Long-Term Water Transfers

Addendum to the 2019 Final Environmental Impact Report/Environmental Impact Statement

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Addendum to 2019 Long-Term Water Transfers Final EIS/EIR

Chapter 1 Introduction

This is an Addendum to the 2019 Long-Term Water Transfers Final EIS/EIR (2019 LTWT Final EIS/EIR) (Bureau of Reclamation and San Luis & Delta-Mendota Water Authority 2019) prepared pursuant to Public Resources Code section 21166 and CEQA Guidelines sections 15162-15164.

1.1 Background

1.1.1 Long-Term Water Transfers EIS/EIR

The Long-Term Water Transfers EIS/EIR evaluates a range of potential water transfers by CVP contractors located south of the Delta or in the San Francisco Bay Area between April and September. The Draft Long-Term Water Transfers EIS/EIR (2014 Draft EIS/EIR) was completed in December 2014 and the Final Long-Term Water Transfers EIS/EIR (2015 Final EIS/EIR) was completed in March 2015. The 2015 Final EIS/EIR was challenged in United States District Court for the Eastern District of California in the case AquAlliance, et al., v. U.S. Bureau of Reclamation, et al. on July 5, 2018, the District Court entered judgment, vacating the San Luis & Delta-Mendota Water Authority's (SLDMWA) decision to certify the Final Long-Term Water Transfers EIS/EIR and vacating the U.S. Fish and Wildlife Service's biological opinion. As a result, the United States Bureau of Reclamation (Reclamation) and SLDMWA released the Long-Term Water Transfers Revised Draft EIR/Supplemental Draft EIS (RDEIR/SDEIS) in February 2019 to address the specific issues identified in the ruling. The LTWT Final EIS/EIR was released in September 2019[1]. Reclamation signed the Record of Decision (ROD) in April 2020. This ROD was amended in May 2021 to clarify the Endangered Species Act (ESA) Interagency Cooperation responsibilities as they pertain to transfers involving cropland idling and crop shifting (Reclamation 2021).

The 2019 LTWT Final EIS/EIR used assumptions from the biological opinions (BOs) on the Coordinated Operations of the CVP and State Water Project (SWP) (United States Fish and Wildlife Service [USFWS] 2008; National Oceanic and Atmospheric Administration Fisheries Service [NOAA Fisheries] 2009), which analyzed transfers through the Delta from July to September that are up to 600,000 acre-feet in critical years and dry years (following dry or critical years). For all other year types, the maximum transfer amount is up to 360,000 acre-feet. In October 2019, USFWS and NOAA Fisheries released biological opinions (BOs) on the effects of coordinated long-term operations of the CVP and SWP (USFWS 2019; NOAA Fisheries 2019). The 2019 BOs analyze transfers through the Delta that are up to 600,000 acre-feet in critical years and dry years (following

[1] The 2019 Long-Term Water Transfers Final EIS/EIR is available for review at the following hyperlink: https://sldmwa.org/water-transfers/

dry or critical years), same as the 2008 USFWS and NOAA Fisheries BOs, however the transfer window was extended through November 30.

In 2021, conveyance of transfer water was proposed to extend to the fall months (October and November) due to restrictive operations required to address worsening drought conditions and cold-water pool management at Folsom and Shasta reservoirs. Because the 2019 LTWT Final EIS/EIR analyzes the environmental effects associated with conveyance of transfer water from July through September, this Addendum provides an analysis of the effects of expanding the transfer conveyance period if such a shift were to occur. Specifically, this Addendum analysis evaluates the effects of conveying transfer water in October and November, which extends the transfer period of July through September covered in the 2019 LTWT Final EIS/EIR. The Addendum analysis evaluates the extended transfer period during each year from 2021 through 2024.

1.1.1.1 Proposed Project Presented in the 2019 LTWT Final EIS/EIR

The Proposed Project presented in the 2019 LTWT Final EIS/EIR included making water available for transfer through four methods: groundwater substitution, cropland idling/shifting, stored reservoir release, and conservation. The upper limit for transfers in any one year was 250,000 acre-feet and up to 60,693 acres of cropland that could be idled, with transfer water made available from July through September.

1.1.1.2 Impact Summary

Impacts associated with water transfers under the 2019 LTWT Final EIS/EIR Proposed Project are related to the method of making water available for transfer. Stored reservoir release and water conservation are structured such that they have insubstantial effects associated with making water available.

