority of barge traffic be contained within the San Joaquin River, out of the Sacramento River and the narrow, shallow sloughs of the Delta, is likely to limit exposure. Barge traffic and the potential for propeller entrainment is likely to result in adverse effects to only a medium proportion of juvenile and adult sDPS green sturgeon.

There is little evidence to suggest that sDPS green sturgeon are subjected to any degree of predation that might adversely impact their population numbers in the river or Delta. It is conceivable that juvenile sturgeon may be subjected to some amount of predation in the upper river owing to their smaller body size and the fact that their protective scutes are less well developed and not yet fully formed, but there is scant evidence in the way of research or literature that would support the conclusion that any of the projects actions that might result in increased levels of predation on salmonids would have the same effect on juvenile sturgeon, or to the same degree. Likewise, most of the operations-related effects are expected to have a universally low magnitude of impact on exposed green sturgeon juveniles because of their large size (relative to migrating salmonid juveniles). Predation associated with permanent in-water structures, screen impingement, and reduced Delta flows are all expected to have minimal impacts to green sturgeon juveniles such that they are unlikely to result in any appreciable reduction in the productivity VSP parameter of the population.

Green Sturgeon Spatial Structure:

The spatial structure parameter of a VSP is determined by the availability, diversity, and utilization of properly functioning habitats and the connections between such habitats. Green sturgeon are primarily limited in spatial structure as they comprise only one population that spawns in the Sacramento River but also breeds opportunistically in the Feather River and possibly even the Yuba River. The listing highlighted this as a major threat to the species, and to reduce this risk, consistent spawning is needed in at least one additional location outside the mainstem Sacramento River. Given the relative lack of habitat available to green sturgeon in the baseline, there could be considerable impact to the spatial structure VSP parameter if it is further reduced. Stressors, attributed to the PA, that would increase or further limit access to available habitats would be expected to affect the spatial structure VSP parameter.

As described in section 2.5.1.1 Construction Effects, and given the level of exposure to green sturgeon to the construction-related impacts, the PA could result in further limiting the species ability to move between habitats. Some stressors, such as physical impacts to fish from activities such as pile driving are expected to cause displacement or delayed migrations for a large portion of post-spawn adults. Based on the current proposed action description, the temporal exposure of sub-adult and adult green sturgeon to impact pile driving at the NDD location is mid-June to mid-September. Although adult and subadult sDPS green sturgeon are likely able to swim away from acoustic disturbances and thereby avoid the long term exposure to sustained acoustic disturbances that would result in physical injury, this behavioral change will cause disruption and delays to migrations each year for the duration of the NDD construction schedule. In section 2.5.1.2.1 Increased Upstream Temperature, the effects of temperatures under both the PA and the NAA were above the critical threshold for salmonid spawning and incubation during certain months for both the PA and NAA scenarios. These temperature-related effects are not expected for green sturgeon, however, because the species has a higher optimal temperature compared to the salmonid species. Therefore, the proposed action, when added to the environmental baseline, would not result in upstream conditions that would diminish the spatial structure VSP parameter in a way that is expected to limit the appropriate exchange of spawners or the expansion of a population into underused habitat.

As described in section 2.5.1.2 Operation Effects, under the proposed action, the spatial structure VSP parameter of green sturgeon would be further impacted because of decreasing flows and increasing travel time through the north Delta due to NDD operations, further altering the natural hydrograph of the Delta and its tributaries which limits access to habitats. As described in section 2.5.1.2.7 Reduced In-Delta Flows, operations under the proposed action would also reduce the reverse flows in the south Delta which would improve conditions in the south Delta relative to current conditions. And while the reduced reverse flows in the south Delta represent an improvement compared to current conditions, the PA includes operations of the existing facilities in the south Delta, which will still result in some negative effects. By limiting access to adequate habitat and constraining habitat connectivity, quantity and quality, the current risk of extinction for the green sturgeon population is maintained. However, a significant part of the revised PA is the re-commitment to key non-operational RPA actions in the NMFS 2009 BiOp, and the commitment to restore in Delta habitat for the express purpose of reducing tidal forcing, the combined effect of which are expected to benefit the spatial structure VSP parameter of green sturgeon.

Green Sturgeon Diversity:

The diversity VSP parameter comprises the three key attributes of (1) variation in traits such as run timing, age structure, size, fecundity, morphology, behavior and genetic characteristics, (2) resilient gene flow among populations that is limited, and (3) maintenance of ecological variation (McElhany et al. 2000b). Diversity is related to population viability because it allows a species to exploit a wider array of environments, protects against short-term spatial and temporal changes in the environment, and provides the raw material for surviving long-term environmental changes. At this time, we do not have methods to directly measure diversity or compare or assess changes to the present and historical levels of diversity. However, stressors, attributed to the PA that would limit the variation in green sturgeon traits, or that would select for a particular behavior or life history, would be expected to influence the diversity VSP parameter of the green sturgeon population.

Overall, the PA is not expected to exert any selective pressure on green sturgeon and the diversity VSP parameter of the population is expected to remain unchanged. The effects of construction-related activities will be experienced equally among the different run-timing, morphology and behaviors, such that there would be no selection for, or against a particular life history strategy. Likewise the effects of operations will also be experienced equally among the different run-timing, morphology and behaviors, the one possible exception being selective pressure on smaller fish. A number of operations-related effects have a diminishing level of impact that corresponds to size. Screen impingement and predation will primarily affect smaller fish, such that there would be an artificial selection for larger sized fish or increased duration of upstream rearing. This effect will be minor, if it manifests at all, and it is not expected to alter the diversity VSP parameter of the green sturgeon population.

2.7.7.4 Assess the Risk to ESU/DPS

Given that the entire Southern DPS of North American green sturgeon is represented by a single population, the discussion points above apply equally to both the population level analysis and that of the DPS as a whole. As described in section 2.5 Effects of the Action on Species and summarized in the VSP analysis, the proposed action is expected to have an adverse effect on the population, but it will not appreciably reduce the viability of the sDPS of green sturgeon.

Analysis of the effects of the action indicate that some elements of the proposed action exacerbate or maintain the conditions that contribute to the species extinction risk. The effects of the PA add numerous stressors to the species' baseline stress regime described in section 2.4 Environmental Baseline, and with the integration of the cumulative effects, described in section 2.6 Cumulative Effects, this analysis shows how the green sturgeon population will respond to these additional stressors throughout the species' life cycle every year for the duration of the proposed action. Although exact design and post-construction operation of the NDDs will be determined in the future, the commitments in the PA and revised PA, including that the final NDD design and operations will be established based on significant monitoring, testing, refinement, and adaptive management, support a conclusion that the proposed action will not appreciably reduce the viability of the sDPS of green sturgeon. Furthermore, proposed operations described by the PA would not preclude the establishment of the additional population necessary for the recovery of the sDPS. Based on our analysis, NMFS concludes the proposed action is not expected to appreciably reduce the likelihood of both the survival and recovery of the Southern DPS of North American green sturgeon.

Table 2-261. Reasoning and decision-making steps for analyzing the effects of the proposed action on green sturgeon. Bold type identifies the conclusion at each step of decision-making. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and not likely/likely to jeopardize (NLJ/LJ).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment. Available Evidence: The PA will produce multiple stressors that will adversely affect green sturgeon including, but not limited to: acoustic effects, contaminant effects, reduced prey availability, impingement and entrainment, and effects related to reduced Delta flows.	True	End
		False	**Go to B**
B	Listed individuals are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action. Available Evidence: A medium proportion of individuals from the sDPS population are expected to be exposed to construction related activities occurring both during the construction work-window and throughout the year over multiple years of construction, as well as to the effects of operations after construction has been completed.	True	NLAA
		False	**Go to C**
C		True	NLAA

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Listed individuals are not likely to respond upon being exposed to one or more of the stressors produced by the proposed action. Available Evidence: Multiple stressors, including but not limited to those associated with pile driving, barge traffic, dredging, and operations, will rise to a level of effect that will engender a response from exposed individuals.	**False**	**Go to D**
D	Any responses are not likely to constitute "take" or reduce the fitness of the individuals that have been exposed. Available Evidence: Multiple stressors, including but not limited to those associated with pile driving, barge traffic, dredging, and operations, are expected to result in a reduction of overall fitness of individuals which could rise to the level of "take."	True	NLAA
		False	**Go to E**
E	Any reductions in individual fitness are not likely to reduce the viability of the populations those individuals represent. Available Evidence: The overall reduction in fitness of individuals caused by the PA is expected to reduce some of the parameters describing a viable population; however, those reductions would not constitute a reduction in viability of the population or an increase in extinction risk for the species.	**True**	**NLJ**
		False	Go to F
F	Any reductions in the viability of the exposed populations are not likely to reduce the viability of the species. Available Evidence: NA	True	NLJ
		False	LJ

2.7.8 Green Sturgeon Critical Habitat

- Critical habitat designated October 9, 2009 (74 FR 52300)

2.7.8.1 Status

As described in section 2.2.4.2 (and at length in Appendix B Rangewide Status of the Species and Critical Habitat), designated critical habitat for sDPS green sturgeon includes freshwater riverine, estuarine, and coastal marine areas, including the mainstem Sacramento River from the I Street Bridge in Sacramento, California to Keswick Dam, as well as the Yolo and Sutter bypasses, portions of the lower San Joaquin, American, Feather, and Yuba rivers, the Sacramento-San Joaquin Delta, coastal bays and estuaries including San Francisco, San Pablo, and Suisun bays in California, and the nearshore marine habitat out to the 60 fathom depth bathymetry line. Designated critical habitat for green sturgeon is composed of seven PBFs that are shared among different life stages across the different habitat types. All of those PBFs are considered necessary habitat features that facilitate successful spawning, rearing, and migration. Therefore, we have evaluated the effect of the PA in terms of its effect on the PBFs present in the freshwater and estuarine habitats for rearing juveniles and migrating juveniles, adults, and sub-adults.

As described in Appendix B Rangewide Status of the Species and Critical Habitat, many of the PBFs of sDPS green sturgeon designated critical habitat are currently degraded or impaired and provide limited high quality habitat. Features that lessen the quality of migratory corridors and rearing habitat for juveniles include unscreened or inadequately screened diversions, altered flows in the Delta, and the presence of contaminants in sediment. Although the current conditions of green sturgeon critical habitat are significantly degraded, the spawning habitat, migratory corridors, and rearing habitat that remain in both the Sacramento/San Joaquin River watersheds and the Delta are considered to have high intrinsic value for the conservation of the species.

2.7.8.2 Summary of Proposed Action Effects on Designated Critical Habitat

Detailed descriptions regarding the impacts to designated critical habitat caused by stressors associated with the proposed action are presented in section 2.5.2, Effects of the Action to Critical Habitat. The proposed action-related effects to green sturgeon designated critical habitat have been further separated by life-stage specific habitat type and assessed by the effects on the PBFs found therein. Much like the effects to the species, the effects to green sturgeon designated critical habitat are summarized in Table 2-262.

Table 2-262. Integration and synthesis of effects on green sturgeon critical habitat.

Section Number	Action Component	Location of Effect	Physical and Biological Features Affected	Response and Rationale of Effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in PBF
2.5.2.3.1	Upstream Temperatures (section 2.5.1.2.1); Reduced In-Delta Flows (section 2.5.1.2.7); Redd Dewatering (section 2.5.1.2.2).	Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Larvae: Upper Sacramento River (RBDD to GCID)	- Substrate type or size; - Water flow; - Water quality	Flow changes are not expected to affect the availability or quality of spawning substrates. Temperature changes are unlikely to have a demonstrable effect on sturgeon spawning, growth, or survival.	Low – flow fluctuations may maintain a degraded function of these PBFs.	Medium – Multiple peer reviewed sources support conclusions. Modeling is somewhat limited by the coarse resolution of data.	NA
2.5.2.3.2	Construction Effects (section 2.5.1.1); Contaminant Exposure (section 2.5.1.1.3).	Freshwater Rearing Habitat for Juveniles and Sub-adults: Lower Sacramento, San Joaquin, and American Rivers and Delta (NDD to GG Bridge)	- Food resources; - Water flow; - Water quality; - Sediment quality; - Depth	Degradation to PBFs is anticipated as a result of physical disturbance to the benthic habitat and increased exposure to contaminants released from construction related activities.	Medium – Contaminant burden in benthic prey organisms and exposed bottom sediments likely to be increased.	Medium – Multiple peer reviewed sources support conclusions. Uncertainty with regard to baseline contaminant availability and extent of possible exposure.	Temporary reduction in quantity of: - Food resources (dredging), - Water flow (operations), And reduction in quality of: - Food resources (contaminants) - Water quality (turbidity, contaminants), - Sediment quality (contaminants) - Depth (dredging, operations),
2.5.2.3.3	Construction Effects (section 2.5.1.1); Contaminant	Freshwater Migratory Corridors for Outmigrating	- Migratory corridor; - Depth; - Sediment quality	Exposure to re-suspended sediments or turbidity events, physical or acoustic disturbances	Medium – Increased risk of propeller entrainment	Medium – Multiple peer reviewed sources support	Reduction in quality of: - Migratory corridor,

	Exposure (section 2.5.1.1.3); Barge Propeller Injury and Entrainment (section 2.5.1.1.7.3); Reduced In-Delta Flows (section 2.5.1.2.7).	Juveniles and Spawning Adults: Sacramento River and Delta (GCID to GG Bridge)		associated with barge traffic and construction activities, and an overall degradation of the benthic environment may temporarily degrade the PBFs of the migratory corridor associated with this habitat type.	associated with barge traffic, higher exposure to contaminants released from construction activities, both combined with potentially reduced flows and delayed migration timing.	conclusions. Understanding of the extent of the effect is somewhat limited by the uncertainty associated with the frequency and duration of barge traffic, baseline contaminant availability, and magnitude of flow reduction.	- Depth (dredging, operations) - Sediment quality (contaminants).
2.5.2.3.4	Construction Effects (section 2.5.1.1); Contaminant Exposure (section 2.5.1.1.3); Barge Propeller Injury and Entrainment (section 2.5.1.1.7.3); and Reduced In-Delta Flows (section 2.5.1.2.7).	Estuarine Habitat for Rearing and Migration: the Delta and SF, Suisun, and San Pablo Bays (NDD to GG Bridge)	- Migratory corridor; - Depth; - Sediment quality; - Water quality.	Degradation to PBFs is anticipated as a result of physical disturbance to the benthic habitat and increased exposure to contaminants released from construction related activities and barge traffic.	Medium – Increased risk of propeller entrainment associated with barge traffic, higher exposure to contaminants released from construction activities, both combined with potentially reduced flows and delayed migration timing.	Medium – Multiple peer reviewed sources support conclusions. Understanding of the extent of the effect is somewhat limited by the uncertainty associated with the frequency and duration of barge traffic, baseline contaminant availability, and magnitude of flow reduction.	Reduction in quality of: - Migratory corridor, - Depth (dredging, operations), - Sediment quality (contaminants), - Water quality (turbidity, contaminants).

Habitat for Spawning Adults, Incubation of Eggs, and Rearing for Fry

With the PA, NMFS expects no appreciable reduction in the PBFs of the green sturgeon critical habitat used for spawning of adults, incubation of eggs, and rearing for larvae. Specifically the PA is not expected to adversely impact the PBFs of these habitats including: substrate type or size, water flow, and water quality. Although differences between the PA and NAA are minor and not significantly different, the PA, when combined with the environmental baseline (represented by the NAA), will have periods of higher temperature; and flow changes as are projected to occur in certain months and certain water year types (see Section 2.5.1.2 Operations Effects). The PA also does not include any in-water activity that would disturb, contaminate, remove, or otherwise degrade the substrate type or size within the known spawning range for green sturgeon in the Sacramento River. Based on related entries in Table 2-262, the combined effects of the PA, environmental baseline, and cumulative effects are not expected to adversely affect these PBFs.

Freshwater Rearing Habitat for Juveniles

With the PA, construction-related effects are expected to cause some intermittent and small impacts to the PBFs of green sturgeon critical habitat, specifically with regards to food resources; water flow; water quality; sediment quality; and depth. As a result of the construction, freshwater rearing habitat for juveniles and sub-adults will be degraded by the effective removal of 20.1 acres of tidal perennial habitat and 1.02 linear miles of channel margin habitat; increased contaminant burden in benthic prey organisms; installation of interim structures and corresponding reduction of habitat complexity at the NDD sites; and an increase in construction-related disturbances which reduce the habitat’s capacity for successful juvenile development and survival. These direct effects are partially mitigated by the commitment of habitat restoration acreages described in the revised PA. These revisions include 80 acres of expanded habitat upstream of Red Bluff Diversion Dam and 1,800 acres of habitat in the Delta. Given the relative scale of permanent loss compared to the total abundance of adequate habitat in the immediate area and the commitment to provide specific habitat mitigation/compensation described in the revised PA, it is likely that the PA will lead to a temporary reduction in food resource availability and diminish the habitat sediment quality; and depth. Operations impacts of the PA would result in a direct reduction in water flow in the area of the NDD such that the PBFs in the freshwater rearing habitat are reduced.

Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults

Construction and operation of the NDD are expected to result in some, minor, degradation to the migratory PBFs for juvenile, subadult, and adult life stages in that area. Degradation of benthic habitat, exposure to sedimentation events, and risk of physical and acoustic disturbance are stressors that may reduce survival or impact behavior during migration, thus degrading the migratory corridor. The increased risk of propeller entrainment associated with barge traffic will also impede upstream migration, degrading these PBFs.

Estuarine Habitat for Rearing and Migration

Construction activities of the proposed action are expected to cause some intermittent and minor impacts to the PBFs of migratory corridors, depth, sediment quality, and water quality. Riparian and estuarine PBFs will experience minor degradation due to physical disturbance and risk of propeller entrainment year-round as barge operations are carried out in the Delta. However, given the temporary nature of the disturbance, coupled with the BMPs proposed as part of the PA, it is unlikely that the resultant disturbances will lead to a significant degradation of these PBFs. Changes to in-Delta flow caused by operation of the NDD are projected to reduce access to the migratory corridors for the PA relative to the NAA because lower flows downstream of the NDD reduce the inundation of the existing wetland and riparian benches that provide rearing habitats. The riparian bench inundation index below the NDD is shown to decrease for all water year types with the PA affecting the PBFs of depth, and water quality.

2.7.8.3 Impact to the Critical Habitat of the Species at the Designation Level

Although individual PBFs in several exposed areas will be diminished during construction, and to a lesser degree afterwards, the habitat is nevertheless expected to retain its restorative potential, and gradually improve in condition following completion of the construction phase of the PA, the implementation of adaptive management protocols, and habitat mitigation measures which are reasonably certain to occur. Additionally, the exposed areas are sparsely distributed throughout the action area and distantly separated within the broader context of the relatively larger areas of surrounding designated critical habitat that will remain largely unaffected, and which will likely yield the source material (sediments, structure, food resources) for the restorative potential of the PBFs in the adjacent exposed and affected areas following implementation of the PA. Although individual PBFs will be impacted because of decreasing flows and increasing travel time through the north Delta due to NDD operations and operations of the existing facilities in the south Delta, those impacts are largely expected to be minimized through conservation measures and adaptive management. Therefore, considering the resiliency of the particular PBFs to be affected, the ability of the surrounding habitat to contribute to the restorative potential of those PBFs over time following a disturbance, and the relative size and scale of the exposed areas within the context of the broader designated critical habitat as a whole, and conservation measures and adaptive management related to operations, the overall value of the critical habitat for the conservation of the species is not expected to be appreciably diminished. Based on our analysis, NMFS concludes that the proposed action is not likely to appreciably diminish the value of the critical habitat for the conservation of the Southern DPS of North American green sturgeon.

Table 2-263. Reasoning and decision-making steps for analyzing the effects of the proposed action on designated critical habitat for sDPS green sturgeon. Acronyms and abbreviations in the action column refer to not likely to adversely affect (NLAA) and destruction or adverse modification of critical habitat (D/AD MOD).

Step	Apply the Available Evidence to Determine if…	True/False	Action
A		True	End

Step	Apply the Available Evidence to Determine if…	True/False	Action
	The proposed action is not likely to produce stressors that have direct or indirect adverse consequences on the environment. Available Evidence: The PA will produce multiple stressors that will adversely affect the environment including, but not limited to: acoustic effects, contaminant effects, reduced prey availability, impingement and entrainment, and effects related to altered flows.	**False**	**Go to B**
B	Areas of designated critical habitat are not likely to be exposed to one or more of those stressors or one or more of the direct or indirect consequences of the proposed action. Available Evidence: Areas of designated critical habitat for sDPS green sturgeon will be exposed to multiple stressors produced by the PA, including habitats such as: Freshwater Rearing Habitat for Juveniles and Subadults; Freshwater Migratory Corridors for Outmigrating Juveniles and Spawning Adults; and Estuarine Habitat for Rearing and Migration.	True	NLAA
		False	**Go to C**
C	The quantity or quality of any physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to be reduced upon being exposed to one or more of the stressors produced by the proposed action. Available Evidence: In multiple instances the quantity and quality of the PBFs of green sturgeon designated critical habitat, or in some cases the capacity of the critical habitat to develop those features, will be reduced by the PA. For example, construction related activities will temporarily diminish the quantity and quality of available food resources for rearing and migrating individuals of all life stages of green sturgeon at various times and at several discrete locations along the migratory corridor throughout their residency in the action area over a period of multiple years. In addition, the sediment and water quality, depth, and flow at those discrete locations are also expected to be reduced by the construction and operation of the PA.	True	NLAA
		False	**Go to D**
D		True	NLAA

Step	Apply the Available Evidence to Determine if…	True/False	Action
	Any reductions in the quantity or quality of one or more physical or biological features or primary constituent elements of critical habitat or capacity of that habitat to develop those features over time are not likely to reduce the value of critical habitat for the conservation of the species in the exposed area. Available Evidence: The reductions in quantity and quality of PBFs, as well as the reductions in the capacity of the critical habitat to develop these features over time is expected to reduce the value of the habitat. Particularly with regard to the Freshwater Rearing Habitat for Juveniles and Subadults and the Estuarine Habitat for Rearing and Migration, the PA is expected to further impair the already degraded waterways of the Delta and their ability to function as quality rearing habitat.	**False**	**Go to E**
E	Any reductions in the value of critical habitat for the conservation of the species in the exposed area of critical habitat are not likely to appreciably diminish the overall value of critical habitat for the conservation of the species. Available Evidence: Although individual PBFs in several exposed areas will be diminished during construction, and to a lesser degree afterwards, the habitat is nevertheless expected to retain its restorative potential, and gradually improve in condition following completion of the construction phase of the PA, the implementation of adaptive management protocols, and habitat mitigation measures which are reasonably certain to occur. Additionally, the exposed areas are sparsely distributed throughout the action area and distantly separated within the broader context of the relatively larger areas of surrounding designated critical habitat that will remain largely unaffected, and which will likely yield the source material (sediments, structure, food resources) for the restorative potential of the PBFs in the adjacent exposed and effected areas following implementation of the PA. Therefore, considering the resiliency of the particular PBFs to be effected, the ability of the surrounding habitat to contribute to the restorative potential of those PBFs over time following a disturbance, and the relative size and scale of the exposed areas within the context of the broader designated critical habitat as a whole, the overall value of the critical habitat for the conservation of the species is not expected to be appreciably diminished.	**True** False	**No D/AD MOD** D/AD MOD

2.7.9 **Fall-run and Late Fall-run Chinook Salmon**

The effects to ESA-listed Chinook salmon from the PA have been described (section 2.5 Effects of the Proposed Action), and summarized in this Integration and Synthesis section. The effects to fall-run and late fall-run Chinook salmon and described in section 2.5 Effects of the Proposed Action and referred to in section 2.5.3 Southern Resident Killer Whale Effects Analysis. Although Integration and Synthesis of effects to these non-listed Chinook ESUs is not required in this biological opinion, assessing the impacts to non-ESA-listed Chinook salmon and their habitat is performed as part of the Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat consultation provisions, and is essential in integrating the effects of the PA on Southern Residents. Because of these purposes, unlike the analyses used for the ESA-listed species, this sub-section is organized in the following stepwise order: (1) Summary of Proposed Action Effects to Fall-run and Late Fall-run Chinook Salmon Individuals; (2) Factors Affecting the Abundance and Productivity of Fall-run and Late Fall-run Chinook Salmon Populations.

2.7.9.1 Summary of Proposed Action Effects to Fall-run and Late Fall-run Chinook Salmon Individuals

Detailed descriptions regarding the exposure, response, and risk of fall-run and late fall-run to stressors associated with the proposed action are presented in section 2.5, Effects of the Action. As for the other salmon species the proposed action-related effects to fall-run have been split between construction-related and those that are related to operations. The distinction was made based on differences in expected duration of effect where effects of construction activities are generally expected to occur over a finite period while operations-related effects and the effects of permanent structures have been analyzed well into the future. The construction-related effects on fall-run and late fall-run are expected to occur over the span of up to 8 years and are summarized in Table 22-263:

Table 2-264. Integration and synthesis of construction related effects with the environmental baseline and cumulative effects on fall-run (FR) and late fall-run (LFR) Chinook salmon.

Section Number	Stressor	Life Stage (Location)	Life Stage Timing (Work Window Intersection)	Individual Response and Rationale of Effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of Overall Effect (PA + Baseline + Cumulative Effects (CE))
2.5.1.1.1.1	Pile Driving (Acoustic)	Juvenile rearing and emigration; Adult immigration (NDD)	FR Juvenile: Dec. – July (June 15, – July); FR Adults: July – Dec. (July – Sept. 15); LFR Juvenile: July – Jan. (July – Sept. 15); LFR Adults: late Oct. – March (rare)	Juveniles: Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed. Adults: Behavioral modification, injury or mortality (rare)	Medium - Expected acute effect limited to a small proportion of juvenile FR and adult LFR; but a large proportion adult FR and juvenile LFR.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Medium - Expected acute effect limited to a small proportion of juvenile FR and adult LFR; but a large proportion adult FR and juvenile LFR, would be affected, plus baseline, and CE add “periodic” pile driving effects (section 2.4.4.6).
		Juvenile rearing and emigration; Adult immigration (CCF)	FR Juvenile: Jan. – June (~1% July – Oct.); FR Adults: July – Dec. (July – Oct.); LFR Juvenile: July – Dec. (~1% July – Oct.) LFR Adults: late Oct. – March (late Oct.)	Juveniles: Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed. Adults: Behavioral modification, injury or mortality (rare)	Low - Expected acute effect limited to a very small proportion of juvenile FR and LFR; but a large proportion adult FR, particularly for the San Joaquin basin segment of the FR population.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Low to Medium - Expected acute effect limited to a very small proportion of juvenile FR and LFR; but a large proportion adult FR, particularly for the San Joaquin basin segment of the FR population. Baseline, and CE add “periodic” pile driving effects (section 2.4.4.6)
		Adult immigration (HOR gate)	FR Adults: July – Dec. (Aug – Oct.)	Adults: Behavioral modification, injury or mortality (rare)	Low - Expected acute effect limited to a small proportion of adult FR immigrating to	High – Multiple technical publications including	Reduced reproductive success	Low - Expected acute effect limited to a small proportion of adult FR immigrating to the San Joaquin

					the San Joaquin basin.	quantitative modeling results.		basin; baseline, and CE add "periodic" pile driving effects (section 2.4.4.6).
		Juvenile rearing and emigration; Adult immigration (barge landings)	FR Juvenile: Dec. – July (July); FR Adults: July – Dec. (July - Aug.); LFR Juvenile: July – Jan. (July - Aug.); LFR Adults: Oct. – March (rare)	Juveniles: Injury or mortality caused by anthropogenic noise-induced barotrauma which may be instantaneous or delayed. Adults: Behavioral modification, injury or mortality (rare)	Medium - Expected acute effect limited to a small proportion of juvenile FR and LFR as well as adult LFR; but a large proportion adult FR. These effects will be more pronounced for the San Joaquin basin segment of the FR population.	High – Multiple technical publications including quantitative modeling results.	Reduced survival	Medium - Expected acute effect limited to a small proportion of juvenile FR and LFR as well as adult LFR; but a large proportion adult FR. These effects will be more pronounced for the San Joaquin basin segment of the FR population. Baseline, and CE add "periodic" pile driving effects (section 2.4.4.6).
2.5.1.1.1.2	Barge Traffic (Acoustic)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Reduced feeding/foraging behavior due to increased stress, distraction (foraging success) and prey masking.	Low - Generally sublethal effect, but expected to be imposed on a small proportion of the FR and LFR populations	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration and extent of barge operations.	Reduced growth; reduced reproductive success	Low to Medium - Generally sublethal effect, but expected to be imposed on a small proportion of the FR and LFR populations; however baseline adds that portions of the action area "experience heavy commercial and recreational vessel traffic". (section 2.4.4.5).
2.5.1.1.2.1	Pile Driving (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (NDD)	FR Juvenile: Dec. – July (June 15, – July); FR Adults: July – Dec. (July – Sept. 15);	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a small proportion of juvenile FR and adult LFR; and a large proportion	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of	Reduced growth; reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of juvenile FR and adult LFR; and a large proportion adult FR and juvenile LFR. Baseline, and

		LFR Juvenile: July – Jan. (July – Sept. 15); LFR Adults: late Oct. – March (rare)		adult FR and juvenile LFR.	uncertainty regarding extent of sediment resuspension.		CE add “periodic” pile driving effects (section 2.4.4.6).
	Juvenile rearing and emigration; Adult immigration (CCF)	FR Juvenile: Jan. – June (~1% July – Oct.); FR Adults: July – Dec. (July – Oct.); LFR Juvenile: July – Dec. (~1% July – Oct.) LFR Adults: late Oct. – March (late Oct.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a very small proportion of juvenile FR and LFR; and a large proportion adult FR, particularly for the San Joaquin basin segment of the FR population.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of juvenile FR and LFR; and a large proportion adult FR, particularly for the San Joaquin basin segment of the FR population. Baseline, and CE add “periodic” pile driving effects (section 2.4.4.6).
	Adult immigration (HOR gate)	FR Adults: July – Dec. (Aug – Oct.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin. Baseline, and CE add “periodic” pile driving effects (section 2.4.4.6).
	Juvenile rearing and emigration; Adult immigration (barge landings)	FR Juvenile: Dec. – July (July); FR Adults: July – Dec. (July - Aug.); LFR Juvenile: July – Jan. (July - Aug.); LFR Adults: Oct. – March (rare)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a small proportion of juvenile FR and LFR as well as adult LFR; but a large proportion adult FR. These effects will be more	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent	Reduced reproductive success.	Low - Generally sublethal effect limited to a small proportion of juvenile FR and LFR as well as adult LFR; but a large proportion adult FR. These effects will be more pronounced for the San Joaquin

					pronounced for the San Joaquin basin segment of the FR population.	of sediment resuspension.		basin segment of the FR population. Baseline, and CE add "periodic" pile driving effects (section 2.4.4.6).
2.5.1.1.2.2	Barge Traffic (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in turbidity.	Low - Generally sublethal effect, but expected to be imposed on a small proportion of the FR and LFR populations	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding timing, duration and extent of barge operations.	Reduced growth; reduced reproductive success	Low to Medium - Generally sublethal effect, but expected to be imposed on a small proportion of the FR and LFR populations; however, baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic (section 2.4.4.5).
2.5.1.1.2.3	Geotechnical Analysis (Sediment Concentration)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	No response, as turbidity associated with geotechnical analysis is likely imperceptible.	NA	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	NA	NA (Geotechnical analysis is not included in the Environmental Baseline section 2.4).
2.5.1.1.2.4	Dredging (Sediment Concentration) + Facility Maintenance (2.5.1.2.9.1)	Juvenile rearing and emigration; Adult immigration (NDD)	FR Juvenile: Dec. – Aug. (June – Aug.); FR Adults: July – Dec. (July – Oct.); LFR Juvenile: July – Jan. (July – Oct.);	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a small proportion of the FR and LFR populations.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty	Reduced growth; reduced reproductive success	Low to Medium - Generally sublethal effect limited to a small proportion of the FR and LFR populations. The baseline adds "periodic" dredging projects in the Action

	LFR Adults: late Oct. – March (late Oct.)			regarding extent of sediment resuspension.		Area, that are of “varying scope and scale” (section 2.4.4.4)
Juvenile rearing and emigration; Adult immigration (CCF)	FR Juvenile: Jan. – June (~1% July – Nov.); FR Adults: July – Dec. (July – Nov.); LFR Juvenile: July – Dec. (~1% July – Nov.) LFR Adults: late Oct. – March (late Oct. - Nov)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a very small proportion of FR and LFR populations, with a slight increase in exposure for the San Joaquin basin segment of the FR population.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced growth; reduced reproductive success	Low to Medium- Generally sublethal effect limited to a very small proportion of FR and LFR populations, with a slight increase in exposure for the San Joaquin basin segment of the FR population. The baseline adds “periodic” dredging projects in the Action Area, that are of “varying scope and scale” (section 2.4.4.4).
Adult immigration (HOR gate)	FR Adults: July – Dec. (Aug – Oct.)	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable because of uncertainty regarding extent of sediment resuspension.	Reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin. The baseline adds “periodic” dredging projects in the Action Area, that are of “varying scope and scale” (section 2.4.4.4).
Juvenile rearing and emigration; Adult immigration (barge landings)	FR Juvenile: Dec. – July (rare); FR Adults: July – Dec. (Aug. – Oct.);	Sublethal gill clogging, abrading or flaring; and decreased feeding and sheltering behavior caused by increases in localized turbidity.	Low - Generally sublethal effect to a large proportion of juvenile LFR, and a small proportion of FR and LFR adults.	Medium – A few scientific publications and nature of outcome is somewhat unpredictable	Reduced growth; reduced reproductive success	Low to Medium - Generally sublethal effect to a large proportion of juvenile LFR, and a small proportion of FR and LFR adults. The

			LFR Juvenile: July – Jan. (Aug. – Oct.); LFR Adults: Oct. – March (October)			because of uncertainty regarding extent of sediment resuspension.		baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale" (section 2.4.4.4)
2.5.1.1.3.1	Pile Driving (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (NDD)	FR Juvenile: Dec. – July (June 15, – July); FR Adults: July – Dec. (July – Sept. 15); LFR Juvenile: July – Jan. (July – Sept. 15); LFR Adults: late Oct. – March (rare)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of juvenile FR and adult LFR; and a large proportion adult FR and juvenile LFR.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced lifetime reproductive success	Low to Medium - Generally sublethal effect limited to a small proportion of juvenile FR and adult LFR; and a large proportion adult FR and juvenile LFR. The baseline, however, adds "periodic" dredging projects in the Action Area that are of "varying scope and scale" (section 2.4.4.4).
		Juvenile rearing and emigration; Adult immigration (CCF)	FR Juvenile: Jan. – June (~1% July – Oct.); FR Adults: July – Dec. (July – Oct.); LFR Juvenile: July – Dec. (~1% July – Oct.) LFR Adults: late Oct. – March (late Oct.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a very small proportion of juvenile FR and LFR; and a large proportion adult FR, particularly for the San Joaquin basin segment of the FR population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced lifetime reproductive success	Low to Medium - Generally sublethal effect limited to a very small proportion of juvenile FR and LFR; and a large proportion adult FR, particularly for the San Joaquin basin segment of the FR population. The baseline, however, adds "periodic" dredging projects in the Action Area that are of "varying scope and scale" (section 2.4.4.4).

		Adult immigration (HOR gate)	FR Adults: July – Dec. (Aug – Oct.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced reproductive success	Low to Medium - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin. The baseline, however, adds "periodic" dredging projects in the Action Area that are of "varying scope and scale" (section 2.4.4.4).
		Juvenile rearing and emigration; Adult immigration (barge landings)	FR Juvenile: Dec. – July (July); FR Adults: July – Dec. (July - Aug.); LFR Juvenile: July – Jan. (July - Aug.); LFR Adults: Oct. – March (rare)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of juvenile FR and LFR as well as adult LFR; but a large proportion adult FR. These effects will be more pronounced for the San Joaquin basin segment of the FR pop.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced lifetime reproductive success	Low to Medium - Generally sublethal effect limited to a small proportion of juvenile FR and LFR as well as adult LFR; but a large proportion adult FR. These effects will be more pronounced for the San Joaquin basin segment of the FR population. The baseline, however, adds "periodic" dredging projects in the Action Area that are of "varying scope and scale" (section 2.4.4.4).
2.5.1.1.3.2	Barge Traffic (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood	Low - Generally sublethal effect expected to a small proportion of the FR and LFR populations.	Low - Understanding is Medium but nature of outcome is somewhat unpredictable owing to	Reduced growth; reduced lifetime reproductive success	Low to Medium - Generally sublethal effect expected to a small proportion of the FR and LFR populations. The baseline, however, adds "documented

				enzyme and ion levels), and histological changes		uncertainty regarding timing, duration and extent of barge operations as well as sediment composition.		high levels of contaminants" in the action area (section 2.4.4.1).
2.5.1.1.3.3	Geotechnical Analysis (Contaminant Exposure)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal and localized effect limited to a very small proportion of the FR and LFR populations.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced lifetime reproductive success	Low - Generally sublethal and localized effect limited to a very small proportion of the FR and LFR populations however, the baseline adds "documented high levels of contaminants" in the action area (section 2.4.4.1).
2.5.1.1.3.4	Dredging (Contaminant Exposure) + Facility Maintenance (2.5.1.2.9.1)	Juvenile rearing and emigration; Adult immigration (NDD)	FR Juvenile: Dec. – Aug. (June – Aug.); FR Adults: July – Dec. (July – Oct.); LFR Juvenile: July – Jan. (July – Oct.); LFR Adults: late Oct. – March (late Oct.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of the FR and LFR populations.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced lifetime reproductive success	Low - Generally sublethal effect limited to a small proportion of the FR and LFR populations. The baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale" (section 2.4.4.4).
		Juvenile rearing and emigration; Adult immigration (CCF)	FR Juvenile: Jan. – June (~1% July – Nov.); FR Adults: July – Dec. (July – Nov.); LFR Juvenile: July – Dec. (~1% July – Nov.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood	Low - Generally sublethal effect limited to a very small proportion of FR and LFR populations, with an increased exposure for the San Joaquin basin	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding	Reduced growth; reduced lifetime reproductive success	Low - Generally sublethal effect limited to a very small proportion of FR and LFR populations, with an increased exposure for the San Joaquin basin segment of the

			LFR Adults: late Oct. – March (late Oct. - Nov)	enzyme and ion levels), and histological changes	segment of the FR population.	sediment composition and extent of exposure.		FR population. The baseline adds “periodic” dredging projects in the Action Area, that are of “varying scope and scale” (section 2.4.4.4).
		Adult immigration (HOR gate)	FR Adults: July – Dec. (Aug – Oct.)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin. The baseline adds “periodic” dredging projects in the Action Area, that are of “varying scope and scale” (section 2.4.4.4).
		Juvenile rearing and emigration; Adult immigration (barge landings)	FR Juvenile: Dec. – July (rare); FR Adults: July – Dec. (Aug. – Oct.); LFR Juvenile: July – Jan. (Aug. – Oct.); LFR Adults: Oct. – March (October)	Behavioral effects (e.g., swimming, feeding, and attraction-avoidance), physiological effects (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes	Low - Generally sublethal effect limited to a small proportion of LFR adults but a large proportion of FR and LFR adults, with an increased exposure for the San Joaquin basin segment of the FR population.	Low - Understanding is Medium but nature of outcome is unpredictable owing to uncertainty regarding sediment composition and extent of exposure.	Reduced growth; reduced lifetime reproductive success	Low - Generally sublethal effect limited to a small proportion of LFR adults but a large proportion of FR and LFR adults, with an increased exposure for the San Joaquin basin segment of the FR population. The baseline adds “periodic” dredging projects in the Action Area, that are of “varying scope and scale” (section 2.4.4.4).
2.5.1.1.4.1	Clearing and Grubbing (Increased	Juvenile rearing and emigration; Adult	FR Juvenile: Dec. – Aug.;	No response, as temperature changes associated with removal	NA	Medium - Understanding is High but nature	NA	Low-“Due to levee construction, and shoreline

	Temperature) + Facility Maintenance (2.5.1.2.9.2)	immigration (Delta)	FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	of riparian vegetation is likely imperceptible.		of outcome is somewhat unpredictable owing to uncertainty regarding the extent of thermal change.		development [which involves the removal of riparian vegetation], estuarine habitat in the Delta is significantly degraded from its historical condition." Some restoration work in the action area is improving this condition (section 2.4.2.3).
2.5.1.1.5.1	Pile Driving (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Increasing feeding success rate as anthropogenic waves may inject prey species into the water column or expose benthic infauna.	Low - Minor or short-term effect that impacts a small proportion of the FR and LFR populations.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	Increased growth	Low - Minor or short-term effect that impacts a small proportion of the FR and LFR populations, and the baseline and CE add "periodic" pile driving (section 2.4.2.3).
2.5.1.1.5.2	Barge Traffic (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Increasing feeding success rate as anthropogenic waves may inject prey species into the water column or expose benthic infauna.	Low – A minor effect that impacts a small proportion of the population.	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to timing, duration and extent of barge operations as well as the extent	Increased growth	Low – A minor effect that impacts a small proportion of the population; however, the baseline adds that portions of the action area "experience heavy commercial and recreational vessel traffic". Section 2.4.4.5.

						of prey availability.		
2.5.1.1.5.3	Geotechnical analysis (Reduced Prey)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	No response, as changes in prey abundance and availability associated with geotechnical analysis is likely imperceptible.	NA	Low - There are few papers or technical documents to support and the nature of outcome is unpredictable owing to uncertainty related to extent of prey availability.	NA	NA (Geotechnical analysis is not included in the Environmental Baseline section 2.4).
2.5.1.1.5.4	Dredging (Reduced Prey) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Reduced prey availability, decreasing feeding success caused by the removal of benthic sediments and infauna (prey base).	Low - Generally sublethal effect limited to a very small proportion of the population.	Medium - Understanding is High but nature of outcome is somewhat unpredictable because of uncertainty regarding sediment/prey composition.	Reduced growth	Low - Generally sublethal effect limited to a very small proportion of the population. The baseline adds “periodic” dredging projects in the Action Area that are of “varying scope and scale.” (section 2.4.4.4).
2.5.1.1.5.5	Clearing and Grubbing (Reduced Prey) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Changes in prey abundance and availability associated with removal of riparian vegetation.	Low - Generally sublethal effect limited to a very small proportion of the population.	High - multiple scientific and technical publications,	Reduced growth	Medium - Generally sublethal effect limited to a very small proportion of the population. The baseline diminishes available prey because “Due to levee construction, and shoreline development [which involves the removal of riparian vegetation], estuarine habitat in the Delta is

								significantly degraded from its historical condition." Some restoration work in the Action Area is improving this condition (section 2.4.2.3).
2.5.1.1.6.1	Pile Driving (Increased Predation)	Juvenile rearing and emigration; (NDD)	FR Juvenile: Dec. – July (June 15 – July); LFR Juvenile: July – Jan. (July – Sept. 15);	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Medium - Expected acute effect limited to a small proportion of juvenile FR, and a large proportion of juvenile LFR.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Medium - Expected acute effect limited to a small proportion of juvenile FR, and a large proportion of juvenile LFR.
		Juvenile rearing and emigration; (CCF)	FR Juvenile: Jan. – June (~1% July – Oct.); LFR Juvenile: July – Dec. (~1% July – Nov.)	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Low - Expected acute effect limited to a very small proportion of juvenile FR and LFR.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Medium - Expected acute effect limited to a very small proportion of juvenile FR and LFR. Baseline and CE add "periodic" pile driving (Section 2.4.4.6).
		Adult immigration (HOR gate)	FR Adults: July – Dec. (Aug – Oct.)	No anticipated effect or response from returning adults.	NA	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	NA	NA – Adults not affected by increased predation.
		Juvenile rearing and emigration; Adult immigration (barge landings)	FR Juvenile: Dec. – July (July); LFR Juvenile: July – Jan. (July - Aug.);	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	Medium - Expected acute effect limited to a small proportion of juvenile FR and LFR.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	Medium - Expected acute effect limited to a very small proportion of juvenile FR and LFR. Baseline and CE add "periodic" pile driving (Section 2.4.4.6).