Cropland Idling/Crop Shifting Transfers of water made available from cropland idling actions would require idling fields that were previously farmed. Transfers of water made available from crop shifting actions would require shifting from a higher water-use crop to a lower water-use crop. Cropland idling could include a variety of crops but idling in upland areas would be within the historic range of variation and would have less than significant effects on natural communities and special-status species.

Idling of seasonally flooded agricultural fields (primarily rice) could affect species that rely on flooded crops or related infrastructure (such as delivery and drainage ditches). Idling seasonally flooded agricultural fields could cause habitat fragmentation, inhibit normal wildlife migration and dispersal of individuals, and potentially dissociate habitats for roosting from those for foraging. These impacts would be detrimental to individual fitness and be potentially significant effects to wildlife. For species that migrate into the area seasonally (mainly birds), effects would be insubstantial because the fields would already be idled when they arrive, and they would select suitable habitat in other locations. For year-round residents (i.e., pond turtle, giant garter snake) the potential impacts would be greater (see Section 3.8.2.4.1 of the 2019 LTWT Final EIS/EIR). These effects are mitigated through measures discussed in Section 3.8.4 of the 2019 LTWT Final EIS/EIR, that maintain water in ditches which support these species and avoid priority habitat areas.

Cropland idling could affect land categorized as Prime Farmland, Farmland of Statewide Importance, or Unique Farmland under the Farmland Mapping and Monitoring Program (FMMP), but this effect would be mitigated by avoiding idling that would result in changes to FMMP land use classifications (see Section 3.9.2.4 of the 2019 LTWT Final EIS/EIR). Cropland idling could also reduce farm income, which would affect farm employment and farm-related businesses (see Section 31 3.10.2.3 of the 2019 LTWT Final EIS/EIR).

Groundwater Substitution Transfers of water made available from groundwater substitution pumping actions would involve growers using groundwater instead of surface water supplies; and would result in a reduction in stored groundwater. The storage would be filled over time from surface water, which would reduce flow in streams. In major water bodies, the CVP and SWP would release more water from storage to maintain flows as needed, which could affect their operations. This effect would be mitigated by applying a streamflow depletion factor to transfers to account for the groundwater/surface water interactions.

Depleting water in small streams could affect natural communities or special-status species in some waterways, including Cache Creek and Stony Creek. These impacts would be avoided or substantially reduced by monitoring groundwater near those areas to avoid changing groundwater levels that could affect stream flows or riparian vegetation.

Groundwater substitution actions could decrease the groundwater aquifer; however, groundwater storage could refill at any time. Water made available for transfer from groundwater substitution pumping actions would reduce groundwater levels near the participating wells, which could affect surrounding third parties or potentially cause subsidence. These effects would be avoided or substantially reduced through monitoring and mitigation plans. If groundwater levels fall below local Basin Management Objectives or historic low groundwater levels, transfer pumping would stop until groundwater levels recover. This requirement would avoid potential groundwater pumping related-land subsidence, which could occur when groundwater levels fall below historic low levels. The mitigation plan discussed in Section 3.3.4 of the 2019 LTWT Final EIS/EIR, includes measures to account for potential impacts to third parties (such as increased pumping costs at nearby wells or the requirements to deepen a pump).

Groundwater wells in the Sacramento Valley have multiple sources of power, including electric, diesel, and natural gas engines. Increased pumping, particularly with older diesel engines, could increase emissions of criteria pollutants. These emissions would exceed criteria within the Feather River Air Quality Management District area, and the emissions would need to be reduced by either pumping more of the transferred water with electric engines or transferring less water.

Water Conveyance Conveying water made available for transfer would increase flows in the river upstream from the Delta during the transfer period. Water made available for transfer would also increase Delta inflows and Delta exports. Stored reservoir release would reduce surface storage, until refill occurs. Surface storage could only be refilled during wetter periods when it would not otherwise affect downstream users or the ability to meet water quality or flow standards. When the Delta is in balance (Delta inflows are equal to Sacramento Valley in-basin needs, Delta outflows, and Delta exports), the CVP and SWP would maintain flows as required under the operational plans. During wetter conditions, when the Delta is in excess conditions, Delta inflows and outflows may decrease because of storage refills. However, these changes would be insubstantial and take place only during wetter conditions, at times when the changes would not affect resources in the rivers or the Delta.