2.5.1.1.6.2	Barge Traffic (Increased Predation)	Juvenile rearing and emigration (Delta)	FR Juvenile: Dec. – Aug.; LFR Juvenile: July – Jan.	Increased mortality (predation) of juveniles caused by anthropogenic noise masking acoustic predator cues, compromising predator avoidance.	High - Acute effect to a medium proportion of the FR and LFR populations.	Medium - There are a few publications regarding the effects of sound on predator-prey interactions.	Reduced survival	High - Acute effect to a medium proportion of the FR and LFR populations. Baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic." (section 2.4.4.5).
2.5.1.1.6.3	Interim in-water structures (Increased Predation)	Juvenile rearing and emigration (Delta)	FR Juvenile: Dec. – Aug.; LFR Juvenile: July – Jan.	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Medium - Acute effect limited to a small to medium proportion of the FR and LFR populations.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	High - Acute effect limited to a small to medium proportion of the FR and LFR populations. Added to a baseline of diminished habitat complexity. Some restoration work in the Action Area is improving this condition (section 2.4.2.3).
2.5.1.1.6.4	Clearing and Grubbing (Increased Predation) + Facility Maintenance (2.5.1.2.9.2)	Juvenile rearing and emigration (Delta)	FR Juvenile: Dec. – Aug.; LFR Juvenile: July – Jan.	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Low - Acute effect limited to a small area and therefore a small proportion of the FR and LFR populations.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium - Acute effect limited to a small area and therefore a small proportion of the FR and LFR populations. Added to a baseline of diminished habitat complexity. Some restoration work in the Action Area is improving this condition (section 2.4.2.3).
2.5.1.1.7.1	Pile Driving (Physical	Juvenile rearing and emigration; Adult	FR Juvenile: Dec. – July (June 15, – July);	Sublethal, behavioral response. Displacement or delayed emigrations	Low - Generally sublethal effect limited to a small	High – Multiple technical publications	Reduced growth (juveniles);	Low - Generally sublethal effect limited to a small

Impacts to Fish)	immigration (NDD)	FR Adults: July – Dec. (July – Sept. 15); LFR Juvenile: July – Jan. (July – Sept. 15); LFR Adults: late Oct. – March (rare)	(juveniles) and immigrations (adults) as pile driving-induced sound creates a temporary barrier to migration.	proportion of juvenile FR; and a large proportion adult FR and juvenile LFR.	including quantitative modeling results.	reduced reproductive success (adults)	proportion of juvenile FR; and a large proportion adult FR and juvenile LFR. The baseline and CE add “periodic” pile driving effects (section 2.4.4.6).
	Juvenile rearing and emigration; Adult immigration (CCF)	FR Juvenile: Jan. – June (~1% July – Oct.); FR Adults: July – Dec. (July – Oct.); LFR Juvenile: July – Dec. (~1% July – Oct.) LFR Adults: late Oct. – March (late Oct.)	Sublethal, behavioral response. Displacement or delayed emigrations (juveniles) and immigrations (adults) as pile driving-induced sound creates a temporary barrier to migration.	Low - Generally sublethal effect limited to a very small proportion of juvenile FR and LFR; and a large proportion adult FR, particularly for the San Joaquin basin segment of the FR population.	High – Multiple technical publications including quantitative modeling results.	Reduced growth (juveniles); reduced reproductive success (adults)	Low - Generally sublethal effect limited to a very small proportion of juvenile FR and LFR; and a large proportion adult FR, particularly for the San Joaquin basin segment of the FR population. The baseline and CE add “periodic” pile driving effects (section 2.4.4.6).
	Adult immigration (HOR gate)	FR Adults: July – Dec. (Aug – Oct.)	FR Adults: July – Dec. (Aug – Oct.)	Low - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin.	High – Multiple technical publications including quantitative modeling results.	Reduced reproductive success	Low - Generally sublethal effect limited to a small proportion of adult FR immigrating to the San Joaquin basin. The baseline and CE add “periodic” pile driving effects (section 2.4.4.6).
	Juvenile rearing and emigration; Adult immigration (barge landings)	FR Juvenile: Dec. – July (July); FR Adults: July – Dec. (July - Aug.); LFR Juvenile: July – Jan. (July - Aug.);	FR Juvenile: Dec. – July (July); FR Adults: July – Dec. (July - Aug.); LFR Juvenile: July – Jan. (July - Aug.); LFR Adults: Oct. – March (rare)	Low - Generally sublethal effect limited to a small proportion of juvenile FR and LFR as well as adult LFR; but a large proportion adult FR. These	High – Multiple technical publications including quantitative modeling results.	Reduced growth (juveniles); reduced reproductive success (adults)	Low - Generally sublethal effect limited to a small proportion of juvenile FR and LFR as well as adult LFR; but a large proportion adult FR. These effects will be more pronounced

			LFR Adults: Oct. – March (rare)		effects will be more pronounced for the San Joaquin basin segment of the FR pop.			for the San Joaquin basin segment of the FR population. The baseline and CE add "periodic" pile driving effects (section 2.4.4.6).
2.5.1.1.7.2	Dredging entrainment (Physical Impacts to Fish) + Facility Maintenance (2.5.1.2.10)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Mortality from entrainment into dredge cutterhead.	Low - Expected acute effect limited to a very small proportion of the FR and LFR populations.	High – There are multiple scientific and technical publications	Reduced survival	Low to Medium - Expected acute effect limited to a very small proportion of the FR and LFR populations. The baseline adds "periodic" dredging projects in the Action Area, that are of "varying scope and scale" (section 2.4.4.4).
2.5.1.1.7.3	Propeller entrainment (Physical Impacts to Fish)	Juvenile rearing and emigration; Adult immigration (Delta)	FR Juvenile: Dec. – Aug.; FR Adults: July – Dec.; LFR Juvenile: July – Jan.; LFR Adults: late Oct. – March	Injury and mortality from entrainment into the propellers of passing barges.	Medium - Expected acute effect on a medium proportion of the FR and LFR populations. Barge traffic and routing offers limited protections to FR and LFR juveniles given the overlap of the period of unrestricted barge operations (June 1 – Oct. 31) and juvenile migrations.	Medium - Understanding is High but nature of outcome is somewhat unpredictable owing to timing, duration and extent of barge operations.	Reduced survival	Medium - Expected acute sustained population effect across a large area for both FR and LFR. The baseline and CE adds that portions of the action area "experience heavy commercial and recreational vessel traffic" (section 2.4.4.5).
2.5.1.1.7.4	Dewatering (Physical Impacts to Fish) + Facility Maintenance (2.5.1.2.10)	Juvenile rearing and emigration; Adult immigration (NDD)	FR Juvenile: Dec. – Aug. (June – Aug.); FR Adults: July – Dec. (July – Oct.);	Injury and mortality from dewatering and handling during rescue operations. Adult fish are not expected to be affected.	Low - Generally acute lethal effect limited to a small proportion of juvenile FR and a large proportion juvenile LFR.	High – There are multiple scientific and technical publications	Reduced survival	Low - Generally acute lethal effect limited to a small proportion of juvenile FR and a large proportion juvenile LFR (dewatering is

		LFR Juvenile: July – Jan. (July – Oct.); LFR Adults: late Oct. – March (late Oct.)					not included in the Baseline (section 2.4)).
	Juvenile rearing and emigration; Adult immigration (CCF)	FR Juvenile: Jan. – June (~1% July – Nov.); FR Adults: July – Dec. (July – Nov.); LFR Juvenile: July – Dec. (~1% July – Nov.) LFR Adults: late Oct. – March (late Oct. - Nov)	Injury and mortality from dewatering and handling during rescue operations. Adult fish are not expected to be affected.	Low - Generally acute lethal effect limited to a very small proportion of juvenile FR and LFR; particularly for the San Joaquin basin segment of the FR pop.	High – There are multiple scientific and technical publications	Reduced survival	Low - Generally acute lethal effect limited to a very small proportion of juvenile FR and LFR; particularly for the San Joaquin basin segment of the FR population (dewatering is not included in the Baseline (section 2.4)).
	Adult immigration (HOR gate)	FR Adults: July – Dec. (Aug – Oct.)	Adult fish are not expected to be affected.	NA	High – There are multiple scientific and technical publications	NA	Low - Generally acute lethal effect limited to a very small proportion of adult FR; particularly for the San Joaquin basin segment of the FR population (dewatering is not included in the Baseline (section 2.4)).

The post-construction operational effects of the action on fall-run and late fall-run are summarized in Table 2-265. It should be noted that a complete understanding of the effects of operations is still being developed, and will continue to be developed during the phased test period described in section 3.3.2.1 of the BA. During the phased test period what will ultimately be considered “full operation” will depend on the development of a number of design criteria and real-time factors. This Opinion analyzes a range of effects dependent on an initial set of proposed operations with an expected use of proposed operational criteria and factors. The expectation remains, however, that the analysis of these effects will be reevaluated during the phased test period and through proposed research, monitoring, and adaptive management. This expectation is confirmed in Chapter 7 of the BA (Effects Determination) where, “the RTO and adaptive management and monitoring provisions included in the PA provide additional opportunities to refine the operating criteria and make adjustments to CVP/SWP Delta operations to minimize the risks of incidental take while maximizing water supply.” NMFS’ assessment of operational effects relies on the best scientific and commercial data available (section 2.5.1.2 Operations Effects) with the understanding that operational and design criteria will continue to be refined within the bounds of the RTO and adaptive management and monitoring programs.

Table 2-265. Integration and synthesis of post-construction, operational effects with the environmental baseline and cumulative effects on fall-run (FR) and late fall-run (LFR).

Section Number	Stressor	Life Stage (Location)	Life Stage Timing	Individual Response and Rationale of effect	Magnitude of PA Effect	Weight of Evidence	Probable Change in Fitness	Magnitude of Overall Effect (PA + Baseline + Cumulative Effects)
2.5.1.2.1	Operations (Increased Upstream Temperature)	Spawning Adults, Egg incubation, and alevin emergence (Sacramento River upstream of RBDD)	FR: September - January	Prespawn mortality, and egg mortality caused by increased temperatures, and daily fluctuation of temperatures.	Low or No expected adverse effect - Effects of the action are difficult to distinguish compared to the NAA.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival, Reduced reproductive success	High – The combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts is expected to result in significant adverse effects to FR eggs and alevin.
		Fry and Juvenile rearing, and outmigration (Sacramento River upstream of Knights Landing)	FR: January - June	Mortality caused by increased temperatures, and daily fluctuation of temperatures.	Low or No expected adverse effect - Effects of the action are difficult to distinguish compared to the NAA.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival	Medium – Temperature effects place a medium magnitude stress on the species and accounts for a significant amount of mortality particularly in the months of May and June during rearing and migration.
		Adult immigration and holding, (Sacramento River)	FR: July - December	Prespawn mortality of eggs caused by increased temperatures, and daily fluctuation of temperatures.	Low or No expected adverse effect - Effects of the action are difficult to distinguish compared to the NAA.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However, there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced reproductive success	Low – Temperature effects place a high magnitude stress on the species where it has a significant effect on egg prespawn mortality and adult reproductive success.
		Spawning Adults, Egg incubation,	FR: October - February	Prespawn mortality, and egg mortality	Low or No expected adverse effect - Effects of the action	Medium: Supported by multiple scientific and technical publications,	Reduced survival, Reduced	High – Temperature effects place a high magnitude stress on

		and alevin emergence (American River)		caused by increased temperatures, and daily fluctuation of temperatures.	are difficult to distinguish compared to the NAA.	including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	reproductive success	the species and accounts for a large amount of mortality.
		Fry and Juvenile rearing, and outmigration (American River)	FR: December - June	Mortality caused by increased temperatures, and daily fluctuation of temperatures.	Low or No expected adverse effect - Effects of the action are difficult to distinguish compared to the NAA.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival	Medium – Temperature effects place a medium magnitude stress on the species and accounts for a significant amount of mortality, particularly during the later months of rearing and migration.
		Adult immigration and holding, (American River)	FR: September - December	Prespawn mortality of eggs caused by increased temperatures, and daily fluctuation of temperatures.	Low or No expected adverse effect - Effects of the action are difficult to distinguish compared to the NAA.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced reproductive success	Low – Temperature effects place a medium magnitude stress on the species where it has a significant effect on egg prespawn mortality and adult reproductive success.
2.5.1.2.2	Operations (Redd Dewatering)	Egg incubation, Fry rearing (Sacramento River upstream of RBDD)	FR Egg and Fry: September – January; LFR Egg and Fry: December - April	Redd dewatering; loss of a portion, or all eggs in a redd	No expected adverse effect or Low beneficial effect- The PA relative to the NAA shows consistently similar or lower redd dewatering percentages for all water year types combined.	Medium: Supported by multiple scientific and technical publications, including quantitative data, and modeled results. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival	High – Dewatering of redds places a high magnitude stress on the species and accounts for a large amount of mortality. The percentage of dewatered redds under the PA ranges between 15% and 36% across all river segments.
		Egg incubation, Fry rearing	FR Egg and Fry: October - February;	Redd dewatering; loss of a	No expected adverse effect or Low beneficial effect- The PA	Low: The specific relationship between American River flow and fall-run Chinook salmon	Reduced survival	Low to Medium – Dewatering of redds places a high magnitude stress on the species but some level of dewatering is only

		(American River)		portion, or all eggs in a redd	relative to the NAA shows consistently similar or lower flow reductions such that there would be the same or reduced level of redd dewatering.	redd dewatering is unknown. There is also uncertainty with the modeling results which are based on downscaled monthly data.		expected in 15% to 34% of years.
2.5.1.2.3	Operations (Redd Scour)	Egg incubation, Fry rearing (Sacramento River)	FR Egg and Fry: September – January; LFR Egg and Fry: December - June	Mortality either directly as high flows displace or disrupt redds or flows may increase fine sediment infiltration and indirectly decrease egg survival.	Low or No expected adverse effect - Effects of the action are similar to those of the NAA.	Medium: Supported by multiple scientific and technical publications. However there is uncertainty with the modeling results which are based on downscaled monthly data.	Reduced survival	Medium – Scour of redds places a high magnitude stress on FR and LFR but is limited to a small proportion of months that account for a small amount of egg mortality for both species.
		Egg incubation, Fry rearing (American River)	FR Egg and Fry: October – February	Mortality either directly as high flows displace or disrupt redds or flows may increase fine sediment infiltration and indirectly decrease egg survival.	Low or No expected adverse effect - Effects of the action are similar to those of the NAA.			Low – Scour of redds places a high magnitude stress on FR but is limited to a very small proportion of months (1.5%) that would account for a very small amount of egg mortality for the species.
2.5.1.2.4	Operations (Stranding)	Fry rearing (Sacramento and American Rivers)	FR Fry: December - June	Mortality either directly through desiccation or indirectly through predation or reduced water quality.	Low or No expected adverse effect – Flows (and the potential for stranding) associated with the PA are similar to those of the NAA.	High: Supported by multiple scientific and technical publications including recent and historic observations.	Reduced survival	Medium - Expected acute population effect on a small proportion of the population;

2.5.1.2.5	Operations (Impingement and Entrainment)	Juvenile migration and rearing (NDD)	FR Juvenile: Dec. – Aug.; LFR Juvenile: July – Jan.	Mortality from contact with fish screen, and indirectly predation; sublethal effects from injury (e.g. loss of scales, disorientation) .	Medium - Expected sustained population effect. For all three intakes combined expected annual entrainment will be <1.1% for FR and <8.0% for LFR. Combined injury and mortality from impingement would be <10% for FR and <17% for LFR. The proportion of the population exposed is expected to be reduced by the commitment to UPP and phased testing to ensure the fish screens meet NMFS criteria.	Medium - Understanding is High but nature of outcome is somewhat unpredictable due to uncertainty of exposure.	Reduced survival	Medium - Expected sustained population effect. For all three intakes combined expected annual entrainment will be <1.1% for FR and <8.0% for LFR. Combined injury and mortality from impingement would be <10% for FR and <17% for LFR. The proportion of the population exposed is expected to be reduced by the commitment to UPP and phased testing to ensure the fish screens meet NMFS criteria.
2.5.1.2.6.1	Permanent In-water Structures (Increased Predation)	Juvenile migration and rearing (NDD)	FR Juvenile: Dec. – Aug.; LFR Juvenile: July – Jan.	Increased mortality (predation) caused by a reduction in habitat complexity and shading which offer no refugia for small fish.	Medium - Expected sustained population effect on a moderate proportion of the population.	Medium – There are few publications regarding the relationship between predation and reduced habitat complexity.	Reduced survival	Medium - Effect limited to a moderate proportion of the population. Added to a baseline of diminished habitat complexity when “levee construction involves the removal of riparian vegetation, resulting in reduced habitat complexity and shading, making juveniles more susceptible to predation” (Section 2.4.2.3)
2.5.1.2.7	NDD Operations (Travel Time)	Juvenile migration and rearing (Delta)	FR Juvenile: Dec. – Aug.; LFR Juvenile: July – Jan	Mortality caused by increased migration times, with increases in predator exposure.	Low - Expected sustained population effect on a large proportion of the population. Increased travel times are	High - There are a number of publications regarding the relationship between flow, river velocity, and Delta survival and travel time in the North Delta; conclusions supported by modeling results.	Reduced survival	Medium - Expected sustained population effect on a large proportion of the population.

					somewhat mitigated by UPP, which are more protective for WR and SR.			
2.5.1.2.7.2	NDD Operations (Outmigration routing)	Juvenile migration and rearing (Delta)	FR Juvenile: Dec. – Aug.; LFR Juvenile: July – Jan	Mortality caused by routing into interior Delta routes with lower survival.	Medium - Expected sustained population effect on a medium proportion of the population.	High - There are a number of publications regarding the relative survival in various North Delta and Central Delta migratory routes; conclusions supported by modeling results.	Reduced survival	Medium - Expected sustained population effect on a medium proportion of the population.
2.5.1.2.7.3	Operations (Altered South Delta hydro-dynamics due to South Delta exports and HOB operations)	Juvenile migration and rearing (Delta)	FR Juvenile: Dec. – Aug.; LFR Juvenile: July – Jan	Mortality or decreases in condition due to migratory delays due to altered hydrodynamics and loss of migratory cues. Delays increase exposure to sources of mortality and morbidity (predation, poor water quality, contaminants, etc.)	Medium - Expected sustained population effect on a medium proportion of the population.	Medium to High – Delta hydrodynamics well studied. Effects of Delta hydrodynamics on salmonids more uncertain.	Reduced survival, reduced growth	High - Expected sustained population effect on a medium proportion of the population.
2.5.1.2.7.3.1	CVP/SWP Operations (Entrainment and loss at South Delta export facilities)	Juvenile migration and rearing (Delta)	FR Juvenile: Dec. – Aug.; LFR Juvenile: July – Jan	Loss is approximately 35% of entrained fish at the CVP's Tracy Fish Collection Facility, and 84% at the	Low - Expected sustained population effect on a small proportion of the population.	High – Numerous studies have evaluated screening efficiency, predation, and overall salvage operations survival	Reduced survival	Low - Expected sustained population effect on a small proportion of the population.

				SWP's Skinner Delta Fish Protective Facility.				
2.5.1.3.1.1	Suisun Marsh Salinity Control Gates	Juvenile rearing and emigration; Adult immigration (Suisun Marsh)	Juveniles: Year-round; Adults: Year-round	Limited effect to juveniles; sublethal, behavioral effect to adults, migration delay and changes to routing.	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population.	Medium – Delta hydrodynamics well studied. Effects of Delta hydrodynamics on salmonid migration more uncertain.	Reduced reproductive success	Low - Generally sublethal effect, expected to be imposed on a small proportion of the adult population. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.1.2	Roaring River Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Mortality caused by entrainment into pumps distributing water to Suisun Marsh.	None – Fish screens of adequate size and approach velocities slow enough to exclude juveniles from entrainment.	Medium – Fish/Screen interactions well studied. Observations at this location limited.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.1.3	Morrow Island Distribution System	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Mortality caused by entrainment into culverts diverting from Goodyear Slough, and draining into Grizzly Bay or Suisun Slough.	None – Entrainment of juveniles unlikely because of location of intakes and probable size of fish. Baseline effects of MIDS are attributed to the PA.	Medium – Inference based on understanding of fish life history. Observations at this location limited, but include entrainment of fall-run Chinook salmon.	NA	None – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.1.4	Goodyear Slough Outfall	Juvenile rearing and emigration; (Suisun Marsh)	Juveniles: Year-round	Passive entrainment into Suisun Marsh, possible improvement to water quality and available	None or Low – Entrainment of juveniles unlikely because of location of intakes and probable size of fish.	Low – Inference based on understanding of fish life history. No observations at this location.	Improved growth	None or Low – Discountable effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.

				foraging habitat.				
2.5.1.3.2	North Bay Aqueduct	Juvenile rearing and emigration; (Delta)	Juveniles: Year-round	Injury and mortality caused by entrainment into pumps or impingement in screens at North Bay Aqueduct, Barker Slough Intake.	None or Low – Entrainment or impingement of juveniles unlikely because of location of intakes, efficacy of fish screens and probable size of fish.	Low to Medium – Inference based on understanding of fish life history. Observations at this location limited.	Reduced survival	None or Low – Insignificant effect. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.
2.5.1.3.3	Contra Costa Canal Rock Slough Intake	Juvenile rearing and emigration; (Delta)	Juveniles: Year-round	Injury and mortality caused by entrainment into pumps or impingement in screens at Contra Costa Canal Rock Slough Intake.	None or Low – Entrainment or impingement of juveniles unlikely because of location of intakes, and probable effectiveness of fish screens.	Low to Medium – Inference based on understanding of fish life history. Continued testing of fish screen and vegetation removal expected until at least 2018.	Reduced survival	None or Low – Insignificant effect pending resolution of fish screen sweeping efficiency. Effects of the baseline and CE are superseded by the PA such that there is no additional impact.

2.7.9.2 Summary of Factors Affecting the Abundance and Productivity of the Stock

As outlined in the Analytical Approach, for a threatened or endangered species, NMFS applies the VSP concept to determine the extinction risk of an ESU or DSP. In the case of fall-run and late fall-run Chinook salmon, which are not ESA listed species, but that are the preferred prey species of the ESA listed Southern Resident Killer Whale; NMFS limits it's analysis to assessing the elements of the PA that would affect the relative size of the fall-run and late fall-run populations.

A number of construction-related effects would be expected to reduce the overall abundance and/or productivity of fall-run and late fall-run Chinook salmon. These construction-related effects include:

- Acoustic effects associated with pile driving activities (section 2.5.1.1.1.1), where a moderate proportion of returning adult fall-run and juvenile late fall-run will be exposed to noise-induced barotrauma that is capable of causing injury or mortality which can be instantaneous or delayed. Very small numbers of juvenile fall-run and adult late fall-run, migrating at the margins of the work windows would also be subject to the pile driving effects. Juveniles exposed to the pile driving activities will also experience an increase in predation (section 2.5.1.1.6.1), as noise produced will have a disorientating effect on juvenile fish, mask acoustic predator cues, and ultimately compromise predator avoidance. Furthermore, there are a number of sublethal stressors associated with pile driving activities, such as the effects of sediment resuspension (section 2.5.1.1.2.1), contaminant exposure (section 2.5.1.1.3.1) and physical impacts leading to migration delay (section 2.5.1.1.2.1) which, while unlikely to cause mortality, are likely to manifest as behavioral responses that can diminish an individual's growth (juveniles) or reproductive success (adults). Considering that construction activities are expected to continue for up to 8 years, the exposure to a moderate proportion of the fall-run and late fall-run populations to the annual effects of the pile driving activities throughout the Delta (particularly at the NDD site and barge landing locations) is expected to have an adverse effect on the abundance of fall-run and late fall-run.

- The increase in Delta barge traffic associated with construction activities is expected to cause injury and mortality through propeller entrainment (section 2.5.1.1.7.3), and from increased predation (section 2.5.1.1.6.2) caused by vessel noise having a disorientating effect on juvenile fish, masking acoustic predator cues, and ultimately compromise predator avoidance. Although the majority of barge traffic will be localized in the central and south Delta which limits the exposure of fall-run and late fall-run originating in the Sacramento, Feather, and American Rivers; all migrating fish will be exposed to some level of increased barge traffic. The proposed timing and routing of construction-related barge traffic does not offer significant protection to fall-run and late fall-run because of the significant overlap of unrestricted barge traffic (June 1 – October 31) and juvenile migrations. Estimates of annual fall-run and late fall-run mortality, caused by propeller entrainment, are in excess of 35,000 and 280 juveniles respectively. Estimates of entrainment, those fish potentially injured by barge traffic and possibly more susceptible to predation are estimated at greater than 90,000 and 700 juveniles, fall-run and late fall-run. This loss would be expected each year for the duration of the increased barge activities.
- The construction-related effects to fall-run and late fall-run of dredging operations, geotechnical analysis, clearing and grubbing, and temporary in-water structures, were all found to be of relatively low magnitude. Although in these cases the level of exposure for fall-run (adults) and late fall-run (juveniles) was not insignificant, the overall effect of these activities were found to be de minimis because the expected spatial extent of these activities is small.

A number of effects related to operations would also be expected to reduce the overall abundance and/or productivity of fall-run and late fall-run Chinook salmon beyond the period of construction. These operation-related effects include:

- Upstream temperatures described by operations under the PA were not found to be significantly different from those described by the NAA. However, the absolute measure of upstream temperatures, those described by both the PA and NAA, were found to have a significant impact on the survival of fall-run and late fall-run early life stages. For both the PA and the NAA the temperature related impacts of operations were found to limit salmon egg survival to less than 50% throughout much of the spawning habitat in September and early October, for all water years. Under the PA the temperature dependent survival translates to a mean annual pre-spawn, egg and alevin mortality estimated at 5,683,877 for all water year types in the Sacramento River. Upstream temperatures would also result in some marginal adverse effects to fry rearing, and outmigration as well as adult holding. Conditions in the American River are also expected to be similar under both the PA and NAA.

- The effects of flow on fall-run and late fall-run include redd dewatering (section 2.5.1.2.2), scour (section 2.5.1.2.3), and stranding (section 2.5.1.2.4), all of which are expected to have a similar level of impact under the operational alternatives. In the Sacramento River, the number of fall-run Chinook salmon eggs and alevins predicted to die from redd dewatering and scour during incubation ranges from 94,913 in above normal years to 4,066,702 in wet years, with an average over all water year types of 1,477,164. Similarly in the American River flow related mortality is a medium magnitude stressor given that at least some redd dewatering is expected in 15 to 34 percent of years, but that extensive redd dewatering has a relatively low frequency of occurrence.
- Impingement and entrainment of juvenile fish passing the screens of the NDD (section 2.5.1.2.5) is expected to have a significant adverse effect to all passing juvenile salmonids, including Sacramento, Feather, and American River fall-run. The effect of impingement at the screens for all three intakes combined would be an expected 3.75% suffering injury and 7.05% mortality, on an annual basis. The permanent in-water structures of the NDD (section 2.5.1.2.6.1), would also be expected to provide habitat that disproportionately favors predatory fish species that prey on juvenile salmonids. Although it is difficult to quantify the effect of any potential increase in predation, those juvenile salmon injured at the NDD screens will be more susceptible to predation such that a substantial portion of the 3.75% suffering injury could subsequently die from predation. However, as described for other species, the operational phasing commitment described in the PA will be used to demonstrate compliance with the then-current NMFS and CDFW screening design and operating criteria. The PA states that, "The fish and wildlife agencies (i.e., USFWS, NMFS, and CDFW) retain responsibility for determination of the operational criteria and constraints (i.e. which pumping stations are operated and at what pumping rate) during testing." Therefore, the extent of effect is limited to a smaller proportion of what would be expected in the PA until design and operation of the screens is sufficiently tested. The NDD screens will be designed to meet NMFS screening criteria and incorporate (as yet determined) predator refugia, which NMFS expects will minimize screen impingement and associated predation.
- Reduced in-Delta flows (section 2.5.1.2.7), would also be expected to result in mortality caused by increased migration times, and changes to Delta routing and entrainment, both of which increase predator exposure. Again the level of effect that reduced in-Delta flows would have on survival is difficult to quantify in terms of percent reduction in population survival; however, modeling consistently shows that reducing Delta flows through operation of the NDD would cause a reduction in survival. However, with the revised PA (unlimited pulse protections), median survival reductions are improved with a range from 0.7% to 3% as compared to the original PA where juvenile survival was reduced during the core migratory months ranging from 0.5% to 12% (median). In addition, RMA modeling showed that tidal Delta habitat restoration at the level proposed in the revised PA should be able to influence the tidal prism enough to prevent the exacerbation of reverse flows from the NDD operations. Also included in the revised PA is a renewed commitment to winter-run Chinook salmon reintroduction to the Sacramento River above Shasta Dam and Battle Creek. Habitat expansion through reintroduction and restoration is expected to begin improving Chinook salmon productivity by the time PA operations commence and continue to improve productivity over the long-term.

2.7.9.3 Southern Resident Killer Whales

- Listed as endangered (November 18, 2005, 70 FR 69903).

The status of the species and environmental baseline for Southern Residents has been described in sections 2.2 and 2.4, respectively. As discussed in the analytical approach (section 2.1.3.1.3 Approach Specific to Southern Resident Killer Whales), our analysis of effects to Southern Residents relies upon on the expected impacts of the PA on the abundance and availability of Chinook salmon for them, and how any expected changes in prey availability will affect the fitness of Southern Residents and ultimately the abundance, reproduction, and distribution of the Southern Resident DPS. Considering that Chinook salmon from the Central Valley are largely comprised of fall-run Chinook salmon, any assessment of the expected impacts of the PA on the abundance and availability of Chinook salmon must include the effects of the action on fall-run. With this understanding, NMFS' approach to analyzing the effects of the action has considered the PA's effects on fall-run, and with a level of scrutiny commensurate with that which was applied to the ESA-listed species of salmon. In addition, we also consider the impact of the PA to ESA-listed winter-run and spring-run Chinook salmon in the Central Valley since they are also potential prey for Southern Residents along the coast. Where appropriate, we refer to the effects of the PA on the VSP parameters of abundance, productivity, spatial structure, and diversity of Chinook salmon populations.

2.7.10.1 Status of the Species and Environmental Baseline

The Southern Resident population is made up of three pods (J, K, and L), two of which (K and L) are more likely to occur in the action area at times during the winter and spring. Over the last 5 decades, the Southern Resident population has generally remained at a similarly low population size of about 80-90 individuals, and currently consists of 78 individuals. Chinook salmon has been confirmed to be the preferred prey of Southern Residents, and both the survival and fecundity of Southern Residents have previously been linked to the abundance of Chinook salmon that may be available for them as prey. There is weak evidence of a decline in fecundity rates through time for reproductive females, which may be linked to fluctuations in abundance of Chinook salmon prey among other factors. Other signs of poor health (peanut head) have been observed in a number of individuals as well. All of the recent observations of poor body condition, along with limited reproductive success in recent years, are possible indications that nutritional stress may be occurring for individuals of this population at times.

Currently, the abundance of Chinook salmon in the action area (as has been described for Chinook salmon ESUs in this biological opinion) is limited by numerous major influences on the fresh water environment, including water operations in the Central Valley and climate change. The harvest of Chinook salmon in the ocean also reduces the abundance of prey for Southern Residents. It is also likely that the accumulation of pollutants through consuming Chinook salmon presents a significant risk of decreased fitness. No single threat has been directly linked to or identified as the cause of the relative lack of growth of the Southern Resident population over time, but the relative small Southern Resident population size remains the primary source of concern for this species.

2.7.10.2 Summary of Proposed Action Effects

Based on the analysis in Section 2.5.3 Effects of the Action on Southern Residents and Section 2.7.9 Integration and Synthesis of Fall-run and Late Fall-run Chinook Salmon, NMFS expects that the PA will reduce the amount of Central Valley Chinook salmon (especially fall-run Chinook salmon) available in the ocean for Southern Residents to forage throughout the duration of the proposed action, including construction and post-construction operations. Several of the operational effects of the PA are expected to result in effects to Chinook salmon, including fall-run Chinook salmon, which are very similar and/or cannot be discriminated from the current environmental baseline conditions. However, there are some effects which are expected to lead to reductions in the abundance of Chinook salmon when added to the current environmental baseline conditions. Based on the analyses that have been performed and the limitations of the available tools, the expectations for the absolute magnitude of these reductions in total are not clear. However, the expectations for reduced abundance of Chinook salmon from the Central Valley as a result of the PA based on the analyses that have been completed are clear enough that we expect that Southern Residents will at times be required to spend more time foraging, which increases energy expenditures and the potential for nutritional stress, especially members of K and L pods. The stress of decreased fitness resulting from increased energy expenditures increases the potential risks of reduced survival and reproduction. Additional risks are associated with the possible accumulation of persistent organic pollutants by Southern Residents as a result construction activities, although the potential exposure of Southern Residents to any increased contaminant levels in Central Valley Chinook salmon is unclear at this time.

2.7.10.3 Assess Risk to the ESU/DPS

Because Southern Residents represent a single population, the risks to the population represent the risks to the entire DPS. The current status of Southern Residents indicates that the reproductive capacity of this population has been limited, which may be related in part to the relative abundance of preferred prey items such as Chinook salmon. Numerous factors are continuing to challenge the baseline conditions for Southern Residents, and overall environmental baseline conditions in the action area are already challenging for Chinook salmon individuals, limiting the potential productivity of the entire system for all Chinook salmon populations in the Central Valley. While numerous aspects of the PA are not expected to further compromise the situation for Chinook salmon in the Central Valley, some aspects are expected to reduce the amount of prey that may be available for Southern Residents. Although the absolute magnitude of the reduction is not clear, there are several characteristics of Southern Residents and the PA that are expected to minimize the extent of harm resulting from the PA.

As described in Section 2.5.3 Effects of the Action on Southern Residents, the overlap in distribution of Southern Residents and Central Valley Chinook salmon occurs when Southern Residents are occasionally in the southern part of their range along the coast of California and Oregon during the winter and spring. If prey fields are not sufficient in a portion of their foraging range, Southern Residents are known to engage commonly in prey sharing, and are also known to switch to other sources of prey during those times, which helps to distribute and minimize the extent of effects to individuals across the population. Although survival and fecundity of Southern Residents may be linked to the abundance of Chinook prey available to them in total, we do not expect that the relatively small reductions in Central Valley Chinook salmon compared to the several millions of Chinook that are expected to be available to Southern Residents in the ocean in the southern portion of their foraging range in the ocean each year over the duration of the PA are likely significantly alter the fitness of individuals enough to compromise and reduce Southern Resident survival and reproduction rates. During times when other Chinook salmon populations are doing fairly well and abundances are relatively high in the ocean, it is likely that any reductions in Central Valley Chinook are less noticeable as Southern Residents look to find and exploit areas where prey resources are more abundant. During times when Chinook salmon populations are not doing well and abundances are relatively low in the ocean, it is likely that reductions in Central Valley Chinook are more noticeable to Southern Residents as additional energy expenditures and potential nutritional stress resulting from moving around to find areas where prey resources maybe more abundant are more likely to occur.

In this Integration and Synthesis, we have characterized the expected impacts of the PA on the viability of Central Valley Chinook populations. In general, we have concluded that VSP parameters such as abundance and productivity of ESA-listed populations may be reduced to a degree by certain aspects of the PA based on the analyses that have been completed. Analysis of the effects of the action indicate that the proposed action exacerbates or maintains the conditions of the factors that contribute to limited Chinook salmon productivity in the Central Valley, and ultimately potential prey for Southern Residents in the ocean. These risks are further increased by adding numerous stressors to the species' baseline stress regime described in section 2.4 Environmental Baseline. With the integration of the cumulative effects, described in section 2.6 Cumulative Effects, this analysis shows how Chinook salmon populations will respond to these additional stressors throughout their life cycle every year for the duration of the proposed action. Consequently, Southern Residents will be affected by these stresses on their prey every year for the duration of the project, in addition to the other ongoing stresses they directly face throughout their range. Furthermore, effects of the action, status, baseline, and cumulative effects of the PA on Chinook salmon populations, and ultimately to Southern Residents, are expected to be impacted by climate change.

Despite uncertainty associated with the absolute magnitude of impact, a number of revised PA elements and commitments support the conclusion that the revised PA will reduce the impacts to Chinook salmon abundance from the PA as analyzed without those elements and commitments. For example, the commitments made by Reclamation and DWR in the revised PA, including the revised real-time operations for the NDDs, the operational phasing, and the restoration of Delta habitat, are expected to lessen the impact of operations on all Chinook salmon populations in the Central Valley. As a result, we have concluded in this Integration and Synthesis that the PA is not expected to appreciably reduce the viability of the population of ESA-listed Chinook salmon populations in the Central Valley. Although a similar ESA determination has not been made for the non-ESA listed fall-run and late fall-run Chinook salmon, the relative benefits from the revised PA elements and commitments underlying the determinations for ESA-listed Chinook are generally applicable to all Central Valley Chinook salmon populations. As a result, we expect that the overall magnitude of the reduction in Chinook abundance in the ocean available for Southern Resident foraging will also be minimized. Consequently, we do not expect that the PA will lead to overall reductions in Chinook salmon in the ocean of a magnitude that would be expected to lead directly to mortality of individual Southern Residents or significantly alter individual fitness enough to further compromise and reduce Southern Resident survival and reproduction rates from their current level.

Based on the discussion above, NMFS concludes the proposed action would not appreciably reduce the viability of the Southern Resident killer whale DPS. Based on our analysis, NMFS concludes the proposed action is not expected to appreciably reduce the likelihood of both the survival and recovery of the Southern Resident killer whale DPS.

2.8 Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, any effects of interrelated and interdependent activities, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, CCV steelhead, Southern DPS of North American green sturgeon or destroy or adversely modify designated critical habitat for these listed species.

After reviewing and analyzing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed action, any effects of interrelated and interdependent activities, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of Southern Resident killer whale.

2.9 Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this incidental take statement.

An incidental take statement (ITS) is not required for a framework programmatic action, i.e., an action "that approves a framework for the development of future action(s) that are authorized, funded, or carried out at a later time, and any take of a listed species would not occur unless and until those future action(s) are authorized, funded, or carried out and subject to further section 7 consultation" (50 CFR 402.02, 402.14(i)(6)). For a mixed programmatic action, an ITS is required only for those program actions that are reasonably certain to cause take and are not subject to further section 7 consultation (50 CFR 402.14(i)(6)). A mixed programmatic action is defined as, "for the purposes of an [ITS], a Federal action that approves action(s) that will not be subject to further section 7 consultation, and also approves a framework for the development of future action(s) that are authorized, funded, or carried out at a later time and any take of a listed species would not occur unless and until those future action(s) are authorized, funded, or carried out and subject to further section 7 consultation" (50 CFR 402.02). However, if an action agency designs a programmatic action or a mixed programmatic action that approves a framework for development of future action(s) that are authorized, funded, or carried out at a later time, and provides adequate information to inform the development of a biological opinion with an incidental take statement related to future actions implemented under the program, NMFS may be able to include an ITS related to such an action if it determines that the action is reasonably certain to cause incidental take of listed species. This Opinion assesses the effects of the construction of the PA, as well as operational activities. Based on these assessments, NMFS could determine that the PA is reasonably certain to result in incidental take of listed species as described in Section 2.9.1 Amount or Extent of Anticipated Take. Incidental take for those activities that approve a framework for development of future actions that are authorized, funded, or carried out at a later time and any take of a listed species would not occur unless and until those future actions are carried out at a later time and subject to further section 7 consultation, and which lack sufficient detail to analyze to level of take, is not included in this ITS (see 2.5.1.4 Programmatic Activities).

NMFS is also using the interim guidance on the ESA term of "harass" (Wieting 2016) in this consultation. Based on that interim guidance, "harass" means to "create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering."

2.9.1 Amount or Extent of Anticipated Take

In the biological opinion, NMFS determined that incidental take is reasonably certain to occur as follows:

NMFS anticipates that the PA will result in the incidental take of individual Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, CCV steelhead, and sDPS of North American green sturgeon. For the reasons described in Section 2.9.1.2.9, the amount or extent of incidental take anticipated for Southern Resident killer whales is not included in this ITS at this time.

Incidental take associated with this action is expected in one or more of the following forms: mortality, harm, harassment, capture, and collection of adult and juvenile Sacramento River winter-run Chinook salmon, adult and juvenile CV spring-run Chinook salmon, adult and juvenile CCV steelhead and adult and juvenile sDPS of North American green sturgeon. Incidental take is expected to result from construction activities due to:

(1) Noise associated with vibratory and impact pile driving of sheet piles and foundation piles at construction sites throughout the Delta, including the NDD intakes, CCF modifications, HOR gate installation, and barge landings.

(2) Avoidance and behavioral modifications related to underwater noise generated by barge traffic associated with the PA construction.

(3) Avoidance and behavioral modifications related to increased turbidity and resuspended sediment concentrations in the water column due to construction, dredging, geotechnical surveys, and barge traffic actions within the Delta.

(4) Physiological and behavioral effects related to exposure to contaminants contained in resuspended bottom sediments during construction, dredging, geo-technical surveys, and barge traffic within the Delta related to PA activities.

(5) Increased predation due to displacement of fish from preferred habitat caused by temporary in-water structures and increased barge traffic.

(6) Physical impacts related to construction dredging activities of the PA within the Delta.

(7) Injuries and behavioral modifications due to propeller entrainment related to increased barge traffic associated with the PA.

(8) The entrapment, handling, and release of listed fish captured within the confined waters created by the installation of cofferdams at the NDD intake locations, the HOR gate location, and the CCF modifications due to dewatering and fish rescue and salvage actions.

Incidental take is expected to result from operations post-construction due to:

(1) Increased predation related to permanent structures built within the Delta due to PA activities (NDDs and HOR gate).

(2) Avoidance and behavioral modifications related to increased turbidity and resuspended sediment concentrations in the water column due to maintenance actions within the Delta.

(3) Physiological and behavioral effects related to exposure to contaminants contained in resuspended bottom sediments due to maintenance actions within the Delta.

(4) Physical impacts related to maintenance dredging activities of the PA within the Delta.

(5) Impacts related to the operations of the NDDs related to mortality and injury of listed fish exposed to the intakes' fish screens.

(6) Operations of the CVP and SWP export facilities in the South Delta and their effect on salvage and loss of listed fish, hydrodynamics, and behavioral effects.

(7) Operations of the NDD and their effects on Delta hydrodynamics, behavioral effects and survival of listed fish in the Delta.

(8) Operations of the DCC radial gates and their effects on the entrainment of listed fish into the open DCC junction.

This ITS will use surrogates to establish the expected level of take due to project actions when direct quantification of take of individuals is not possible. Surrogates are used for this ITS since it is nearly impossible to quantify the number of individuals of listed species exposed to the PA's activities, but it is reasonably certain that those individuals that are exposed will incur some level of adverse response to the exposure resulting in take as defined under the ESA. This ITS explains the causal link between the surrogate and take of the listed species; explains the reason it is impractical to express the amount or extent of anticipated take or to monitor take-related impacts in terms of the amount of individuals of the listed species; and finally, establishes a clear standard for determining when the level of anticipated take is exceeded (the surrogate parameter). Generally, unless the amount or number of individuals is listed in the ITS below, it is impossible to quantify and track the amount or number of individuals that are expected to be incidentally taken per species as a result of the PA due to the variability and uncertainty associated with the response of listed species to the effects of the PA, the varying population size of each species, annual variations in the timing of spawning and migration, and individual habitat use within the action area.

2.9.1.1 Construction-related Effects

2.9.1.1.1 Acoustic Stressors

Because the level of acoustic noise generated by pile driving and tugboat and barge operations can be accurately and consistently measured, it provides a quantifiable metric for determining incidental take of listed fish. The number of fish exposed to the noise associated with pile driving and barge operations cannot be quantified with available monitoring data, though it is assumed that all fish passing through or otherwise present in waterways during pile driving or when tugboats and barges are active will be exposed to the noise and potentially adversely affected. The effects of sound upon the physiology and fitness of exposed fish has been described in Section 2.5.1.1.1 Acoustic Stress.

2.9.1.1.1.1 Pile Driving

It is impossible to quantify and track the amount or number of individuals that are expected to be incidentally taken per species as a result of the PA due to the variability and uncertainty associated with the response of listed species to the effects of the PA, the varying population size of each species, annual variations in the timing of spawning and migration, and individual habitat use within the action area. The take analysis has evaluated the amount of sound associated with the pile driving actions by populating the NMFS spreadsheet calculator with information from the effects analysis in Section 2.5.1.1 and data from the Caltrans compendium (Caltrans 2015) for steel sheet piles and steel piles driven by an impact hammer. The analysis of this Opinion assumes the use of steel piles at each activity location as specified below. Different methodologies or types of pile driving equipment will alter the characteristics of the acoustic noise generated during pile installation, which affects the physiological and behavioral response of the fish present in the vicinity of the construction activities. While the number, size, and material of the pilings will affect the amount of sound energy generated during the pile driving that was analyzed for this project, NMFS assumes that the action agency and applicant will adhere to the PA and will not depart from that description in any meaningful or demonstrable way.

2.9.1.1.1.1.1 North Delta Intake Locations

Based on the PA, the temporal exposure of migrating listed fish to vibratory pile driving at the location of the NDDs is June 15 through October 31, with impact pile driving occurring from June 15 through September 15, with some flexibility for work window extensions if sound attenuation efforts are successful. It is expected that five years of pile driving actions (2022-2026) are required to complete the installation of the cofferdams and foundation piles for the NDDs (intakes #2, #3, and #5). NMFS expects the following species and life stages will potentially be present during the pile driving portion of the construction window:

- Winter-run Chinook salmon: no adults; very low numbers of juveniles in fall
- Spring-run Chinook salmon: low numbers of adults in June; very low numbers of juveniles in June and fall
- Steelhead: high numbers of adults August through October; very low numbers of juveniles in fall
- sDPS green sturgeon: medium number of adults and juveniles throughout work window

Incidental take of adult and juvenile listed fish species as a result of exposure to the noise generated by both vibratory and impact pile driving activities in the form of death, harm, and harassment. Because the level of acoustic noise provides a quantifiable metric for determining incidental take of listed fish, the measurement of acoustic noise generated during impact pile driving of the steel sheet pile sections and the 42-inch steel foundation piles described in the PA will serve as a physically measurable surrogate for the incidental take of listed fish species.

The analysis of the effects of the proposed cofferdam installation and placement of foundation piles assumed that the steel sheet piles would be represented by the use of 24-inch wide steel sheet piles and that 40-inch diameter steel piles will adequately represent the 42-inch steel piles described in the PA. Based on the effects analysis conducted for this consultation, and using the data from the Caltrans compendium (Caltrans 2015) for steel sheet piles and steel piles driven by an impact hammer to populate the NMFS spreadsheet calculator, the amount of generated sound associated with the pile driving actions shall not exceed the values in Table 2-266 below.

Table 2-266. Surrogates for Incidental Take Levels Based on the Measured Sound Parameters at 10 meters and the Distance at which Physical Injury and Behavioral Modification Thresholds are met for the NDD Location.

Site[1]	Attenuation from bubble curtain or dewatered cofferdam (dB)[2]	Assumed Source levels (dB) at 10 m, single strike			Distance (ft) to threshold		
					Onset of Physical Injury		Behavioral
					Peak SPL	Cumulative SEL dB	RMS
		Peak	SEL	RMS	206 dB	Fish ≥ 2g 187 dB SEL	150 dB
Intake sheet pile cofferdam[3]	0[3]	205[5]	179	189	29.5	2814	13061
Intake sheet pile cofferdam w/ attenuation	-5	200	174	184	13	1306	6063
Intake steel pile foundation[4] w/o attenuation	0	208	180	195	46	3281	32808
Intake steel pile foundation w/ attenuation	-5	203	175	190	19.7	1522	15230

Notes:
1. All intake locations will have the same acoustic measurements based on the type of materials and the pile driving method used during construction.
2. Use of bubble curtain is probably not feasible with sheet piles, but project applicants have indicated that they will try to implement a sound attenuation device for this project element. Assume 5 dB reduction for sound attenuation calculations.
3. Source of data: Caltrans 2015. Table I.2-3. 24-inch AZ steel sheet pile driven in water at Port of Oakland.
4. Source of data: Caltrans 2015. Table I.2-3. 40-inch steel pipe driven in water in Alameda Estuary.

If any of these surrogates are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.1.1.2 Clifton Court Forebay

Based on the PA, the temporal exposure of migrating listed fish to vibratory and impact pile driving at CCF is July 1 through October 31. It is expected that five years of pile driving actions is required to complete the installation of the cofferdams and foundation piles for the modifications of CCF. NMFS expects these species and life stages to potentially be present during the pile driving portion of the construction window:

- Winter-run Chinook salmon: no adults; very low numbers of juveniles in fall

- Spring-run Chinook salmon: no adults; very low numbers of juveniles in fall
- Steelhead: high numbers of adults August through October; very low numbers of juveniles in fall
- sDPS green sturgeon: medium numbers of adults and juveniles throughout work window

Incidental take of adult and juvenile listed fish species is expected to occur during the four-month construction period from July 1 through October 31 as a result of exposure to the noise generated by both vibratory and impact pile driving activities in the form of death, harm, and harassment. Because the level of acoustic noise provides a quantifiable metric for determining incidental take of listed fish, the measurement of acoustic noise generated during impact pile driving of the sheet pile sections and the 14-inch steel or concrete foundation piles described in the PA, will serve as a physically measurable surrogate for the incidental take of listed fish species.

The analysis of the effects of the proposed cofferdam installation and placement of foundation piles assumed that the steel sheet piles would be represented by the use of 24-inch wide steel sheet piles and 20-inch diameter steel piles found in the Caltrans compendium (Caltrans 2015), which are the closest matches to the sizes of the sheet pile and steel pilings described in the PA. Based on the effects analysis conducted for this consultation, and using the data from the Caltrans compendium (Caltrans 2015) for steel sheet piles and steel piles driven by an impact hammer to populate the NMFS spreadsheet calculator, the amount of generated sound associated with the pile driving actions shall not exceed the values in Table 2-267 below.

Table 2-267. Surrogates for Incidental Take Levels Based on the Measured Sound Parameters at 10 meters and the Distance at which Physical Injury and Behavioral Modification Thresholds are met for the Clifton Court Forebay Location.

Site[1]	Attenuation from bubble curtain or dewatered cofferdam (dB)[2]	Assumed Source levels (dB) at 10 m, single strike			Distance (ft) to threshold		
					Onset of Physical Injury		Behavioral
					Peak SPL	Cumulative SEL dB	RMS
		Peak	SEL	RMS	206 dB	Fish ≥ 2g 187 dB SEL	150 dB
Sheet pile cofferdam[3]	0[3]	205[5]	179	189	29.5	2814	13061
Sheet pile cofferdam w/ attenuation	-5	200	174	184	13	1306	6063
NCCF Siphon steel pile foundation[4] w/o attenuation	0	208	176	187	46	1774	9607
NCCF Siphon steel pile foundation w/ attenuation	-5	203	171	182	19.7	823	4459

Notes:
1. All cofferdam and foundation pile locations will have the same acoustic measurements based on the type of materials and the pile driving method used during construction.

2. Use of bubble curtain is probably not feasible with sheet piles, but project applicants have indicated that they will try to implement a sound attenuation device for this project element.
3. Source of data: Caltrans 2015. Table I.2-3. 24-inch AZ steel sheet pile driven in water at Port of Oakland.
4. Source of data: Caltrans 2015. Table I.2-3. 20-inch steel pipe driven in water in San Joaquin River.

If any of these surrogates are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.1.1.3 HOR Gate

Based on the PA, the temporal exposure of migrating listed fish to vibratory and impact pile driving at the HOR gate is August 1 through October 31. It is expected that two years of pile driving actions (in-water work windows in 2020 and 2021) are required to complete the installation of the cofferdams and foundation piles for the constructions of the HOR gate. NMFS expects these species and life stages to be potentially present during the pile driving portion of the construction window:

- Winter-run Chinook salmon: no adults or juveniles
- Spring-run Chinook salmon: no adults or juveniles
- Steelhead: low to medium numbers of adults August through October; very low number of juveniles in fall
- sDPS green sturgeon: medium numbers of adults and juveniles throughout work window

Incidental take of adult and juvenile listed fish species is expected to occur during the 3-month construction period from August 1 through October 31 as a result of exposure to the noise generated by both vibratory and impact pile driving activities in the form of death, harm, and harassment. Because the level of acoustic noise provides a quantifiable metric for determining incidental take of listed fish, the measurement of acoustic noise generated during the construction phase, and in particular the impact pile driving of the sheet pile sections and the 14-inch steel or H-pile foundation piles described in the PA, will serve as a physically measurable surrogate for the incidental take of listed fish species.

The analysis of the effects of the proposed cofferdam installation and placement of foundation piles assumed that the steel sheet piles and foundation piles would be represented by the use of 24-inch wide steel sheet piles and 20-inch diameter steel piles found in the Caltrans compendium (Caltrans 2015), which are the closest matches to the sizes of the sheet pile and steel pilings described in the PA. Based on the effects analysis conducted for this consultation, and using the data from the Caltrans compendium (Caltrans 2015) for steel sheet piles and steel piles driven by an impact hammer to populate the NMFS spreadsheet calculator, the amount of generated sound associated with the pile driving actions shall not exceed the values in the Table 2-268 below.

Table 2-268. Surrogates for Incidental Take Levels Based on the Measured Sound Parameters at 10 meters and the Distance at which the Physical Injury and Behavioral Modification Thresholds are met for the HOR Gate Location.

Site[1]	Attenuation from bubble curtain or dewatered cofferdam (dB)[2]	Assumed Source levels (dB) at 10 m, single strike			Distance (ft) to threshold		
					Onset of Physical Injury		Behavioral
					Peak SPL	Cumulative SEL dB	RMS
		Peak	SEL	RMS	206 dB	Fish ≥ 2g 187 dB SEL	150 dB
Sheet pile cofferdam[3]	0[3]	205	179	189	29.5	2814	13061
Sheet pile cofferdam w/ attenuation	-5	200	174	184	13	1306	6063
HOR Gate steel pile foundation[4] w/o attenuation	0	208	176	187	46	1774	9607
HOR Gate steel pile foundation w/ attenuation	-5	203	171	182	19.7	823	4459

Notes:
1. Both sides of the HOR gate cofferdams and foundation pile locations will have the same acoustic measurements based on the type of materials and the pile driving method used during construction.
2. Use of bubble curtain is probably not feasible with sheet piles, but project applicants have indicated that they will try to implement a sound attenuation device for this project element.
3. Source of data: Caltrans 2015. Table I.2-3. 24-inch AZ steel sheet pile driven in water at Port of Oakland.
4. Source of data: Caltrans 2015. Table I.2-3. 20-inch steel pipe driven in water in San Joaquin River.

If any of these surrogate are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.1.1.4 Barge Landing Locations

Based on the PA, the temporal exposure of migrating listed fish to vibratory and impact pile driving at the barge landing locations is July 1 through August 31. It is expected that 2 years of pile driving actions are required to complete the installation of the piles which will support the overwater dock structures of the barge landings. NMFS expects these species and life stages to be potentially present during the pile driving portion of the construction window:

- Winter-run Chinook salmon: no adults or juveniles present
- Spring-run Chinook salmon: no adults or juveniles present
- Steelhead: medium number of adults July through August; very low number of juveniles
- sDPS green sturgeon: medium numbers of adults and juveniles throughout work window

Incidental take of adult and juvenile listed fish species is expected to occur during the 2-month construction period from July 1 through August 31 as a result of exposure to the noise generated by both vibratory and impact pile driving activities in the form of death, harm, and harassment. Because the level of acoustic noise provides a quantifiable metric for determining incidental take of listed fish, the measurement of acoustic noise generated during the construction phase, and in particular the impact pile driving of the 24-inch steel piles described in the PA, will serve as a physically measurable surrogate for the incidental take of listed fish species.

The analysis of the effects of the proposed placement of foundation piles assumed that the steel piles would be represented by the use 20-inch diameter steel piles found in the Caltrans compendium (Caltrans 2015), which are the closest match to the size of the steel pilings described in the PA. Based on the effects analysis conducted for this consultation, and using the data from the Caltrans compendium (Caltrans 2015) for steel piles driven by an impact hammer to populate the NMFS spreadsheet calculator, the amount of generated sound associated with the pile driving actions shall not exceed the values in the Table 2-269 below.

Table 2-269. Surrogates for Incidental Take Levels Based on the Measured Sound Parameters at 10 meters and the Distance at which the 206 dB Peak SPL Thresholds are met for the Barge Landing Locations.

Site[1]	Attenuation from bubble curtain or dewatered cofferdam (dB)[2]	Assumed Source levels (dB) at 10 m, single strike			Distance (ft) to threshold		
					Onset of Physical Injury		Behavioral
					Peak SPL	Cumulative SEL dB	RMS
		Peak	SEL	RMS	206 dB	Fish ≥ 2g 187 dB SEL	150 dB
Barge Landing steel support pilings[3] w/o attenuation	0	208	176	187	46	1774	9607
Barge Landing steel support pilings[3] w/ attenuation	-5	203	171	182	19.7	823	4459

Notes:
1. All barge landing locations will have the same acoustic measurements based on the type of materials and the pile driving method used during construction.
2. Use of bubble curtain is probably not feasible with sheet piles, but project applicants have indicated that they will try to implement a sound attenuation device for this project element.
3. Source of data: Caltrans 2015. Table I.2-3. 20-inch steel pipe driven in water in San Joaquin River.

If any of these surrogates physical condition that can represent SSC levels in the water column, although is not a direct measurement of it, as turbidity represents the transmission of light through a given linear length of water rather than the amount of sediment suspended in a given volume of water. Light transmission is affected by particles of matter in the water. Particulate matter can include sediment - especially clay and silt (components of SSC), fine organic and inorganic matter (also considered as a source of resuspended contaminants when contaminants are associated with these materials), soluble colored organic compounds, algae, and other microscopic organisms that absorb, block, or scatter the transmission of light. Levels of turbidity that have been identified as a cause of concern for aquatic life in the Delta have been recognized in the water quality criteria for the State of California. Therefore, the numeric water quality criteria for turbidity provided in the Central Valley Region Basin Plan for the Sacramento River and San Joaquin River Basin are used as a surrogate for incidental take of listed fish species (CVRWQCB 2016).

It is unlikely, given the migration, feeding, and spawning patterns of winter-run, and spring-run Chinook salmon, and juvenile steelhead, that these fish will be exposed to SSC concentrations that cause incidental take during the in-water construction window (June 15 – October 31). However, since barge traffic will occur year round within certain areas of the Delta, particularly along the mainstem of the San Joaquin River between the Port of Stockton and Bouldin Island, adult and juvenile life stages of winter-run and spring-run Chinook salmon, as well as juvenile steelhead, may be exposed to resuspended sediment in conjunction the ingress and egress of barges to the Bouldin Island barge landing and with docking activities adjacent to this barge landing, where river channels are shallower and more confined than the more open waters of the Stockton DWSC. The movement of barges in the Stockton DWSC is not expected to create the resuspension of sediment to any great extent due to propeller wash or wakes. Furthermore, since adult steelhead forage and feed in the Delta and green sturgeon reside in the Delta year round, NMFS anticipates these species will have prolonged exposure to increased SSC. NMFS expects incidental take of these individuals and alterations in their habitat will occur in the form of harm as a result of construction activities (i.e., dredging, pile driving, geotechnical boring, and cofferdam installation) and barge traffic. NMFS also anticipates incidental take of adult and juvenile winter-run and spring-run Chinook salmon, adult and juvenile steelhead and adult and juvenile green sturgeon may occur from fluctuations in SSC related to construction actions and barge traffic when their presence overlaps with these activities.

Implementation of the turbidity surrogates will require taking water samples 100 meters upstream of the construction site during construction activities or prior to the arrival of barge traffic within a 100-meter radius of the landing dock (down current from the dock) and measuring the turbidity levels in NTUs to establish the natural background levels of turbidity. Turbidity levels will be measured 100 meters downstream of the construction site during construction actions at 30 minute intervals or at the barge landing sampling site every 15 minute during docking activities while the barge and tugboat are maneuvering and docking. These measurements will be compared to the natural background levels measured and compared to the table to ascertain compliance with the take standards. The 100-meter distance from the construction site or barge landing dock allows for dilution and dissipation of the turbidity cloud created by construction or docking actions and creates a zone of dilution for compliance.

Incidental take of adult steelhead and adult and juvenile green sturgeon is limited to areas where in-water construction effects are expected to exceed the turbidity criteria listed in Table 2-270 (i.e., shallow areas with high organic matter deposition and where in-water construction activities cause disturbance of shore and bottom sediments such as dredging and barge traffic). Thus, increases in SSC attributable to construction activities shall not exceed the surrogates for incidental take levels for adult steelhead and adult and juvenile green sturgeon listed in Table 2-270. The incidental take associated with these actions are anticipated to occur throughout various phases of the PA.

Table 2-270. Turbidity Criteria for Adult Steelhead and Juvenile/Adult Green Sturgeon Based on the Location of In-water Construction Activities (i.e., dredging and barge traffic) and Timing (June 15 – October 31) for Construction Activities within the Action Area and Year-round for the Bouldin Island Barge Landing Location.

Turbidity Criteria	Delta in-water work construction locations
Where numeric turbidity is less than 1 NTU, controllable factors shall not cause downstream turbidity to exceed 2 NTU.	· Bouldin Island · Potato Slough · Venice Island · Middle River (Mandeville) · Old River (Wood court) · Clifton Court Forebay · Snodgrass Slough (high organic matter conditions are suitable for increased SSC unlikely fish present) · Frank's Tract · Sacramento Pumping Stations
Where natural turbidity is between 1 and 5 NTUs increases shall not exceed 1 NTU.	
Where natural turbidity is between 50 and 100 NTUs, increases shall not exceed 10 NTUs.	
Where natural turbidity is greater than 100 NTUs, increases shall not exceed 10 percent.	

Note: Current state regulations are Nephelometric Turbidity Unit – based (NTU)

2.9.1.1.1.2 Dissolved Toxic Contaminants

Benthic sediments in the Delta are known to contain toxic contaminants including heavy metals, pesticides, and other toxic organic compounds that may cause lethal or nonlethal effects. Sublethal or nonlethal effects indicate that death is not the primary toxic endpoint, (i.e. indirect mortality). Most common sublethal endpoints in aquatic organisms are behavioral (e.g., swimming, feeding, attraction-avoidance, and predator-prey interactions) (Scott and Sloman 2004), physiological (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological changes. Changes in certain behaviors, such as swimming or olfactory responses, may diminish the ability of listed fish to find food (Kasumyan 2001) or escape from predators and may ultimately result in death. Some sublethal effects may have little or no long-term consequences to the fish because the effects are rapidly reversible or diminish and cease with time (Tierney et al. 2010). Individual fish of the same species may exhibit different responses to the same concentration of toxicant because the original condition of the fish can significantly influence the outcome of the toxicant exposure.

Many contaminants lack defined regulatory exposure criteria that are relevant to listed salmonids, and yet may have effects on salmonids (Ewing 1999). It follows that some organisms may be negatively affected by contaminants while regulatory thresholds for the contaminants are not exceeded during measurements of water or sediments (Scholz et al. 2012). The EPA and NMFS have developed criteria that relate the adverse physiological responses of different aquatic organisms to different contaminants and have developed thresholds for adverse responses to these contaminants based on the duration of exposure. In general, higher contaminant concentrations are required for organisms to exhibit adverse effects over a short time period (acute exposure), compared to much lower concentrations over a longer timer period (chronic exposure). Thus, we use aquatic life criteria (EPA 2017) and the NOAA Screening Quick Reference Tables (NOAA SQuiRTs) as surrogates for assessing the incidental take of listed fish species from toxic contaminants released from resuspended sediments. NOAA has developed Screening Quick Reference Tables, or SQuiRTs, to help evaluate potential risks from contaminated water, sediment, or soil. This reference tool presents screening concentrations for inorganic and organic contaminants in various environmental media (water and soil). EPA has developed the aquatic life criteria table to identify thresholds for contaminant concentrations that if exceeded would have a high likelihood of causing toxicity to exposed aquatic organisms. In both the NOAA SQuiRT and EPA aquatic life criteria table, threshold levels for different contaminants can be used to ascertain whether contaminant concentrations measured in the sediments or the water column would be expected to harm any exposed listed fish in those water bodies without having to actually observe the fish or its responses. Thus, the concentration of the chemical constituent can be used as a surrogate for harm to the listed fish based on the threshold values presented in these tables.

It is unlikely, given the migration, feeding, and spawning patterns of winter-run and spring-run Chinook salmon, and juvenile steelhead, that these fish will be exposed to contaminant concentrations that cause incidental take during the in-water construction window (June 15 - October 31). However since barge traffic will occur year round within certain areas of the Delta, particularly along the mainstem of the San Joaquin River between the Port of Stockton and Bouldin Island, adult and juvenile life stages of winter-run and spring-run Chinook salmon, as well as juvenile steelhead may be exposed to resuspended sediment in conjunction with the ingress and egress of barges to the Bouldin Island barge landing and with docking activities adjacent to this barge landing, where river channels are shallower and more confined than the more open waters of the Stockton DWSC. The movement of barges in the Stockton DWSC is not expected to create the resuspension of sediment to any great extent due to propeller wash or wakes. Furthermore, since adult steelhead forage and feed in the Delta and green sturgeon reside in the Delta year round, NMFS anticipates these species will have prolonged exposure to increased contaminants. NMFS expects incidental take of these individuals and alterations in their habitat (bioaccumulation in prey items) will occur in the form of harm as a result of construction activities (i.e., dredging, pile driving, geotechnical boring, and cofferdam installation). NMFS also anticipates incidental take of adult steelhead and adult and juvenile green sturgeon may occur from unavoidable fluctuations in contaminants that may persist in the water column.

Incidental take of adult steelhead and adult and juvenile green sturgeon is limited to areas where in-water construction effects or resuspended sediment due to barge traffic are expected to exceed the aquatic life criteria listed in Table 2-271 (i.e., shallow areas with high organic matter deposition and where in-water construction activities cause disturbance of shore and bottom sediments such as dredging and barge traffic). Thus, increases in contaminant concentrations attributable to construction activities shall not exceed the surrogates for incidental take levels for adult steelhead and adult and juvenile green sturgeon listed in Table 2-271. The incidental take associated with these actions are anticipated to occur throughout various phases of the PA.

Table 1-271. Surrogates for Incidental Take Levels for Adult Steelhead and Adult and Juvenile Green Sturgeon based on USEPA-recommended Aquatic Life Criteria for Potential Toxic contaminants from Suspended Sediment in the Action Area.

Contaminant	Freshwater CMC (acute) (µg/L)	Freshwater CCC (chronic) (µg/L)	Saltwater CMC (acute) (µg/L)	Saltwater CCC (chronic) (µg/L)
Cadmium	1.8	0.72	33	7.9
Carbaryl	2.1	2.1	1.6	No Data
Chlordane	2.4	0.0043	0.09	0.004
Chloropyrifos	0.083	0.041	0.011	0.0056
Chromium (III)	570	74	No Data	No Data
Chromium (VI)	16	11	1100	50
Copper	No Data	No Data	4.8	3.1
Diazinon	0.17	0.17	0.82	0.82
Lead	65	2.5	210	8.1
Malathion	No Data	0.1	No Data	0.1
Mercury Methylmercury	1.4	0.77	1.8	0.94
Nickel	470	52	74	8.2
Polychlorinated Biphenyls (PCBs)	No Data	0.014	No Data	0.03
Selenium	No Data	No Data	290	71
Zinc	120	120	90	81
4,4'-DDT	1.1	0.001	0.13	0.001

Notes:
CMC = Criterion maximum concentration
CCC = Criterion continuous concentration.

The concentrations of the contaminants should be measured in the field or laboratory to determine if the criteria in Table 2-271 are exceeded.

2.9.1.1.2 Increased Water Temperature from Riparian Vegetation Loss

Incidental take is not expected as a result of this effect as the scale of changes in ambient water temperatures within the affected construction sites are minimal. Water temperature changes due to clearing of riparian vegetation will be difficult to impossible to demonstrate, and thus a causal link between the clearing of riparian vegetation from the levee banks, changes in water temperature, and adverse effects to listed fish present in these waters cannot be made. This analysis is presented in section 2.5.1.1.4 of the opinion.

2.9.1.1.3 Reduced Prey Availability

Incidental take is not expected as a result of the potential reduction of prey availability to listed fish due to the effects of construction activities. The expected scope of altered habitat due to pile driving, barge traffic, dredging, geotechnical surveys, and shoreline alterations on levee banks is minimal compared to the availability of undisturbed habitat in close proximity to those disturbed by construction activities. Thus, the availability of undisturbed habitat in close proximity to disturbed areas should alleviate any reduction in foraging success of listed species encountering the disturbed areas during their migrations or rearing within the Delta.

2.9.1.1.4 Increased Predation

The acoustic noise generated by tugboats and their barges delivering materials to the various barge landings as well as the pile driving of sheet piles and steel pilings during construction of the in-water infrastructure will mask the approach of predators during predation events as well as distract the individual fish from detecting approaching predators. It is impossible to track individual fish through the multiple areas of exposure and to observe their response to the noise generated by the barge traffic and construction actions. It is reasonably certain that those individuals that are exposed to the acoustic stressor will incur some level of adverse response to the exposure resulting in take, including behavioral modifications that reduce their ability to detect and avoid predators. NMFS has used the level of underwater noise exceeding 150 dB as the threshold for the onset of behavioral modifications, which would include the inability to detect the approach of predators or the creation of conditions that distract fish form being aware of their surroundings including predators. Because the underwater level of acoustic noise generated by pile driving and tugboat and barge operations that exceeds 150 dB can be accurately and consistently measured, it provides a quantifiable metric for determining incidental take of listed fish. Therefore, underwater sound levels exceeding 150 dB will be used as the surrogate for determining when incidental take related to increased vulnerability to predation due to the masking of predators and their approach or creating distractions to exposed fish that prevents them for detecting the approach of predators.

2.9.1.1.4.1 Pile Driving

The take analysis has evaluated the amount of sound associated with the pile driving actions by populating the NMFS spreadsheet calculator with information from the effects analysis in Section 2.5.1.1 and data from the Caltrans compendium (Caltrans 2015) for steel sheet piles and steel piles driven by an impact hammer or vibratory hammer. The analysis in this opinion assumes the use of steel piles at each activity location as specified below. Different methodologies or types of pile driving equipment will alter the characteristics of the acoustic noise generated during pile installation, which affects the physiological and behavioral response of the fish present in the vicinity of the construction activities. While the number, size, and material of the pilings will affect the amount of sound energy generated during the pile driving that was analyzed for this project, NMFS assumes that the action agency and applicant will adhere to the PA and will not depart from that description in any meaningful or demonstrable way.

NMFS anticipates that only juvenile life stages of listed salmonids and sDPS green sturgeon will be vulnerable to predation in response to pile driving construction activities of the PA. The acoustic noise generated by pile driving will mask the approach of predators during predation events and distract the prey fish from predator detection. In addition, injuries sustained by listed fish in the vicinity of the pile driving actions may render them more susceptible to predation events (see Section 2.5.1.1.6.1).

2.9.1.1.4.1.1 North Delta Intake Locations

Based on the PA description, the temporal exposure of migrating listed fish to vibratory pile driving at the location of the NDD is June 1 through October 31, with impact pile driving occurring from June 15 through September 15, with some flexibility for work window extensions if sound attenuation efforts are successful. It is expected that 5 years of pile driving actions (2022-2026) are required to complete the installation of the cofferdams and foundation piles for the NDD (intakes #2, #3, and #5). NMFS expects the following species and juvenile life stages may be potentially present during the pile driving portion of the construction window:

- Winter-run Chinook salmon: very low numbers of juveniles in fall
- Spring-run Chinook salmon: very low numbers of juveniles in fall and June
- Steelhead: very low numbers of juveniles in fall
- sDPS green sturgeon: medium numbers of juveniles throughout work window

Incidental take of juvenile listed fish species is expected to occur during the five-month construction period occurring from June 1 through October 31 as a result of exposure to the noise generated by both vibratory and impact pile driving activities in the form of increased predation vulnerability. Because the level of acoustic noise provides a quantifiable metric for determining incidental take of listed fish, the measurement of acoustic noise generated during impact pile driving of the steel sheet pile sections and the 42-inch diameter steel foundation piles described in the PA will serve as a physically measurable surrogate for the incidental take of listed fish species.

The analysis uses the distance values for sound energy which exceeds the behavioral threshold criteria (150 dB RMS) for the limit of elevated predation risks for fish exposed to the pile driving actions at the NDD. The analysis of the effects of the proposed cofferdam installation and placement of foundation piles assumed that the steel sheet piles would be represented by the use of 24-inch wide steel sheet piles and the foundation piles by 40-inch diameter steel piles found in the Caltrans compendium (Caltrans 2015), which are the closest matches to the sizes of the sheet pile and steel pilings described in the PA. Based on the effects analysis conducted for this consultation, and using the data from the Caltrans compendium (Caltrans 2015) for steel sheet piles and steel piles driven by an impact hammer or vibratory hammer to populate the NMFS spreadsheet calculator, the amount of generated sound associated with the pile driving actions shall not exceed the values in Table 2-272:

Table 2-272. Surrogates for Incidental Take Levels Based on the Measured Sound Parameters at 10 meters and the Distance at which the 150 dB RMS Thresholds are met for the NDD Location.

Site[1]	Attenuation from bubble curtain or dewatered cofferdam (dB)[2]	Assumed Source levels (dB) at 10 m, single strike			Distance (ft) to threshold Behavioral RMS
		Peak	SEL	RMS	150 dB
Intake sheet pile cofferdam[3] Vibratory[3]	0	175	162	163	245
Intake sheet pile cofferdam[3] Impact	0[3]	205	179	189	13,061

Site[1]	Attenuation from bubble curtain or dewatered cofferdam (dB)[2]	Assumed Source levels (dB) at 10 m, single strike			Distance (ft) to threshold Behavioral RMS
		Peak	SEL	RMS	150 dB
Intake sheet pile cofferdam w/attenuation Impact	-5	200	174	184	6,063
Intake steel pile foundation[4] w/o attenuation Vibratory	0	185	175	175	1,522
Intake steel pile foundation[5] w/o attenuation Impact	0	208	180	195	32,808
Intake steel pile foundation w/attenuation Impact	-5	203	175	190	15230

Notes:

1. All intake locations will have the same acoustic measurements based on the type of materials and the pile driving method used during construction.
2. Use of bubble curtain is probably not feasible with sheet piles, but project applicants have indicated that they will try to implement a sound attenuation device for this project element. Assume 5 dB reduction for sound attenuation calculations.
3. Source of data: Caltrans 2015. Table I.2-3. 24-inch AZ steel sheet pile driven in water at Port of Oakland
4. Source of data: Caltrans 2015 Table I.2-2. – 36-inch steel pipe driven by vibratory hammer
5. Source of data: Caltrans 2015. Table I.2-3. 40-inch steel pipe driven in water in Alameda Estuary

If any of these surrogates are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.4.1.2 CCF Modifications

Based on the current project description, the temporal exposure of migrating listed fish to vibratory and impact pile driving at the CCF is July 1 through October 31. It is expected that five years of pile driving actions are required to complete the installation of the cofferdams and foundation piles for the modifications of the CCF. NMFS expects these species and life stages to be potentially present during the pile driving portion of the construction window:

- Winter-run Chinook salmon: very low numbers of juveniles in fall
- Spring-run Chinook salmon: very low numbers of juveniles in fall and June
- Steelhead: very low numbers of juveniles in fall
- sDPS green sturgeon: medium numbers of juveniles throughout work window

Incidental take of juvenile listed fish species is expected to occur during the four-month construction period occurring from July 1 through October 31 as a result of exposure to the noise generated by both vibratory and impact pile driving activities in the form of increased predation vulnerability. Because the level of acoustic noise provides a quantifiable metric for determining incidental take of listed fish, the measurement of acoustic noise generated during impact pile driving of the sheet pile sections and the 14-inch diameter steel or concrete foundation piles described in the PA will serve as a physically measurable surrogate for the incidental take of listed fish species.

The analysis uses the distance values for sound energy which exceeds the behavioral threshold criteria (150 dB RMS) for the limit of elevated predation risks for fish exposed to the pile driving activities in CCF. The analysis of the effects of the proposed cofferdam installation and placement of foundation piles assumes that the steel sheet piles would be represented by the use of 24-inch wide steel sheet piles and foundation piles by 13-inch steel pipes (vibratory hammer) or 20-inch diameter steel piles (impact hammer) found in the Caltrans compendium (Caltrans 2015), which are the closest matches to the sizes of the sheet pile and steel pilings described in the PA. Based on the effects analysis conducted for this consultation, and using the data from the Caltrans compendium (Caltrans 2015) for steel sheet piles and steel piles driven by an impact hammer or vibratory hammer to populate the NMFS spreadsheet calculator, the amount of generated sound associated with the pile driving actions shall not exceed the values in Table 2-273.

Table 2-273. Surrogates for Incidental Take Levels Based on the Measured Sound Parameters at 10 meters and the Distance at which the 150 dB RMS Thresholds are met for the Clifton Court Forebay Location.

Site[1]	Attenuation from bubble curtain or dewatered cofferdam (dB)[2]	Assumed Source levels (dB) at 10 m, single strike			Distance (ft) to threshold Behavioral RMS
		Peak	SEL	RMS	150 dB
Sheet pile cofferdam[3] Vibratory[3]	0	175	162	163	245
Sheet pile cofferdam[3] Impact	0[3]	205	179	189	13,061
Sheet pile cofferdam w/ attenuation Impact	-5	200	174	184	6,063
NCCF Siphon steel pile foundation[4] w/o attenuation -vibratory	0	171	155	155	72
NCCF Siphon steel pile foundation[5] w/o attenuation -impact	0	208	176	187	9,607
NCCF Siphon steel pile foundation w/attenuation - impact	-5	203	171	182	4,459

Notes:

1. All cofferdam and foundation pile locations will have the same acoustic measurements based on the type of materials and the pile driving method used during construction.
2. Use of bubble curtain is probably not feasible with sheet piles, but project applicants have indicated that they will try to implement a sound attenuation device for this project element. Assume 5 dB reduction for sound attenuation calculations.
3. Source of data: Caltrans 2015. Table I.2-3. 24-inch AZ steel sheet pile driven in water at Port of Oakland
4. Source of data: Caltrans 2015 Table I.2-2. – 13-inch steel pipe driven by vibratory hammer in water– Mad River
5. Source of data: Caltrans 2015. Table I.2-3. 20-inch steel pipe driven in water in San Joaquin River

If any of these surrogates are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.4.1.3 HOR Gate

Based on the PA, the temporal exposure of migrating listed fish to vibratory and impact pile driving at the HOR gate location is August 1 through October 31. It is expected that two years of pile driving activities are required to complete the installation of the cofferdams and foundation piles for the construction of the HOR gate. NMFS expects the following species and life stages to be potentially present during the pile driving portion of the construction window:

- Winter-run Chinook salmon: no juveniles
- Spring-run Chinook salmon: no juveniles
- Steelhead: very low numbers of juveniles in fall
- sDPS green sturgeon: medium numbers of juveniles throughout work window

Incidental take of juvenile listed fish species is expected to occur during the three-month construction period occurring from August 1 through October 31 as a result of exposure to the noise generated by both vibratory and impact pile driving activities in the form of increased predation vulnerability. Because the level of acoustic noise provides a quantifiable metric for determining incidental take of listed fish, the measurement of acoustic noise generated during the construction phase, and in particular the impact pile driving of the sheet pile sections and the 14-inch diameter steel pipe or H-pile foundation piles described in the PA will serve as a physically measurable surrogate for the incidental take of listed fish species.

The analysis uses the distance values for sound energy which exceeds the behavioral threshold criteria (150 dB RMS) for the limit of elevated predation risks for fish exposed to the pile driving actions at the HOR gate. The analysis of the effects of the proposed cofferdam installation and placement of foundation piles assumes that the steel sheet piles would be represented by the use of 24-inch wide steel sheet piles and foundation piles by 13-inch diameter steel pipes (vibratory hammer) or 20-inch diameter steel piles (impact hammer) found in the Caltrans compendium (Caltrans 2015), which are the closest matches to the sizes of the sheet pile and steel pilings described in the PA. Based on the effects analysis conducted for this consultation, and using the data from the Caltrans compendium (Caltrans 2015) for steel sheet piles and steel piles driven by an impact hammer or vibratory hammer to populate the NMFS spreadsheet calculator, the amount of generated sound associated with the pile driving actions shall not exceed the values in Table 2-274.

Table 2-274. Surrogates for Incidental Take Levels Based on the Measured Sound Parameters at 10 meters and the Distance at which the 150 dB RMS Thresholds are met for the HOR Gate Location.

Site[1]	Attenuation from bubble curtain or dewatered cofferdam (dB)[2]	Assumed Source levels (dB) at 10 m, single strike			Distance (ft) to threshold: Behavioral RMS
		Peak	SEL	RMS	150 dB
Sheet pile cofferdam[3] Vibratory[3]	0	175	162	163	245
Sheet pile cofferdam[3] Impact	0[3]	205	179	189	13061
Sheet pile cofferdam w/attenuation Impact	-5	200	174	184	6063
HOR gate steel pile foundation[4] w/o attenuation -vibratory	0	171	155	155	72
HOR gate steel pile foundation[5] w/o attenuation -impact	0	208	176	187	9607
HOR gate steel pile foundation w/attenuation - impact	-5	203	171	182	4459

Notes:

1. Both sides of the HOR gate cofferdams and foundation pile locations will have the same acoustic measurements based on the type of materials and the pile driving method used during construction.
2. Use of bubble curtain is probably not feasible with sheet piles, but project applicants have indicated that they will try to implement a sound attenuation device for this project element. Assume 5 dB reduction for sound attenuation calculations.
3. Source of data: Caltrans 2015. Table I.2-3. 24-inch AZ steel sheet pile driven in water at Port of Oakland
4. Source of data: Caltrans 2015 Table I.2-3. – 13-inch steel pipe driven by vibratory hammer in water– Mad River
5. Source of data: Caltrans 2015. Table I.2-3. 20-inch steel pipe driven in water in San Joaquin River

If any of these surrogates are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.4.1.4 Barge Landings

Based on the PA, the temporal exposure of migrating listed fish to vibratory and impact pile driving at the barge landing locations is July 1 through August 31. It is expected that two years of pile driving actions are required to complete the installation of the support piles for the construction of the barge landings. NMFS expects these species and life stages to be potentially present during the pile driving portion of the construction window:

- Winter-run Chinook salmon: no juveniles
- Spring-run Chinook salmon: no juveniles
- Steelhead: very low numbers of juveniles in fall
- sDPS green sturgeon: medium numbers of juveniles throughout work window

Incidental take of juvenile listed fish species is expected to occur during the two-month construction period occurring from July 1 through August 31 as a result of exposure to the noise generated by both vibratory and impact pile driving activities in the form of increased predation vulnerability. Because the level of acoustic noise provides a quantifiable metric for determining incidental take of listed fish, the measurement of acoustic noise generated during impact pile driving of the 24-inch diameter steel support piles described in the PA will serve as a physically measurable surrogate for the incidental take of listed fish species.

The analysis uses the distance values for sound energy which exceeds the behavioral threshold criteria (150 dB RMS) for the limit of elevated predation risks for fish exposed to the pile driving actions at the barge landings. The analysis of the effects of the proposed installation and placement of support piles assumed that the steel piles would be represented by 36-inch steel pipes (vibratory hammer) or 20-inch diameter steel piles (impact hammer) found in the Caltrans compendium (Caltrans 2015), which are the closest matches to the sizes of the sheet pile and steel pilings described in the PA. Based on the effects analysis conducted for this consultation, and using the data from the Caltrans compendium (Caltrans 2015) for steel sheet piles and steel piles driven by an impact hammer or vibratory hammer to populate the NMFS spreadsheet calculator, the amount of generated sound associated with the pile driving actions shall not exceed the values in Table 2-275.

Table 2-275. Surrogates for Incidental Take Levels Based on the Measured Sound Parameters at 10 meters and the Distance at which the 150 dB RMS Thresholds are met for the Barge Landing Locations.

Site[1]	Attenuation from bubble curtain or dewatered cofferdam (dB)[2]	Assumed Source levels (dB) at 10 m, single strike			Distance (ft) to threshold Behavioral RMS
		Peak	SEL	RMS	150 dB
Barge Landing steel pile support[3] w/o attenuation -vibratory	0	180	170	170	705
NCCF Siphon steel pile foundation[4] w/o attenuation -impact	0	208	176	187	9,607
NCCF Siphon steel pile foundation w/attenuation - impact	-5	203	171	182	4,459

Notes:

1. All barge landing locations will have the same acoustic measurements based on the type of materials and the pile driving method used during construction.
2. Use of bubble curtain is probably not feasible with sheet piles, but project applicants have indicated that they will try to implement a sound attenuation device for this project element. Assume 5 dB reduction for sound attenuation calculations.
3. Source of data: Caltrans 2015 Table I.2-2. – 36-inch steel pipe driven by vibratory hammer in water
4. Source of data: Caltrans 2015. Table I.2-3. - 20-inch steel pipe driven in water in San Joaquin River

If any of these surrogates are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.4.2 Barge Traffic

NMFS anticipates that only juvenile life stages of listed salmonids and sDPS green sturgeon will be vulnerable to predation in response to barge traffic associated with construction actions for the PA. The acoustic noise generated by tugboats and their barges will mask the approach of predators during predation events as well as distract the individual fish from detecting approaching predators. Based on the PA, the following migrating listed fish have the potential to be exposed to the acoustic effects of barge traffic throughout the year:

- Winter-run Chinook salmon: juveniles present in the waterways adjacent to the mouth of the Mokelumne River in the lower San Joaquin River from November 1 through May 31; a small percentage of the juvenile winter-run Chinook salmon population within the Sacramento River migratory route may be exposed during precipitation events occurring in October
- Spring-run Chinook salmon: juveniles from the Sacramento River basin present in the waterways adjacent to the mouth of the Mokelumne River in the lower San Joaquin River as well as from Bouldin Island to the Port of Stockton (progeny of the San Joaquin River experimental population) from November 1 through May 31. A small number of juveniles may be present in the Sacramento River migratory route during June
- Steelhead: juvenile steelhead will have the potential to be exposed to barge traffic along the San Joaquin River migratory corridor the entire year; a small proportion of juvenile steelhead (≤2% of the Sacramento River basin population) will be exposed to barge traffic along the Sacramento River migratory corridor from June through October

- sDPS green sturgeon: all juvenile sDPS green sturgeon occupying waters of the Delta will have the potential to be exposed to acoustic noise from barge traffic throughout the entire year; NMFS assumes that the presence of juvenile sDPS green sturgeon in the Delta occurs year round within any accessible waterway in the Delta, but in particular the main riverine corridors of the Sacramento and San Joaquin rivers

NMFS has already described incidental take for the acoustic effects of barge traffic related to construction actions in the Delta. Part of the effects analysis for the acoustic stressors related to barge traffic concerns the diminishment of predator avoidance due to the masking of a predator's approach by increased noise in the aquatic environment. The result of this reduction in predator avoidance is an increase in predation. The metric used in the Section 2.9.1.1.1.2 regarding the acoustic effects of barge traffic on listed fish applies to increased predation rates; that is, an effect to the behavior of exposed fish is expected within the area of water that is above 150 dB (or above normal background noise if the background noise is greater than 150 dB) along the route of the barge traffic. It is anticipated that sound produced by the passage of the barge strings will decrease to 150 dB or less at 100 yards from the travel line of the tugboats and barges (or to background levels if ambient noise is greater than 150 dB) within 80 seconds.

2.9.1.1.4.3 Interim In-water Structures

2.9.1.1.4.3.1 North Delta Intake Cofferdams

Section 2.5.1.1.6.3 presents the impacts of interim in-water structures on the predation rate of juvenile listed fish species. Adult listed fish species are not expected to incur any additional predation risks. As described in Section 2.5.1.1.6.3.1, each of the three NDD cofferdams will be installed and remain in place for approximately four to five years. All three cofferdams will concurrently exist for at least two years (2025 and 2026) based on the proposed construction schedule, occupying 5,367 lineal feet of shoreline and nearshore habitat. The cofferdams are constructed of interlocking sheet pile sections that create structurally-simple habitat of vertical walls within the littoral zone of the Sacramento River, with 18-inch indentations due to the shape of the individual sheet pile sections. This simplified habitat, lacking any complexity, offers minimal refugia to smaller fish such as juvenile salmonids and green sturgeon that are considered as prey for larger piscivores in the system. The year-round presence of the cofferdams during construction creates substantial spatial and temporal overlap between predators and prey at these locations. Furthermore, since both prey and predators are attracted to the in-water structure created by the vertical cofferdam walls, prey are exposed to an elevated predation risk within this simplified habitat. The shape and configuration of the proposed cofferdam walls creates hydraulic conditions that push migrating fish away from the shoreline and into deeper water found offshore from the river's banks, exposing them to open water predators. Finally, the shape of the indentations generates turbulence and eddies along the face of the cofferdam wall that forms holding areas where fish can congregate, creating overlap between predators and prey.