1.2 CEQA Requirements

This Addendum has been developed for compliance with the California Environmental Quality Act (CEQA). Reclamation has concluded that additional National Environmental Policy Act (NEPA) compliance is not required for the refinement proposed under this Amendment, as the 2019 USFWS and NOAA Fisheries BOs covers conveyance of transfer water through the Delta from July through November.

Public Resources Code Section 21166 sets forth the requirements for how a lead agency is to consider changes to a proposed project or the availability of new information that occurs after an EIR for the project has been completed, and Section 15162 of the State CEQA Guidelines reiterates those requirements, along with additional guidance. Public Resources Code Section 21166 states:

> *When an environmental impact report has been prepared for a project pursuant to this division, no subsequent or supplemental environmental impact report shall be required by the lead agency or by any responsible agency, unless one or more of the following events occurs:*
>
> *(a) Substantial changes are proposed in the project which will require major revisions of the environmental impact report.*
>
> *(b) Substantial changes occur with respect to the circumstances under which the project is undertaken which will require major revisions in the environmental impact report.*
>
> *(c) New information, which was not known and could not have been known at the time the environmental impact report was certified as complete, becomes available.*

Section 15162 of the State CEQA Guidelines indicates that:

> *(a) When an EIR has been certified or a negative declaration adopted for a project, no subsequent EIR shall be prepared for that project unless the lead agency determines, on the basis of substantial evidence in the light of the whole record, one or more of the following:*
>
> *(1) Substantial changes are proposed in the project which will require major revisions of the previous EIR … due to the involvement of new significant environmental effects or a substantial increase in the severity of previously identified significant effects;*
>
> *(2) Substantial changes occur with respect to the circumstances under which the project is undertaken which will require major revisions of the previous EIR … due to the involvement of new significant environmental effects or a substantial increase in the severity of previously identified significant effects; or*
>
> *(3) New information of substantial importance, which was not known and could not have been known with the exercise of reasonable diligence at the time the previous EIR was certified as complete … shows any of the following:*
>
> *(A) The project will have one or more significant effects not discussed in the previous EIR;*
>
> *(B) Significant effects previously examined will be substantially more severe than shown in the previous EIR;*

(C) Mitigation measures or alternatives previously found not to be feasible would in fact be feasible, and would substantially reduce one or more significant effects of the project, but the project proponents decline to adopt the mitigation measure or alternative; or

(D) Mitigation measures or alternatives which are considerably different from those analyzed in the previous EIR would substantially reduce one or more significant effects on the environment, but the project proponents decline to adopt the mitigation measure or alternative.

Section 15164 of the State CEQA Guidelines states that an Addendum to an EIR should be prepared "…if some changes or additions are necessary but none of the conditions described in Section 15162 calling for preparation of a subsequent EIR have occurred." An addendum is appropriate to describe the effects of extending the transfer window because that refinement to the originally proposed Project would not result in any of the conditions described above relative to CEQA Section 21166 *et. seq.* and State CEQA Guidelines Section 15162 *et. seq.* (i.e., would not result in new or substantially more severe significant environmental effects requiring major revisions to the 2019 LTWT Final EIS/EIR). The decision-making body will consider the Addendum in concert with the Final EIR prior to making a decision on the Project.

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Chapter 2 Project Description

2.1 Proposed Project

This Addendum refines the transfer window analyzed in the 2019 LTWT Final EIS/EIR and extends the potential timeframe for conveying transfer water across the Delta into October and November. The upper limit for transfers (250,000 AF) and the maximum acreage of cropland idled (60,693 acres) would remain the same as presented in the 2019 LTWT Final EIS/EIR.

2.1.1 Water Transfer Methods

As described above, the 2019 LTWT Final EIS/EIR analyzed water made available through four mechanisms: groundwater substitution, cropland idling/crop shifting, stored reservoir release, and conservation (see Section 2.2.2.1 of the 2019 LTWT Final EIS/EIR). Conserved water transfer from Browns Valley Irrigation District will not be analyzed in this Addendum because the timing of these transfers is not expected to change from that evaluated in the 2019 LTWT Final EIS/EIR. As such, the transfers taking place during the extended transfer window included in this Addendum could use any ofthe following methods:

- Groundwater substitution: groundwater substitution transfers occur when sellers choose to pump groundwater in lieu of diverting surface water supplies, thereby making the surface water available for transfer.