NMFS expects the following listed species and life stages to be potentially exposed to the NDD cofferdams:

- Winter-run Chinook salmon: all juveniles passing downstream in the Sacramento River (excludes those emigrating through the Yolo Bypass)
- Spring-run Chinook salmon: all juveniles from the Sacramento River basin remaining in the Sacramento River and not entering the Yolo Bypass

- Steelhead: all juveniles from the Sacramento River basin remaining in the Sacramento River and not entering the Yolo Bypass
- sDPS green sturgeon: all juveniles from the Sacramento River basin remaining in the Sacramento River and not entering the Yolo Bypass

It is impossible to track individual fish through the three locations of the NDD intakes and the areas in front of the cofferdams where predation may occur. It is reasonably certain however, that those individuals that pass downstream through the reaches of the Sacramento River adjacent to the interim cofferdam structures are exposed to the altered instream habitat created by the cofferdam structures that favors predators and successful predation events and will incur some level of adverse response to the exposure resulting in take. Since the physical presence of the cofferdam structures and their shape creates the habitat conditions for enhanced predation vulnerability to listed salmonids and green sturgeon juveniles, the take analysis uses the lineal length for each of the cofferdams as a surrogate for the number of fish exposed to the project-related effects. The lineal length represents the relative size of the adverse habitat created by the project and, by reference, the scope of potential predation increases on emigrating listed fish.

Based on the effects analysis conducted for this consultation and data from the BA and Section 2.5.1.1.6.3, the lineal length of each of the intake cofferdams shall not exceed the values in Table 2-276.

Table 2-276. Dimensions of the incidental take surrogates for overall length of cofferdams in front of NDD Intakes.

NDD Intake Number	Overall Length of cofferdam (ft)
#2	1,969
#3	1,497
#5	1,901
Total Length	**5,367**

If any of these surrogates (maximum length of each cofferdam) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.4.3.2 Cofferdams Associated with Clifton Court Forebay

The effects of the extensive cofferdam installation for the modification of CCF has been described in Section 2.5.1.1.6.3.2.1. This includes elevated predation vulnerability to juvenile listed fish due to the year-round presence of the sheet pile cofferdams and the alterations to local hydrodynamics and fish behavior associated with the presence of those cofferdams during construction activities. Adult listed fish are not expected to incur any additional predation risks. NMFS expects that the following listed species and life stages have the potential to be exposed to the cofferdam structures related to the CCF modifications:

- Winter-run Chinook salmon: all juveniles that enter the CCF through the radial gates during their migratory movements
- Spring-run Chinook salmon: all juveniles that enter the CCF through the radial gates during their migratory movements
- Steelhead: all juveniles that enter the CCF through the radial gates during their migratory movements

- sDPS green sturgeon: all juveniles that enter the CCF through the radial gates during their migratory movements

The CCF modifications will include the following interim cofferdam structures, which will create enhanced predation vulnerability to listed fish within the CCF waterbody:

- The dividing sheet pile cofferdam that will separate the new NCFF from the new SCCF will be approximately 9,800 feet long from the northern side of the current CCF outlet to the pumping plant inlet channel to the levee on the eastern side of CCF. It will be in place year-round for about three years (summer 2025 through summer 2028), the time necessary to install the cofferdam, complete the earthen embankment, then remove or cut off the cofferdam at the mudline to expose the new earthen dike between the NCCF and SCCF waterbodies.
- The total length of the NCCF siphon cofferdam will be 3,260 feet, with half of the channel occupied by the cofferdam for the siphon construction in each year of the two-year construction schedule. Based on engineering drawings in Appendix 3C of the BA, NMFS estimates that in each construction season, two walls 750 feet long will be installed on each side of the siphon alignment, with an end wall 130 feet long joining the two parallel cofferdam walls. This creates the dewatered work space for construction of the three 23-foot wide siphon box culverts. These cofferdams will be in place a total of two years and will be removed following completion of the siphon construction.
- Cofferdam walls will be constructed on both the eastern and western sides of the current CCF to allow for construction of new earthen embankments along the perimeter of the future SCCF. On the eastern side of the CCF the cofferdams will extend from the current location of the radial gates to the dividing cofferdam reaching across the current CCF. This cofferdam will be 6,000 feet long. The cofferdam on the western side of the current CCF will reach from the current southern boundary of CCF to the southern tip of the outlet channel. This cofferdam will be 4,000 feet long. The total length of cofferdams for this portion of the construction action is 10,000 lineal feet. The cofferdams are expected to be in place approximately one year (summer 2027 through summer 2028), the time necessary to install the cofferdams, complete the earthen embankments, and then remove or cut off the cofferdam at the mudline to expose the new earthen dikes on the eastern and western sides of the new SCCF waterbody.
- Finally, a cofferdam channel will be constructed in the southern existing earthen embankment of CCF to allow for controlled flooding of the newly created area for the expansion of the SCCF. The total lineal length of sheet pile used to construct this channel is 580 feet, with a 60-foot-wide channel formed by two parallel 200-foot long cofferdam walls. Additional sheet piles will be installed to create the temporary end wall and end return walls. The cofferdam channel is expected to be in place 254 days.

Since the physical presence of the cofferdam structures and their shape creates the habitat conditions for enhanced predation vulnerability to listed salmonids and green sturgeon juveniles, NMFS will use the lineal length for each of the cofferdams as a surrogate for the number of fish exposed to the project related effects. The lineal length represents the relative size of the adverse habitat created by the project, and by reference the scope of potential predation increases on emigrating listed fish.

Based on the effects analysis conducted for this consultation, and data from the BA and Section 2.5.1.1.6.3.2.1, each cofferdam shall not exceed either the lineal length values or the expected duration of in-water presence identified in Table 2-277.

Table 2-277. Dimensions of the incidental take surrogates for the total length and duration of in-water presence for the Clifton Court Forebay cofferdams.

Cofferdam Name	Total Length (ft)	In-water Duration
Cross CCF dividing partition	9,800	~3 years (July 2025-October 2027 + removal; summer 2028)
NCCF Siphon cofferdam	3,260	~2 years
Eastern CCF cofferdam	6,000	~1 year (July 2027–April 2028 +removal; summer 2028)
Western CCF cofferdam	4,000	~1 year (July 2027–April 2028 +removal; summer 2028)
SCCF Channel cofferdam	580	254 days

If any of these surrogates (total length of each cofferdam and duration of in-water presence) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.4.3.3 HOR Gate Cofferdams

The effects of the cofferdam installation for the construction of the HOR gate has been described in Section 2.5.1.1.6.3.3. This includes elevated predation vulnerability due to the year-round presence of the sheet pile cofferdams and the alterations to local hydrodynamics and fish behavior associated with the presence of those cofferdams during the duration of construction activities. NMFS expects that the following listed species and life stages will potentially be exposed to the cofferdam structures related to the HOR gate construction:

- Winter-run Chinook salmon: no winter-run are expected at this location at any time of year
- Spring-run Chinook salmon: all juveniles that pass downstream in the San Joaquin River during their migratory movements (progeny of experimental population)
- Steelhead: all juveniles that pass downstream in the San Joaquin River during their migratory movements
- sDPS green sturgeon: all juveniles that are present at this location during their rearing movements in the South Delta

Since the physical presence of the cofferdam structures and their shape creates the habitat conditions for enhanced predation vulnerability to listed salmonids and green sturgeon juveniles, NMFS will use the lineal length for each of the cofferdams as a surrogate for the number of fish exposed to the project related effects. The lineal length represents the relative size of the adverse habitat created by the project, and by reference the scope of potential predation increases on emigrating listed fish.

The HOR gate cofferdams will block a portion of the Old River channel during each year of the projected two-year construction schedule. Based on the information provided in BA Appendix 3B, Appendix 3C, and Appendix 3D, construction will occur in two phases. Phase one will consist of construction of the boat lock, masonry control building, boat lock operator’s building, and one half of the operable gate. The second phase will occur the following year and will include construction of the remainder of the operable gate, the equipment storage area, communications towers, and the fish passage structure. Each year, 275 sheet piles will be installed at the HOR gate location within the active river channel or tied into the levee face. This will result in the installation of 550 lineal feet of sheet piles each year (assuming that each pile is 2 feet wide) and an equivalent amount of local aquatic habitat altered to potentially enhance predation rates on listed salmonids and juvenile sDPS green sturgeon.

Based on this analysis, no more than 550 lineal feet of cofferdam shall be present per year in the active river channel. If any of these surrogates (assumed length of each cofferdam and duration of in-water presence) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.4.3.4 Barge Landing Construction

The effects of the construction of barge landings on elevated predation vulnerability to juvenile listed salmonids and sDPS green sturgeon has been described in Section 2.5.1.1.6.3.4. These effects are related to:

- The year-round presence of the numerous support pilings for the overhead dock structures and vehicle bridges to the adjacent levees
- The shading created by the overhead dock structures and the vehicle bridges to the adjacent levee
- The alterations to the local hydrodynamics caused by support pilings in the waterways underneath and adjacent to the barge landing for the duration of the construction schedule (10 – 11 years)

As proposed in the BA, there are eight locations for barge landings in the Delta, from the Sacramento River location of the NDD in the northern Delta to the CCF location on West Canal in the south Delta. NMFS expects that the following listed species and life stages have the potential to be exposed to the barge landing pilings and overhead structures related to the construction and operations of the barge landings:

- Winter-run Chinook salmon: all juveniles that enter the Delta via the Sacramento River and Yolo Bypass during their migratory movements within the Delta
- Spring-run Chinook salmon: all juveniles that enter the Delta from the Sacramento River basin or San Joaquin River basin (progeny of experimental population) during their migratory movements
- Steelhead: all juveniles that enter the Delta from the Sacramento River, San Joaquin River, or eastside tributaries during their migratory movements
- sDPS green sturgeon: all juveniles that are present in the Delta during their migratory and rearing movements

More specifically, the PA describes at least eight potential locations for barge landings in the Delta along the alignment of the two tunnels, requiring over 800 pilings being placed into Delta waters to support these structures (107 pilings per barge landing). These pilings will create vertical structural habitat that is anticipated to provide both velocity breaks and shaded conditions. Both predators and small fish such as salmonids are attracted to these habitat features created by the pilings, producing a potential overlap in their spatial and temporal occurrence. Pilings have little habitat complexity to offer refuge to small fish from co-occurring predators, and therefore the overlap in spatial and temporal occurrence is expected to increase predation vulnerability. Additionally, the large overwater dock structures will create tens of thousands of square feet of shaded water that will adversely affect nearshore habitat as described previously (Section 2.5.1.1.6.3), enhancing the vulnerability to predation and potentially reducing productivity by shading submerged aquatic vegetation.

Since the physical presence of the barge landing structures and their overwater shading creates the habitat conditions for enhanced predation vulnerability to listed salmonids and green sturgeon juveniles, the take analysis uses the number of piles for each landing and the square footage of the over-water dock structures as a surrogate for the number of fish exposed to the project-related effects. The combination of the number of piles for each landing and the area of shading represents the relative size of the adverse habitat created by the project and by reference the scope of potential predation increases on emigrating listed fish.

Each barge landing will have up to 51 pilings supporting the main overwater dock structure, with each piling being a 24-inch diameter steel pile. Pilings will be spaced every 20 feet under the dock. The main dock dimensions have been described as 300 feet long by 50 feet wide for an overwater area of 15,000 square feet per barge landing. An additional 56 piles will be used to support the vehicle bridge connecting the main dock structure to the levee, for a total of 107 pilings per barge landing. If all 8 barge landings are constructed, a total of 120,000 square feet of overhead dock structure will be constructed, and a grand total of 856 piles installed into the waterways of the Delta. The BA does not provide details on the layout of the vehicle bridges connecting the docks to the levees, so no estimates of shaded area can be made for this element of the construction plans.

Based on this analysis, no more than 107 piles shall be installed at each barge landing location as described above, with the overwater dock structure footprint not to exceed 15,000 square feet (nominally a 300 feet long by 50 feet wide structure, but which also excludes any area shaded by the connecting bridge to the shore for which design elements were not provided in the PA). No more than eight barge landings may be constructed, per the following locations described in the BA and Section 2.5.1.1.1.1.4:

- NDD, Intake 2
- Intermediate Forebay/ Snodgrass Slough
- Bouldin Island
- Venice Island
- Mandeville Island
- Bacon Island
- Victoria Island/ Old River
- Clifton Court Forebay Pumping Plant/ West Canal

If any of these surrogates (assumed number of pilings per barge landing, square footage of overwater dock structure, or number or locations of barge landings) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5 Physical Impacts to Fish

2.9.1.1.5.1 Dredging

During the construction of the PA, dredging will occur to remove materials from the surroundings of the permanent structures. This will include the NDD, the SCCF basin, and the HOR gate. In addition, construction dredging will occur adjacent to the temporary barge landings and along the barge traffic routes to remove materials that would impede navigation of the barges and tugboats. Dredging may cause entrainment of fish into hydraulic dredges, or crushing from mechanical excavation using dragline clamshell dredges mounted on barges or tracked equipment (see Section 2.5.1.1.7.2). Entrainment or crushing will result in adverse effects ranging from injury to death. In addition to this effect, disturbed and removed sediment during dredging will remove, kill, or displace benthic invertebrates that may be part of the forage base for listed salmonids and green sturgeon. Restoration of the benthic community will take several months to potentially years to reestablish itself in the disturbed areas. The extent of the exposure to physical harm due to entrainment, crushing, or reduced forage base is represented by the foot print of the dredging action and the timing of the in-water work window.

2.9.1.1.5.1.1 North Delta Intake Locations

It is assumed that in preparation for construction, dredging of the Sacramento River channel in front of each intake location will occur during the in-water work window of June 15 through October 31. Activity will include barge mounted suction dredging and mechanical excavation around the location of the intake structures. Mechanical dredging will use track-mounted equipment and a clamshell dragline. Mechanical excavation will occur behind a floating turbidity control curtain. Activities will include actions described in AMM 6 of BA Appendix 3F.

The timing of dredging activities will substantially reduce the exposure of juvenile listed salmonids to the potential physical effects of dredging (see Section 2.5.1.1). In addition, mechanical dredging activities will use a floating turbidity curtain, which will also effectively exclude fish from close proximity to the dragline clamshell dredge during all dredging activities.

Construction related dredging will occur along the banks of the Sacramento River at intake sites 2, 3, and 5. The maximum length of dredging along the river bank will be 1,969 feet for intakes 2 and 5 and 1,497 feet at intake 3. It is assumed that an area equivalent to approximately 10 percent of the river channel width will be dredged in front of the intake locations to remove materials that may hinder construction of the cofferdams. This is equivalent to 70 feet for intake 2, 50 feet for intake 3, and 60 feet for intake 5.

NMFS expects the following species and life stages will potentially be present during the construction dredging portion of the construction window:

- Winter-run Chinook salmon: no adults; very low numbers of juveniles in fall
- Spring-run Chinook salmon: low numbers of adults in June; very low numbers of juveniles in June and fall
- Steelhead: high numbers of adults August through October; very low numbers of juveniles in fall
- sDPS green sturgeon: medium number of adults and juveniles throughout work window

Quantification of the number of individual fish exposed to the dredging actions associated with the removal of material in front of the NDD fish screens is not possible. It is impossible to track individual fish through the three locations of the NDD intakes and the areas of the river channel in front of the fish screens where entrainment or physical injury from the dredging actions may occur with available monitoring data and methods. It is reasonably certain, however, that those individuals that pass downstream through the reaches of the Sacramento River adjacent to the permanent fish screens during construction dredging operations will be exposed to the potential for entrainment into the hydraulic dredgers or crushing from mechanical dredging and will incur some level of adverse response to the exposure resulting in take. Since the physical impacts of dredging on listed salmonids and sDPS green sturgeon is related to the area of river channel that must be dredged and the season during which it occurs, NMFS uses the physical dimensions of the dredging footprint and the in-water work window as surrogates for incidental take.

The maintenance dredging activities shall not exceed the dimensions provided in Table 2-278.

Table 2-278. Dimensions of the Incidental Take Surrogates for Maintenance Dredging, including the In-water Work Window.

Intake	Maximum Channel Length (feet)	Dredge area width (feet)	Maximum Dredge Area (square feet)	Season of in-water work
Intake 2	1,969	70	137,830	6/15 – 10/31
Intake 3	1,497	50	74,850	6/15 – 10/31
Intake 5	1,969	60	118,140	6/15 – 10/31

If any of these surrogates (assumed length and width of dredging areas and seasons in which dredging occurs) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5.1.2 South Clifton Court Forebay

It is assumed that the construction dredging in the CCF will occur over the course of five years (2022 to 2026). The NCCF basin is not assumed to need any construction dredging due to the installation of the dividing cofferdam, dewatering, and removal of material by excavators in the dry to achieve design elevations for the NCCF basin. Likewise, removal of soil from the expansion area of the SCCF will occur in the dry using earth moving equipment and will not require dredging to achieve project design elevations. Dredging in the central portion of the existing CCF would occur in the same manner as described in section 2.5.1.1.2.4.2, and will include any AMMs described in the BA and the use of silt curtains to isolate approximately 200 acres (~9 million square feet) per dredging cycle to avoid blocking flows through the SCCF and reducing suspended sediment in the exported water at the SWP. Dredging will occur during the in-water work window of July 1 to October 31, when the risk of exposure to juvenile salmonids is considered to be very low. However, adult steelhead and adult and juvenile sDPS green sturgeon have the potential to be present during this time period.

NMFS expects these species and life stages to potentially be present during the construction dredging portion of the construction window:

- Winter-run Chinook salmon: no adults; very low numbers of juveniles in fall
- Spring-run Chinook salmon: no adults; very low numbers of juveniles in fall

- Steelhead: high numbers of adults August through October; very low numbers of juveniles in fall
- sDPS green sturgeon: medium numbers of adults and juveniles throughout work window

Quantification of the number of fish present in the SCCF during maintenance dredging operations is impossible to determine given the large acreage of this waterbody, abundant submerged aquatic vegetation, and constant exchange of water with the Delta through the radial gates which may entrain additional fish into the forebay with each gate opening and the ongoing fish salvage operations which removes fish from the forebay with export pumping. Furthermore, the initial number of individual listed fish potentially present in the area to be dredged is difficult to determine due to the variations in fish presence related to migrational timing in the Delta and physical distribution within the entire CCF in relation to the area being dredged. Since the physical impacts of dredging on listed salmonids and sDPS green sturgeon is related to the area of forebay bed that must be dredged and the season during which it occurs, NMFS uses the physical dimensions of the dredging footprint and the in-water work window as surrogates for determining the extent of incidental take.

Therefore, the dredged area, frequency, and timing shall not exceed the incidental take surrogates defined in Table 2-279.

Table 2-279. Surrogate Criteria for the Extent of the Incidental Take Associated with Construction Dredging within the CCF.

Location	Dredged area/ cycle	Duration of construction dredge cycles	Silt Curtain Employed	In-water work Season
CCF	200 acres	5 years	Yes	7/1 to 10/31

If any of these surrogates (assumed area of dredging, use of silt curtains, and seasons in which dredging occurs) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5.1.3 HOR Gate

It is assumed that construction dredging for the HOR gate will occur over the course of the first year of construction. Dredging to prepare the channel for construction of the boat locks and gate structure will occur along 500 feet of channel, from 150 feet upstream of the proposed gate, to 350 feet downstream of the gate. A total of up to 1,500 cubic yards of material will be dredged. Dredging will last approximately 15 days. A barge-mounted hydraulic cutterhead or mechanical sealed clamshell dredge will be used to remove sediment from the Old River channel. Construction dredging will only occur during the August 1 through October 31 in-water work window designated for this location.

NMFS expects that the presence of juvenile salmonids will be very unlikely during this period and that exposure is more likely for adult steelhead, adult sDPS green sturgeon, and juvenile sDPS green sturgeon. These species and life stages are expected to be present in the waters of the south Delta and lower San Joaquin River during this work window.

Quantification of the number of individual fish present at the HOR gate during construction dredging operations is impossible to determine due to the variations in fish presence related to migrational timing and distribution within the Old River channel at the HOR gate location.

Given the relatively narrow confines of the Old River channel, it is reasonably certain, however, that those individuals that pass downstream through the Old River channel past the proposed HOR gate location during dredging operations will be exposed to the potential for entrainment into the hydraulic dredgers or injury from mechanical dredging and will incur some level of adverse response to the exposure resulting in take. Since the physical impacts of dredging on listed salmonids and sDPS green sturgeon is related to the area of Old River channel bed that must be dredged and the season in which it will occur, NMFS will use the physical dimensions of the dredging footprint, the expected volume of dredged material, and the in-water work window as surrogates for determining take.

Therefore, the dredging length, volume, frequency, and timing shall not exceed the numerical levels of the incidental take surrogates defined in Table 2-280.

Table 2-280. Surrogate Criteria for the Extent of the Incidental Take Associated with Construction Dredging for the HOR Gate.

Location	River Channel Length		Dredged Volume	Duration of Construction Dredging	In-water work season
	Upstream	Downstream			
HOR Gate	150 feet	350 feet	1500 yds^3	<20 days (first construction season)	8/1 to 10/31

If any of these surrogates (assumed length of dredging areas, dredged volumes, duration of dredging, and seasons in which dredging occurs) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5.1.4 Barge Routes and Landings

Dredging associated with barge operations can be expected during the construction activity period of the proposed action. Barge landings are distributed over a broad area of the Sacramento – San Joaquin Delta. The Sacramento-San Joaquin Delta barge routes will cover nearly 100 miles of waterways from San Francisco to the Port of Stockton and landing locations at the NDD intake location and CCF.

During the 5 to 6 years of construction, barge landing sites (described in Section 2.5.1.1.1.1.4 Barge Landing Locations) and the barge routes themselves (described in Section 2.5.1.1.1.2 Barge Traffic) may need to be periodically dredged of collected sediment to adequate depths to maintain passage and vessel safety. Initial dredging at barge landings and along barge routes will occur at the beginning of the construction phase of the PA as needed and up to two additional spot dredging actions at barge landings and along barge routes as needed during the remainder of the construction schedule (up to 6 years). NMFS also assumes that the in-water work window for dredging activities associated with barge operations will be the same as that used for construction at the barge landings (July 1 through October 31). This work window is expected to minimize exposure to listed fish species under NMFS' authority.

Dredging operations that occur when fish are present are expected to result in exposure to physical impacts due to entrainment into the hydraulic cutterheads or crushing injuries form the dragline clamshell dredges, which may result in adverse effects to fish. The proposed action includes implementation of BMPs and AMMs, which are expected to minimize the potential for injury during dredging activities (BA Appendix 3F).

NMFS expects these species and life stages to be potentially present during the construction dredging portion of the construction window for the barge landings:

- Winter-run Chinook salmon: no adults or juveniles present
- Spring-run Chinook salmon: no adults or juveniles present
- Steelhead: medium number of adults July through August; very low number of juveniles
- sDPS green sturgeon: medium numbers of adults and juveniles throughout work window

Quantification of the number of individual fish present at the barge landings or along the barge routes where dredging may occur during construction is impossible to determine due to the variations in fish presence related to migrational timing and distribution within the Delta waterways at the various barge landing locations and along barge routes through the Delta. Given the relatively narrow confines of the channels adjacent to the some of the proposed barge landing locations, it is reasonably certain that those individuals that pass through these waterways during dredging operations will be exposed to the potential for entrainment into the hydraulic dredgers or injury from mechanical dredging and will incur some level of adverse response to the exposure resulting in take. There is less certainty regarding exposure in the more open channels where some landings are located and through which barge traffic will operate leading to those barge landing locations. The physical impacts of dredging on listed salmonids and sDPS green sturgeon are related to the area of river channel bed that must be dredged and the season and frequency in which it will occur. However, since the areas that must be dredged have not been physically identified at this stage of the project development, the dredged area cannot be used as a surrogate for incidental take. Only the in-water work window for the Delta has been established, as well as the maximum number of barge landings to be constructed, and the maximum frequency of dredging to allow the use of the barge landings. NMFS will use the in-water work window and frequency of dredging as surrogates for determining incidental take.

Therefore, the number of barge landings, the dredging frequency and timing, and the duration of the PA construction schedule shall not exceed the numerical levels of the incidental take surrogates defined in Table 2-281.

Table 2-281. Surrogate Criteria for the Extent of the Incidental Take Associated with Construction Dredging for the Barge Landings and Barge Routes.

Number of Barge Landings Sites	In-water Work Window	Frequency of Dredging	Duration of Construction Schedule
8	July 1 to August 31	1 initial dredging at start of construction schedule plus up to 2 additional dredging events over the course of the Construction schedule	6 years

2.9.1.1.5.2 Propeller Entrainment

Section 2.5.1.1.7.3 of this opinion assesses the effects of barge traffic and the potential for injury and death associated with propeller entrainment for juvenile salmonids and green sturgeon. In estimating the magnitude of propeller entrainment, monthly average fish densities for juvenile salmonids were obtained from the USFWS Delta Juvenile Fish Monitoring Program data for the

Chipps Island Trawl and Sacramento Trawl at Sherwood Harbor and historical seasonal data for Prisoners Point and Jersey Point. Ratios between Chipps Island fish densities and those for Prisoners Point and Jersey Point for the overlapping periods of sampling data were developed to extrapolate the missing months of the year for which Prisoners Point and Jersey Point data were not available. The variability of these data sets makes them inappropriate for determining specific incidental take levels; however, they were appropriate for determining potential project-level effects for the jeopardy analysis of this project. Furthermore, there are no current practicable methods available to monitor for fish entrained through tugboat propellers for each barge string transit from port of origin to barge landing destination and compare them to projected monthly entrainment numbers. NMFS expects that juvenile salmonids and sDPS green sturgeon have a higher vulnerability to propeller entrainment than adults due to their smaller size, relatively slower absolute swimming velocity based on their smaller sizes (and thus reduced ability to avoid barges and tugboats), and, for salmonids, their orientation towards shallower depths during migratory movements, which places them at the same depth as the tugboat propellers. NMFS realizes that adult life stages of listed fish are also vulnerable to propeller entrainment, but a data set is not available to determine fish density as related to depth distribution for their level of vulnerability (however, see references on the vulnerability of adult sturgeon to propeller strikes in Brown and Murphy (2010) and Balazik et al. (2012), indicating that adult sturgeon are vulnerable to deep draft vessels).

The known project elements for barge traffic includes the schedule for barge traffic throughout the year in different regions of the Delta, the cumulative number of trips to each barge landing over the course of the multi-year construction schedule, and the upper limit of the size of tugboats considered for use in the barge traffic element of the project. These factors are used as surrogates for determining incidental take as each factor impacts the level of effects considered in the analysis.

The annual schedule for barge movements to each of the barge landings is:

- June 1 through October 31: Barge traffic is allowed to all barge landing locations within the Delta and may originate from any of the three ports of origin identified in the BA (San Francisco, Antioch, and Stockton).
- November 1 through February 28: Barge traffic is limited to originating at the Port of Stockton and delivering materials to the Bouldin Island barge landing. Barge traffic will use the mainstem San Joaquin River/Stockton Deep Water Ship Channel as its transit route until reaching the western terminus of Potato Slough, where barges will gain access to the Bouldin Island barge landing on Potato Slough.
- March 1 through May 31: Barge traffic will originate from the Port of Stockton and deliver materials to the Bouldin Island barge landing site as stated above, except that trips will be limited to only those deemed absolutely necessary to move critical materials or construction equipment that cannot be moved via land routes due to size or weight.

Based on the information provided in the BA and documents received regarding the barge landings and barge traffic, no more than four trips per day will go to either the Bouldin Island or CCF barge landings (8 total one-way trips or 16 round trips) and may originate from any of the three points of origin during the June 1 through October 31 period. These barge landings have been identified as the main destinations for materials and equipment in the PA. During the remainder of the year, no more than four barge trips to the Bouldin Island barge landing from the Port of Stockton may occur per day, in addition to the previous restrictions described above.

Other locations are likely to have much lower frequencies of deliveries based on the description of barge traffic in the BA and supporting materials and documents and will comply with the restrictions described above.

The analysis is based the description of tugboats readily available in the San Francisco Bay region and information provided in the supporting documents for the PA. Reclamation and DWR indicate that the assumed length of tug boats will be 65 to 100 ft (19.8 to 30.5 m) with a beam of approximately 35 ft (10.7 m) and a draft of approximately 6 to 8 ft (1.8 to 2.4 m). To estimate the potential effects of increased barge traffic on listed species because of direct injury from propellers, NMFS assumes that propeller disc diameter is approximately 70% of the draft, or 50 to 70 in. (1.3 to 1.8 m) in diameter. This corresponds to dimensions for typical tug boats operating in the Delta and San Francisco Bay. Three sizes of propellers that span the middle range of diameters are used for the effects assessment (1.3-, 1.5- and 1.8-meter diameter). These sizes correspond to ships with drafts from 1.86 to approximately 2.6 m.

The effects analysis for propeller entrainment risk uses:

- The frequency of daily barge traffic in the waters of the Delta to the barge landings
- The timing of trips seasonally to different barge landings
- The range of sizes of the propeller discs on tugboats, and the distances travelled within the Delta from ports of origin to final destination barge landings to calculate the volume of water passing through the propellers
- The average monthly density of listed salmonids at different locations to assess the magnitude of potential entrainment of listed salmonids into the propellers of tugboats pushing barges through the Delta as part of the PA.

As fish density is variable, and methods to physically count fish passing through the propellers are not technically feasible at this time, the barge traffic schedule, physical dimensions of the propeller disc, and frequency of daily trips are used as surrogates for identifying incidental take.

NMFS expects the following listed fish species and life stages will be potentially present during the year-round barge traffic anticipated for the PA:

- Winter-run Chinook salmon: juveniles are likely to be present in the waterways adjacent to the mouth of the Mokelumne River in the lower San Joaquin River from November through May; a small percentage of the juvenile winter-run Chinook salmon population within the Sacramento River migratory route may be exposed during precipitation events occurring in October; adult fish will be present from November through July in both the mainstem Sacramento River and the lower portions of the San Joaquin River downstream and including the Georgiana Slough/ Mokelumne River junction
- Spring-run Chinook salmon: juveniles from the Sacramento River basin and from the San Joaquin River basin are likely to be present in the waterways adjacent to the mouth of the Mokelumne River in the lower San Joaquin River from November through May; juveniles from the San Joaquin River may be present from the Port of Stockton to the mouth of the Mokelumne River from November through May a small number of juveniles may be present in the Sacramento River migratory route during June; adult spring-run Chinook salmon may be present in the Sacramento and San Joaquin rivers within the Delta during their upstream migrations from January through February in the Delta

- Steelhead: juvenile steelhead will have the potential to be exposed to barge traffic along the San Joaquin River migratory corridor the entire year, but particularly from January through May with a peak in April and May due to San Joaquin River basin outmigrants; a small proportion of juvenile steelhead (≤2% of the Sacramento River basin population) will be exposed to barge traffic along the Sacramento River migratory corridor from June through October; adult steelhead will be exposed from June through October in the Sacramento River migratory corridor and year round in the San Joaquin River corridor
- sDPS green sturgeon: all adult and juvenile sDPS green sturgeon occupying waters of the Delta will have the potential to be exposed to barge traffic throughout the entire year; NMFS assumes that the presence of juvenile sDPS green sturgeon in the Delta occurs year round within any accessible waterway in the Delta, but in particular the main riverine corridors of the Sacramento and San Joaquin rivers

Based on the effects analysis conducted for this consultation and the BA, supporting materials, and Section 2.5.1.1.7.3 of this Opinion, Table 2-282 presents the surrogate values to express the incidental take for propeller entrainment with the identified restrictions regarding the anticipated size of tugboats and their propellers and the schedule of barge traffic to different locations.

Table 2-282. Surrogates for Incidental Take Levels Based on the Number of One-way Barge Trips, Maximum Duration of Construction, and Season of Barge Trips by Barge Landing Location.

Barge Landing Location[1]	One-way Barge trips[2]	Maximum Construction Duration (days)[3]	Season of Barge Trips
Intermediate Forebay	435	2,175	June 1-Oct 31
Bouldin Island	3,344	2,336	All Year[4]
Venice Island	500	375	June 1 – Oct 31
Mandeville Island	400	500	June 1 – Oct 31
Bacon Island	2,150	1,056	June 1 – Oct 31
Victoria Island	375	792	June 1 – Oct 31
Clifton Court Forebay	2,185	2,100	June 1 – Oct 31

Notes:

1. Detailed information for the NDD barge landing location was not provided by the applicant, but is still considered as a potential site for a landing.
2. Total number of trips within waterways is twice the one-way trips value. No more than 4 one-way trips per day to any barge landing. Further restrictions identified in text.
3. Total construction days occur within the time line to complete construction of the PA, anticipated to be up to 6.5 years.
4. Trips to Bouldin Island follow the schedule described in the text, originating only from the Port of Stockton from November 1 through May 31.

If any of these surrogates (assumed number of barge trips to each barge landing, maximum duration of construction days, and the seasonal schedule of barge activities) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5.3 Dewatering

During construction of the cofferdam, attempts will be made to herd fish out of the waters behind the cofferdam as the structure is elongated, if feasible. These swept areas will be isolated by block nets to prevent fish from re-entering (see AMM 8 in BA Appendix 3.F). Fish that are trapped behind the cofferdam following closure will be captured and relocated prior to complete dewatering. The capture and relocation efforts are unlikely to be completely effective, and some fish will avoid capture and die behind the cofferdam as it is dewatered. The sequence of dewatering, fish rescue, and salvage will apply to all cofferdams in the PA.

2.9.1.1.5.3.1 NDD Cofferdams

Based on the PA, the temporal exposure of migrating listed fish to entrapment or delay behind the NDD cofferdam locations is June 15 to October 31. NMFS expects the following species and life stages to be potentially present during the construction window for the NDD cofferdams:

- Winter-run Chinook salmon: no adults, very low level of juveniles in fall
- Spring-run Chinook salmon: low level of adults in June, very low level of juveniles in fall and June
- CCV steelhead: high level of adults August through October; very low level of juveniles in fall
- sDPS green sturgeon: medium level of adults and juveniles throughout work window

Incidental take of adult and juvenile listed fish species is expected to occur during the five-month construction period occurring between June 15 and October 31 and take in the form of mortality, harm, harassment, trapping, capture, and collection of listed fishes. Enumerating individual fish that become entrapped behind the cofferdams is impossible to do given the current monitoring programs available. Furthermore, fish trapped behind the cofferdam may be subject to predation or consumption by predators or scavengers when they die prior to dewatering and fish rescue actions, and thus be unavailable for census under any monitoring program. Since it is impossible to know how many fish will be exposed to entrapment behind the cofferdam, and how many individual fish will actually be trapped behind the cofferdam following closure, NMFS must rely on surrogates to determine incidental take levels. Only the timing of construction of the cofferdams and the footprint of the three cofferdam structures constructed on the Sacramento River are known with any certainty, and thus the construction schedule and footprint of each structure will serve as a proxy for the level of take associated with the cofferdams and their dewatering. The footprint of each cofferdam will determine the area of water that will be isolated from the open river. The open water is where free fish movement is possible. The area of isolated water behind the cofferdam will serve as a surrogate for the amount of available habitat along the nearshore environment that will be impacted, where free fish movement has been prevented or diminished, and where take will occur. In addition, the construction schedule will influence the extent of temporal overlap with the presence of the different listed species and their life history stages at the intake locations. The construction schedule was developed to avoid, to the greatest extent possible, temporal overlap with the presence of both adult and juvenile listed salmonids. However, it does not completely avoid all periods when listed fish are present, particularly green sturgeon and adult steelhead.

Table 2-283 presents the surrogates for incidental take levels based on the length of the cofferdam construction, the area of tidal perennial habitat isolated from the main river, and the construction schedule for the three NDD intake locations.

Table 2-283. Surrogates for Incidental Take Levels Based on the Length of NDD Intake Structures, Area of Perennial Tidal Habitat Enclosed by NDD Cofferdams, and the In-water Construction Season for the NDD Intakes.

Intake	Overall structure length along the Sacramento River Bank (feet)	Area of Tidal Perennial Habitat Isolated by Cofferdams–(acres)	Construction Season
Intake 2	1,969	2.6	6/15 – 10/31
Intake 3	1,497	1.8	6/15 – 10/31
Intake 5	1,901	2.3	6/15 – 10/31
Total	**5,367**	**6.7**	

If any of these surrogates (maximum length of in-water cofferdam, acreage of isolated waters, or construction season) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5.3.2 Clifton Court Forebay

Based on the PA, the temporal exposure of migrating listed fish to entrapment or delay behind the CCF cofferdam locations is July 1 to October 31. It is expected that five years of construction actions are required to complete the installation of the cofferdams for the modifications of the CCF. NMFS expects these species and life stages to be potentially present during the in-water construction window:

- Winter-run Chinook salmon: no adults; very low level of juveniles in fall
- Spring-run Chinook salmon: no adults; very low level of juveniles in fall
- CCV Steelhead: high level of adults August through October; very low level of juveniles in fall
- sDPS green sturgeon: medium level of adults and juveniles throughout work window

The construction of the cofferdams for the CCF modifications will create areas of enclosed water behind the cofferdam structures that are isolated from the main waterbody of CCF. The largest such isolated area will be the area to the north of the dividing cofferdam separating the future NCCF from the SCCF. There is the potential that listed fish will be trapped and delayed behind the cofferdams during construction actions and completely trapped following the final closure of the cofferdam structures at the end of construction (see Section 2.5.1.1.7.4.1).

2.9.1.1.5.3.2.1 NCCF Dewatering

Based on information provided in BA Appendix 3B, the size of the proposed NCCF following installation of the dividing cofferdam will be nominally 806 acres, leaving approximately 1,394 acres of the original CCF to the south of the cofferdam dividing wall, with the assumption that the current CCF has a surface area of 2,200 acres. The BA has described that the additional area to be flooded to the south of the current CCF in order to enlarge the SCCF is 590 acres, and that the nominal surface area of the new SCCF will be 1,691 acres after construction. Final closure of the cofferdam dividing the current CCF to form the NCCF and the SCCF will occur in the second summer of construction when the two 100 foot openings are sealed with sheet piles (July 1 through August 11, 2026). Dewatering of the isolated NCCF will commence following closure, with fish salvage and rescue initiated as soon as practicable.

Quantification of the number of fish trapped behind the dividing cofferdam is impossible to determine given the large acreage of the isolated waterbody, abundant submerged aquatic vegetation, and high predator population that may consume listed species during dewatering actions. Furthermore, the initial number of individual listed fish potentially present in the area to be dewatered is difficult to determine due to the variations in fish presence related to migrational timing and distribution within the entire CCF. Therefore, the timing of the closure of the dividing cofferdam and the area of the isolated waterbody are used as surrogates for incidental take. Closure during the summer, when ambient water temperatures are typically greater than 68°F (20ºC) in CCF, will reduce the number of listed salmonids expected to be present in the forebay due to water temperature preferences of salmonids. Presence of sDPS green sturgeon is assumed to be likely due to the year-round rearing of juveniles in the Delta and historical observations of juveniles in the CVP/SWP fish salvage during the summer. Presence of adult sturgeon is also possible due to their migratory behavior and observations of individuals in the recreational fishery during the summer period in waters of the Delta. The area of the isolated water body is a proxy for the extent of aquatic habitat that is affected by the dewatering and may contain listed species when isolated from the surrounding water body.

Therefore, if closure of the cofferdam dividing wall occurs at a time other than July 1 through August 11 or if the acreage of the isolated northern forebay exceeds 806 acres, the PA will be considered to have exceeded anticipated incidental take levels.

2.9.1.1.5.3.2.2 NCCF Siphons

The area within the NCCF siphon cofferdams will be dewatered for construction of the three box culverts that form the siphon. The construction of the siphons will occur over two construction seasons, with each season used to construct one half of the culverts across the intake channel. Each season, one side of the channel will be blocked off by the cofferdam structure, the area within the cofferdam dewatered, and construction completed in the dry. Following completion of that half of the siphon structure, the cofferdam will be flooded, the cofferdam sheet piles removed or cutoff at the mudline, and the second cofferdam installed and dewatered for construction of the remaining half of the siphon during the following in-water work season. The in-water work season for the installation of the cofferdams is July 1 to October 31. The anticipated area bounded by each cofferdam installation is approximately 97,500 square feet (2.25 acres) based on an estimated dimension of 750 feet long by 130 feet wide area for each season of work. Quantification of the number of fish trapped behind the NCCF siphon cofferdams is impossible to determine given the size of the isolated waterbody, abundant submerged aquatic vegetation, and high predator population that may consume listed species during dewatering actions. Furthermore, the initial number of individual listed fish potentially present in the area to be dewatered is difficult to determine due to the variations in fish presence related to migrational timing and distribution within the entire CCF. Construction during the summer will have the same potential for trapping salmonids and sDPS green sturgeon as described for the NCCF dewatering. Therefore, the timing of the installation of the NCCF siphon cofferdam and the area of the isolated waterbody contained within each season's cofferdam installation are used as surrogates for incidental take using the same reasoning as presented for the NCCF dewatering action.

Therefore, if closure of the cofferdam occurs at a time other than July 1 through October 31 or if the acreage of the isolated work area within the NCCF siphon cofferdams exceeds 2.25 acres in each year of the two-year construction schedule, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5.3.2.3 East-Side Embankment Cofferdams

The east side cofferdam is estimated to be 4,900 feet in length based on the engineering drawings in BA Appendix 3C. The alignment of the cofferdam is approximately 560 feet away from the toe of the current levee and 200 feet further than the toe of the proposed earthen embankment to be constructed for the new SCCF eastern perimeter. This equates to 2,744,000 square feet (63 acres) of water surface area between the cofferdam and the current levee on the eastern side of CCF. Quantification of the number of fish trapped behind the eastern embankment cofferdams is impossible to determine given the large acreage of the isolated waterbody, abundant submerged aquatic vegetation, and high predator population that may consume listed species during dewatering actions. Furthermore, the initial number of individual listed fish potentially present in the area to be dewatered is difficult to determine due to the variations in fish presence related to migrational timing and distribution within the entire CCF. Construction during the summer will have the same potential for trapping salmonids and sDPS green sturgeon as described for the NCCF dewatering. Therefore, timing of the installation of the eastern embankment cofferdam and the area of the isolated waterbody contained between the cofferdam and the current existing levee face are used as surrogates for incidental take.

Therefore, if closure of the cofferdam occurs at a time other than July 1 through October 31 or if the acreage of the isolated work area between the eastern embankment cofferdam and the existing levee exceeds 63 acres, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5.3.2.4 West-Side Embankment Cofferdam

The west side cofferdam is estimated to be 3,400 feet in length based on the engineering drawings in BA Appendix 3C. The alignment of the cofferdam is approximately 750 feet away from the toe of the current levee and 200 feet further than the toe of the proposed earthen embankment to be constructed for the new SCCF western perimeter. The additional distance from the current levee face is to accommodate the proposed canal to carry water from the NCCF siphons to the intake channel of the SWP. This equates to 2,550,000 square feet (58.54 acres) of water surface area between the cofferdam and the current levee on the western side of CCF. Quantification of the number of fish trapped behind the western embankment cofferdams is impossible to determine given the large acreage of the isolated waterbody, abundant submerged aquatic vegetation, and high predator population that may consume listed species during dewatering actions. Furthermore, the initial number of individual listed fish potentially present in the area to be dewatered is difficult to determine due to the variations in fish presence related to migrational timing and distribution within the entire CCF. Construction during the summer will have the same potential for trapping salmonids and sDPS green sturgeon as described for the NCCF dewatering. Therefore, the timing of the installation of the western embankment cofferdam and the area of the isolated waterbody contained between the cofferdam and the current existing levee face are used as surrogates for incidental take.