- Cropland idling/crop shifting: cropland idling makes water available for transfer that would have been used for agricultural production. For crop shifting transfers, water is made available when farmers shift from growing a higher water use crop to a lower water use crop. Impacts from crop shifting would be similar to, but less intense than, cropland idling impacts. The 2019 LTWT Final EIS/EIR includes the potential crops that could be idled or shifted in Section 3.10.

- Reservoir releases: Buyers could acquire water by purchasing surface water stored in reservoirs owned by non-Project entities (not part of the CVP or SWP). To ensure that purchasing this water would not affect downstream users, Reclamation would limit transferred water to what would not have otherwise been released downstream absent the transfer. Additionally, each reservoir release transfer would include a refill agreement between the seller and Reclamation (developed in coordination with the California Department of Water Resources [DWR]) to prevent impacts to downstream users following a transfer.

The refinement to the Proposed Project considered in this Addendum does not consider changes to the timing of groundwater substitution transfers pumping, cropland idling/ crop shifting transfers; or the upper limit for transfers presented in the 2019 LTWT Final EIS/EIR. The refinements only involve extending the timeframe or "window" for conveyance of transfer water made available through potential groundwater substitution and cropland idling transfers into October and November.

The refinement of the Proposed Project also considers conveying water made available through reservoir releases from non-Project entity reservoirs (PCWA's Hell Hole and French Meadow's and Merced ID's Lake McClure) over the extended timeframe or "window" i.e. October and November. Alternatively, Reclamation could store water made available through reservoir releases in downstream reservoirs (Folsom Reservoir for releases from PCWA's Hell Hole and French Meadow's reservoirs; Oroville for Camp Far West and Merle Collins reservoirs) for release/conveyance over the extended timeframe. Releases out of Camp Far West and Merle Collins reservoirs would occur from July and September and would be backed up in Lake Oroville for release in October and November. Agreements with DWR would be required for use of SWP facilities to facilitate transfers of water Reclamation is required by SWRCB's 2021 TUCP Order to maintain cold water pool for salmon and steelhead in downstream reservoirs (Shasta and Folsom Reservoirs). Reclamation would review each transfer proposal to meet these requirements. Reclamation could consider reregulating flows through Folsom Reservoir to help meet SWRCB's 2021 TUCP Order, which would include a power letter of agreement between the seller and Reclamation (developed in coordination with Western Area Power Administration [WAPA]) to prevent impacts to WAPA power users.

2.1.2 Potential Transfer Participants

The refinement to the Proposed Project does not consider changes to the potential sellers as presented in Table 2-2 of the 2019 LTWT Final EIS/EIR or to the potential upper limit of available water for transfer by each agency for each method of transfer as presented in Table 2-3 of the 2019 LTWT Final EIS/EIR.

The buyers, SLDMWA including its Participating Members, Contra Costa Water District, and East Bay Municipal Utility District, were included in the 2019 LWTW Final EIS/EIR. All three buyers (SLDMWA including its Participating Members, Contra Costa Water District, and East Bay Municipal Utility District) were evaluated under the refined Proposed Project for purchasing water in the extended transfer window.

2.1.3 Water Transfer Operations

Transfers under the refined Proposed Project could affect river flows and timing of flow upstream and downstream from the point of diversion. The following section describes how the extended transfer window would operate on rivers in the Sellers' Service Area.

Water conveyed for transfer during the extended transfer period (October and November) that must be conveyed through the Delta is limited to periods when capacity at C.W. "Bill" Jones Pumping Plant (Jones Pumping Plant) or Harvey O. Banks Pumping Plant (Banks Pumping Plant) is available, and only after CVP and SWP needs are met. Reclamation and DWR must also declare that the Delta is in "balanced conditions" under the terms of the Addendum to COA[2] (Reclamation 2018).

[2] The Delta is declared to be "Balanced" by Reclamation and DWR when it is agreed that releases from upstream reservoirs plus unregulated flow exceed Sacramento Valley in basin uses, plus exports (Reclamation and DWR 1986).

The timing of water made available for transfer by potential agricultural sellers upstream from the Delta through groundwater substitution, cropland idling, and crop shifting actions would continue to be dictated by the irrigation season as analyzed in the 2019 LTWT Final EIS/EIR.