Therefore, if closure of the cofferdam occurs at a time other than July 1 through October 31 or if the acreage of the isolated work area between the western embankment cofferdam and the existing levee exceeds 58.54 acres, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5.3.3 HOR Gate Cofferdams

Based on the PA, the temporal exposure of migrating listed fish to entrapment or delay behind the cofferdams at the HOR gate location is August 1 through October 31. It is expected that two years of in-water construction actions (2020 -2021) are required to complete the installation of the cofferdams and foundation piles for the construction of the HOR gate. NMFS expects these species and life stages to be potentially present during the in-water construction window:

- Winter-run Chinook salmon: no adults or juveniles
- Spring-run Chinook salmon: no adults or juveniles
- CCV steelhead: low to medium level of adults August through October; very low level of juveniles in fall
- sDPS green sturgeon: medium level of adults and juveniles throughout work window

Entrapment and take of adult and juvenile listed fish species is expected to occur from August 1 through October 31, when the sheet pile cofferdam is closed and the work area is dewatered to allow construction of the HOR gate elements. Construction of the HOR gate elements will occur over two construction seasons, with each season used to construct one half of the HOR gate project across the channel of Old River. Each season, one side of the channel will be blocked off by the cofferdam structure, the area within the cofferdam dewatered, and construction completed in the dry. Following completion of that half of the gate structure, the cofferdam will be flooded, the cofferdam sheet piles removed or cutoff at the mudline, and the second cofferdam installed and dewatered for construction of the remaining half of the gate the following in-water work season. In the first year of construction, the boat locks and one half of the gate structure will be built. Based on the engineering drawings in BA Appendix 3C, the projected area encompassed by the cofferdam in the first work season is 15,375 square feet (0.35 acres). The projected area encompassed by the sheet pile cofferdam in year two is 5,625 square feet (0.13 acres), for a cumulative area of approximately 21,000 square feet or approximately 0.5 acres of water surface area.

Quantification of the number of individual fish trapped behind the HOR gate cofferdams is impossible to determine due to the variations in fish presence related to migrational timing and distribution within the Old River channel at the HOR gate location. In addition, high predator populations in the area make it likely that predators will become trapped inside the cofferdams with listed fish, and may consume listed species during dewatering actions. Construction during the summer will have a low potential for trapping salmonids as described for the CCF dewatering elements of the project due to ambient water temperatures and migration timing of listed fish. Individual sDPS green sturgeon may be present due to their use of the Delta waterways for rearing and migration on a year-round basis. Therefore, timing of the installation of the HOR gate cofferdams each summer and the area of the isolated waterbody contained within the cofferdam walls are used as surrogates for incidental take.

Therefore, if closure of the cofferdam occurs at a time other than from August 1 through October 31 or if the acreage of the isolated work areas between the cofferdam walls exceeds 0.5 acres total area, the PA will be considered to have exceeded anticipated take levels.

2.9.1.1.5.4 Fish Salvage and Rescue Actions

Fish rescues and salvage will occur during the in-water work windows immediately following the closure of the cofferdams and the initiation of dewatering of the isolated spaces behind the cofferdams. Fish salvage and rescue will occur after the isolated waters behind the cofferdams are dewatered to the point where biologists and workers can enter the enclosed area to efficiently conduct seine netting, dip netting, or electrofishing, which will depend on water depth and bathymetry. NMFS expects that few juvenile salmonids will be potentially present during these fish rescue actions as the summer in-water work windows are designed to avoid the majority of migratory periods for juvenile listed salmonids. It is likely that adult steelhead will be present among the fish rescued from behind the cofferdams, as the in-water work windows overlap with a substantial proportion of the adult upstream migratory season. In addition to adult steelhead, adult and juvenile sDPS green sturgeon may be present in the waters isolated behind the cofferdams constructed for the PA since both life history stages can be found in the Delta year round.

Based on previous fish rescues and scientific monitoring using nets, traps, and electrofishing, NMFS does not expect that more than 2 percent of the fish captured by seine or dip netting or electrofishing techniques will incur injuries leading to death, provided that sufficient resuscitation efforts are practiced (see AMM8 in BA Appendix 3F). Mortalities due to handling during the fish rescue and salvage efforts will be considered as those individuals:

- Captured by seine and/or dip nets or electrofishing that do not recover after capture even after resuscitation efforts are made. Recovery is considered complete when fish regain normal equilibrium, swimming behavior, respiratory function, and general behavior and response to external stimuli.
- Obviously injured by becoming ensnared by net meshes leading to damage to gill structures (gilling), cuts and abrasions leading to wounds with large amounts of bleeding, scale loss, loss of body mucous coat, or injury to eyes or injured due to debris in the net which are likely to lead to death or a high potential for latent morbidity after release.
- Immediately killed or injured due to electrofishing, with death a likely outcome after a latency period (e.g., internal bleeding, fractures of vertebrae, notochords, or other skeletal structures, internal scarring due to the passage of the electrical current through the fish’s body).

Observation and recovery of fish that are already dead, in the process of dying, or obviously highly stressed, prior to the onset of fish rescue and salvage actions shall be considered take under the dewatering process, and not the handling of fish under the fish rescue and salvage plan. The percentage of fish killed by the handling of rescued fish will be determined by enumerating the number of mortalities by listed species group (i.e., winter-run and spring-run Chinook salmon, steelhead, and green sturgeon) due to handling and dividing by the total number of listed fish, by species group, captured during the rescue and salvage efforts at each location where cofferdams or structures have been dewatered. NMFS shall be informed weekly of the progress of the salvage rescue actions at each location. In the event that the observed population of listed fish species that will require salvage and rescue is in the high hundreds (>500 individuals) or larger, NMFS shall be notified immediately upon this determination, and daily reports sent to NMFS detailing the running tally of mortalities for that location. Take levels will apply to each individual location in which rescue and salvage actions take place.

2.9.1.2 Operations-related Effects

2.9.1.2.1 Permanent Structures

2.9.1.2.1.1 Predation

The PA has two main permanent infrastructure sites in the Delta: the three fish screen structures in the north Delta, and the HOR gate structure on Old River in the south Delta. Like the interim structures, these structures will be in place in the waterways of the Delta year-round and will impact all listed fish species and life stages. Similar to temporary structures, these structures are likely to attract and congregate both predators and prey; however, there are additional habitat issues created by the final designs of the permanent structures.

2.9.1.2.1.1.1 North Delta Intake Locations

The permanent in-water infrastructure for the three NDD include the following:

- Sheet pile training walls extending from the levee face to the intake screens
- Cut off sheet pile walls along the length of the screen forming the edge of the sill
- Fish screens with refugia located between screen bays
- Floating debris boom along outside face of the fish screens
- Debris boom piles to support floating debris boom

These structures create habitat which is conducive to providing holding and cover habitat for predators in the vicinity of the intakes. The footprint of each intake structure, including cofferdams, transition wall structures, and bank protection (i.e., riprap), would result in the permanent loss of approximately 6.6 acres of tidal perennial habitat and 1.02 linear miles of shoreline and associated riparian vegetation. At each intake location, these structures would encompass 1,600-2,000 linear feet of shoreline and 35 feet (5-7%) of the total channel width. In addition, sheet pile walls, riprap, and other artificial structures provide physical and hydraulic conditions that may attract predatory fish species (e.g., striped bass, largemouth bass, smallmouth bass, and Sacramento pikeminnow) and potentially increase their ability to ambush juvenile salmonids and other fishes. Table 2-284 provides the project design for the fish screen dimensions of the NDD.

Table 2-284. Design Parameters of the NDD Intakes.

Intake	Screen Height(ft)	Screen Width (ft)	Number of Screens	Total length of fish screens[1] (ft)	Total length of NDD structures[1] (ft)
Intake 2	12.6	15	90	1,350	1,969
Intake 3	17.0	15	74	1,110	1,497
Intake 5	12.6	15	90	1,350	1,901

Note:

Fish screen length is less than total length of structures because the structure length includes refugia, sheet pile training walls, and concrete approach sections.

Each screen is designed to have a 22-foot-wide fish refugia between each of the six screen bay groups. For intakes 2 and 5, this is equivalent to 15 screen sections per bay group, and for intake 3, 12 screens are in each bay group. For intakes 2 and 5 the distance between refugia is nominally 225 feet, and for intake 3, the distance between refugia is nominally 180 feet.

In addition to the vertical habitat created by the sheet pile training walls and fish screen elements of the intakes, each intake will have a debris boom supported by multiple piles in front of the screens to protect them from damage by drifting debris in the Sacramento River. These structures provide additional habitat for predators and prey. Based on the design drawings in BA Appendix 3C, the project will have two log booms that are approximately 1,700 feet long (intakes 2 and 5) and one boom approximately 1,300 feet long (intake 3). Approximately 32 pilings will support the log boom for intake 3 and approximately 40 pilings each for intakes 2 and 5, for a total number of approximately 112 pilings. Each piling and the associated floating log boom will provide both structure and shade in an offshore environment which is expected to attract both predatory fish and listed salmonid juveniles.

Quantification of the number of individual fish exposed to the increased predation associated with the presence of the NDD is not possible. It is impossible to track individual fish through the three locations of the NDD intakes and the areas in front of the fish screens where predation may occur with available monitoring data and methods. It is reasonably certain, however, that those individuals that pass downstream through the reaches of the Sacramento River adjacent to the permanent fish screen and log boom structures are exposed to the altered instream habitat created by the permanent structures that favors predators and successful predation events and will incur some level of adverse response to the exposure resulting in take. Since the physical presence of the intake structures and their shape creates the habitat conditions for enhanced predation vulnerability of listed salmonids and juvenile green sturgeon, NMFS uses the lineal length for each of the intakes as well as the length of the floating debris log boom and number of support piles as a surrogate for the number of fish exposed to the project-related effects. The lineal length of the screens and the log boom structure represents the relative size of the adverse habitat created by the project, and by reference the scope of potential predation increases on emigrating listed fish.

Based on these analyses, lineal lengths of the intake structures and debris log booms and the number of support piles shall not exceed the values in Table 12-285 NDD which serve as surrogates for incidental take levels for this component of the PA.

Table 2-285. Surrogates for Incidental Take Levels Based on the Lengths of each NDD Structure, the Protective Log Booms, and the Number of Support Pilings Creating In-water Structure.

Intake	Length of NDD Structure[1] (ft)	Length of Log Boom (ft)	# of Log boom support piles
Intake 2	1,969	1,700	40
Intake 3	1,497	1,300	32
Intake 5	1,901	1,700	40

Note:

Includes the total length of the fish screens, sheet pile training walls and concrete approach structures for each intake.

If any of these surrogates (assumed length of intake structures, length of log booms, or number of support piles for the log booms) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.2.1.1.2 HOR Gate

An operable gate will be constructed at the HOR to prevent migrating juvenile salmonids (San Joaquin River-origin steelhead, spring-run Chinook salmon, and fall-run Chinook salmon) from entering Old River from the San Joaquin River, thereby minimizing their exposure to the CVP/SWP pumping facilities. The permanent in-water infrastructure for the HOR gate will include the following elements:

- The gate will be located in Old River channel approximately 400 feet downstream of the junction of Old River with the San Joaquin River.
- The overall gate structure across the Old River channel will be 210 feet long and 30 feet wide, with a top elevation of +15 feet and include seven 25–foot-wide bottom-hinged gates (two in the boat lock and five along the channel bottom of Old River) forming the barrier totaling approximately 125 feet in length.
- The gate will include a fish passage structure (fish ladder), a boat lock, boat docks on either side of the boat lock, and dolphins and pilings to assist the boat lock operations.
- The boat lock will be approximately 20 feet wide and 70 feet long with operable gates at either end.
- The fish passage structure will be approximately 10 feet wide and 40 feet long with a maximum 1-foot head differential between each set of baffles. The structure will be located at the end of a channel created by steel sheet piles adjacent to the boat lock that is approximately 120 feet in length.

These structures create habitat which is conducive to providing holding and cover habitat for predators in the vicinity of the gate structure. Operations of the gates during the juvenile migratory periods (winter and spring) can allow juvenile salmonids migrating downstream in the mainstem San Joaquin River to enter the Old River channel and proceed towards the CVP and SWP facilities through the waterways of the south Delta. Likewise, operations of the boat lock when the gates are raised can provide an alternative route into the Old River channel downstream of the HOR gate location. Finally, operations of the fish ladder to provide access upriver past the gate for migrating adult steelhead and Chinook salmon can also provide a route downstream for emigrating juvenile salmonids to enter the Old River channel downstream of the gate.

In summary, the structure and operations of the gate will create several habitat elements that will increase the potential for predation of emigrating juvenile salmonids, but overall will prevent fish from entering the Old River migratory corridor and facing potentially higher predation and mortality associated with these waterways and the operations of the SWP and CVP export facilities.

Quantification of the number of individual fish exposed to the increased predation associated with the presence of the HOR gate structure is not possible. It is impossible to track individual fish through the junction of the Head of Old River and the San Joaquin River and the areas in front of the gates, fish ladders, and boat lock where predation may occur with available monitoring data and methods. It is reasonably certain, however, that those individuals that pass downstream through the reaches of the Old River occupied by the permanent gate, the fish ladder, and boat lock structures are exposed to the altered instream habitat created by the permanent structures that favors predators and successful predation events and will incur some level of adverse response to the exposure resulting in take. Since the physical presence of the gate structures and their shape, the boat lock and associated docks, fish passage structure, and location of the gate structure in the Old River channel create the habitat conditions for enhanced predation vulnerability to listed salmonids and green sturgeon juveniles, NMFS uses the physical dimensions of the structure and its footprint as surrogates for determining take.

Incidental take related to predation will be based on the footprint of the HOR gate structure as the structure represents the relative size of the adverse habitat created by the project, and by reference the scope of potential predation increases on emigrating listed fish. The values of lineal lengths for the different elements of the HOR gate structure shown in Table 2-286 will serve as the incidental take surrogates (values derived from sheet 95 in BA Appendix 3C of the BA).

Table 2-286. Surrogates for incidental take levels based on the dimensions and numbers of each component of the HOR Gate structure.

Structure	Length (ft)	Width (ft)	Number of Structures	Notes
Boat lock	70	20	1	2 gates in boat lock
Fish Ladder	40	10	1	4 baffles, 4 ft drop
Cross Channel wall[1]	210	NA	1	Length of original cofferdam wall to northern bank
Gate foundation	165	50	1	5 gates, original size of cofferdam foundation for gates
Boat docks	55	8	2	Located on either end of boat lock
Pilings	NA	NA	8	6 for boat docks, 2 for anchoring safety buoys across channel
Entrance Channel to fish ladder	135	10	1	Channel to eastern end of fish ladder
Southern Bank structure[2]	175	80	1	Footprint of boat lock, fish ladder, and abutments to the levee shoreline.
Total square footage of HOR gate footprint: 22,250 ft^2				

If any of these surrogates (assumed length of structures, or number of element components) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.2.2 Maintenance Dredging – Physical Impacts

During the lifetime of the PA, maintenance dredging will occur to remove accumulated materials from the surroundings of the permanent structures. This will include the NDD, the SCCF basin, and the HOR gate. Dredging may cause entrainment of fish into hydraulic dredges, or crushing from mechanical excavation using dragline clamshell dredges mounted on barges or tracked equipment (see Section 2.5.1.1.7.2). In addition to this effect, disturbed and removed sediment during dredging will remove, kill, or displace benthic invertebrates that may be part of the forage base for listed salmonids and green sturgeon. Restoration of the benthic community will take several months to potentially years to reestablish itself in the disturbed areas. The extent of the exposure to physical harm due to entrainment, crushing, or reduced forage base is represented by the foot print of the dredging action and the frequency of maintenance dredging.

2.9.1.2.2.1 North Delta Intake Locations

It is assumed that maintenance dredging of the Sacramento River channel in front of each intake will occur every 3-5 years. Additionally, a larger maintenance dredging effort may be necessary on a less frequent schedule after high flows events which move large amounts of bedload in the river. NMFS assumes that high flows sufficient to move large amounts of bedload will occur approximately every 10-15 years based on recent historic frequency of high flow events (>100,000 cfs). Activity will include suction dredging and mechanical excavation around intake structures using track-mounted equipment and a clamshell dragline. Mechanical excavation will occur behind a floating turbidity control curtain. Activities will include actions described in AMM 6 of BA Appendix 3F.

Maintenance dredging will only occur during the in-water work window of June 15 through October 31 at the NDD intake locations. Such timing of dredging activities will substantially reduce the exposure of juvenile listed salmonids to the potential physical effects of dredging (see Section 2.5.1.1). In addition, mechanical dredging activities will use a floating turbidity curtain, which will also effectively exclude fish from close proximity to the dragline clamshell dredge during all dredging activities.

Maintenance dredging will occur along a minimum of 1,350 feet of fish screen at intakes 2 and 5, and 1,110 feet at intake 3. The maximum length of dredging will be 1,969 feet for intakes 2 and 5 and 1,497 feet at intake 3, which is the longest of the three structures. It is assumed that an area equivalent to approximately 10 percent of the river channel width will be dredged in front of the screens to remove materials that may be drawn into the intake bays. This is equivalent to 70 feet for intake 2, 50 feet for intake 3, and 60 feet for intake 5.

Quantification of the number of individual fish exposed to the dredging actions associated with the maintenance of the bathymetry in front of the NDD fish screens is not possible. It is impossible to track individual fish through the three locations of the NDD intakes and the areas of the river channel in front of the fish screens where entrainment or physical injury from the dredging actions may occur with available monitoring data and methods. It is reasonably certain, however, that those individuals that pass downstream through the reaches of the Sacramento River adjacent to the permanent fish screens during maintenance dredging operations will be exposed to the potential for entrainment into the hydraulic dredgers or injury from mechanical dredging and will incur some level of adverse response to the exposure resulting in take. Since the physical impacts of dredging on listed salmonids and sDPS green sturgeon is related to the area of river channel that must be dredged and the season during which it occurs, NMFS uses the physical dimensions of the dredging footprint and the in-water work window as surrogates for incidental take. The maintenance dredging activities shall not exceed the dimensions provided in Table 2-287.

Table 2-287. Dimensions of the Incidental Take Surrogates for Maintenance Dredging, including the In-water Work Window.

Intake	Maximum Channel Length (feet)	Dredge area width (feet)	Maximum Dredge Area (square feet)	Season of in-water work
Intake 2	1,969	70	137,830	6/15 – 10/31
Intake 3	1,497	50	74,850	6/15 – 10/31
Intake 5	1,969	60	118,140	6/15 – 10/31

Dredging will occur no more frequently than every three years.

If any of these surrogates (assumed length and width of dredging areas and seasons in which dredging occurs) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.2.2.2 South Clifton Court Forebay

It is assumed that the maintenance dredging in the CCF will occur every 10 to 15 years based on the rate of sediment deposition, and that this dredging will only occur in the SCCF. The NCCF basin is not assumed to need any maintenance dredging due to the low suspended sediment levels entering the basin from the NDD tunneled conveyance. Dredging would occur in the same manner as described in section 2.5.1.1.2.4.2, and will include any AMMs described in the BA and the use of silt curtains to isolate approximately 200 acres (~9 million square feet) per dredging cycle to avoid blocking flows through the SCCF and reducing suspended sediment in the exported water at the SWP. Dredging will occur during the in-water work window of July 1 to October 31, when the risk of exposure to juvenile salmonids is considered to be very low. However, adult steelhead and adult and juvenile sDPS green sturgeon have the potential to be present during this time period.

Quantification of the number of fish present in the SCCF during maintenance dredging operations is impossible to determine given the large acreage of this waterbody, abundant submerged aquatic vegetation, and constant exchange of water with the Delta through the radial gates which may entrain additional fish into the forebay with each gate opening and the ongoing fish salvage operations which removes fish from the forebay with export pumping. Furthermore, the initial number of individual listed fish potentially present in the area to be dredged is difficult to determine due to the variations in fish presence related to migrational timing in the Delta and physical distribution within the entire CCF in relation to the area being dredged. Since the physical impacts of dredging on listed salmonids and sDPS green sturgeon is related to the area of forebay bed that must be dredged and the season during which it occurs, NMFS uses the physical dimensions of the dredging footprint and the in-water work window as surrogates for determining the extent of incidental take. Therefore, the dredged area, frequency, and timing shall not exceed the levels of the incidental take surrogates defined in Table 2-288.

Table 2-288. Surrogates for incidental take levels based on the area, frequency, use of silt curtains, and in-water work windows for maintenance dredging in the SCCF.

Location	Dredged area/ cycle	Frequency of dredge cycle	Silt Curtain Employed	In-water work Season
SCCF	200 acres	10 -15 years	Yes	7/1 to 10/31

If any of these surrogates (assumed area of dredging, use of silt curtains, and seasons in which dredging occurs) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.2.2.3 HOR Gate

It is assumed that maintenance dredging for the HOR gate will occur every 3-5 years depending on the deposition rate of material at this location. A barge-mounted hydraulic cutterhead or mechanical sealed clamshell dredge will be used to remove accumulated sediment from around the gate structure and the approaches to the gate structure in the Old River channel. The area of dredging is expected to follow the original dredging footprint of 500 linear feet of Old River (350 feet downstream of the gate's location and 150 feet upstream of the gate's location). It is assumed in the BA that the volume of this material will be no more than 25% of the original dredged amount (original dredged volume is expected to be approximately 1,500 cubic yards). The volume of material removed for maintenance dredging is therefore expected to be 375 cubic yards of material. Periodic removal of accumulated sediment after major flow events (> 30,000 cfs) is assumed to occur every 5-10 years based on recent historic Vernalis flows. Maintenance dredging will only occur during the August 1 through October 31 in-water work window designated for this location.

NMFS expects that the presence of juvenile salmonids will be very unlikely during this period and that exposure is more likely for adult steelhead, adult sDPS green sturgeon, and juvenile sDPS green sturgeon. These species and life stages are expected to be present in the waters of the south Delta and lower San Joaquin River during this work window.

Quantification of the number of individual fish present at the HOR gate during maintenance dredging operations is impossible to determine due to the variations in fish presence related to migrational timing and distribution within the Old River channel at the HOR gate location. Given the relatively narrow confines of the Old River channel, it is reasonably certain however, that those individuals that pass downstream through the Old River channel past the permanent HOR gate structures during maintenance dredging operations will be exposed to the potential for entrainment into the hydraulic dredgers or injury from mechanical dredging and will incur some level of adverse response to the exposure resulting in take. Since the physical impacts of dredging on listed salmonids and sDPS green sturgeon is related to the area of Old River channel bed that must be dredged and the season in which it will occur, NMFS will use the physical dimensions of the dredging footprint, the expected volume of dredged material, and the in-water work window as surrogates for determining take. Therefore, the dredging length, volume, frequency, and timing shall not exceed the numerical levels of the incidental take surrogates defined in Table 2-289.

Table 2-289. Surrogates for incidental take levels based on the channel length, dredged material volume, dredging frequency, and in-water work windows for maintenance dredging the HOR Gate location

Location	River Channel Length		Dredged Volume	Frequency of Maintenance Dredging	In-water work season
	Upstream	Downstream			
HOR Gate	150 feet	350 feet	375 yds^3	No more than every 3 years	8/1 to 10/31

If any of these surrogates (assumed length of dredging areas, dredged volumes, and seasons in which dredging occurs) are exceeded, the PA will be considered to have exceeded anticipated take levels.

2.9.1.2.3 Maintenance Dredging – Sediment and Turbidity

In conjunction with maintenance dredging performed during the life of the project at the NDD intake sites, SCCF, and the HOR gate, NMFS anticipates that sedimentary materials from the channel bed will be resuspended into the overlying water column. As previously described in Section 2.5.1.1.2 and Sections 2.9.1.1.2.1, maintenance dredging will occur during the in-water work windows and in the same locations as the initial construction dredging activities. The exposure to listed fish will be the same as that described in the construction dredging section above. Therefore, the same criteria for suspended sediment concentration and turbidity for incidental take apply to the routine maintenance actions for the PA.

2.9.1.2.4 Maintenance Dredging – Contaminants

As described in Section 2.9.1.1.2.3 regarding suspended sediments and contaminants for construction related activities, routine maintenance dredging is also likely to increase the probability of exposing and resuspending contaminants associated with the sediments being removed. Maintenance dredging will occur during in-water work windows designed to avoid most listed fish species presence in the area to be dredged. NMFS expects that the exposure vulnerability of listed fish to contaminants released by maintenance dredging will be the same as already described for the construction dredging action. The incidental take for exposure to contaminants during maintenance dredging actions will use the same criteria for contaminant concentrations described in section 2.9.1.1.2.3 of this incidental take statement for construction activities.

2.9.1.2.5 Operations of NDD Fish Screens

2.9.1.2.5.1 Entrainment and Impingement

The PA includes construction of three intakes for the NDD located on the eastern bank of the Sacramento River between Clarksburg and Courtland in Sacramento County, California. The intakes are designed as on-bank screens that expect to minimize the risk of fish entrainment into the intakes and impingement onto the screens. Screen lengths are 1,350 ft each at two of the three intakes (Intakes 2 and 5) and 1,110 ft at the third intake (Intake 3), for a combined total screen length of 3,810 ft. When fish migrate past the fish screens, there is potential for impact of entrainment of small fish through the fish screens, and impingement of larger fish on the screens even if the screens are appropriately designed and constructed.

Section 2.5.1.2.5 evaluates the effects of the proposed operations of the fish screens on entrainment and impingement. In estimating the magnitude of screen entrainment and impingement, catch data for juvenile salmonids were obtained from the USFWS DJFMP data for the Chipps Island Trawl, the Sacramento Trawl at Sherwood Harbor, and regional beach seines in the vicinity of the NDD as well as sources of information from commercially and privately available literature regarding these elements of fish screen performance for vertical profile bar screens meeting NMFS screening criteria (NMFS 1999, NMFS 2011).

NMFS expects that these permanent intake structures will impact all listed fish species and life stages that pass them at times when the intakes are diverting water. Thus, juvenile winter-run, spring-run, fall-run, and late fall-run Chinook salmon and juvenile steelhead will be exposed to the operations of the intakes each year of operation for the lifetime of the screens. Likewise, juvenile sDPS green sturgeon will be exposed to the operations of the intakes during their migrations and/or rearing in the vicinity of the intakes. During these periods of exposures, individual fish will be vulnerable to entrainment through the vertical bar screen if they are less than 32 mm in length, or to impingement or contact with the screens at any length. Impingement can result in injuries or death (harm) due to abrasions, exhaustion, descaling, or other forms of injury. Death may occur immediately or at some time in the future due to injuries that do not heal. Wounds that are minor should heal, allowing the fish to recover from its injuries.

Instances of actual impingement or entrainment are difficult to observe in real time. Given the long length of the three screen structures, the low clarity of the Sacramento River water that limits visibility to a few feet during periods of salmonid and green sturgeon migration, the relatively small size of vulnerable fish, and the location of the actual screen face near the bottom of the water column, it is highly unlikely that the act of entrainment or impingement will be observed. Furthermore, the variability in population abundance, in migration timing (migratory pulses), distribution of fish within the cross section of the river channel, and differences between nocturnal and diurnal movements reduces the probability of observing these effects at any given specific time, making accurate quantification nearly impossible to achieve. Therefore, physical surrogates are used to express the amount or extent of take. In developing the physical structure of the fish screens, the criteria for screen materials, the width of gaps between vertical profile bars, approach velocity, and sweeping velocity are used to minimize the effects of entrainment and impingement. Because the screened intakes are located in waters where salmonids less than 60 mm in length (i.e., fry) are present, certain criteria with greater protection are appropriate. The specific criteria that must be met for the physical characteristics of the screens are presented in Table 2-290.

Table 2-290. Surrogates for Surrogates for incidental take levels based on the screen material type, gap width, approach velocity, sweeping velocity, and screen porosity for the NDD intake fish screens.

Design Element	Criterion Value	Notes
Gap width of vertical profile Bars	1.75 mm	Material is corrosion resistant and uniformly smooth
Approach Velocity	0.33 feet per second	Fry present, rivers, and streams
Sweeping Velocity	Twice approach velocity (CDFW criteria)	Fry present, rivers, and streams
Screen Porosity	Screen material shall provide a minimum of 27% open area	Screen area based on diverted flow and approach velocity
The screen design must provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity. This may be accomplished by providing adjustable porosity control on the downstream side of the screens, unless it can be shown unequivocally (such as with a physical hydraulic model study) that localized areas of high velocity can be avoided at all flows.		

Prior to full operations, the fish screen must be shown, at a minimum, to have met these criteria and thereafter maintained to meet these criteria through all operational conditions for the life of the project.

In addition to these physical design criteria, NMFS uses values in its assumptions for the effects analysis for the operations of the fish screens, which include the rate of entrainment through the fish screens for fish smaller than 32 mm total length and the rate of injury and mortality associated with impingement and contact with the fish screen during operations. These biological factors will be impractical to measure on a real-time basis and it will be impractical to detect individual fish that experience these effects. It is difficult to observe fish that are of the size that are vulnerable to entrainment (< 32 mm in total length) given the clarity of the Sacramento River water and the depth of the screens in the water column. Furthermore, the likelihood of making an observation of a fish being entrained or impinged along the entire length of the three fish screens in real time at the moment a vulnerable fish encounters the screen is very remote. Recovery of a fish that has experienced impingement to examine it for injuries is even more remote, unless specific studies are designed to increase the probability of observations and recovery of these fish. In the PA, several monitoring studies are described that are expected to collect data to ascertain various biological endpoints that would include entrainment and impingement effects. These studies will take place in laboratory and field settings and will help inform the design of the screens and the operational characteristics of the screens during post-construction periods. Results of these studies will be useful in determining whether the fish screens are functioning in the way anticipated and analyzed in the effects analysis of this Opinion.

NMFS has used the following biological criteria for the daily operational effects of the NDD; these shall serve as surrogates for incidental take levels related to entrainment and impingement at NDD screens:

- Fish less than or equal to 32 mm in total length are vulnerable to entrainment through the 1.75 mm vertical bar screen, no fish larger than this will be able to pass through the vertical bars.
- Entrainment rate is 2% of the population of fish less than or equal to 32 mm in total length
- Injury rate for fish impinged on vertical bar screen is less than or equal to 2.5% as defined by greater than 20% descaling of fish exposed to the operations of the screens
- Mortality rate of fish impinged on vertical bar screen is less than or equal to 3.7% of fish exposed to the operations of the screens
- 50% of fish within the river adjacent to the fish screen (per each screen) will be close enough in proximity to the face of the screen to be exposed to the effects of the screen

The findings of the pre- and post-construction monitoring studies will be used to inform whether the assumptions made in the effects analysis are valid. Should findings based on these studies indicate that the effects of the screen operations are worse than assumed, then the take associated with the operations of the screens will be considered to have been exceeded.

2.9.1.2.6 Operations of the South Delta Fish Salvage Facilities

Exports through the South Delta result in multiple hydrodynamic effects that likely alter fish behavior and increase indirect mortality. For example, some fish may tend to follow the "downstream flow" towards the Federal and State pumps and be subjected to multiple stressors in the Delta. Section 2.5.1.2.7.3 South Delta Operations discuss these stressors and potential mechanisms of indirect mortality. Incidental take associated with hydrodynamic changes and increased predation, however, are difficult to impossible to quantify. Therefore, NMFS utilizes salvage and loss at the Federal and State fish facilities as one form of incidental take, but also as a surrogate for the multiple forms of incidental take associated with hydrodynamic effects in the Delta associated with the Project.

2.9.1.2.6.1 Salvage and Loss

Section 2.5.1.2.7.9 assesses the changes in projected salvage and loss of juvenile winter-run, spring-run, fall-run, and late fall-run Chinook salmon, juvenile steelhead, and juvenile sDPS green sturgeon at the SWP and CVP fish salvage facilities for the PA and NAA operational scenarios. Based on the results of the different modeling exercises presented in the BA, the PA will reduce the number of fish salvaged, and by inference due to the methods of calculating loss, the number of fish lost to the south Delta export facilities compared to the NAA scenario. This is caused by the anticipated reduction in exports at the south Delta facilities during periods of NDD operations.

The modeling in the BA assumes that all parameters other than exports remain static; only the volume of water exported from the south Delta changes with the scenarios. The main method used for estimating the changes in salvage between the PA and the NAA scenarios is the loss density method, which is applied to the listed salmonids and green sturgeon as well as non-listed fall-run and late fall-run Chinook salmon. The salvage estimate is calculated monthly for each species at each facility, and the loss-density is calculated as the number of fish lost divided by the volume of exported water (in thousand acre-feet), assuming a linear relationship between fish loss and water export volume. The loss-density was obtained using historical water export and salvage-derived loss data for water years 1995–2009. These loss-density data provided the basic estimates of fish density (i.e., number of fish salvaged per volume of water exported) that were subsequently multiplied by simulated water export data for the CALSIM modeling period of 82 years (1922–2003) to assess differences between the PA and NAA. The second method described in the BA applies only to hatchery-reared winter-run Chinook salmon juveniles. Zeug and Cavallo (2014) developed regression models that link historical water export and Sacramento River flow to the historical proportional loss of hatchery-reared juvenile winter-run Chinook salmon. The established models are then used to estimate winter-run Chinook salmon juvenile losses for the PA and NAA using simulated 82-year data for water exports and Sacramento River flows.

NMFS expects that the following listed species and life stages have the potential to be exposed to the salvage and loss related to the operations of the SWP and CVP export facilities and their associated fish protection facilities:

- Winter-run Chinook salmon: all juveniles that enter the CCF through the radial gates, or through the trash racks at the Tracy Fish Collection Facility, during their migratory movements
- Spring-run Chinook salmon: all juveniles that enter the CCF through the radial gates, or through the trash racks at the Tracy Fish Collection Facility, during their migratory movements
- Steelhead: all juveniles and adults that enter the CCF through the radial gates, or through the trash racks at the Tracy Fish Collection Facility, during their migratory movements
- sDPS green sturgeon: all juveniles that enter the CCF through the radial gates, or through the trash racks at the Tracy Fish Collection Facility, during their migratory movements

Quantification of the exact number of fish exposed to the physical effects of the fish salvage process at both the SWP and CVP facilities is not possible with available monitoring data. In estimating the number of salvaged fish and fish that are lost to the system due to fish salvage operations, a mixture of physical observations and extrapolations based on theoretical constants are used to provide salvage and loss estimates. The number of juvenile fish salvaged per day represents the fish successfully screened during the export actions and directed into the holding tanks. The majority of these fish are expected to be returned alive to the western Delta following collection, holding, trucking, and release. This number is estimated by expanding the number of fish observed during each fish count by the fraction of the period pumping was occurring between each fish count interval with the assumption that the remaining period of time within each sampling period will have the same density of fish in the water that is being diverted and redirected into the holding tanks. For example, if a fish count is made for 30 minutes out of a 2-hour period of pumping, the number of fish collected in the 30-minute count would be expanded by four. This allows for the simple expansion of the number of fish salvaged by the fraction of time an actual count is made during the sampling period. This assumption doesn’t hold true if fish are very rare in the sampling count and are missed in the fraction counted. Likewise, if export rates are changing or fish density changes during the sampling period, simple expansion may not produce a valid expansion of fish for cumulative salvage over the entire sampling period. The number of fish lost to the system is calculated by using the physical constants associated with predation loss, louver efficiency, flow velocity, and the loss associated with collection, handling, trucking, and release of the salvaged fish. Since these are static values based on long term averages from studies, day to day variations are not addressed, and the actual numbers of fish lost to the salvage process are likely to be different than the calculated one. These calculations, however, are the current methodology used at both the CVP and SWP to calculate salvage and loss and represent the best available source of data for these parameters even with the acknowledged uncertainties present in the data collection.

Currently, incidental take for the operations of the SWP and CVP are addressed in the NMFS 2009 biological opinion for the Long-Term Operations of the CVP and SWP (see Table 13-1 on pages 730-769 in NMFS 2009). The specific amount or extent of incidental take or the surrogate used to express the amount or extent of anticipated incidental take for listed fish in the NMFS 2009 biological opinion specifically afforded to the Federal and State fish facilities are provided in Table 2-291.

Table 2-291. Extent of incidental take for the loss of listed salmonids and sDPS green sturgeon at the South Delta export facilities as described in the 2009 NMFS Biological Opinion for the Long-Term Operations of the CVP and SWP.

Species/Run	Amount or extent or surrogate of incidental take	Notes
Winter-run Chinook salmon (wild)	2% annual Juvenile Production Estimate reaching the Delta	Loss of wild WRCS (unclipped)
Winter-run Hatchery produced	1% of annual hatchery production reaching the Delta	Adipose fin clipped and CWT
Spring-run Chinook salmon (yearlings)	1% Surrogate late fall-run CS releases	Adipose fin clipped and CWT, represent older yearling SRCS, not YOY fish.
CCV steelhead	3,000 juvenile and adult	Loss of wild fish (adipose fin intact)
sDPS green sturgeon	74 salvage, 106 loss/ year	

These amounts or extents of incidental take or surrogates are modified by the modeled changes to the number of fish salvaged and lost based on the fish density model used in the BA. The fish density model is used since it was applied for all species of salmonids and sDPS green sturgeon present in salvage, and not just the winter-run Chinook salmon hatchery production (Zeug and Cavallo model [2014]). The new take levels use water year as categories to modify the amounts or extents of incidental take or surrogates from the NMFS 2009 biological opinion, based on the projected reductions in salvage due to changed export levels for the PA, as shown in the following tables.

2.9.1.2.6.1.1 Winter-run Chinook Salmon

NMFS currently produces a Juvenile Production Estimate (JPE) of wild and hatchery-produced juvenile winter-run Chinook salmon entering the Delta. These estimates serve as the basis for determining annual take at the CVP and SWP fish protection facilities in the south Delta. The current extent of annual take for the fish protection facilities is the loss of 2% of the JPE for wild fish (unclipped, based on the Delta length-at-date model, or 1% based on genetic identification of winter-run) and loss of 1% for clipped and coded wire tagged (CWT) hatchery-produced fish. Since hatchery fish can be positively identified through the external adipose fin clip, and their origin identified by reading the internal CWT, the proportion of the hatchery winter-run Chinook salmon population taken by the CVP and SWP can be determined with more accuracy. Likewise, use of genetics is a considerably more accurate method to identify winter-run. Genetic identification of fish salvaged at the Federal and State fish facilities in the past few years have indicated that less than half of the fish identified as winter-run based on length-at-date using the Delta model were in fact genetic winter-run.

Term and condition 5.a in NMFS' 2009 biological opinion requires Reclamation and DWR to submit to NMFS an annual report documenting the monitoring and incidental take of anadromous fish species associated with the CVP and SWP operations. Table 2-292 provides data on the estimated percent loss of natural and hatchery juvenile winter-run Chinook salmon from implementation of NMFS' 2009 biological opinion for brood years 2009 through 2015.

Table 2-292. Juvenile Production Estimates, Combined Loss at the Federal and State Fish Facilities, and Percent Loss Based on Winter-run Brood years 2009-2015 Based on the Length-at-date Model for the Delta.

Brood Year (BY)	Natural WR JPE	2% ITL	Length-at-date loss	% loss	Hatchery WR JPE	1% ITL	Loss	% loss
BY 2009	1,180,000	23,593	1,660	0.001	108,725	1,087	140	0.13
BY 2010	332,012	6,640	4,360	1.310	66,734	667	0	0
BY 2011	162,051	3,241	2,079	1.283	96,525	965	17	0.018
BY 2012	532,809	10,656	731	0.137	96,525	965	9	0.933
BY 2013	1,196,387	23,928	336	0.028	30,880	309	0	0
BY 2014	124,521	2,490	132	0.106	185,600	1,856	8.4	0.005
BY 2015	101,716	2,034	56	0.055	155,400	1,554	11.2	0.007

Table 2-293. Fish Density Model-based Changes to the SWP and CVP Cumulative Loss of Sacramento River Winter-run Chinook for the NAA and PA Scenarios

Water Year Type	Cumulative Loss CVP and SWP Winter-run Chinook Salmon				Adjusted annual amount of incidental take based on annual JPE and the highest % losses of wild (1.31%) and hatchery (0.93%) juvenile winter-run in Table 2-292.	
	NAA	PA	Difference (NAA – PA)	% reduction[1]	Wild[2]	Hatchery3
Wet	12,033	3,779	8,254	69%	0.4%	0.3%
AN	6,608	3,207	3,401	51%	0.6%	0.5%
BN	6,445	3,963	2,482	39%	0.8%	0.6%
Dry	4,058	3,256	802	20%	1.0%	0.7%
Critical	1,222	1,016	206	17%	1.1%	0.8%

Notes:

1. Percentage reduction is the calculated reduction in loss of fish using the fish density method of estimating salvage and loss based on the changes of exports predicted for the PA.
2. This colored column represents the extent of allowable annual incidental take for wild juvenile winter-run Chinook salmon based on a percentage of the annual JPE value. The percentage is derived from the reduction in loss calculated from the fish density modeling for each water year type, multiplied by the highest percentage of fish loss over the period of WY 2009-2015.
3. This colored column represents the extent of allowable incidental take for hatchery produced juvenile winter-run Chinook salmon using the same method as described in footnote 2.

The annual extent of incidental take for juvenile winter-run Chinook salmon will be adjusted, based on the JPE.

2.9.1.2.6.1.2 Spring-run Chinook Salmon

The NMFS 2009 biological opinion requires the release of groups of late fall-run Chinook salmon from Coleman National Fish Hatchery as surrogates to natural yearling spring-run Chinook salmon emigrating from the tributaries to the Sacramento River. Term and condition 5.a in NMFS' 2009 biological opinion requires Reclamation and DWR to submit to NMFS an annual report documenting the monitoring and incidental take of anadromous fish species associated with the CVP and SWP operations. Table 2-294 provides data on the estimated percent loss of each surrogate group release from implementation of NMFS' 2009 biological opinion for brood years 2009 through 2015.

Table 2-294. Surrogate Group Size, Combined Loss at the Federal and State Fish Facilities, and Percent Loss Based on Brood Years 2010-2015.

Brood Year (BY)	Surrogate group size	1% ITL	Combined Loss	% loss	Cumulative Loss (%)
BY 2009	75,676	757	57	0.075	0.407
	174,386	1,744	960	0.44	
BY 2010	76,171	761	125	0.160	0.083
	157,719	1,577	68	0.043	
BY 2011	62,400	624	3	0.005	0.038
	80,800	808	52	0.064	

Brood Year (BY)	Surrogate group size	1% ITL	Combined Loss	% loss	Cumulative Loss (%)
	72,974	730	76	0.104	
BY 2012	70,287	703	140	0.199	0.108
	80,191	802	25	0.031	
	68,516	685	0	0.000	
BY 2013	81,962	820	0	0.000	0
	72,857	729	0	0.000	
	77,000	770	35	0.045	
BY 2014	78,000	780	45.5	0.058	0.034
	83,100	831	0	0.000	
	77,000	770	128	0.166	
BY 2015	68,000	680	189	0.278	0.28
	67,700	677	279	0.412	

The extent of incidental take for surrogate yearling spring-run Chinook salmon shall be adjusted according to the values in the following table. Should 1) real-time genetic testing be incorporated into the salvage process to identify genetic spring-run Chinook salmon from other runs, and 2) population level estimates of annual juvenile spring-run Chinook salmon production become available through monitoring programs, then the adjusted annual extent of incidental take of the annual population will apply to the yearling and young-of-the-year juvenile spring-run Chinook salmon salvaged at the facilities. Table 2-295 shows the annual extent of incidental take for spring-run Chinook salmon.

In determining the annual extent of incidental take of spring-run Chinook salmon, NMFS will develop a technical memorandum annually to ensure that avoidance of take of Central Valley spring-run Chinook salmon originating from reintroduction to the San Joaquin River does not cause more than a de minimus impact on water supply, additional storage releases, and bypass flows associated with the operations of the CVP and SWP as described in 50 CFR 223.301(b)(5)(ii)(B).

Table 2-295. Fish Density Model-based Changes to the SWP and CVP Cumulative Loss of Central Valley Spring-run Chinook for the NAA and PA Scenarios.

Water Year Type	Cumulative Loss CVP and SWP Spring-run Chinook Salmon				Adjusted annual amount of incidental take of hatchery LFRCS surrogates for yearling SRCS based on the highest % cumulative loss (0.407%) in Table 2-294.
	NAA	PA	Difference (NAA – PA)	% reduction	
Wet	40,793	6,868	33,925	83%[1]	0.07%[2]
AN	22,099	3,908	18,191	82%	0.07%
BN	5,745	3,703	2,042	36%	0.26%
Dry	13,207	9,033	4,174	32%	0.28%
Critical	7,850	6,581	1,269	16%	0.34%

Notes:

1. Percentage reduction is the calculated reduction in loss of fish using the fish density method of estimating salvage and loss based on the changes of exports predicted for the PA.

2. This colored column represents the extent of allowable annual incidental take for hatchery produced LFRCS surrogates for yearling SRCS. The percentage is derived from the reduction in loss calculated from the fish density modeling for each water year type, multiplied by the highest percentage of fish loss over the period of WY 2009-2015.

2.9.1.2.6.1.3 Steelhead

Currently, the cumulative amount of annual incidental take allowed for unclipped steelhead (wild) is 3,000 fish under the 2009 NMFS biological opinion for the long-term operations of the CVP and SWP. There is no incidental take level in NMFS' 2009 biological opinion for hatchery steelhead because the steelhead produced in only 2 of the hatcheries in the Central Valley are listed and therefore protected under the ESA, take of adipose fin clipped CCV steelhead is not prohibited, and incidental take levels for natural steelhead provide a sufficient standard for determining when the level of anticipated take has been exceeded. Term and condition 5.a in NMFS' 2009 biological opinion requires Reclamation and DWR to submit to NMFS an annual report documenting the monitoring and incidental take of anadromous fish species associated with the CVP and SWP operations. Table 2-296 provides data on the estimated percent loss of adult and juvenile wild steelhead from implementation of NMFS' 2009 biological opinion for water years 2009 through 2015.

Table 2-296. Combined Salvage of Natural and Hatchery Steelhead at the Federal and State Fish Facilities in Water Years 2009-2015.

Water Year (WY)	Natural steelhead salvage	Hatchery steelhead salvage
WY 2009	1,029	3,585
WY 2010	738	882
WY 2011	332	605
WY 2012	798	709
WY 2013	185	230
WY 2014	43	523
WY 2015	36	119

The amount of incidental take for adult and juvenile steelhead shall be adjusted according to the values in Table 2-297. Should the development of a region-wide steelhead population monitoring program allow for the development of an emigrating juvenile steelhead population estimate, then the amount or extent of incidental take will be adjusted to an annual maximum of 1 percent of the emigrating population.

Table 2-297. Fish Density Model-based Changes to the SWP and CVP Cumulative Loss of California Central Valley Steelhead for the NAA and PA Scenarios.

Water Year Type	Cumulative Salvage CVP and SWP CCV steelhead				Adjusted annual amount of incidental take of adult and juvenile natural steelhead based on the highest amount of salvage (1,029) in Table 2-296.
	NAA	PA	Difference (NAA – PA)	% reduction	
Wet	6,509	1,883	4,626	0.71[1]	299[2]
AN	13,055	7,078	5,977	0.46	556

BN	10,750	7,004	3,746	0.35	669
Dry	9,772	7,690	2,082	0.21	813
Critical	5,657	5,368	289	0.05	978

Notes:

1. Percentage reduction is the calculated reduction in loss of fish using the fish density method of estimating salvage and loss based on the changes of exports predicted for the PA.
2. This colored column represents the extent of allowable annual incidental take of adult and juvenile naturally produced (wild) steelhead. The percentage is derived from the reduction in loss calculated from the fish density modeling for each water year type, multiplied by the highest number of fish salvaged over the period of WY 2009-2015.

2.9.1.2.6.1.4 Green Sturgeon

The salvage of green sturgeon at either the SWP or CVP has become rare in recent years, as shown in Table 2-298.

Table 2-298. Combined Green Sturgeon Salvage and the Federal and State Fish Facilities in Water Years 2009-2015.

Water Year (WY)	Combined green sturgeon salvage
WY 2009	0
WY 2010	14
WY 2011	0
WY 2012	0
WY 2013	0
WY 2014	0
WY 2015	1

The fish density model did not have enough recent data to demonstrate differences by water year type. The model did provide information that annual salvage of juvenile green sturgeon would be reduced by approximately 55% for the PA scenario compared to the NAA scenario. Therefore, annual salvage and loss levels provided in the NMFS 2009 biological opinion for the long-term operations of the CVP and SWP will be adjusted by 55%, resulting in incidental take levels as salvage of 41 and loss of 58 juvenile green sturgeon per year.

Decreasing the annual amounts or extents of incidental take associated with the operations of the south Delta components of the CVP and SWP avoids increasing the overall incidental take of listed fish in the Delta through the concurrent operations of the NDD. The proposed action should not increase the overall cumulative take of listed fish beyond the current amount or extent associated with the operations of the south Delta components of the CVP and SWP operations.

2.9.1.2.7 Operations of NDD – Delta Survival

The operations of the NDD are modeled to show how the operations of these facilities alter flows entering the Delta through the diversion of water at the intakes and the resulting cascade of changes in Delta hydrodynamics related to this reduction in flows (Sections 2.5.1.2.6 through 2.5.1.2.7.1). The analyses include alterations in the percentage of flow routed at key channel junctions, magnitude of channel velocities, magnitude of negative velocities, and the proportion of each day that velocity is negative in the key study channels. These modeled hydrodynamic changes are then used to inform several models regarding Chinook salmon survival through the Delta (2003 Newman Model, Delta Passage Model, SalSim, and the Perry Survival Model (2017)). NMFS considers the Perry Survival Model to include the most complete and recent scientific and commercial data available to assess survival changes in the north and central Delta between the NAA and PA. This model includes updated flow-survival relationships (as measured at Freeport) using acoustically-tagged hatchery smolts from 2006 through 2011. This acoustic tagging study data allows for individual tracking of smolts to understand the proportion that use specific migratory routes as well as specific route-survival and overall through-Delta survival.

The output of the Perry Survival Model provides information on the reduction in survival of juvenile Chinook salmon through specific river reaches in the northern and central Delta on a daily basis and summarizes overall through-Delta survival by month and water year type between the PA and NAA operational scenarios.

Quantification of the number of Chinook salmon exposed to the hydrodynamic effects associated with the operations of the NDD intakes and their individual survival is not possible with available monitoring data. However, modeling of the physical hydrodynamic changes related to the volume of water diverted at the NDD is possible, and the relationship between these hydrodynamic variables and Chinook salmon survival can be modeled based on prior studies to provide an estimate of fish survival for the PA and NAA scenarios. These modeled estimated survival values are used as surrogates for actual survival rates for listed Chinook salmon exposed to the effects of the NDD operations in the northern and central Delta. Survival rates for listed steelhead and green sturgeon are likely different from those estimated for Chinook salmon by the Perry Survival Model and can only be assessed in a general way. NMFS assumes that the general finding that the PA will reduce the survival rate of juvenile Chinook salmon exposed to the PA operations will apply to the survival rate of juvenile steelhead, and will follow a similar pattern to those used for Chinook salmon for months and water year types. CCV steelhead migrate downstream within the same migratory corridors within the lower Sacramento River basin and Delta as do juvenile winter-run and spring-run Chinook salmon. They will experience the same flow conditions and route junctions that co-occurring listed Chinook salmon will during their outmigration. NMFS assumes that juvenile steelhead will respond to the physical aspects of flow conditions and route junctions in a similar manner as Chinook salmon, but the magnitude of such responses may differ. Furthermore, survival may be of a similar nature as Chinook salmon, given that predation rates upon steelhead in CCF by predatory fish was of the same magnitude as that observed for Chinook salmon in the same waterbody, even though steelhead are typically larger than emigrating Chinook salmon. There is insufficient information to make an assessment for changes in survival for juvenile green sturgeon due to a lack of studies directed at green sturgeon survival during their downstream migration. However, reduced flows are not likely to benefit juvenile green sturgeon migrating through or rearing in the northern or central Delta regarding route selection. Changes in flows and water velocities will alter the entrainment potential into different channel junctions and may delay juvenile green sturgeon’s migration into the lower Delta due to rerouting out of the Sacramento River channel into alternative paths such as the DCC and Georgiana Slough. The effect of this is uncertain as juvenile green sturgeon rear in multiple areas of the Delta, including waterways in the central and southern Delta for several months to years before migrating to marine waters.

Adult life stages are not expected to experience any mortality or reduction in survival due to the operations of the NDD. It is expected that only juvenile life stages will be susceptible to alterations in their survival due to changes in the regional hydrodynamics associated with NDD operations. NMFS expects that the following listed species and life stages have the potential to be exposed to the operations of the NDD and the alterations in survival caused by the changes in hydrodynamic conditions in the waterways of the northern and central Delta:

- Winter-run Chinook salmon: all juveniles that enter the Delta during their migratory movements from the Sacramento River basin or are present within the western Delta in waters affected by the operations of the NDD
- Spring-run Chinook salmon: all juveniles that enter the Delta during their migratory movements from the Sacramento River basin and those fish from the San Joaquin River basin present within the western Delta in waters affected by the operations of the NDD
- Steelhead: all juveniles that enter the Delta during their migratory movements from the Sacramento River basin and those fish from the San Joaquin River basin present within the western Delta in waters affected by the operations of the NDD

The 50th percentile of the estimated differences between the PA and NAA scenarios, representing the estimated amount of reduction in survival between the two scenarios, will be used as a surrogate for the incidental take of listed winter-run Chinook salmon, spring-run Chinook salmon, and steelhead, as a result of the effects of operations of the NDD on Delta survival. Results of survival studies during the pre- and post-operational conditions will be used to compare the measured survival differences with the modeled estimates used in the effects analyses. If the differences in the survival rate for pre- and post-operational conditions are more negative than the 50th percentile of the modeled survival rate differences for a given condition, incidental take will be considered to have been exceeded. Tables 2-299 through 2-304 provide the differences in survival reduction for Chinook salmon exposed to the operations of the NDD for PA as compared to NAA.

Table 2-299. Average Monthly Absolute Changes (percentage) in Through-Delta Survival Between the PA and NAA Operational Scenarios (PA-NAA) for all Water Years Combined.

Statistic	Month								
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Max reduction[1]	-23.3%	-23.3%	-12.1%	-9.6%	-10.1%	-11.2%	-6.8%	-12.4%	-20.5%
75th percentile	-8.7%	-9.2%	-1.9%	-1.9%	-3.2%	-5.0%	-1.2%	-1.6%	-4.6%
median	-4.3%	-5.4%	-0.9%	-1.0%	-1.2%	-1.6%	-0.5%	-0.8%	-2.0%
25th percentile	-0.7%	-0.9%	-0.3%	-0.6%	-0.7%	-0.8%	0.0%	-0.1%	-0.3%
Min reduction[2]	7.6%	3.8%	4.1%	6.0%	2.1%	2.6%	2.7%	1.7%	4.0%

Notes:

1. Maximum reduction is the difference between the survival rates of the PA and NAA operational scenarios. It is represented by a negative number indicating that survival is greater under the NAA scenario.

2. Minimum reduction of survival rates between the PA and NAA operational scenarios can be represented by a negative number (reduction in survival) or a positive number (increased survival).

Table 2-300. Average Monthly Absolute Changes (percentage) in Through-Delta Survival Between the PA and NAA Operational Scenarios (PA-NAA) for Wet Water Years.

Statistic	Month								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Max reduction[1]	-23.3%	-21.0%	-7.8%	-7.7%	-9.4%	-10.2%	-3.4%	-12.4%	-20.5%
75th percentile	-9.6%	-10.1%	-2.6%	-2.6%	-2.6%	-5.4%	-1.5%	-2.0%	-10.0%
median	-6.6%	-7.4%	-0.9%	-1.0%	-0.8%	-1.9%	-0.9%	-1.5%	-4.9%
25th percentile	-1.5%	-2.9%	-0.2%	-0.5%	-0.5%	-0.7%	-0.4%	-0.9%	-1.9%
Min reduction[2]	1.0%	0.8%	3.8%	1.1%	2.1%	0.3%	0.8%	0.7%	4.0%

Notes:

1. Maximum reduction is the difference between the survival rates of the PA and NAA operational scenarios. It is represented by a negative number indicating that survival is greater under the NAA scenario.

2. Minimum reduction of survival rates between the PA and NAA operational scenarios can be represented by a negative number (reduction in survival) or a positive number (increased survival).

Table 2-301. Average Monthly Absolute Changes (percentage) in Through-Delta Survival Between the PA and NAA Operational Scenarios (PA-NAA) for Above Normal Water Years.

Statistic	Month								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Max reduction[1]	-22.0%	-23.3%	-8.5%	-7.1%	-10.0%	-10.5%	-6.8%	-7.7%	-19.6%
75th percentile	-9.2%	-8.2%	-2.0%	-2.4%	-4.4%	-5.9%	-1.8%	-2.1%	-4.4%
median	-4.5%	-6.1%	-0.9%	-1.2%	-1.1%	-2.3%	-1.0%	-1.3%	-3.0%
25th percentile	-0.6%	-0.3%	-0.5%	-0.7%	-0.6%	-0.9%	-0.3%	-0.7%	-1.7%
Min reduction[2]	7.6%	2.5%	2.2%	2.9%	0.7%	2.0%	2.0%	0.6%	3.1%

Notes:

1. Maximum reduction is the difference between the survival rates of the PA and NAA operational scenarios. It is represented by a negative number indicating that survival is greater under the NAA scenario.

2. Minimum reduction of survival rates between the PA and NAA operational scenarios can be represented by a negative number (reduction in survival) or a positive number (increased survival).

Table 2-302. Average Monthly Absolute Changes (percentage) in Through-Delta Survival Between the PA and NAA Operational Scenarios (PA-NAA) for Below Normal Water Years.

Statistic	Month								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Max reduction[1]	-20.6%	-22.5%	-12.1%	-8.3%	-10.1%	-11.2%	-5.5%	-5.7%	-11.7%
75th percentile	-8.5%	-9.7%	-2.9%	-2.2%	-3.7%	-6.4%	-1.4%	-1.4%	-4.2%
median	-4.2%	-6.7%	-0.9%	-1.2%	-1.6%	-4.0%	-0.7%	-0.8%	-1.2%
25th percentile	-1.1%	-3.1%	-0.3%	-0.7%	-0.9%	-1.7%	-0.1%	-0.1%	0.2%
Min reduction[2]	0.6%	0.7%	3.8%	2.3%	0.4%	2.6%	0.8%	1.0%	2.9%

Notes:

1. Maximum reduction is the difference between the survival rates of the PA and NAA operational scenarios. It is represented by a negative number indicating that survival is greater under the NAA scenario.

2. Minimum reduction of survival rates between the PA and NAA operational scenarios can be represented by a negative number (reduction in survival) or a positive number (increased survival).

Table 2-303. Average Monthly Absolute Changes (percentage) in Through-Delta Survival Between the PA and NAA Operational Scenarios (PA-NAA) for Dry Water Years.

Statistic	Month								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Max reduction[1]	-20.1%	-23.0%	-11.0%	-9.6%	-8.7%	-9.7%	-3.9%	-4.0%	-8.4%
75th percentile	-8.5%	-8.1%	-1.4%	-1.4%	-3.3%	-4.6%	-0.5%	-0.6%	-2.6%
median	-4.4%	-3.6%	-0.9%	-1.0%	-1.4%	-1.6%	0.1%	0.0%	-0.8%
25th percentile	-0.7%	-1.0%	-0.2%	-0.7%	-0.9%	-0.9%	0.5%	0.4%	-0.2%
Min reduction[2]	1.8%	1.1%	3.0%	0.1%	0.1%	1.4%	2.7%	1.7%	1.6%

Notes:

1. Maximum reduction is the difference between the survival rates of the PA and NAA operational scenarios. It is represented by a negative number indicating that survival is greater under the NAA scenario.

2. Minimum reduction of survival rates between the PA and NAA operational scenarios can be represented by a negative number (reduction in survival) or a positive number (increased survival).

Table 2-304. Average Monthly Absolute Changes (percentage) in Through-Delta Survival Between the PA and NAA Operational Scenarios (PA-NAA) for Critical Water Years.

Statistic	Month								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Max reduction[1]	-13.1%	-21.4%	-6.1%	-8.0%	-9.9%	-6.0%	-1.2%	-2.2%	-4.7%
75th percentile	-4.1%	-6.0%	-1.3%	-1.2%	-2.1%	-1.2%	-0.5%	-0.5%	-0.5%
median	-0.7%	-0.2%	-0.9%	-0.9%	-1.2%	-0.8%	-0.2%	-0.2%	-0.2%
25th percentile	0.0%	0.3%	-0.5%	-0.4%	-0.9%	-0.2%	0.0%	0.0%	0.0%
Min reduction[2]	1.2%	3.8%	4.1%	6.0%	0.5%	2.2%	0.8%	0.7%	0.7%

The real-time operations described the PA include unlimited pulse protections (UPP) in the operational criteria of the NDD; these are assessed in Section 2.5.1.2.7.3 *The Revised PA Unlimited Pulse Protection Scenario (UPP)*. Information regarding Chinook salmon recoveries at the Knights Landing RST, flows at Freeport, and expected levels of diversion for an operational scenario that protects each pulse of fish moving through the Delta system, as indicated by the presence of fish at the Knights Landing RST, have been analyzed to examine the changes in through delta survival rates for the UPP operational scenario. For the eleven years of data used in the analysis (2003-2012, and 2014), the average median difference in through delta survival between the UPP operational scenario and the NAA operational scenario is -1.43%. The 90^{th} percentile (most negative difference) for the difference in survival over this set of data is -2.21%, which is the same magnitude as the 50^{th} percentile of the unmodified PA-NAA analysis for all water years combined. NMFS believes that the difference in survival for the UPP scenario will not exceed the median values that were derived from the modeling for the initial PA and NAA scenarios, and therefore the median values will serve as appropriate surrogates for take under future operations, which include the UPP options.

2.9.1.2.8 Operations of the Delta Cross Channel Gates

The modeling of the proposed operations of the PA results in an increase in the percentage of days in which the Delta Cross Channel radial gates will remain open in October, November, December, and June compared to the NAA. This is in response to the reduction in the flows in the Sacramento River below the location of the NDD as a result of the diversion of water at the NDD (Table 2-305). By reducing the flows in the Sacramento River downstream of the intakes, the PA decreases the probability of reaching the 25,000 cfs flow trigger that requires gate closure for flood protection downstream and to prevent scour at the gate location. The operation of the gates affects juvenile salmonids more negatively than adults by entraining fish into the DCC when gates are open. October, November, and December is a time of early migration of listed juvenile salmonids, in particular winter-run Chinook salmon. When the DCC gates are open, any fish moving past the junction between the Sacramento River and the DCC has the potential for entrainment into the DCC and the interior Delta where survival for juvenile fish is reduced compared to the northern Delta waterways. Perry et al. (2017) modeled that this probability of entrainment is enhanced by an increase in the frequency (i.e., probability of flow reversal) and duration of reverse flows (i.e., proportion of day with reversed flows) in the vicinity of the DCC gates for the operations of the PA. The modeling by Perry et al. (2017) shows that the frequency of reverse flows and their duration will increase for the PA compared to the NAA, making entrainment of juvenile salmonids into the DCC more likely.

Conversely, adult listed salmonids and green sturgeon are negatively affected when the gates are closed by blocking an alternative migratory route into the Sacramento River basin via the Mokelumne River system. When the gates are open, Sacramento River water flows into the Mokelumne River system, providing a false attractant cue for upstream migration to fish with origins in the Sacramento River basin. There is minor migrational delay as long as the gates are open and access to the Sacramento River is available. When the gates are closed in winter (December through early June) there is still some leakage of Sacramento River water into the DCC which can still attract Sacramento River basin fish. Adult fish that move up into the DCC are blocked from the Sacramento River and must move back downstream to find an alternative route such as Georgiana Slough to complete their migration. This leads to increased delays in their upstream movements to spawning grounds. It is believed that this comprises a small proportion of the population of listed salmonids and green sturgeon since the vast majority of Sacramento River flow is directed downstream in its natural channel and not through the artificial DCC route. Thus, the strongest Sacramento River flows that cue upstream movements remain in the Sacramento River migratory route (which also includes the natural Georgiana Slough channel) and will attract fish upstream from the western Delta. In fall, the increased frequency of opening of the gates will have minor impacts to upstream migrating salmonids, in particular steelhead adults, as it will provide an open migratory pathway to the Sacramento River for those fish moving through the Mokelumne River system. In a similar fashion, increased openings in June will provide access for late migrating adult winter-run or spring-run Chinook salmon to the Sacramento River that have moved into the Mokelumne River system.

Hydrodynamic modeling described in the BA (BA Appendix 5.B, Table 5B.5-24) shows that the long term 82-year simulation indicates that DCC gates will be open on average 8% more in October, 26% more in November, and 4% more in December for the PA compared to the NAA operations scenario. The projected percentage of days in which the gates will be open is higher for wetter years than for drier years. During drier years, the flows in the Sacramento River are more similar between the PA and NAA scenarios. During wetter years, the NDD are able to divert more of the elevated flows from October through December, and maintain flows downstream of the intake locations below the threshold for closing the DCC gates. It is during these wetter years that more juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead are expected to have earlier outmigrations due to more precipitation events and precipitation induced pulses of flow moving downriver and inducing migrations.

Table 2-305. Surrogate Criteria for the Extent of the Incidental Take Associated with Operations of the Delta Cross Channel: Average Number of Days with Gates

Open Modeled for the NAA and PA Scenarios, Average Difference in Days Open Between Scenarios, and Percentage Difference in Days that DCC Gates are Open.

Average number of days with Gates open												
	October				November				December			
	NAA	PA	Diff	% Diff	NAA	PA	Diff	% Diff	NAA	PA	Diff	% Diff
Long Term Average	23	27	2	8%	10	12	3	26%	6	6	0	4%1
Water Year Type												
Wet (32%)2	19	24	5	25%	3	7	4	150%	6	6	0	8%
Above normal (16%)	24	27	3	13%	7	12	5	66%	5	5	0	5%
Below normal (13%)	28	28	0	1%	15	16	1	8%	7	7	0	-1%
Dry (24%)	29	30	1	2%	12	13	1	11%	5	5	0	2%
Critical (15%)	31	31	0	-1%	19	19	0	0%	8	8	0	2%

Notes:

1. Actual differences are less than one and rounded to nearest whole number. Percentages are based on the actual modeled numbers.

2. Percentages in parentheses are the percentage of years of that water year type over the 82-year sample period.

For all populations of listed salmonids, the month of October has very few juveniles in the vicinity of the DCC gates based on regional monitoring. In October, less than 1% of winter-run Chinook salmon are expected to be present, and for those that are, their presence is usually the result of early storms moving through the upper Sacramento River watershed, resulting in sudden, transient increases in the flows in the Sacramento River. Even fewer juvenile spring-run Chinook salmon are present due to the timing of their spawning. In contrast, yearling spring-run Chinook salmon may be present if their natal tributaries experience sudden increases in flows due to precipitation events and downstream migration is triggered in response to the elevated flows. Likewise, steelhead smolts may exit tributaries in the Sacramento River watersheds in response to these increased flow events. By November, more winter-run Chinook salmon are present in the system. It is estimated that approximately 1% are present in the upper Delta in drier years, when precipitation events are still uncommon early in the winter, but in wetter years approximately 5% of the annual population has migrated into the Delta. Few juvenile spring-run Chinook salmon or steelhead are present in the Delta during November, and are quite rare in any of the monitoring actions conducted in the lower Sacramento River or upper Delta regions. In December, winter-run Chinook salmon juveniles are still rare in the upper Delta in drier water year types (~1% of annual population). However, in wet years, approximately 25% of the annual juvenile population may be present in the upper Delta in response to higher flows in the Sacramento River. Approximately 7% of the juvenile spring-run Chinook salmon population and ~2% of juvenile steelhead may be present in the upper Delta in wetter years. As stated before, elevated flows or pulses of flows in response to increased precipitation in the upper watersheds serve to induce migratory behaviors in these salmonids.

It is unknown what percentage of the juvenile population of green sturgeon is present adjacent to the DCC gate junction or what their behavior is in relation to the position of the gates. NMFS assumes that these life stages are present year round in the vicinity of the DCC gate junction and are therefore present during the operations from October through December. It is unknown what changes in survival occur to juvenile green sturgeon in the Delta interior, but it is assumed that since these juvenile life stages rear for multiple years in the Delta, that exposure to Delta interior waterways are likely to occur at some point in their juvenile rearing phase and is not likely to be an additional adverse effect in their life history that does not normally occur.

Quantification of actual individual listed juvenile salmonids entering the DCC route while the gates are open is not possible with available monitoring data. Presence in the vicinity is assumed based on past monitoring efforts in the lower Sacramento River at Knights Landing (RST monitoring) and in the upper Delta (Sacramento River trawl) that have given historical proportions of annual population presence during this time frame. Near real time presence of migratory pulses are determined from the same monitoring efforts and can inform when pulses of listed fish are expected to be present in the upper Delta region adjacent to the DCC which may result in protective closures of the DCC gates to avoid entrainment of these pulse. Mandatory protective closures of the DCC gates occur in mid-December and continue through the middle of June due to Federal and State restrictions regarding the operations of the DCC Gates (e.g., NMFS 2009 biological opinion for the long-term operations of the CVP and SWP, the State's water rights decision D-1641). There are currently no monitoring efforts that have reasonable success in capturing juvenile green sturgeon migrating downstream in the vicinity of the DCC gates, and therefore there is no ability to detect any individuals that may be present and vulnerable to the operations of the gates.

Since quantification of individual listed salmonids is not possible, NMFS uses physical surrogates as well as historical population trends to estimate the proportion of the population vulnerable to incidental take due to the operations of the DCC gates related to the PA. The number of days that the DCC gates will be open during October, November, and December, as estimated from the modeling, will serve as the physical surrogate, and will be represented as the percentage of days in the month that the gates are in an open position. The information from the lower Sacramento River and upper Delta monitoring actions will be used to estimate the proportion of the annual juvenile outmigration that overlaps with the three months of interest. The product of the two variables will represent the proportion of the population exposed to the open DCC gates and the potential to be entrained into the Delta interior. These proportions are represented in Table 2-306.

Table 2-306. Proportion of Listed Salmonids Exposed to Open DCC Gates under the PA that will be Used as Surrogate Criteria for the Extent of the Incidental Take Associated with DCC Gate Operations.

		October		November		December	
Percentage of month that gates are open	**Wet[1]**	**82.3%**		**31.7%**		**17.7%**	
	Dry[2]	**95.7**		**53.3%**		**21.5%**	
Species		**% pop[3]**	**% exp[4]**	**% pop**	**% exp**	**% pop**	**% exp**
WRCS[5]	Wet	0.5%	0.4%	5%	1.6%	25%	4.5%
	Dry	0.1%	0.1%	1%	0.5%	1%	0.2%
SRCS[6]	Wet	0.5%	0.4%	0.5%	0.16%	7%	1.24%
	Dry	0.1%	0.1%	0.1%	0.05%	1%	0.22%
CCVSH[7]	Wet	0.5%	0.4%	0.5%	0.16%	2%	0.35%

		October		November		December	
Percentage of month that gates are open	**Wet[1]**	**82.3%**		**31.7%**		**17.7%**	
	Dry[2]	**95.7**		**53.3%**		**21.5%**	
Species		**% pop[3]**	**% exp[4]**	**% pop**	**% exp**	**% pop**	**% exp**
	Dry	0.1%	0.1%	0.1%	0.05%	1%	0.22%

Notes:

1. Wet water years include Wet and above normal water years.
2. Dry water years include below normal, dry, and critical water years.
3. Percentage of population is derived from monitoring data from the Knights Landing RSTs and the Sacramento River trawls. In October and November 0.5% represents <1% of population present, 0.1% represents a "zero" percentage of population present.
4. Percentage of population exposed is the product of the percentage of month that DCC gates are open under the PA and the percentage of the population present during that month.
5. WRCS = Sacramento River winter-run Chinook salmon
6. SRCS = CV spring-run Chinook salmon
7. CCVSH = California Central Valley steelhead

Should the monthly percentage of days that the gates are open be exceeded or the anticipated percentage of the population present be exceeded, then the anticipated proportion of the population exposed to the open DCC gates under the PA will be exceeded and NMFS' assessment of effects will not be valid; thus, incidental take will be considered to be exceeded for this aspect of the PA operations. The percentage of days with the gates open will be known by the end of the month, while the percentage of the annual population of listed fish will not be known until the end of the migration year.

2.9.1.2.9 Southern Resident Killer Whales

NMFS is not including any incidental take level for Southern Resident killer whales in this ITS at this time because the incidental take of marine mammals has not been authorized under section 101(a)(5) of the Marine Mammal Protection Act. Following issuance of applicable regulations or authorizations under section 101(a)(5) of the Marine Mammal Protection Act, NMFS may amend this Opinion to include an incidental take statement for Southern Resident killer whales.

2.9.2 Effect of the Take

In the biological opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, California Central Valley steelhead DPS, sDPS of North American green sturgeon, or destruction or adverse modification of their critical habitats.

Body Text

2.9.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" are nondiscretionary measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02).

As stated in the Endangered Species Act Consultation Handbook “Section 7 requires minimization of the level of take. It is not appropriate to require mitigation for the impacts of incidental take. Reasonable and prudent measures can include only actions that occur within the action area, involve only minor changes to the project, and reduce the level of take associated with project activities. These measures should minimize impacts of take to the extent reasonable and prudent” (USFWS and NMFS 1998, p. 4-53). Details on how to implement each of these measures are described in Section 2.9.4 Terms and Conditions.

1. Ensure that non-operational restoration components of the RPA included in the NMFS (2009) biological opinion (and 2011 amendment) on the coordinated operations of the CVP/SWP, as described in Section 3.4.3.1.2 Restoration Actions of the BA, are implemented or completed (as detailed in that section of the BA) before commencement of operations of the north Delta diversions and revised operations of the existing south Delta facilities (unless superseded by subsequent consultation).

   Biological Goal: The goal is to minimize the impacts associated with operation of the NDD as analyzed in this Opinion, which is based in part on the reasonable expectation supported by the BA and the Sacramento Valley Salmon Resiliency Strategy (Salmon Resiliency Strategy) (California Natural Resources Agency 2017) that non-operational habitat restoration actions described in the NMFS (2009) biological opinion RPA and 2011 amendment (unless superseded by subsequent consultation) and BA Section 3.4.3.1.2 Restoration Actions are implemented or completed (as detailed in the BA), prior to commencement of operations of the NDD. The effects are expected to increase fitness and survival of juvenile salmonids and sturgeon.

2. Minimize impacts on listed species by full inclusion and participation of NMFS in technical teams (described herein) that will ensure the consideration of species impacts and minimization of effects. Reclamation and DWR, at their discretion, may submit to the Interagency Implementation Coordination Group (IICG) all reporting and plans identified in the following terms and conditions consistent with the IICG’s role identified in the CWF BA Appendix 3.H Adaptive Management Program Agreement for Implementation of an Adaptive Management Program for Project Operations to “Review scientific information and recommend changes to monitoring schema and management actions to the appropriate agency” either prior to or at the same time as their submission to NMFS. NMFS’ review and concurrence will be required for (1) plans for monitoring before, during, and after construction; (2) the construction approach and any revisions during construction; (3) structure/component design and any revisions based on new information; and (4) structure/component operations for the initial phased testing period, initial full operations, and ongoing full operations.

   Biological Goal: The goal is to minimize the adverse effects of construction and operations of the CWF facilities by providing a better understanding of species presence and response to construction activities and operations, by developing a structure design and approach to construction that use best practices to minimize and avoid adverse effects to the species, and to develop and assess operations that reduce the risks of impingement, entrainment, and other effects to listed fish.

3. Minimize predation of listed fish species covered in this biological opinion resulting from temporary or permanent physical alterations that create predator habitat in the mainstem

Sacramento River and in areas of the Delta that will experience impacts due to infrastructure installation, including the north Delta diversions, Clifton Court Forebay, barge landing locations, the head of Old River gate facility and associated cofferdam structures required for their construction.

Biological Goal: The goal is to minimize predation-related mortality of smaller fish caused by an increase in predator habitat and a reduction in refugia due to alteration of natural habitat complexity and shading caused by temporary and permanent in-water structures, including the north Delta diversions, CCF, barge landing locations, the head of Old River gate facility and associated cofferdam structures required for their construction. These effects (reduced natural habitat complexity and shading) are expected to reduce the survival of juvenile salmonids and sturgeon.

4. Monitor juvenile salmonid through-Delta survival, behavioral impacts, and habitat impacts to listed species that are likely to result from the construction, installation, maintenance, and operation of all physical infrastructure, such as the NDD, CCF, barge landings, and HOR gate, associated with the PA.

   Biological Goal: The goal is to monitor and minimize take that is anticipated to occur as a result of the construction, installation, and operation of CWF infrastructure. In addition to species monitoring described in the Terms and Conditions for RPMs 1, 2, and 3, additional monitoring shall occur to ensure that take does not exceed levels issued in the incidental take statement for impingement/entrainment at NDD sites, barge traffic, and increased predation associated with PA construction and operations. These components of the PA are expected to result in decreased survival and fitness of salmonids and sturgeon.

5. Implement a phased test period at the NDD to include monitoring of biological and physical parameters across a range of pumping rates and flow conditions prior to operating the north Delta diversions at full capacity.

   Biological Goal: The goal is to minimize take that is associated with increased predation risk, reduced river and Delta flows, impingement and entrainment, and increased entrainment into the central Delta given the uncertainty of the magnitude of adverse effects with the commencement of operations.

6. Ensure that the activities identified in BA Appendix 3.H Adaptive Management Program (AMP) are scientifically robust, in accordance with the implementation structure, and reasonably certain to occur as described in the administrative record for this biological opinion, regarding interagency assessments of AMP continuing and new funding needs.

   Biological Goal: The goal is to minimize the effects of operations on listed species by continuing to identify the means by which uncertainties regarding the performance of facility design and operational criteria will be measured and reduced. Operational and design criteria will be refined within the bounds of the Adaptive Management Program such that adverse effects to species fitness and survival are reduced.

7. Minimize take associated with acoustic disturbance from pile driving, geotechnical boring, and barge operations.

   Biological Goal: The goal is to minimize the biological (e.g., barotrauma) and behavioral (e.g., reduced feeding/foraging) effects of increased noise levels caused by construction activities that are expected to reduce the survival and growth of juvenile and adult salmonids and survival, fitness, and growth of juvenile, sub-adult, adult, and post-spawn adult sturgeon.

8. Minimize turbidity and sedimentation events resulting from the construction of the NDD, HOR gate and its associated appurtenances, barge landing sites, and any other actions resulting in disturbance to sediment in the vicinity of a waterway (e.g., temporary roads, access paths).

   Biological Goal: The goal is to minimize the physical (e.g., sublethal gill clogging, abrading, or flaring) and behavioral (e.g., decreased feeding and sheltering behavior caused by increases in turbidity) effects of increased suspended sediment concentration caused by construction activities that are expected to reduce the growth and reproductive success of juvenile and adult salmonids and sturgeon.

9. Minimize exposure of listed species to contaminants that may be re-mobilized due to benthic disturbance associated with pile-driving, dredging, geotechnical boring, or other activities, or contaminants that may be introduced in the course of construction activities.

   Biological Goal: The goal is to minimize the behavioral (e.g., swimming, feeding, and attraction-avoidance), physiological (e.g., growth, reproduction, and development), biochemical (e.g., blood enzyme and ion levels), and histological effects of the re-mobilization of latent contaminants or introduction of new contaminant sources caused by construction activities that are expected to reduce the growth and reproductive success of juvenile, smolt, and adult salmonids and sturgeon.

10. Minimize physical and behavioral impacts to listed fish, including disruption of normal behaviors, displacement, and increased stress levels, during all construction phases.

    Biological Goal: The goal is to minimize injury or mortality due to handling of listed fish in the process of dewatering cofferdams, as well as any injury or mortality that may occur as a result of construction activities occurring in water or adjacent to waterways when listed fish species are present. These activities are expected to result in reduced survival of salmonids and sturgeon.

11. Minimize impacts to migratory behavior of listed species in the Delta due to reductions in flow downstream of the NDD sites.

    Biological Goal: The goal is to minimize impacts to migratory behavior that are expected to occur as a result of changes to flow regimes (including reduced in-Delta flow) throughout the Delta downstream of NDD sites. The operations of the north Delta diversions are expected to cause salmonids to experience reduced flow rates in the Sacramento River, increased travel times, and increased entrainment into the central Delta. These effects are expected to result in decreased survival of outmigrating juveniles.

12. Minimize impacts to rearing behavior of listed species in the Delta due to reductions in flow downstream of the NDD sites.

    Biological Goal: The goal is to minimize impacts to rearing behavior that are expected to occur as a result of reduced in-Delta flow and increased tidal forcing throughout the Delta downstream of NDD sites. The operation of the north Delta diversions is expected to cause salmonids to experience increased exposure to entrainment into the central Delta and reduced in-Delta rearing conditions. These activities are expected to result in decreased survival and fitness of outmigrating juveniles.

13. Minimize effects to listed species due to maintenance activities associated with all facilities.

    Biological Goal: The goal is to minimize the physical, behavioral, physiological, biochemical, histological effects and the risk of injury or mortality due to maintenance activities that may cause increases in increased suspended sediment concentration, re-mobilization or introduction of contaminant sources, or direct contact between fish and maintenance implements. These effects are expected to reduce the growth, reproductive success, and survival of salmonids and sturgeon.

14. Minimize the effects to listed species due to the revised operations of the existing south Delta export facilities at the CVP and SWP when CWF operations commence.

    Biological Goal: The goal is to minimize the take associated with the pumping and fish collection activities of the existing CVP and SWP south Delta facilities when operations of the PA commence. These effects are expected to reduce survival of salmonids and sturgeon.

2.9.4 Terms and Conditions

The terms and conditions described below are non-discretionary. Reclamation, the Corps, DWR, and all assignees must comply with them in order to implement the reasonable and prudent measures (50 CFR 402.14). Reclamation, the Corps, DWR, and all assignees have a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this incidental take statement (50 CFR 402.14).

An Interagency Implementation Coordination Group (IICG) is being established with primary responsibility for support, coordination, and implementation of the Adaptive Management Program for the PA. The IICG consists of representatives of USFWS, NMFS, Reclamation, DWR, CDFW, and the public water agencies (PWAs). Many of the terms and conditions listed here as the responsibility of Reclamation, the Corps, DWR, or a specific work group will be carried out through the IICG, as described by the Adaptive Management Program.

1. The following terms and conditions implement reasonable and prudent measure 1 (Ensure that non-operational restoration components of the RPA included in the NMFS (2009) biological opinion (and 2011 amendment) on the coordinated operations of the CVP/SWP, as described in Section 3.4.3.1.2 Restoration Actions of the BA, are implemented or completed (as detailed in that section of the BA) before commencement of operations of the north Delta diversions and revised operations of the existing south Delta facilities (unless superseded by subsequent consultation).):

1a. Reclamation[1] and DWR[2] shall ensure that all of the following non-operational components of the RPA included in the NMFS (2009) biological opinion and 2011 amendment (unless superseded through subsequent consultation), which are included in Section 3.4.3.1.2 of the BA and the Salmon Resiliency Strategy, are implemented or completed (as detailed in those documents), as well as meeting the performance measures detailed in the Salmon Resiliency Strategy, before the NDD facilities commence operations. Reclamation and DWR shall develop a plan with a schedule for implementation or completion of each action before the NDD facilities commence operation consistent with the NMFS (2009) biological opinion RPA and amendments, Section 3.4.3.1.2 of the BA, and the Salmon Resiliency Strategy; submit the plan to NMFS by December 31, 2018, for review and concurrence; and submit annual reports to NMFS detailing progress toward implementation or completion of the actions in accordance with the plan. After NMFS' concurrence on the plan, if additional time is needed under the plan's schedule for completion of any of these actions based on unforeseen circumstances, Reclamation and DWR shall submit to NMFS for review and concurrence prior to the applicable date in the plan's schedule revisions to the plan for completion of any such action before the NDD facilities commence operation with an explanation of the unforeseen circumstances resulting in the need for additional time and any measures that can be taken to preclude any additional delays.

- NMFS 2009 RPA Action I.7: Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass
  - Relevant components from Salmon Resiliency Strategy – Improve Yolo Bypass Adult Fish Passage
- NMFS 2009 RPA Action I.6.1: Restoration of Floodplain Rearing Habitat
  - Relevant components from Salmon Resiliency Strategy - Increase Juvenile Salmonid Access to Yolo Bypass, and Increase Duration and Frequency of Yolo Bypass Floodplain Inundation
- NMFS 2009 RPA Action NF 4: Implementation of Pilot Reintroduction Program
- NMFS 2009 RPA Action I.2.6. Restore Battle Creek for Winter-Run, Spring-Run, and CV Steelhead
  - Relevant components from Salmon Resiliency Strategy – Complete Battle Creek Salmon and Steelhead Restoration Project
- NMFS 2009 RPA Action IV.1.3: Consider Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta, and Reduce Exposure to CVP and SWP Export Facilities
  - Relevant components from Salmon Resiliency Strategy – Construct Permanent Georgiana Slough Non-Physical Barrier

[1] As per the November 29, 2016, correspondence from Reclamation to NMFS (Reclamation 2016), Reclamation is the lead Federal agency for the ESA section 7 consultation and has been designated by the Corps to act on their behalf for the purposes of this current consultation.
[2] As per June 13, 2017, correspondence from DWR to NMFS (DWR 2017), references to DWR are intended to include DWR's agents and those who act under DWR's supervision.

2. The following terms and conditions implement reasonable and prudent measure 2 (Minimize impacts on listed species by full inclusion and participation of NMFS in technical teams (described herein) that will ensure the consideration of species impacts and minimization of effects. Reclamation and DWR, at their discretion, may submit to the Interagency Implementation Coordination Group (IICG) all reporting and plans identified in the following terms and conditions consistent with the IICG's role identified in the CWF BA Appendix 3.H Adaptive Management Program Agreement for Implementation of an Adaptive Management Program for Project Operations to "Review scientific information and recommend changes to monitoring schema and management actions to the appropriate agency" either prior to or at the same time as their submission to NMFS. NMFS' review and concurrence will be required for 1) plans for monitoring before, during, and after construction; (2) the construction approach and any revisions during construction; (3) structure/component design and any revisions based on new information; and (4) structure/component operations for the initial phased testing period, initial full operations, and ongoing full operations.):

2.a. Within one year of biological opinion issuance, Reclamation and DWR shall establish the following multi-agency technical teams for major components of the PA.

The new technical teams shall include:

- Fish Facilities Technical Team (FFTT), which shall focus on monitoring, design, and operational activities of the north Delta diversions, including the program of phased testing of the diversions. Consistent with the PA, DWR shall lead this team in close collaboration with NMFS and DFW; the team may include other members.
- HOR Gate Technical Team (HGTT), which shall focus on monitoring, design, and operational activities of the HOR gate, fish ladder, boat lock, and control building.
- Clifton Court Forebay Technical Team (CCFTT), which shall focus on monitoring, design, and operational activities of the modified CCF before, during, and after construction.
- Barge Operations Technical Team (BOTT), which shall focus on operational activities and monitoring of all barge-related activities including barge operations and construction and maintenance of barge landings.
- Habitat Mitigation Technical Team (HMTT), which shall focus on monitoring, design, and performance of all mitigation-related habitat restoration activities associated with the PA.

Each new technical team shall include at least one NMFS staff member with appropriate expertise for the project component and at the discretion of Reclamation, and DWR, shall allow for at least one representative from each of the IICG representative groups. As noted in BA Section 3.1.7, the existing Delta Operations for Salmonids and Sturgeon (DOSS) workgroup will remain consistent with its current membership as described in the NMFS (2009) biological opinion, and continue to provide advice to WOMT and to NMFS on issues related to fisheries and water resources in the Delta and recommendations on measures to reduce adverse effects of Delta operations of the CVP and SWP on salmonids and green sturgeon. DOSS will continue to review CVP and SWP operations in the Delta, including for both the north Delta and south Delta diversions, and the collected data from the different ongoing monitoring programs, while assuming additional roles and responsibilities for new operational considerations with the implementation of the PA operations. The existing real-time operations workgroup structure and function, as described in the NMFS (2009) biological opinion, shall remain and be unchanged by this Opinion, consistent with the PA for this Opinion.

2.b. Technical Team Framework: Each new technical team shall draft a framework and schedule that shall include an outline of the roles and responsibilities of each member and a schedule to guide the team's process for completing tasks outlined in the terms and conditions for this Opinion. The draft framework and schedule shall be submitted to Reclamation, DWR, and NMFS for review and concurrence no later than 6 months after convening the technical team. The framework and schedule must receive NMFS' concurrence in writing before the team undertakes the substantive technical steps outlined in subsequent terms and conditions. All of the tasks/work products described in Term and Condition 2.c. are anticipated to require varying degrees of interaction among or between the team, Reclamation, DWR, and NMFS. At their discretion, Reclamation and DWR may submit work products for review to the IICG. However, all products require written concurrence from NMFS, as outlined below and/or defined in the operating framework and schedule.