2.1.3.1 Sacramento River

Potential sellers on the Sacramento River receive CVP Project water that could be stored upstream from their service areas in Shasta Reservoir. With the refinements to the Proposed Project, this water could be backed up in Shasta Reservoir for later release in October and November. Reclamation would only consider storing water made available for transfer if it would not affect releases for temperature. Backing up water may be possible if the Delta is in balanced conditions and instream standards are being met. The decision to back up water made available for transfer would be made on a case-by-case basis, but the effects analysis completed herein evaluates the potential to convey the backed-up transfer water in October and November, in the event Reclamation determines that storage is possible in a specific year.

Under the refined Proposed Project, conveyance capacity in the Delta would be available when conditions for sensitive species are acceptable to NOAA Fisheries and USFWS, typically from July through November, consistent with the 2019 USFWS and NOAA Fisheries BOs. Water made available through groundwater substitution and cropland idling/crop shifting action would be available from April through September consistent with the analysis in the 2019 LTWT Final EIS/EIR.

As presented in the 2019 LTWT Final EIS/EIR, proposed sellers divert water from various locations along the Sacramento River or the Sutter Bypass. If a seller shifts from using surface water to groundwater to make water available for transfer, river flows would not decrease from Shasta Reservoir to the seller's point of diversion; however, river flow would increase from the seller's point of diversion downstream to the buyer's point of diversion because water is not diverted for use until it reaches the Delta. With the refinements to the Proposed Project, if Reclamation determines that it can store water in Shasta Reservoir, the flows in the Sacramento River between Shasta Reservoir and the point of diversion of transfer water would decrease, in the same manner as presented in the 2019 LTWT Final EIS/EIR. However, with the refinements to the Proposed Project, these reductions would occur during the April through September period and increases would occur in October and November.

The evaluation presented in this Addendum was based on two flow scenarios, which maximize the volume of water conveyed across the Delta in individual months to capture the maximum potential environmental impacts.

- **Alternative 1: Maximum October** – This alternative conveys as much transfer water as possible in October of each year with up to 209,000 AF in a single month. Remaining transfer water is conveyed across the Delta in November.

- **Alternative 2: Maximum November** – This alternative conveys as much transfer water as possible in November of each year with up to 124,000 AF in a single month. Remaining transfer water is conveyed across the Delta in October.

2.1.3.2 American River
The sellers on the American River divert water from the lower American River or Folsom Reservoir. When transferring water made available through groundwater substitution actions, the sellers would take less surface water, leaving the water in storage in Folsom Reservoir. With the refinements to the Proposed Project, releases from Folsom Reservoir would occur during October and November. This analysis does not change the maximum transfer volume upper limit of 250,000 AF. Storing water in Folsom Reservoir for release in October and November would likely be possible because this water would not otherwise have been released to the river absent the transfer. The extended storage of water in Folsom Reservoir would need to comply with Warren Act contracts and refill agreement requirements.

2.1.3.3 Feather River
DWR operates Lake Oroville on the Feather River, which is upstream from the diversion locations for sellers on the Feather River. With the refinements to the Proposed Action, releases from Lake Oroville would occur during October and November. This analysis does not change the 250,000 AF transfer volume upper limit. The extended storage of water in Lake Oroville for transfer in October and November would still require approval by DWR. DWR cannot approve storage in Lake Oroville if it would affect SWP operations. The transfer water would be the first water spilled if Lake Oroville reaches flood capacity. River flows would increase downstream of the sellers' points of diversion (compared to the No Action/No Project Alternative) when the stored transfer water is released.

2.1.3.4 Delta Region
The 2019 LTWT Final EIS/EIR describes several factors that complicate implementation of transfers from potential sellers in the Delta. These complicating factors are inherent in the implementation of potential water transfers and would continue to exist during both the current transfer window and the extended transfer window under the refined Proposed Project.

2.1.4 Transfer Length
Under the refined Proposed Project, sellers and buyers would continue to negotiate transfer agreements that last one year. The need for conveying water in October and November would be considered each year based on the year's hydrologic conditions.

Chapter 3 Resource Evaluation

The 2019 LTWT Final EIS/EIR analyzed the impacts from transferring the maximum amount of water that was available from willing sellers and could be moved through the Delta through September. This Addendum is analyzing impacts from extending the transfer window and conveying water through October and November. Impacts were determined by comparing the baseline of the existing transfer window to the extended transfer window.