2.c. Technical Team Charter: Reclamation and DWR shall ensure that each technical team, within the first year following its formation, develop a Charter that, at the discretion of Reclamation and DWR, may be submitted to the IICG for review, and shall be submitted to NMFS for review and concurrence. Technical teams shall include in their Charter how each of the following technical team tasks will be completed: developing monitoring plans; influencing and developing structure/component design; informing and developing structure operations; identifying structure/component performance measures; and developing provisions for annual reporting. Teams shall provide a mechanism by which Reclamation and DWR can submit required reports and agencies can exchange proposed approaches or modifications to actions. Each team may submit to the IICG and shall submit to NMFS an annual report that contains: any updates to the team's Charter or personnel; design updates to that team's designated infrastructure or PA component; details of construction progress and any updates to projected construction timelines; results of biological and physical monitoring activities (including data, completed analyses, and relevant findings); results and detailed methods of any physical or biological modelling conducted by the team; plans and timeline for future monitoring and/or modeling proposed by the team to meet requirements set forth in subsequent terms and conditions; a report of incidental take that has occurred; challenges or obstacles encountered by the team; and any additional reports, published studies, or findings related to the listed species and critical habitat addressed in this Opinion. Additional reports on specific activities of the technical teams are identified in other terms and conditions, as appropriate. Some reporting requirements included in subsequent terms and conditions require frequencies other than annually; they are noted as such.

2.d. Consistent with NMFS design criteria, Reclamation and DWR shall submit preliminary designs at 10% completion stage and detailed designs at 50% and 90% completion stage for the NDD, HOR gate and its associated appurtenances, barge landing sites, and CCF facility to NMFS for review and concurrence as to whether impacts to listed species are expected to be minimized, consistent with NMFS criteria. The design plans shall be provided immediately upon completion, delivered separately from the annual reports. The 90% design review shall focus on implementation of previous recommendations to minimize impacts to listed fish.

3. The following terms and conditions implement reasonable and prudent measure 3 (Minimize predation of listed fish species covered in this biological opinion resulting from temporary or permanent physical alterations that create predator habitat in the mainstem Sacramento River and in areas of the Delta that will experience impacts due to infrastructure installation, including the north Delta diversions, Clifton Court Forebay, barge landing locations, the head of Old River gate facility and associated cofferdam structures required for their construction.):

3.a. Reclamation and DWR shall ensure that the technical teams described in Term and Condition 2.a. complete the following tasks:

3.a.i. Within one year of completion of its Charter, each technical team described in Term and Condition 2.a. shall submit a report to NMFS for review and concurrence that includes, as applicable to the team, the team's recommended physical attributes of structure design for prevention or minimization of predation risk to listed species associated with temporary structures during the construction period and permanent structures during on-going operations.

3.a.ii. Within one year of issuance of the biological opinion, the FFTT shall develop and submit to NMFS for review and concurrence a Baseline Predator Density Monitoring Plan for monitoring baseline predator density and distribution and baseline fish surveys. This plan may use as its basis Study 9 Baseline Predator Density and Study 11 Baseline Fish Survey from the FFTT study plan document (FFTT 2013), with any updates or adjustments as needed based on newer information. The Baseline Predator Density Monitoring Plan shall include the schedule, implementation, and monitoring and reporting requirements. Reclamation and DWR shall commence implementation of the plan within six months of concurrence by NMFS. These surveys shall monitor changes in predator community composition and abundance at the NDD facilities before and during construction until operations of CWF facilities commence. Data and analysis shall be included in the FFTT annual report developed and submitted as described in Term and Condition 2.c. Baseline fish surveys shall address the questions identified in the Draft Work Plan of the FFTT (FFTT 2013).

3.a.iii. The FFTT shall also evaluate the effectiveness of using refugia (e.g., small depressions in the intake structure with bar racks to exclude larger predatory fish that can act as rest areas and areas to avoid predation) as part of intake structure and fish screen design to provide holding habitat for juvenile fish passing the screen to recover from swimming fatigue and to avoid exposure to predatory fish. The FFTT shall identify the effectiveness and biological benefits of including refugia into intake structure design and design improvements that would contribute to increasing the benefits and use of intake structure refugia. Effectiveness monitoring at NDD intakes shall address the questions identified in the Draft Work Plan of the FFTT (2013).

3b. In developing the structure design and construction approach to an 80% complete level of design in the required reporting of designs outlined in Term and Condition 2.d, Reclamation and DWR shall include engineering specifications, with concurrence by NMFS and the FFTT, for the following components:

3.b.i. Minimize the amount of cofferdam material to be installed in all phases of construction at all locations to the extent practicable.

3.b.ii. Include refugia features in the NDD screens of sufficient type and interval such that fish migrating past the NDD are not at increased risk of predation to the extent practicable.

3c. Reclamation and DWR shall use the Adaptive Management Program to evaluate risks and threats from predation on salmonids. The program shall evaluate existing analyses and early modeling results to determine whether predation is non-random in the environment, happening mostly in a small percentage of a river system at “hotspots”. The AMP shall develop appropriate methods to determine hotspot locations in the vicinity of the PA facilities (FFTT 2013, Study 5 Predator Habitat Locations).

4. The following terms and conditions implement reasonable and prudent measure 4 (Monitor juvenile salmonid through-Delta survival, behavioral impacts, and habitat impacts to listed species that are likely to result from the construction, installation, maintenance, and operation of all physical infrastructure, such as the NDD, CCF, barge landings, and HOR gate, associated with the PA.):

4.a. Reclamation and DWR shall coordinate through the FFTT to develop a Fish Screen Monitoring Plan to monitor survival of juvenile fish at NDD sites to ensure that effects to migratory behavior are minimized. As described in Term and Condition 2.b., the monitoring plan shall be sent to NMFS for review and concurrence. Reclamation and DWR shall monitor consistent with the Fish Screen Monitoring Plan developed by the FFTT. Data and analysis produced via the following monitoring activities shall be sent by Reclamation and DWR to NMFS and may be submitted for review to the IICG. The Fish Screen Monitoring Plan shall include:

4.a.i. All post-construction inspection, testing, and monitoring shall be performed, at a minimum, according to the most current NMFS Anadromous Salmonid Passage Design criteria (NMFS 2011, or as updated by NMFS).

4.a.ii. Fish screen performance shall be evaluated by Reclamation and DWR, in coordination with the FFTT, for a range of water year types and flow conditions during the phased implementation of the PA. Monitoring of the NDD must occur for at least 10 years after initial operations in order to assess performance over a wide range of hydrologic conditions and population cohorts.

4.a.iii. Development of a hydraulic evaluation study plan must be incorporated into the FFTT team Charter and the study plan shall be submitted by Reclamation and DWR to NMFS for review and concurrence within six months of development of the Charter. The study plan shall be consistent with the NMFS Anadromous Salmonid Passage Design Criteria in place at time of 90% design completion stage (i.e., NMFS 2011, or as updated by NMFS). The study shall include provisions for an inspection of each screen facility to occur once every five years. For post-construction inspection and hydraulic testing, upon completion of screen construction and operation of the system, Reclamation and DWR shall conduct hydraulic testing and collect, at a minimum, data on sweeping velocities, approach velocities, impingement and entrainment of juvenile salmonids, and rate of unimpeded passage by the NDD sites. This monitoring shall be analyzed by the FFTT and reported to NMFS in accordance with requirements set forth in Term and Condition 2.c. The velocity testing must be performed to ensure that approach velocity is consistent with Section 15.2 of NMFS 2011 Anadromous Salmonid Passage Design Criteria:

> "*Hydraulic evaluations of juvenile fish screens must include confirmation of uniform approach velocity and the requisite sweeping velocity over the entire screen face. Confirmation of approach and sweeping velocities must consist of a series of velocity measurements encompassing the entire screen face, divided into a grid with each grid section representing no more than 5% of the total diverted flow through the screen (i.e., at least 20 grid points must be measured). The approach and sweeping velocity (parallel and perpendicular to the screen face) should be measured at the center point of each grid section, as close as possible to the screen face without entering the boundary layer turbulence at the screen face. Uniformity of approach velocity is defined as being achieved when no individual approach velocity measurement exceeds 110% of the criteria. In addition, velocities at the entrance to the bypass, bypass flow amounts, and total flow should be measured and reported.*"

The final hydraulic evaluation should be conducted during maximum diversion flows of 9,000 cfs unless otherwise concurred with by NMFS. The hydraulic evaluation study plan shall include the following three components as described in the NMFS (2011) fish passage guidance document, unless not required by NMFS design criteria in place at time of 90% design completion stage:

- Provisions to verify that the fish passage system is installed in accordance with the approved design.
- Provisions to measure hydraulic conditions to ensure that the facility meets these guidelines and criteria.
- Provisions for the Reclamation and DWR to perform biological assessments to confirm that hydraulic conditions are resulting in successful passage as part of the AMP. NMFS technical staff will work with the FFTT to assist in developing a hydraulic or biological evaluation plan to fit site-specific conditions and species.

4.a.iv. The FFTT shall develop an inspection log for monitoring each screen as a component of the hydraulic evaluation study plan. This log shall be included in Reclamation and DWR annual reporting requirements as described in Term and Condition 2.c. Reclamation and DWR will coordinate with NMFS on adjustments to the operation of the screens. Inspections shall occur on a basis consistent with the plan and starting at a frequency no less than monthly. The log shall include the following information for each inspection:

- Inspection dates, times, and the observer's name.
- Water depth at downstream end of the screen.
- Debris present on the screen, including any sediment retained in the screen openings.
- Fish observed on or passing over the screen surface including information about species, life stage, injuries present, evidence of predation, and any abnormal behavior, in accordance with requirements in Term and Condition 5.c. and 11.c.

- Operational adjustments and maintenance performed on the facility.

4.a.v. In order to meet the ongoing compliance criteria (as defined in Section 3.3.2.1 of the BA Operational Criteria for North Delta CVP/SWP Export Facilities) that listed juvenile salmonid survival is maintained at 95% of existing rates, Reclamation and DWR shall ensure that the FFTT develops and submits to NMFS for review and concurrence an operations plan that maintains listed juvenile salmonid survival rates through the reach containing new north Delta diversion intakes (0.25 mile upstream of the upstream-most intake to 0.25 mile downstream of the downstream-most intake) of 95% or more of the existing survival rate in this reach. The reduction in survival of up to 5% below the existing survival rate shall be cumulative across all screens and measured on an average monthly basis unless otherwise concurred with by NMFS.

4.a.vi. The hydraulic evaluation study shall include: monitoring for sediment and debris; the morphology of the stream channel in the immediate vicinity of the screen for debris; erosion; and sedimentation that may potentially damage screens and their supporting structures or adversely affect screen operation and effectiveness. Bathymetric surveys of the channel within 100 feet upstream and downstream of the footprint shall be submitted to NMFS annually or at a frequency determined by the FFTT.

4.a.vii. As part of the hydraulic evaluation study plan, all backup and alarm systems shall be tested according to manufacturer's recommendations to ensure they are working correctly per the manufacturers' recommendations. Any discrepancies and corrective action shall be included in the FFTT annual report.

4.a.viii. As part of the hydraulic evaluation study plan, Reclamation and DWR shall ensure that project biologists oversee fish rescue operations at NDD construction sites and that these operations comply with requirements described in the Terms and Conditions for RPM 10.a. through e.

4.b. Reclamation and DWR shall ensure that the BOTT incorporates the development and implementation of a barge operations monitoring plan into their team Charter and develops a work schedule for study activities in accordance with the team framework and schedule requirements as described in Term and Condition 2.b. and c. The BOTT monitoring plan shall assess the impacts of barge operations to listed species. Impacts include both acoustic and direct physical impacts. Annual reports shall be sent by Reclamation and DWR to NMFS each year. Take resulting from barge operations shall be reported to NMFS in accordance with Terms and Conditions 15.a. and b. The BOTT monitoring plan shall address the following in order to monitor take, unless alternative methods are included in the monitoring plan, as concurred with by NMFS:

4.b.i. Monitoring of propeller entrainment shall occur using available techniques such as DIDSON and/or ARIS dual-frequency imaging, or some other appropriate technology as practicable, aboard tugboats to characterize take associated with tug and barge operations.

4.b.ii. Acoustic monitoring of barge operations shall occur in order to characterize acoustic impacts to fitness and behavior of listed species.

4.c. Reclamation and DWR shall ensure that the CCFTT incorporates the development and implementation of a CCF monitoring plan into their team Charter and develops a work schedule for study activities in accordance with the team framework and schedule requirements as described in Terms and Conditions 2.b. and c. Reports shall be sent by DWR and Reclamation to NMFS each year. The CCF monitoring plan shall address the following:

4.c.i. Reclamation and DWR shall oversee all fish handling and removal during the course of construction at CCF. Reclamation and DWR shall work in coordination with contractors to ensure that work adheres to all protocols in the Fish Rescue and Salvage Plan described in AMM 8 of the BA as well as the requirements described in Terms and Conditions 10.a. through e. Reclamation and DWR shall advise and apprise the CCFTT of all methods used and results obtained.

4.c.ii. Reclamation and DWR, in coordination with the CCFTT, shall assess survival of relocated fish and provide monthly reports to NMFS on survival of listed fish during handling and relocation in accordance with Terms and Conditions 15.a. and b. Mortalities shall be handled by approved project biologists per the requirements in Term and Condition 10.b., and reported in accordance with the instructions in Term and Condition 15.b.

4.c.iii. Reclamation and DWR shall monitor juvenile survival in the CCF both during construction of the new CCF facility and following completion of construction. Reclamation and DWR shall evaluate whole facility efficiency and develop an appropriate loss equation for the Skinner Fish Facility for the reconfigured Clifton Court Forebay, which shall be sent to NMFS for review and concurrence. Survival data, and a report on efficiency and revisions to the loss equation shall be included in a Reclamation and DWR report to NMFS annually, or as necessary to implement the NMFS (2009) biological opinion.

4.d. Reclamation and DWR shall ensure that the HGTT incorporates the development and implementation of a HOR monitoring plan into their team Charter and develops a work schedule for study activities in accordance with the team framework and schedule requirements as described in Terms and Conditions 2.b. and c. Reclamation and DWR shall monitor survival of fish at HOR during the implementation of the PA and assess performance of the HOR gate facility upon completion. Reclamation and DWR shall include data and analysis in an annual report to the NMFS per the instructions in Term and Condition 2.c. Upon achieving preliminary designs at 10% completion stage and detailed designs at 50% and 90% completion stage, designs and plans shall be sent to NMFS for review and concurrence. The HOR monitoring plan shall include:

4.d.i. Reclamation and DWR shall monitor juvenile migration both upstream and downstream of the proposed gate at the head of Old River during outmigration of spring-run Chinook salmon and steelhead to determine the percentage of juveniles that do not remain in the mainstem of the San Joaquin River and instead are entrained into Old River. Monitoring shall begin before construction, continue during construction, and be maintained after completion of construction for 10 years, or for a duration of length that the HGTT determines includes a robust range of hydrologic and population conditions. Monitoring shall be reported to NMFS on an annual basis, included in the annual reporting requirements set forth in Term and Condition 2.c.

4.d.ii. Reclamation and DWR shall continue to monitor water quality in the San Joaquin River and south Delta (to include the Stockton Deep Water Ship Channel) to assess the efficacy of the head of Old River gate to maintain (and, consistent with BA Section 3.2 Conveyance Facility Construction, improve in fall months) water quality in those areas. Monitoring of these areas shall be conducted in the fall to determine if water quality improvements as stated in Section 3.3.2.3 of the BA Operational Criteria for the Head of Old River Gate are being realized. At a minimum, temperature, salinity, and dissolved oxygen shall be evaluated and compared to baseline conditions. Monitoring shall begin before construction, continue during construction, and be maintained after completion of construction for 10 years or long enough to provide a robust range of hydrologic and population conditions. Monitoring shall be reported to NMFS on an annual basis. Findings shall be included in the annual reporting requirements set forth in Term and Condition 2.c.

4.d.iii. Reclamation and DWR shall conduct hydrologic monitoring to determine the amount of flow that is available for the accompanying fish ladder and Auxiliary Water Supply (AWS). Hydrologic data shall be used to inform an operations plan for the fish ladder and AWS. This operations plan shall be developed by the HGTT and submitted to NMFS for review and concurrence.

4.d.iv. Upon development of gate design, the HGTT will also establish passage performance standards for the ladder and provisions for modifications if the standard is not met. This will be included in a report submitted to NMFS for review and concurrence consistent with the annual reporting requirements set forth in Term and Condition 2.c. Reclamation and DWR shall monitor fish passage performance at the HOR fish ladder. Specifically, this team shall monitor flows through the ladder (including impediment of flow due to sediment accumulation) and assess passage rates under varying hydrologic conditions (seasonal variation as well as inter-annual variation in flow). Flow data and passage rates shall be reported to NMFS on an annual basis. Findings shall be included in the annual reporting requirements set forth in Term and Condition 2.c.

4.d.v. Depending on the ladder type, Reclamation and DWR will monitor pool depth, velocity through slot if vertical slot ladder, water surface differentials through a range of operating conditions, sediment and debris buildup in ladder, and auxiliary water supply.

4.d.vi. Reclamation and DWR shall monitor the boat lock at the HOR gate facility. The operable gates shall be monitored for a minimum of 10 migration seasons or a duration long enough to include a range of hydrologic and population conditions to determine if fish are negatively impacted from the operation. Monitoring data shall be provided to NMFS annually in accordance with reporting requirements described in Term and Condition 2.c.

4.d.vii. DWR shall monitor juvenile predation in the fish ladder and at the entrance and exit, and in the vicinity of the HOR gate facility following completion of construction. NMFS suggests adopting methods similar to those described in Demetras et al. (2016) to monitor predation at a fine spatial scale. If predation is observed at rates that are above the observed baseline, the HGTT shall develop methods within a year to avoid or minimize predation effects and submit these methods to NMFS for review and concurrence. Data on predatory fish community composition and abundance shall be reported to NMFS on an annual basis for the duration of the monitoring plan in accordance with reporting requirements described in Term and Condition 2.c.

4.d.viii. Reclamation and DWR shall monitor noise levels at the facility to determine if the operations exceed levels established as take thresholds in this biological opinion for other construction components. Noise data shall be reported to NMFS on an annual basis for the duration of the monitoring plan in accordance with reporting requirements described in Term and Condition 2.c.

4.d.ix. The HOR monitoring plan shall include performance standards for the HOR gate and all of its associated appurtenances. Performance standards shall include (but are not limited to) criteria for operability, maximum allowable levels of sediment build-up, and maximum allowable levels of predatory fish abundance within the facility footprint. Reclamation and DWR shall develop and implement an operation and maintenance plan that outlines maintenance requirements that will ensure HOR components meet the established performance measures. This operations and maintenance plan shall comply with requirements in Term and Condition 13.a. It may be reviewed by the IICG annually and amended as necessary to ensure that established performance standards are met.

4.d.x. As part of the implementing the HOR monitoring plan, Reclamation and DWR shall ensure that project biologists oversee fish rescue operations at HOR construction sites and that these operations comply with requirements described in the Terms and Conditions for RPM 10.a. through e.

4.d.xi. Reclamation and DWR shall consider designs such as radial or top-hinged gates that would allow a reduced footprint and minimization of bed disturbance and habitat loss is minimized and potential for the creation of localized hydraulic conditions that increase predation risk for salmonids.

4.e. Reclamation and DWR shall ensure that the HMTT incorporates the development and implementation of a habitat monitoring plan into their team Charter and develops a work schedule for study activities in accordance with the team framework and schedule requirements as described in Term and Condition 2.a. Reclamation and DWR shall monitor implementation and efficacy of restoration actions performed as a result of this consultation to mitigate for impacts to listed species and their critical habitat. Reclamation and DWR shall include monitoring data and analysis in the annual report per the instructions in Term and Condition 2.c.

4.e.i. Reclamation and DWR shall develop and report annually to NMFS, including a detailed description of mitigation actions that occurred in the previous year, status of restored areas, replanting ratios and vegetation species used, habitat types restored, contribution of each year's mitigation actions to the entire requirement established during this consultation, financial report describing restoration spending, and a list of restoration priorities for the following three years.

4.f. Within two years of biological opinion issuance, Reclamation and DWR, in coordination with DOSS, shall develop and submit to NMFS for review and concurrence, a plan that minimizes sampling error associated with using length-at-date criteria when identifying juvenile Chinook salmon in research and monitoring programs required by this Opinion. The plan shall include a supplement to or replacement of length-at-date monitoring with genetic sampling, in order to minimize take of listed fish associated with real-time operations, improve annual evaluations of the effectiveness of operating criteria in this Opinion to inform the Adaptive Management Program, and accurately measure take at the north Delta and south Delta facilities. Reclamation and DWR shall implement the plan.

4.f.i. Reclamation and DWR, in coordination with DOSS, shall execute a memorandum of agreement with the monitoring entities to implement sampling methods to obtain tissue samples from a representative number of listed juvenile Chinook salmon and juvenile steelhead that are obtained in the following monitoring programs:

- USFWS Red Bluff Diversion Dam rotary screw trap monitoring station
- USFWS Tisdale and Knight's Landing rotary screw trap monitoring stations
- CDFW's fyke traps on the mainstem Sacramento River
- CDFW's Central Valley steelhead monitoring program
- USFWS/CDFW's Delta Juvenile Fish Monitoring Trawls at West Sacramento, Chipps Island, and Mossdale sampling sites

4.f.ii. Reclamation and DWR, in coordination with DOSS, shall develop protocols for using genetic identification and statistical methods to identify the ESU of every juvenile Chinook salmon obtained in the monitoring programs listed above in Term and Condition 4.f.i.

4.f.iii. Upon implementation of genetic identification protocols, Reclamation and DWR shall use ESU identification data obtained in Central Valley monitoring efforts to inform survival studies described in the Terms and Conditions for RPM 4.

5. The following terms and conditions implement reasonable and prudent measure 5 (Implement a phased test period at the NDD to include monitoring of biological and physical parameters across a range of pumping rates and flow conditions prior to operating the north Delta diversions at full capacity.):

5.a. DWR, in close collaboration with NMFS and DFW, will develop detailed plan for appropriate tests and use those tests to evaluate facility performance across a range of pumping rates and flow conditions. The experimental design is subject to review and concurrence by NMFS. This phased testing period of the NDD will include biological studies and monitoring efforts to enable the measurement of survival rates (both within the screening reach and downstream to Chipps Island) and other relevant biological parameters that may be affected by the operation of the new intakes.

As identified in BA Section 3.3.2.1 Operational Criteria for North Delta CVP/SWP Export Facilities, NMFS, in coordination with the other fish and wildlife agencies, will retain the responsibility for evaluating and determining whether the diversion structures are achieving performance standards for covered fish over the course of the operations, and it retains responsibility for determination of the operational criteria and constraints (i.e., which pumping stations are operated and at what pumping rate) during testing. NMFS, in coordination with the other fish and wildlife agencies, shall determine when the testing period should end and full operations consistent with developed operating criteria can commence. In making this determination, fish and wildlife agencies expect and will consider that, depending on hydrology, it may be difficult to test for a full range of conditions prior to commencing full operations. Therefore, tests of the facility to ensure biological performance standards are met are expected to continue intermittently after full operations begin, to enable testing to be completed for different pumping levels during infrequently occurring hydrologic conditions.

5.b. Within five years after issuance of the biological opinion, the FFTT shall complete and submit to NMFS for review and concurrence a NDD testing plan that includes provisions to monitor sweeping velocity and approach velocity at the intake faces, juvenile survival and reduction in fitness of juveniles related to impingement and entrainment, the rate of predator recruitment and efficacy of fish refugia for predator avoidance, and the ability of the operations of the north Delta diversions to respond to hydrodynamic conditions such that the operations of the NDD conform to the operational criteria of the NDD, as stated in BA Section 3.3.2.1, that flow reversals in the Sacramento River at the Georgiana Slough junction will not increase in magnitude, frequency, or duration above pre-north Delta diversion operations levels. If a plan is not submitted to and concurred with by NMFS within the specified timeline, then NMFS will provide a plan for use when operations commence.

5.c. DWR shall contract with the Delta Science Program to complete an independent science panel review of the NDD testing plan prior to implementation of the plan and a separate review of testing period results prior to full operations of the NDD.

6. The following terms and conditions implement reasonable and prudent measure 6 (Ensure that the activities identified in BA Appendix 3.H Adaptive Management Program (AMP) are scientifically robust, in accordance with the implementation structure, and reasonably certain to occur as described in the administrative record for this biological opinion, regarding interagency assessments of AMP continuing and new funding needs.):

6.a. Reclamation and DWR shall implement monitoring and scientific research actions detailed in the AMP, as coordinated through the IICG, as this effort is required for purposes of monitoring and continuous minimization of take associated with the scientific uncertainties outlined in the analysis contained in this biological opinion. Continuation of core monitoring specified in the NMFS (2009) biological opinion, or the then-governing biological opinion, is required as part of the AMP and included in this Opinion.

6.b. Reclamation and DWR shall prepare and submit to NMFS within one year of biological opinion issuance an initial Adaptive Management Program funding strategy for review and concurrence. The interagency adaptive management effort that developed the Adaptive Management Plan and Agreement for Implementation has identified existing and new monitoring and study efforts to be implemented as part of the AMP in the near term (i.e., 2019-2024) and longer term (i.e., 2025 and later) (see Implementation Schedule for this Adaptive Management Program for the Existing Biological Opinions and CESA Authorizations for the Long-term Operations of the CVP and SWP and for CWF, Appendix 8 to BA Appendix 3.H). The studies that have been identified as ongoing during the near term or required by this Opinion to begin within the near term are identified in the interagency funding assessment documents (e.g., Interagency AMP funding spreadsheet (Wilcox 2017)). The existing annual budget for the studies included in this subset is estimated at $26,700,000. The estimated initial additional annual funding needed to implement the remaining salmonid and sturgeon related studies included in this subset is $60,000,000. Actual funding may be higher or lower than this estimate. This additional funding should include, at a minimum, the following components:

i. Implementation of SAIL recommendations, as an improvement to the core monitoring program
ii. Baseline studies for the north Delta diversions
iii. Improvements to acoustic arrays throughout the Delta, and improved capacity to process acoustic data
iv. Effectiveness monitoring associated with Georgiana Slough barrier
v. Implementation of Collaborative Adaptive Management Team (CAMT) recommendations for salmonids as a result of Salmon Scoping Team report (CAMT 2017)
vi. Salmon life cycle modelling
vii. Predation related studies, including monitoring components of CCF predator control
viii. Baseline studies associated with habitat restoration required in this Opinion.
ix. Additional modelling and decision support (including, for example, e-PTM and data access improvements)
x. Genetic testing to supplement length at date criteria
xi. Costs associated with independent science reviews of products associated with the AMP

Therefore, Reclamation and DWR shall develop a funding strategy that clearly identifies responsible parties and levels of annual and total program funding consistent with the above identified funding needs for implementation of the AMP starting in 2019. The strategy shall include detailed funding and commitments for the first five years (2019-2024), and lesser detail for the studies required after 2024.

Consistent with the role of the IICG as detailed in the AMP, Reclamation and DWR shall submit annual updates to the strategy to NMFS for review and concurrence. These updates should include extension of the detailed funding strategy for five years post submission date. To the degree that annual appropriations are relied upon, the funding strategy shall demonstrate that those funds have been appropriated, similar levels of annual appropriations have been consistently available in past years, and/or that those funds are planned for subsequent appropriations processes. NMFS anticipates that these conditions are fully consistent with the AMP, including the role of the IICG.

6.c. As identified in the Agreement for Implementation of an Adaptive Management Program for Project Operations (Appendix 8 of BA Appendix 3.H), IICG Manager shall manage preparation of the Annual Monitoring and Research Plan. Reclamation and DWR, in coordination with the IICG, shall refer management related actions or proposals, as appropriate, to the Delta Science Program for review by an independent science panel consistent with that agreement.

6.d. With technical assistance from NMFS, Reclamation shall continue development of a peer-reviewed Chinook salmon life-cycle model to refine understanding of how water operations, climate change, and habitat measures upstream and in the Delta, including those proposed as part of the PA, affect the continued existence of the species. Reclamation shall submit this model to NMFS for review and concurrence.

7. The following terms and conditions implement reasonable and prudent measure 7 (Minimize take associated with acoustic disturbance from pile driving, geotechnical boring, and barge operations.):

7.a. Reclamation and DWR, in consultation with the FFTT, BOTT, CCFTT, and HGTT, shall develop an Underwater Noise Monitoring Plan. Components of the plan shall be consistent with terms and conditions 7.b. through h., and shall be submitted to NMFS for review and concurrence prior to implementation of any in-water impact pile driving activities or barge operations. The plan shall evaluate the potential effects of underwater noise on listed species of fish in the context of thresholds established in Section 2.9.1.1.1 Acoustic Stressors. The plan must include the number of piles to be installed, the material composition and size of the piles, and estimated strikes per day based on geotechnical test results. Following completion of pile driving activity, Reclamation and DWR shall provide NMFS with a detailed report including hydroacoustic data and analysis gathered during pile driving activities per the Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish (Caltrans 2015), and follow guidelines contained in Appendix II and Appendix IV of this document for monitoring and reporting in accordance with the Federal Highway Working Group's (FHWG) Underwater Noise Monitoring Plan template. This report shall be included in the annual reporting requirements described in Term and Condition 2.c.

7.b. Acoustic monitoring shall occur throughout the duration of pile driving activities in accordance with the Federal Highway Working Group's (FHWG) Underwater Noise Monitoring Plan template. Physiological stressors to fish, including acute injury and behavioral effects, are described in detail in Section 2.5.1.1.1 Acoustic Stress. Acute injury may include hemorrhaging and rupturing of blood vessels and internal organs or external damage, such as loss of scales or hematoma. Behavioral impacts may include startle responses, changes in swimming directions and speeds, increased group cohesion, and bottom diving. Pile driving in the immediate area in which a noise exceedance occurs shall cease immediately if sound levels with abatement (e.g., measured outside the bubble curtains) exceed the thresholds described in Section 2.9.1.1.1.1 Pile Driving Actions.

7.c. Reclamation and DWR shall ensure the efficacy of bubble curtains (≥5 dB reduction) or any other sound attenuation methods that are to be used to reduce acoustic impacts resulting from in water pile driving. Provisions to monitor the efficacy of sound attenuation methods shall be included in the Underwater Noise Monitoring Plan described in Term and Condition 7.a.

7.d. Reclamation and DWR shall notify NMFS immediately if thresholds measured with abatement established in Section 2.9.1.1.1 Acoustic Stressors are exceeded. Pile driving activities in the immediate area in which a noise exceedance occurs shall be suspended until NMFS, DWR, and Reclamation have determined appropriate corrective action.

7.e. Reclamation and DWR shall monitor the water surrounding sites containing pile driving, geotechnical boring, and barge activities for take of listed fish species within the distances and specifications described in Section 2.9.1.1.1 Acoustic Stressors. Mortalities shall be handled and reported in accordance with instructions provided in Term and Condition 15.b.

7.f. In accordance with details described in AMM 1.b., Reclamation and DWR shall use vibratory pile driving methods to the greatest extent practicable to reduce the frequency and duration of impact pile driving throughout the course of the PA. Consistent with an approved monitoring approach, monitoring shall be conducted during vibratory pile driving to ensure that thresholds for behavioral impacts are not exceeded as described in Section 2.9.1.1.1 Acoustic Stressors. Precautionary methods described in AMM 1.b. shall be implemented in all pile driving activities associated with the PA.

7.g. Reclamation and DWR shall monitor sound generated by in-water geotechnical boring at a single representative site per intake at a 10m range from the boring site, and at a depth of 1m. This data shall be used to determine the extent of the 150dB noise threshold established by NMFS for behavioral effects to anadromous fish. Upon completion of 6 months of geotechnical boring activity, noise data and analysis shall be provided to NMFS by Reclamation and DWR via the reporting instructions described in Term and Condition 2.c., and subsequent reports shall be provided every 6 months.

7.h. Reclamation and DWR shall monitor a representative site for sound generated by barge traffic at a 100 yd range from the vessel transit line to determine if vessel-generated sound has exceeded the 150 dB noise threshold established by NMFS for behavioral effects to anadromous fish. In addition to monitoring vessel noise, natural and ambient background noise shall be determined in an environment free of barge traffic to establish baseline noise occurring within vessel transit lines. To adhere to the incidental take analysis, speed of the tugboat and barge string will be 5 knots loaded and 8 knots unloaded, which is equivalent to 8.43 feet per second at 5 knots and 13.5 feet per second at 8 knots. Operational limitations regarding vessel maneuvering and handling, as described in AMM 7 in Appendix 3.F of the BA shall not be exceeded. Upon completion of 6 months of barge operations activity, noise data and analysis shall be provided to NMFS by Reclamation and DWR via the reporting instructions described in Term and Condition 2.c., and subsequent reports shall be provided every 6 months.

8. The following terms and conditions implement reasonable and prudent measure 8 (Minimize turbidity and sedimentation events resulting from the construction of the NDD, HOR gate and its associated appurtenances, barge landing sites, and any other actions resulting in disturbance to sediment in the vicinity of a waterway (e.g., temporary roads, access paths).):

8.a. Reclamation and DWR, in coordination with the FFTT, BOTT, CCFTT, and HGTT, shall ensure the development and implementation of a turbidity and sedimentation monitoring plan consistent with Clean Water Act section 401 and NPDES permit requirements. Turbidity and sedimentation monitoring plans shall include the following:

8.a.i. Turbidity monitoring shall occur both upstream and downstream (100 yds in each direction) of sites where construction activity could increase suspended sediment concentrations (activities include but are not limited to: pile driving; geotechnical boring; dredging; and terrestrial clearing and grubbing). Upstream sites will be used to determine baseline ambient turbidity levels, and downstream sites will be used to determine turbidity generated by construction activities.

8.a.ii. Suspended sediment concentration levels must adhere to National Pollutant Discharge Elimination System (NPDES) permit and any other applicable Central Valley Regional Water Quality Control Board requirements. In the event that turbidity levels exceed the maximum allowable levels in any water quality permits issued for the PA, and maximum levels described in the incidental take statement (Section 2.9.1.1.2 Suspended Sediments and Contaminants), work in the area where the exceedance occurred shall cease and may not resume until the cause of the elevated turbidity has been identified and addressed such that it will not continue.

8.a.iii. Turbidity and sedimentation monitoring plans shall include provisions to ensure that erosion control measures described in AMM 2 are implemented on water-side levee faces during and following construction actions that may disturb soils adjacent to an active waterway. Water-side levee faces shall be regraded and revegetated in accordance with AMM 2 and prior to October 1 following temporary disturbance to minimize erosion prior to the subsequent rainy season.

8.a.iv. Reclamation and DWR shall provide the reports required under Clean Water Act section 401 and NPDES permits to NMFS, related to turbidity and sedimentation, and may substitute monitoring required by the Clean Water Act section 401 for other monitoring described herein upon concurrence from NMFS.

9. The following terms and conditions implement reasonable and prudent measure 9 (Minimize exposure of listed species to contaminants that may be re-mobilized due to benthic disturbance associated with pile-driving, dredging, geotechnical boring, barge operations, or other activities, or contaminants that may be introduced in the course of construction activities.):

9.a. Reclamation and DWR, in coordination with the FFTT, BOTT, CCFTT, and HGTT, shall ensure the development and implementation of a contaminant monitoring plan per the requirements described in Term and Condition 2.c. Contaminant monitoring plans shall include a comprehensive monitoring plan to conduct contaminant screening in both water and sediment in the vicinity of the PA construction sites in which disturbance to sediment is likely to occur. Contaminants described in Section 2.9.1.1.2.3 Dissolved Toxic Contaminants of the incidental take statement shall be monitored for in all phases of construction. Suspended sediment and contaminant concentrations shall be characterized though this monitoring plan and concentration exceedance shall be determined based on Table2-271. Components of this monitoring plan shall include:

- A procedure to reduce concentration of contaminants from the proposed action area that exceed levels described in Table 2-271. Reclamation and DWR shall use information from geotechnical surveys to identify areas of heightened contaminant concentrations in sedimentary horizons.
- A list of prioritized actions that will be implemented to avoid or minimize contaminant threshold exceedances described in Table 2-271.
- A detailed report of geotechnical survey data generated through implementation of this monitoring plan, which Reclamation and DWR shall provide to NMFS at least 90 days prior to commencement of other in-water construction activities or subsequent maintenance activities in which sediment will be disturbed. Reporting shall occur in accordance with instruction in Term and Condition 2.a.

9.b. In coordination with NMFS, Reclamation and DWR shall develop procedures to ensure that silt curtains used in the dredging of Clifton Court Forebay are moved in such a manner to maintain containment of re-suspended sediment within the silt curtain enclosure.

Procedures shall adhere to turbidity thresholds identified in the monitoring plan described above in Term and Condition 8.a.

9.c. Reclamation and DWR shall dispose of dredged spoil materials in compliance with requirements set forth by the Corps and any permits issued for dredging operations under the PA.

9.d. Reclamation and DWR shall evaluate the species community composition and abundance of benthic invertebrates within a 100 m radius of the footprints of NDD and HOR gate facilities prior to construction to establish baseline conditions of prey items that may act as contaminant vectors for DPS green sturgeon. Reclamation and DWR shall continue to monitor species composition and abundance of benthic invertebrates for three years on an annual basis to document recolonization following disturbance to benthic substrate in the course of construction and maintenance of NDD and HOR facilities. Reclamation and DWR shall provide NMFS data on invertebrate community and abundance collected under this term and condition on an annual basis in accordance with reporting requirements described in Term and Condition 2.c.

9.e. Reclamation and DWR shall adhere to NPDES permits and any other applicable Central Valley Regional Water Quality Control Board requirements. In the event that contaminant levels exceed the maximum allowable levels as a result of construction or maintenance activities in any water quality permits issued for the PA, or maximum levels described in the incidental take statement of this biological opinion (Section 2.9.1.1.2.3 Dissolved Toxic Contaminants), work in the area where the exceedance occurred shall cease and may not resume until the cause of elevated contaminant levels has been identified and addressed such that it will not continue.

9.f. Annual reporting by Reclamation and DWR as described in Term and Condition 2.c. shall include contaminant concentration data taken through monitoring activities, information on sedimentation events that are suspected to have released contaminated sedimentary material, spill events, and any challenges associated with implementing BMPs related to turbidity and sedimentation as described in Appendix 3.F of the BA General Avoidance and Minimization Measures.

10. The following terms and conditions implement reasonable and prudent measure 10 (Minimize physical and behavioral impacts to listed fish, including disruption of normal behaviors, displacement, and increased stress levels, during all construction phases.):

10.a. Reclamation and DWR shall notify NMFS within one working day of the discovery of, injury to, or mortality of a listed species that results from proposed action-related construction activities or is observed at the project site. Notification and reporting shall be made in accordance with the instructions in Terms and Conditions 15.a. and b. If a listed species is injured, general information on the type or extent of injury shall be included. The location of the incident shall be clearly indicated on a U.S. Geological Survey 7.5-minute quadrangle map. The biologist reporting the incident shall include any other pertinent information in the notification.

10.b. Reclamation and DWR shall ensure that biological monitors are on site for the following activities:

- During monitoring activities described in terms and conditions under RPM 5 involving phased testing of the NDD facilities.
- Any activity involving fish rescue and/or relocation.
- Installation of sound attenuation devices and implementation of attenuation methods as described in Term and Condition 7.a through e, and commencement of pile driving activities.
- During sweeping of cofferdam area for fish herding and coffer dam closure.
- Construction components for fish passage.
- Monitoring of hydraulic analysis and tuning of screen intake baffles.
- Initial watering-up of facilities.

Reclamation and DWR shall ensure that biological monitors are professional biologists selected for their knowledge of the listed species that may be affected by construction activities. The biological monitors shall have the authority to temporarily stop work in any area where a listed species has been observed to be at risk of take until that individual is no longer at risk of take.

10.c. Reclamation and DWR or designees shall provide training to field management and construction personnel on the importance of protecting sensitive natural resources (i.e., listed species and designated critical and/or suitable habitat for listed species). Training will be conducted during preconstruction meetings so that construction personnel are aware of their responsibilities and the importance of compliance. All trainees will be required to sign a sheet indicating their attendance and completion of environmental training. The training sheets will be provided to NMFS if requested. These requirements also pertain to operations and maintenance personnel working on proposed action-related operations or facilities maintenance in and adjacent to waterways. Reclamation and DWR shall ensure that construction personnel are educated on the types of sensitive natural resources located in the project area and the measures required to avoid and minimize effects on these resources. All construction personnel shall be provided with a copy of Appendix 3.F, General Avoidance and Minimization Measures, included in the BA. Materials covered in the training program shall include environmental rules and regulations for the specific project, requirements for limiting activities to approved work areas, timing restrictions, and avoidance of sensitive resource areas. Trainings shall include (and shall not be limited to) the following components:

- Important timing windows for listed species including the timing of fish migration, spawning, and rearing.
- Specific training related to the relevant AMMs that will be implemented during construction for the protection of listed species and their habitat.
- The legal requirements for sensitive natural resource avoidance and protection.
- Identification of listed species potentially affected at the worksite.
- Protocol for identifying the proper AMMs to implement for the protection of listed species based upon the nature, timing, and location of construction activities to be performed.
- An overview of the basic life history of listed species addressed in this Opinion.
- Boundaries of the work area.
- Avoidance and minimization commitments.

- Exclusion and construction fencing methods.
- Roles and responsibilities.
- What to do when listed species are encountered (dead, injured, stressed, or entrapped) in work areas.

10.d. Reclamation and DWR shall ensure that a fact sheet, in addition to a copy of Appendix 3.F of the BA, containing information on Avoidance and Minimization Measures included in the PA is prepared and will be distributed along with a list of contacts (names, numbers, and affiliations) prior to initiating construction activities. A representative will be appointed by the project proponent to be the primary point of contact for any employee or contractor who might inadvertently take a listed species, and the representative's name and telephone number shall be provided to NMFS.

If new construction personnel are added to the project following commencement of construction, Reclamation and DWR shall ensure that the personnel receive a copy of Appendix 3.F of the BA, a copy of the fact sheet described above in Term and Condition 10.d, as well as mandatory training and sign a sheet indicating their attendance and completion of the environmental training before starting work. The training sheets for new construction personnel shall be provided to NMFS, if requested.

10.e. Reclamation and DWR shall ensure that fish rescue and relocation are carried out in accordance with protocols included in AMM 8 in the BA. Reclamation and DWR shall provide NMFS with any proposed changes to the details included in AMM 8 for review and concurrence at least three months prior to desired implementation. In addition, Reclamation and DWR shall provide NMFS with the proposed placement location(s) of fish that need to be relocated as a result of dewatering associated with the PA for NMFS' review and concurrence prior to relocation to the location(s). Monitoring of fish handling activities at CCF, NDD, barge landing, and HOR sites will be overseen by Reclamation and DWR. Resuscitation requirements set forth in Appendix 3.F of the BA AMM 8 and Section 2.9.1.1.5.4 Fish Salvage and Rescue Actions of the take statement shall be met with regard to all fish relocation activities associated with the PA. Mortalities of listed species that occur as a result of fish relocation activities shall be handled and reported to NMFS on a daily basis in accordance with the instructions in Term and Condition 15.b.

11. The following terms and conditions implement reasonable and prudent measure 11 (Minimize impacts to migratory behavior of listed species in the Delta due to reductions in flow downstream of the NDD sites.):

11.a. Reclamation and DWR shall, in coordination with DOSS, develop and implement an initial approach to real-time operations of the north Delta diversions consistent with BA Section 3.3.3.1 North Delta Diversions, unless adjusted prior to operations of the NDD. Any revisions to the initial approach to initial operations shall occur through the AMP and shall be reviewed and concurred with by NMFS prior to implementation. Changes to criteria shall be included in annual reports (detailed in Term and Condition 2.c).

11.b. Reclamation and DWR shall design the NDD to implement operational criteria of BA Section 3.3.2.1 such that flow reversals in the Sacramento River at the Georgiana Slough junction will not increase in magnitude, frequency, or duration, above pre-north Delta diversion operations levels. The north Delta diversions shall be designed such that diversion rates can be adjusted (though not fully ramped down) within an hour, as identified in BA

Section 3.3.2 Operational Criteria, or as rapidly as feasible. The FFTT shall include in their Charter development of facility design and operations that would implement these criteria.

11.c. Reclamation and DWR shall ensure that the FFTT includes in its Charter and activities evaluation of Delta hydrodynamics as related to increasing the understanding of tidal forcing and flow conditions in the Sacramento River at the Georgiana Slough junction. Reclamation and DWR shall submit to NMFS for review and concurrence a research and monitoring plan to investigate conditions of Delta hydrodynamics, species presence and behavior, and the interaction of the two from the three intake structures, pre- and post- construction through a series of laboratory, field, and modeling investigations. These studies would support ability to meet the operational criteria of BA Section 3.3.2.1 such that flow reversals in the Sacramento River at the Georgiana Slough junction will not increase in magnitude, frequency, or duration above pre-north Delta diversion operations levels, such that take associated with entrainment of juvenile salmonids into the central Delta is minimized. All pre-construction studies shall commence within one year of concurrence by NMFS. Specifically, these studies shall consider:

- Flow-survival relationships for listed species addressed in this biological opinion for a range of water year types, operational conditions, and species population conditions.
- The spatial and temporal distribution of outmigrating Chinook salmon in order to characterize rearing behavior in the Sacramento River as well as dynamics of outmigration.
- The hydrodynamic conditions at Georgiana Slough junction as related to conditions at other locations in the Delta, providing assurance that NDD operations can be executed in a way that adheres to the operational criteria of not increasing the magnitude, duration, or frequency of reverse flows at that junction.
- The determination of a reverse flow baseline in the Sacramento River at the Georgiana Slough junction. This baseline will be established to identify the benchmark condition of reverse flow frequency, duration, and magnitude given riverine flow conditions, time of year, tidal cycle, and tidal phase; all operational levels of the PA shall use this benchmark as an operational criterion of the NDD, as stated in BA Section 3.3.2.1. Exacerbation of the frequency, duration, or magnitude of reverse flows will be evaluated with respect to impacts on both survival and critical habitat PBFs for listed fish species.

11d. In implementation of a nonphysical fish barrier at Georgiana Slough as identified in BA Section 3.4.3.1.1.1, Reclamation and DWR shall monitor the reduction of entrainment into Georgiana Slough for a minimum of ten years to include a robust representation of a range of water year types, CVP/SWP operational conditions, and population conditions.

12. The following terms and conditions implement reasonable and prudent measure 12 (Minimize impacts to rearing behavior of listed species in the Delta due to reductions in flow downstream of the NDD sites.):

12.a. Reclamation and DWR shall ensure that the Habitat Mitigation Technical Team (HMTT) to develop and submit to NMFS for review and concurrence plans for habitat restoration proposed in Section 3.4.3.1.2 Restoration Actions of the biological assessment. These plans shall include performance measures specific to the amount, type, and location of restoration. These restoration actions are expected to minimize and offset effects of the project on listed salmonids. Consistent with BA Section 3.4.3.1.2 Restoration Actions, the restoration is expected to contribute to improved growth, survival, and migratory success of juvenile winter-run and spring-run Chinook salmon and steelhead.

12.b. The HMTT shall include in its charter the identification of restoration goals (e.g., increase floodplain inundation frequency; increase acreage of available tidal habitat) that shall be submitted to NMFS for concurrence prior to implementation. Restoration actions shall be consistent with the Sacramento Valley Salmon Resiliency Strategy (California Natural Resources Agency 2017) and for both salmonids and green sturgeon to the extent practicable.

12.c. Restoration to mitigate for temporary impacts shall prioritize in-place, in-kind restoration activities to the maximum extent practicable. Offsite restoration shall occur only if concurred with by NMFS and offsite restoration activities shall be implemented in coordination with the HMTT.

12.d. Reclamation and DWR, consistent with the continuing DOSS real-time operations process identified in BA Section 3.1.7, shall optimize the real-time operations of BA Section 3.3.3.1 to allow for the project's objective of water diversion while seeking, where feasible, to achieve survival rates greater than those exempted in the incidental take statement. By operating to a take level below the maximum allowable, negative impacts to salmonids migrating through the Delta will be reduced.

12.e. Reclamation and DWR shall, in coordination with DOSS, develop a real-time operations plan consistent with BA Section 3.3.3.1 North Delta Diversion and Term and Condition 11.a. such that the reduction in through-Delta survival due to operations of the PA, which is the surrogate for the incidental take of listed salmonids, is minimized. Operations plans that are not consistent with BA Section 3.3.3.1 shall not be implemented without submission to and concurrence from NMFS. These operations shall also adhere to the commitments in BA Section 3.4.3.1.2 Restoration Actions that the SWP operate to achieve pre-project winter-run and spring-run Chinook salmon survival rates at Chipps Island (initial target survival rate of 40%) and, consistent with conditions of the draft CDFW California Fish and Game Code Section 2081(b) ITP, that target survival rates may be achieved through the use of alternative migratory routes or other mitigation efforts. Revisions to these criteria shall be coordinated by DOSS and included in annual reports (detailed in Term and Condition 2.c.) for review and concurrence by NMFS.

13. The following terms and conditions implement reasonable and prudent measure 13 (Minimize effects to listed species due to maintenance activities associated with all facilities.):

13.a. Reclamation and DWR shall submit to NMFS for review and concurrence maintenance plans for at the north Delta diversions, the head of Old River gate and its associated appurtenances, the weirs and sluices of CCF, and any permanent barge landings. Reclamation and DWR shall use the respective technical team (i.e., FFTT, HORGTT, CCFTT, BOTT) to contribute to development of maintenance plans consistent with terms and conditions 2.a. through d.

14. The following terms and conditions implement reasonable and prudent measure 14 (Minimize the effects to listed species due to the revised operations of the existing south Delta export facilities at the CVP and SWP when CWF operations commence.):

14.a. Reclamation and DWR shall ensure appropriate staff including biologists are present at the SWP Skinner Delta Fish Protective Facility (SFF) and CVP Tracy Fish Collection Facility (TFCF) at all times that salvage of ESA-listed fish may occur.

14.b. Unless superseded in subsequent consultation, Reclamation and DWR shall develop and submit to NMFS for review and concurrence within five years of issuance of the biological opinion a protocol that outlines pumping restrictions and loss estimated during salvage disruptions. This plan shall be required for commencement of operations of the PA; if a plan is not submitted to and concurred with by NMFS within the specified timeline, then NMFS will provide a plan for use when operations commence.

14.c. Except when required for structural differences between the salvage facilities, DWR and Reclamation will standardize across facilities salvage, fish handling, and reporting protocols, which must be reviewed and concurred with by NMFS. Standardized protocols for the SFF and TFCF must be in place before the North Delta Diversions are in operation, and thereafter should be reviewed and any needed revisions made as soon as is reasonable.

14.d. Reclamation and DWR will work with the IICG and IEP to review, consolidate, and accommodate researcher requests related to special handling of salvaged fish (e.g., release of ad-clipped sutured fish; checking for acoustic tags) unless not practicable. Reclamation and DWR shall respond to such consolidated requests at least annually to assist the IICG and IEP with planning for future years, and any denial of accommodation shall be explained in writing.

14.e. Reclamation and DWR shall report weekly to NMFS and the interagency DAT the incidental take associated with operations of the south Delta export facilities, reporting both salvage and (when available) loss for winter-run, spring-run, fall-run and late-fall-run Chinook salmon, steelhead, and green sturgeon.

14.e.i. During October through June, DWR and Reclamation shall prepare and submit to NMFS and DAT and DOSS weekly reports summarizing salvage and loss over the previous week and for the water year to date.

14.e.ii. No later than November 15, DWR and Reclamation shall submit to NMFS an annual report summarizing salvage and loss over the previous water year (October 1-September 31).

14f. DNA tissue samples and CWT samples from juvenile winter-run and spring-run Chinook salmon and steelhead at the TFCF and SFF shall be collected for genetic analysis or tag removal/reading pursuant to appropriate sampling protocols. Reclamation and DWR shall develop and submit for review and concurrence by NMFS a plan for tissue and whole fish or head processing and storage.

14.g. In order to reduce uncertainties regarding the mechanisms and extent of take in the form of juvenile salmonid behavioral modifications to hydrodynamic changes in the south Delta that are associated with water operations, Reclamation and DWR shall, in close coordination with NMFS, using the Collaborative Science and Adaptive Management Program (CSAMP), IEP, and IICG processes at their discretion, and consistent with the AMP in the CWF PA, implement the recommendations of the CAMT 2017 workplan for salmonids (Collaborative Adaptive Management Team 2017). As part of this workplan, Reclamation and DWR shall fund continued development of enhanced particle tracking modeling that is sensitive to realistic changes in south Delta operations, analyze existing data, and conduct experiments to assist in model development.

14.h. NMFS shall be informed weekly of the progress of the salvage rescue actions at the CVP and SWP fish collection facilities. In the event that the observed population of listed fish species that will require salvage and rescue is in the high hundreds (>500 individuals) or larger, NMFS shall be notified immediately upon this determination, and daily reports sent to NMFS detailing the running tally of mortalities for that location.

15. The following terms and conditions implement reasonable and prudent measures 1-14.

15.a. Any information that is required to be submitted to NMFS per the Terms and Conditions of this biological opinion shall be sent both electronically and by mail to the NMFS CCVO at the following addresses:

The CCVO Division Manager's email address (currently Jeff.McLain@noaa.gov), and via hard copy to:

NMFS CCVO

650 Capitol Mall, Suite 5-100

Sacramento, California 95814

15b. Any observations of mortalities or abnormal behavior shall immediately be reported to NMFS per the instructions in Term and Condition 15.a. within 24 hours. This information shall include species observed, life history stage, location (including GPS coordinates if available), number of fish observed, time of day, as well as any other relevant details that are available. If possible, mortalities shall be collected, frozen, individually labeled with appropriate information, and held for retrieval by NMFS law enforcement personnel.

2.10 Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02).

1. In addition to recovery plan components included in the Terms and Conditions of this BO, Reclamation and DWR should use species recovery plans to help ensure that their mitigation measures will address the underlying processes that limit fish recovery by identifying high priority actions in the action area. The final recovery plan for federally-listed Central Valley salmonids is available at:

   http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/california_central_valley/california_central_valley_salmon_recovery_domain.html

2. The NMFS sDPS North American Green Sturgeon Recovery Plan is expected to be finalized and published in 2017.
3. Reclamation should continue to work cooperatively with other State and Federal agencies, private landowners, governments, and local watershed groups to identify opportunities for cooperative analysis and funding to support salmonid and sturgeon habitat restoration projects within the Sacramento River Basin, Delta, and San Joaquin River Basin.
4. Reclamation and DWR should make all monitoring data collected by implementation of the PA publicly available in order to facilitate integration with concurrent ecological monitoring efforts related to anadromous fish in the California Central Valley.
5. Reclamation and DWR should develop and implement revegetation plans (including planting plans and monitoring plans) for construction activities. Development of revegetation plans should be included in technical team Charters as described in Term and Condition 2.c. Reclamation and DWR should re-vegetate onsite at a 3:1 ratio with native riparian species, immediately following the completion of construction activities for any area consisting of removed or disturbed vegetation in efforts to facilitate the development of SRA habitat. The first component of the revegetation plan should include a detailed planting plan including a list of species and designs depicting the proposed location for each species and their density. The second component should be a vegetation monitoring plan to evaluate the success of the re-vegetation efforts which would indicate the overall performance of the planted vegetation at each site and include guidelines for replacing vegetation that fails to establish. The vegetation monitoring plan should also include proposed irrigation and monitoring schedules which will likely be needed for several years to ensure full establishment of newly planted vegetation.
6. Reclamation should limit the amount of riprap used for bank and in-stream protection in the Central Valley to the minimum amount needed for erosion and scour protection and bench design. Engineering plans should be provided to the contractors that clearly show the amount of riprap to be placed at the project site. Where feasible, agricultural-grade soil should be incorporated into rip rap at a 70:30 rock/soil ratio by volume. Rock should be covered with 6-12 inches of soil and stabilized with an erosion control blanket. Soil should be replanted per the guidance in Conservation Recommendation 4.
7. Reclamation and DWR should consider using alternative methods to traditional rock slope protection for construction of infrastructure associated with the PA, incorporating geotextiles for bank erosion control and prevention. Bioengineered products are available on the market and can be used to protect areas against erosive forces along shorelines and is an alternative to using riprap.
8. Reclamation and DWR should pursue levee vegetation variances from the Corps to plant on levee prisms within project footprints.
9. Reclamation and DWR should post signs in the location of new infrastructure components within the Action Area about storm water pollution and runoff, advising citizens of the presence of listed fish species and to not discharge any chemicals, oils, or other waste products near the adjacent waterway.
10. Reclamation and DWR should post interpretive signs and artwork characterizing local species and ecological function of nearby aquatic systems.
11. Reclamation and DWR should ensure that all hydraulic fluids used in construction equipment are biodegradable.

12. Reclamation and DWR should apply hydroseed mixtures (and other spray-application erosion control measures that may be used on waterside levee slopes) in appropriate amounts, locations, and times of the year such that they minimize inorganic nutrients in surface run-off.
13. Reclamation and DWR should ensure that deterrent devices are installed on newly-constructed pilings, docks, and other infrastructure adjacent to waterways to reduce perching by piscivorous birds.
14. To the maximum practicable extent, Reclamation and DWR should use pre-cast concrete to minimize chemical leeching from curing cement that may come in contact with an active waterway.
15. Reclamation and DWR should ensure that concrete that is cast in place is covered with an impervious material until fully cured to prevent chemical leeching that may occur during a rainfall event.
16. To the maximum practicable extent, Reclamation and DWR should use existing roads and walkways for vehicle and pedestrian access to construction sites.

2.11 Reinitiation of Consultation

This concludes formal consultation for the California WaterFix Project.

As 50 CFR 402.16 states, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if: (1) The amount or extent of incidental taking specified in the ITS is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

The following are examples of when reinitiation of consultation will likely be warranted under 50 CFR 402.16:

1. The development and/or implementation of operational criteria by Reclamation and DWR that is not in accordance with the operational criteria included in the proposed action and analyzed in this Opinion or is not approved by NMFS before adoption and implementation. NMFS expects that operational criteria may be adjusted through the Adaptive Management Program. If an adaptive management adjustment is accompanied by analysis that demonstrates that the adjusted criteria is consistent with the analysis and incidental take statement of this Opinion and is not expected to cause an effect on listed species or critical habitat that was not considered in this Opinion, then NMFS may approve the adjusted criteria without reinitiation. This determination will be made by NMFS on a case-by-case basis, based on the administrative record for the particular adjustment.

2. The conditions of CDFW's final permit for the CWF under California Fish and Game Code Section 2081 change from the draft reviewed in preparation of this Opinion in a manner inconsistent with the analysis of effects of real-time operations of the north Delta diversions in this Opinion such that it is no longer valid due to use of different values for pulse protection triggers, pulse protection duration, and/or off-ramp flowrates.

3. New information reveals that important assumptions in the analysis of effects in this Opinion are incorrect such that the analysis is no longer valid. These include assumptions about climate change and the pace and effectiveness of habitat restoration and other non-operational measures included in the PA. This specifically includes the assumptions applied to estimate incidental take of listed species at the Clifton Court Forebay during construction and after forebay modification.
4. A construction-related activity occurs outside of the work window specified for that specific construction activity and location of activity, unless NMFS has previously determined that conducting that activity outside the work window is not expected to cause an effect on the listed species or critical habitat that was not considered in this Opinion.
5. Any accident, spill, or failure of an AMM that causes exposure of listed species or critical habitat to contaminants in a manner or to an extent not considered in this Opinion.
6. Failure to implement or provide funding necessary to implement any component of the PA, including the Adaptive Management Program and monitoring.
7. Any change to operations of the CVP/SWP upstream of the Delta that may result in effects of the proposed action on listed species or critical habitat in a manner or to an extent not considered in this Opinion.
8. This Opinion has not been superseded or reinitiation of consultation has not occurred for this Opinion before 2030, unless Reclamation and DWR can demonstrate that conditions expected to affect listed species and critical habitat in the action area after 2030 are similar to those analyzed in this Opinion and therefore the effects of the proposed action are not expected to affect listed species or critical habitat in a manner or to an extent not considered in this Opinion.

2.12 “Not Likely to Adversely Affect” Determination

2.12.1 Central California Coast Steelhead

The Central California Coast (CCC) steelhead DPS (*O. mykiss*) is listed as threatened (71 FR 834, January 5, 2006). The 2011 status review by Williams *et al*. (2011) concluded that steelhead in the CCC steelhead DPS remain “likely to become endangered in the foreseeable future,” and while data availability for this DPS remains poor, there is little new evidence to suggest that the extinction risk for this DPS has changed appreciably in either direction since publication of the last viability assessment (Spence 2016). In April 2016, NMFS issued its *2016 5-Year Review: Summary & Evaluation of Central California Coast Steelhead* (NMFS 2016a) and recommended that the CCC steelhead DPS remain listed as threatened. The DPS includes all naturally spawned steelhead populations below natural and manmade impassable barriers in California streams from the Russian River (inclusive) to Aptos Creek (inclusive), and the drainages of San Francisco, San Pablo, and Suisun bays eastward to Chipps Island at the confluence of the Sacramento and San Joaquin Rivers; tributary streams to Suisun Marsh including Suisun Creek, Green Valley Creek, and an unnamed tributary to Cordelia Slough, excluding the Sacramento-San Joaquin River Basin; as well as two artificial propagation programs: the Don Clausen Fish Hatchery, and Kingfisher Flat Hatchery/Scott Creek (Monterey Bay Salmon and Trout Project) steelhead hatchery programs.

CCC steelhead are iteroparous, or capable of spawning more than once before death, although one-time spawners are the great majority (Busby et al. 1996 and Shapovalov and Taft 1954). Young steelhead usually rear in freshwater for 1 to 3 years before migrating to the ocean as smolts. Migration to the ocean usually occurs in the spring. CCC steelhead may remain in the ocean for 1 to 5 years (2 to 3 years is most common) before returning to their natal streams to spawn (Busby et al. 1996). The distribution of steelhead in the ocean is not well known. Inter-annual variations in climate, abundance of key prey items (e.g. squid), and density dependent interactions with other salmonid species are key drivers of steelhead distribution in the marine environment (Atcheson et al. 2012a and Atcheson et al. 2012b). Adult CCC steelhead typically migrate from the ocean to freshwater to spawn between December and April, peaking in January and February, and juveniles migrate as smolts to the ocean from January through May, with peak emigration occurring in April and May (Fukushima and Lesh 1998).

Some of the barge traffic associated with the PA will transit San Francisco and San Pablo bays in the western Delta as they ingress and egress from the Port of San Francisco. However, the timing of CCC steelhead spawning and migration through the action area is such that very few, if any, individuals from the DPS are likely to be exposed to any potential stressors (e.g., increased turbidity, increased propeller entrainment) resulting from barges operating in San Francisco or San Pablo bays from June 1 and October 31 each year. Therefore, potential effects from those stressors are discountable.

CCC steelhead adults and smolts travel through the western portion of Suisun Marsh and Suisun Bay as they migrate between the ocean and these natal spawning streams. CVP and SWP water export facilities in the Delta are approximately 40 miles to the southeast of Suisun Marsh. CCC steelhead are unlikely to travel eastward towards the Delta pumping facilities, because their seaward migration takes them westward of their natal streams. Similarly, DWR’s Suisun Marsh Salinity Control Gates (SMSCG) in Montezuma Slough are located to the east of these three Suisun Marsh steelhead streams and CCC steelhead are unlikely to travel 10-15 miles eastward through Montezuma Slough to the SMSCG. Therefore, it is unlikely that CCC steelhead will encounter the SMSCG or the Delta pumping facilities during their upstream and downstream migrations, because their spawning streams are located in the western portion of Suisun Marsh.

Operations at CVP and SWP Delta facilities, including the SMSCG, affect water quality and river flow volume in Suisun Bay and Marsh. Delta water exports are expected to cause elevated levels of salinity in Suisun Bay due to reductions in the amount of freshwater inflow from the Sacramento and San Joaquin Rivers. Reduced river flow volumes into Suisun Bay can also affect the transport of larval and juvenile fish. CCC steelhead originating from Suisun Marsh tributary streams will be subject to these changes in salinity and river inflow volumes in Suisun Bay, but are not expected to be negatively affected by these conditions. Estuarine areas, such as Suisun Bay, are transitional habitat between freshwater riverine environments and the ocean. Expected changes in Suisun Bay salinity levels due to CVP and SWP exports are within the range commonly encountered in estuaries by migrating steelhead. River flow volumes may be reduced by water exports, but in an estuary, the tidal cycle of the ocean causes semidiurnal changes to salinity, velocity, temperature, and other conditions. Steelhead generally move through estuaries rapidly (Quinn 2005) and CCC steelhead smolts in Suisun Bay are not dependent on river flow to transport them to the ocean. Thus, reductions in river flow volumes and changes in salinity in Suisun Bay due to CVP/SWP operations are not expected to negatively impact CCC steelhead estuarine residence or migration. In consideration of the above and the distance separating CCC steelhead streams from the Delta pumping facilities and the SMSCG, NMFS concurs with Reclamation that the proposed action is not likely to adversely affect CCC steelhead.

2.12.2 CCC Steelhead Critical Habitat

CCC steelhead critical habitat includes San Francisco Bay and San Pablo Bay, but does not extend eastward into Suisun Bay (September 2, 2005, 70 FR 52488). PBFs of designated critical habitat for CCC steelhead are the same as those for CV spring-run Chinook salmon and CCV steelhead and generally include freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas.

The BA for the NMFS 2009 biological opinion determined that CVP/SWP operations will not influence critical habitat for CCC steelhead because Suisun Bay is not a designated area. Due to the location of CCC steelhead critical habitat in San Pablo Bay and areas westward, NMFS concurs with Reclamation's finding that the habitat effects of CVP/SWP operations in this area are insignificant and discountable.

Some of the barge traffic associated with the PA will transit San Francisco and San Pablo bays in the western Delta as they ingress and egress from the Port of San Francisco. However, any degradation of the quality or function of any PBFs resulting from barges operating in San Francisco or San Pablo bays (e.g., increased turbidity) is expected to be insignificant. Therefore, NMFS concurs with Reclamation that the proposed action is not likely to adversely affect CCC steelhead critical habitat.

2.12.3 CCC Coho Salmon

On June 28, 2005, NMFS issued a final listing determination for CCC coho salmon (*O. kisutch*), changing their status from threatened to endangered (70 FR 37160). The most recent status review (Spence and Williams 2011) documents conditions for CCC coho salmon have worsened since the last status review in 2005 (NMFS 2005). Good et al. (2005) concluded the CCC coho salmon ESU was in danger of extinction. For most populations with monitoring, poor returns from 2006 through 2010 indicated that adult abundance for the CCC coho salmon ESU continued to decline and risk of extinction had increased. The 2011 status review indicated that the status of the ESU continued to remain endangered, and its condition was worsening. In April 2016, NMFS issued its *2016 5-Year Review: Summary & Evaluation of Central California Coast Coho Salmon* (NMFS 2016b) and determined that no reclassification for CCC coho salmon ESU is appropriate, and therefore the CCC coho salmon ESU should remain listed as endangered.

Since CCC coho salmon is extirpated from all rivers flowing into San Francisco Bay (NMFS 2012), the potential exposure of any individuals to the potential stressors associated with implementation of the PA is discountable. Therefore, NMFS concurs with Reclamation that the proposed action is not likely to adversely affect CCC coho salmon.

2.12.4 Critical Habitat for CCC Coho Salmon

Critical habitat was designated for CCC coho salmon on May 5, 1999 (64 FR 24049). Critical habitat is designated to include all river reaches accessible to listed coho salmon from Punta Gorda in northern California south to the San Lorenzo River in central California, including Arroyo Corte Madera Del Presidio and Corte Madera Creek, tributaries to San Francisco Bay. Critical habitat consists of the water, substrate, and adjacent riparian zone of estuarine and riverine reaches (including off-channel habitats). Accessible reaches are those within the historical range of the ESU that can still be occupied by any life stage of coho salmon. CCC coho salmon critical habitat was not designated in any areas within the action area. Therefore, section 7 consultation on the effects of the PA on the designated critical habitat for CCC coho salmon is not warranted.

3 MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT CONSULTATION

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. The MSA (section 3) defines EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it, and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on the EFH assessment provided by the Corps and Reclamation, and descriptions of EFH for Pacific Coast groundfish (PFMC 2016), coastal pelagic species (PMFC 1998), and Pacific Coast salmon (PMFC 2014) contained in the fishery management plans (FMPs) developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

The full extent of the CWF action area encompasses designated EFH for Pacific Coast groundfish, coastal pelagic species, and Pacific Coast salmon (Pacific salmon) (PFMC 2016, 2014, 1998). This area includes the entire legal Delta, Suisun Marsh, Suisun Bay, San Francisco Bay, and all channels of the Sacramento and American Rivers below Keswick and Nimbus Dams. The action area in its entirety is described in greater detail in Section 2.3 of this Opinion. Species known to occur within the action area, along with their known abundance and life cycle representation throughout the action area, are listed below (Table 3-1). All three ESUs of Chinook salmon (Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, and CV fall and late fall-run Chinook salmon) are managed under the Pacific salmon FMP, and all occur within the action area.

The PA consists of: (1) Construction and operation of new water conveyance facilities including three intakes, two tunnels, associated facilities, and a permanent head of Old River (HOR) gate; (2) Coordinated operations of existing Central Valley Project (CVP) and State Water Project (SWP) Delta facilities; (3) Maintenance of newly-constructed and existing Delta facilities; (4) Implementation of new and existing conservation measures; and (5) Implementation of an ongoing monitoring and adaptive management program. A more comprehensive description of the PA is described in Section 1.0 of this Opinion. The following EFH consultation will identify any adverse effects the PA would incur on EFH for Pacific Coast groundfish, coastal pelagic species, and Pacific salmon, and will provide conservation recommendations for each adverse effect identified. This EFH consultation

will also concentrate on addressing any adverse effects the PA may incur on the following designated Habitat Areas of Particular Concern (HAPC): (1) Complex Channels and Floodplain Habitats; (2) Thermal Refugia; (3) Spawning Habitat; (4) Estuaries; and (5) Marine and Estuarine Submerged Aquatic Vegetation.

Table 3-1. Essential Fish Habitat Species Known or Likely to Occur in the Action Area (Source: ICF 2013).

Common Name	Scientific Name	Comment
Coastal Pelagic species FMP		
Jack mackerel	*Trachurus symmetricus*	Present; eggs & larvae
Northern anchovy	*Engraulis mordax*	Abundant; eggs, larvae, juveniles & adults
Pacific sardine	*Sardinops sagax*	Rare; juveniles & adults
Pacific Coast Groundfish FMP		
Big skate	*Raja binoculata*	Present; juveniles & adults
Bocaccio	*Sebastes paucispinis*	Rare; juveniles
Brown rockfish	*Sebastes auriculatus*	Abundant; juveniles & adults
Cabezon	*Scorpaenichthys* spp.	Rare; juveniles & adults
Curlfin sole	*Pleuronichthys decurrens*	Present; juveniles
English sole	*Pleuronectes vetulus*	Abundant; juveniles & adults
Kelp greenling	*Hexagrammos* spp.	Present; juveniles & adults
Leopard shark	*Triakis semifasciata*	Present; juveniles & adults
Lingcod	*Ophiodon elongates*	Present; juveniles & adults
Pacific sanddab	*Citharichthys sordidus*	Present; eggs, larvae, juveniles & adults
Pacific whiting (hake)	*Merluccius productus*	Present; eggs & larvae
Sand Sole	*Psettichthys melanostictus*	Present; larvae, juveniles & adults
Soupfin shark	*Galeorhinus zyopterus*	Present; juveniles & adults
Spiny dogfish	*Squalus acanthias*	Present; juveniles & adults
Starry flounder	*Platichthys stellatus*	Abundant; eggs, larvae, juveniles & adults
Pacific Coast Salmon FMP		
Chinook salmon	*Oncorhynchus tshawytscha*	Abundant; eggs, larvae, juveniles & adults
Coho salmon	*Oncorhychus kisutch*	Rare; eggs, larvae, juveniles & adults

3.2 Adverse Effects on Essential Fish Habitat

Based on the best available information, NMFS concludes that the PA would adversely affect EFH for Pacific Coast groundfish, coastal pelagic species, and Pacific salmon. We conclude that the following adverse effects on EFH designated for Pacific Coast groundfish, coastal pelagic species, and Pacific salmon are reasonably certain to occur.

1. Construction of the north Delta intakes, along with construction activities at the proposed barge landings and CCF, is expected to result in increased levels of turbidity and suspended sediments in the surrounding water column that would temporarily or permanently alter the condition of adjacent complex migratory channels and rearing EFH habitats. Increased levels of turbidity and suspended sediments could also reduce the quality of rearing and migratory habitat for Pacific salmon by adversely impacting submerged aquatic vegetation and macrophyte food sources of Pacific salmon both through light attenuation and smothering once suspended sediments have settled (Kemp *et al.* 1983, and Sand-Jlnsen *et al.* 1989). Increased turbidity during the PA's pile

installation activities from June 15 through October 31 could also result in reduced rearing habitat for fall and late fall-run juveniles and fall-run adults, although the magnitude of these negative effects from the PA's barge traffic on Pacific Salmon EFH are generally expected to remain relatively low.

2. Construction-related activities may also affect water quality within EFH habitat for Pacific Coast groundfish, coastal pelagic species, and Pacific salmon, due to accidental spills of contaminants, including cement, oil, fuel, hydraulic fluids, paint, and other construction-related materials, within the temporary and permanent footprints of the intake facilities and barge operation navigation routes. Water quality degradation due to contamination during pile driving and barge traffic activities has the potential to reduce the quality of Pacific rearing and emigration habitat for fall and late fall-run juveniles, and reduce migratory habitat quality for fall-run adults, by reducing the abundance of lower trophic level prey resources for Pacific salmon (Phipps *et al.* 1995, Fleeger *et al.* 2003). The magnitude of these adverse effects on Pacific Salmon EFH are generally expected to remain relatively low.
3. Construction-related activities may also affect water quality within EFH habitat for Pacific Coast groundfish, coastal pelagic species, and Pacific salmon due to the re-suspension of contaminated sediments within the PA area, particularly within the temporary and permanent footprints of the proposed intake facilities, barge landings, and barge traffic routes. Impacts to EFH from re-suspended contaminated sediment include repetitive potential exposure to legacy contaminants such as mercury, methyl mercury, polychlorinated biphenyls (PCBs), heavy metals, and persistent organochlorine pesticides, and repeatedly degrading the quality of juvenile Pacific Coast groundfish, coastal pelagic species, and Pacific salmon rearing habitat, and migratory pathways of Pacific salmon.
4. Underwater noise generated by impact pile driving in or near surface waters could adversely affect EFH by temporarily reducing habitat suitability in the vicinity of the pile driving, promoting conditions which would disrupt adult and juvenile Pacific Coast salmon migration to upstream spawning and rearing habitat, and diverting juvenile fish into unsuitable rearing habitat. Anthropogenic noise effects from pile driving and barge traffic activities could also reduce the quality of EFH for Pacific salmon by masking acoustic predator cues and compromising predator avoidance. Given the extensive construction work window for the PA's pile driving activities and the timing of Pacific salmon juvenile and adult presence, NMFS expects that noise generated by these activities will adversely affect a small portion of juvenile Pacific salmon population known to utilize the action area. Additional adverse effects caused by underwater noise to Pacific salmon habitat are explained in greater detail throughout section 2.5 of this Opinion.
5. Northern anchovy, starry flounder, or Pacific salmon could be present in the vicinity of intake construction on the Sacramento River during the period when cofferdams are installed to isolate work areas, presenting a potential for stranding or temporarily blocking access to complex channels and floodplain habitat, thermal refugia, spawning habitat, estuaries, and/or marine and estuarine submerged aquatic vegetation habitat.
6. Rates of survivability for juvenile and adult Pacific Coast groundfish, coastal pelagic species, and Pacific salmon could be reduced, along with the quality of their rearing and migratory EFH, due to the possibility of direct contact with piles, riprap, dredges, or

vessels during active construction periods. Given the extensive construction work window for the PA's pile driving activities and the timing of Pacific salmon juvenile and adult presence, NMFS expects that proposed actinon's pile driving activities will adversely affect a small portion of juvenile Pacific salmon population known to use the action area. Proposed operation activities of the proposed NDD intakes are also expected to adversely affect Pacific Salmon EFH by posing the threat of injury and impingement to juvenile Pacific salmon.

7. Construction of the north Delta intakes would result in temporary alteration to approximately 29.9 acres of tidal perennial aquatic habitat, and 13,974 linear feet of channel margin from cofferdam installation, dredging, and barge operations. Construction of the intake structure, including fish screen, transition wall structures, and levee armoring would result in the permanent loss of approximately 6.6 acres of tidal perineal habitat and 5,367 feet of channel margin habitat. Construction of the proposed barge landings would permanently alter 22.4 acres of tidal perennial aquatic habitat and 5,307 linear feet of channel margin (average of 3.2 acres or 758 linear feet per barge landing) from the installation of in-water and overwater structures including piles, dolphin docking piles, docks, ramps, and/or conveyors. Finally, CCF construction activities including dredging, cofferdam installation, levee clearing/armoring, and barge operations would result in temporary to permanent losses or alteration to 1,932 acres of tidal perennial aquatic habitat
8. Estuarine EFH and nearshore rearing habitat for Pacific Coast groundfish, coastal pelagic species, and Pacific salmon may be adversely affected over the 5.5 to 6-year proposed construction period due to barge vessel traffic as is described under the PA. Propeller washes directed at confining structures like levee banks or dock structures or in tight quarters requiring extensive maneuvering, accelerates erosion of bottom substrate in such habitats (Hamill et al. 1999). This would result in a reduction of habitat complexity of EFH, degrading rearing, migratory, and resting habitat for juvenile Pacific salmon.
9. Modification of EFH associated with temporary construction could include removal or permanent placement of engineered structures in EFH that may offer cover for predators of special-status species. The low spatial complexity and reduced habitat diversity (e.g., lack of cover) of channelized waterways in the rivers and Delta could reduce refuge space for salmon from predators (Raleigh et al. 1984; Missildine et al. 2001; 70 FR 52488). The PA includes localized reduction of predatory fishes at locations such as CCF to reduce predator abundance, and thereby reduce predation risks to juvenile salmonids; however, the efficacy of such action is uncertain.
10. Flow effects resulting from the PA could adversely affect EFH for Pacific salmon by reducing the quality of spawning, rearing, and migratory habitat in the following ways: A) Reductions of fall flows can strand and dewater Chinook salmon redds that are located in shallow riffle areas in both the upper Sacramento River (Red Bluff Diversion Dam to Keswick Dam) and the American River; B) Reduced flows resulting from the proposed north Delta intake diversions has the potential to affect inundation of riparian and wetland benches that were restored during earlier bank protection actions and projects; C) Flows in the north Delta under the PA could increase migratory travel time and potentially increase the risk of predation for juvenile Pacific salmon, increase the potential for Pacific salmon straying into the interior Delta via Georgiana Slough (a route known for reduced Pacific salmon survivability when compared to the main stem

Sacramento River), and reduce through-Delta survival and outmigration success; D) Diversions at the existing CVP/SWP export facilities in the south Delta are expected to reduce the probability that juvenile salmonids in the south Delta will successfully migrate out past Chipps Island, either via entrainment or mortality in the export facilities, or via changes to migration rates or routes that increase residence time of juvenile salmon in the south Delta and thus increase exposure time to agents of mortality such as predators, contaminants, and impaired water quality parameters (such as dissolved oxygen and water temperature); E) Diversion flows at the proposed north Delta intake diversion facilities could increase rates of predation on juvenile Pacific salmon by prolonging fish passage time across fish-screened water intakes; and F) Impingement and entrainment of juvenile fish passing the screens of the NDD (see Section 2.5.1.2.5), is expected to have a significant adverse effect to all outmigrating juvenile Chinook salmon from the Sacramento River basin ., a total length of 3,810 feet.

3.3 Essential Fish Habitat Conservation Recommendations

As described in the above effects analysis, NMFS has determined that the proposed CWF would adversely affect EFH for Pacific Coast groundfish, coastal pelagic species, and Pacific salmon. The purpose of the following EFH conservation recommendations are to avoid, minimize and/or otherwise mitigate for these adverse effects, while simultaneously benefiting any HAPC affected by the PA.

1. For effect 1 listed above, NMFS does not have any conservation recommendations in addition to implementing the Worker Awareness Training Program, the proposed Construction Best Management Practices (BMPs) and Monitoring Plan, the proposed Stormwater Pollution Prevention Plan, the proposed Erosion and Sediment Control Plan, the proposed Disposal and Reuse of Spoils Plan, the proposed Reusable Tunnel Material and Dredged Material Measures, and the proposed Barge Operations Plan as they are outlined in Appendix 3.F General Avoidance and Minimization Measures of the BA.
2. For effect 2 listed above, in addition to implementing a Spill Prevention, Containment, and Countermeasure Plan, and in addition to implementing a Hazardous Material Management Plan as described in Appendix 3.F of the BA, NMFS recommends that the Corps require additional best management practices to be used to further protect EFH present. This includes measures such as staging areas being set away from water bodies, fueling heavy equipment away from streams and waterbodies connected to EFH, and having all heavy equipment used for PA construction, operation, and/or maintenance activities cleaned prior to arriving on site. Barge vessels should be maintained in good working condition so that the engines are operating at optimal performance with no fluid leaks, and that exhaust discharges into the water column are minimized. Biodegradable hydraulic fluid for construction-related machinery should also be utilized wherever and whenever possible.
3. For effect 3 listed above, in addition to implementing those conservation recommendations outlined for effects 1 and 2 above, NMFS recommends that the Corps and Reclamation should conduct a sediment contaminant analysis of all newly exposed sediment following proposed dredging operations (see the Disposal of Spoils, Reusable Tunnel Material, and Dredged Material management plan as described in Appendix 3.F of the BA). If sediment contamination levels are at, or above, the recommended sediment quality guidelines, then the Corps should evaluate and implement additional measures to

avoid further contaminant exposure from these newly exposed sediments. Acceptable measures may include overdredging the sediments of the contaminated area, and backfilling the contaminated area with clean sand in order to entomb the newly exposed contaminated sediment.

4. For effect 4 listed above, NMFS does not have any further conservation recommendations in addition to implementing the Underwater Sound Control and Abatement Plan, Noise Abatement Plan, and Barge Operations Plan, as described in Appendix 3.F of the BA.
5. For effect 5 listed above, NMFS does not have any conservation recommendations in addition to implementing the proposed Worker Awareness Training Program, the proposed Construction BMPs and Monitoring Plan, and the Fish Rescue and Salvage plan as described in Appendix 3.F of the BA.
6. For effect 6 listed above, NMFS does not have any conservation recommendations in addition to implementing the proposed Worker Awareness Training Program, the proposed Construction BMPs and Monitoring Plan, and the Fish Rescue and Salvage plan as described in Appendix 3.F of the BA. Based upon the shift of the majority of northern anchovy towards San Pablo and the Central Bay during the construction period, the potential for injury to northern anchovy would be minimized, based on the timing of in-water construction activities and likely avoidance of active construction areas because of salinity preferences. In order to minimize the potential of juvenile Pacific salmon from coming into direct physical contact with the proposed NDD intake screens, the smooth surface of the screens would serve to reduce the risk of abrasion and scale loss for any fish that does come into contact with the proposed NDD screens. The proposed NDD intake screens would also be maintained with frequent screen cleaning (cycle time no more than 5 minutes), in order to minimize screen surface impingement of juvenile Chinook salmon.
7. For effect 7 listed above, NMFS recommends the Corps offset any temporary and/or permanent losses to EFH by including a condition in their construction work permit that requires the creation of new aquatic habitat or purchase of aquatic habitat credit at a mitigation bank approved by NMFS at a ratio of 3 acres created or purchased for each acre of tidal perennial aquatic habitat, channel margin habitat, or any other aquatic or shaded riverine and riparian habitat lost as a result of the PA.
8. For effect 8 listed above, NMFS recommends that, to the extent possible, soft approaches (*e.g.*, beach nourishment, vegetative plantings, and placement of large woody debris) to shoreline modifications and bank stabilization projects along estuarine and marine shorelines should be implemented in those estuarine and shoreline areas most likely to be impacted from erosion by long-term barge operations. NMFS also recommends that predation on Pacific salmon at construction sites by minimized by limiting over water construction lighting whenever possible in order to minimize predation on juvenile Pacific salmon during construction periods.
9. For effect 9 listed above, NMFS does not have any further conservation recommendations in addition to implementation of the proposed Construction BMPs and Monitoring Plan, as described in Appendix 3.F of the BA.
10. For effect 10 listed above, NMFS recommends that impacts to fall flows that cause redd dewatering be stabilized or increased, that impacts to existing shaded riverine habitat and riparian vegetation be avoided to the extent possible, and that any temporary and/or

permanent losses by the PA to shaded riverine and riparian habitat be offset by channel margin restoration to offset less inundation of riparian benches, and a Georgiana Slough nonphysical fish barrier to reduce interior Delta entry. This would benefit Pacific salmon EFH by creating additional thermal refugia HAPCs within the PA area, and likely decrease mortality rates from predation.

Fully implementing these EFH conservation recommendations would protect, by avoiding or minimizing the adverse effects described in section 3.2 above, approximately 2,058.45 acres of designated EFH for Pacific salmon, Pacific Coast groundfish, and coastal pelagic species.

3.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the Corps and Reclamation must provide a detailed response in writing to NMFS within 30 days after receiving an EFH conservation recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH conservation recommendations unless NMFS and the Federal action agencies have agreed to use alternative time frames for the Federal action agency response. The response must include a description of measures proposed by the Federal action agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the conservation recommendations, the Federal action agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

3.5 Supplemental Consultation

The Corps and Reclamation must reinitiate EFH consultation with NMFS if the PA is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations (50 CFR 600.920(1)).

4 FISH AND WILDLIFE COORDINATION ACT

The purpose of the FWCA is to ensure that wildlife conservation receives equal consideration, and is coordinated with other aspects of water resources development (16 USC 661). The FWCA establishes a consultation requirement for Federal agencies that undertake any action to modify any stream or other body of water for any purpose, including navigation and drainage (16 USC 662(a)), regarding the impacts of their actions on fish and wildlife, and measures to mitigate those impacts. Consistent with this consultation requirement, NMFS provides recommendations and comments to Federal action agencies for the purpose of conserving fish and wildlife resources, and providing equal consideration for these resources. NMFS' recommendations are provided to conserve wildlife resources by preventing loss of and damage to such resources. The FWCA allows the opportunity to provide recommendations for the conservation of all species and habitats within NMFS' authority, not just those currently managed under the ESA and MSA.

The following recommendations apply to the proposed action:

1. At any project site within the Action Area that experiences foot traffic, the Corps, and Reclamation should require interpretive signs be posted describing the presence of listed fish or critical habitat as well has highlighting their ecological and cultural value.
2. The Corps and Reclamation should support and promote aquatic and riparian habitat restoration throughout the Sacramento River and the Delta, and encourage operation and maintenance procedures for the proposed action's new and existing water conveyance facilities that avoid or minimize negative impacts to salmon, steelhead, and sturgeon critical habitat.
3. The Corps and Reclamation should support anadromous salmonid and sturgeon monitoring programs throughout the Sacramento River, the Delta, and Suisun Bay, in order to improve the understanding of migration and habitat utilization by salmonids in this region.
4. Establishment of a Safety Zone and requirements for marine mammals. If a marine mammal is observed within 510 m for 183-cm piles, 200 m for 122-cm and 107-cm piles, and 150 m for 76- and 61-cm piles during pile-driving, the Corps should delay pile driving until the animal has moved outside of the Safety Zone, or after 15 minutes has elapsed since the last sighting.

The action agency must give these recommendations equal consideration with the other aspects of the proposed action so as to meet the purpose of the FWCA. This concludes the FWCA portion of this consultation.

5 DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

5.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion are the Bureau of Reclamation and the U.S. Army Corps of Engineers. Other interested users could include the California Department of Water Resources. Individual copies of this opinion were provided to the Bureau of Reclamation and the U.S. Army Corps of Engineers. This opinion will be posted on the Public Consultation Tracking System website (https://pcts.nmfs.noaa.gov/pcts-web/homepage.pcts). The format and naming adheres to conventional standards for style.

5.2 Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

5.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data, and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

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