3.1 Resources Not Re-Evaluated

Under the Proposed Project, the methods for making water available for transfer would remain the same as what is presented in the 2019 LTWT Final EIS/EIR. However, the conveyance of transfer water would extend into October and November under the currently proposed refinement to Proposed Project. It was the action of making water available that resulted in impacts in the 2019 LTWT Final EIS/EIR relative to the following resources: groundwater, geology and soils, air quality, climate change, vegetation and wildlife, agricultural land use, cultural resources, visual resources, recreation, power, and flood control. Since the currently proposed refinement to the Proposed Project pertains only to conveyance of transfer water and does not change how the transfer water is made available, impacts related to the aforementioned resources would remain the same as presented in the 2019 LTWT Final EIS/EIR. Cumulative effects for these resources would also be the same as presented in the 2019 LTWT Final EIS/EIR.

Resource areas that would be affected by the proposed change in transfer water conveyance (i.e., extending the transfer period into October and November) include water supply, water quality, and fisheries. Reevaluation of impacts to those resources is provided below in Sections 3.2 through 3.4.

3.2 Water Supply

3.2.1 Existing Environmental Setting

Section 3.1.1 of the 2019 LTWT Final EIS/EIR provides a summary of the environmental setting for water supplies in the area of analysis at the time the EIS/EIR was prepared. The setting includes a description of the water supply source for each of the potential sellers. Since certification of the 2019 LTWT Final EIS/EIR, the water supply sources (including water rights and/or water contracts) have not changed. This Addendum is analyzing a potential extension of the transfer window and there would be no change to the potential buyers and sellers. Because of continued dry hydrologic conditions, CVP agricultural water service contractors' allocations South of the Delta were 55 percent in 2019, 20 percent in 2020, and 0 percent in 2021. M&I water service contractors' allocations South of the Delta were 80 percent in 2019, 70 percent in 2020, and 25 percent in 2021. Hydrologic conditions have continued to fluctuate since the completion of the 2019 LTWT Final EIS/EIR, however, the environmental setting for water supplies in the area of analysis had primarily remained the same.

3.2.2 Evaluation of Impacts

Section 3.1.2 in the 2019 LTWT Final EIS/EIR concluded groundwater substitution water transfers under the Project would have a less than significant impact with mitigation on water supply. Because of surface water and groundwater interaction, losses to surface water flows from groundwater basin recharge would reduce the water supply available to the CVP and SWP. The impacts from streamflow depletion may affect water users that are not parties to water transfers. To reduce these effects, Mitigation Measure WS-1 includes a streamflow depletion factor to be incorporated into transfers to account for the potential water supply impacts to the CVP and SWP. Mitigation Measure WS-1 would reduce the impacts to less than significant.

The refinements to the Proposed Project would not change the action of making water available (i.e. the quantity or timing of groundwater substitution). Therefore, there would be no change to the effects of the Proposed Project on groundwater and surface water interactions related to groundwater substitution in the Seller Service Area. The extension of the transfer window would have similar effects to surface water and groundwater interactions as described in Section 3.1.2 of the 2019 LTWT Final EIS/EIR and would remain less than significant with mitigation.

Section 3.1.2 in the 2019 LTWT Final EIS/EIR evaluated potential impacts from stored reservoir release transfers that would decrease water levels in reservoirs to levels lower than without the water transfer. To refill a reservoir, a seller must capture some flow that would otherwise have gone downstream. Section 3.1.2 of the 2019 LTWT Final EIS/EIR considered the potential for these transfers to affect downstream water users but found that the refill agreement (required by Reclamation) would avoid potential effects to water users or flow and water quality criteria. This impact was found to be less than significant.

Under Proposed Project refinements, diversion of surface water from groundwater substitution pumping and cropland idling/shifting actions would be extended into October and November. The refinements to the Proposed Project would also consider conveying water made available through releases from reservoirs owned by non-Project entities over the extended timeframe. Alternatively, Reclamation could store water made available through reservoir releases in downstream reservoirs (Folsom Reservoir for releases from PCWA's Hell Hole and French Meadow's reservoirs; Oroville for Camp Far West and Merle Collins reservoir) for release/conveyance over the extended timeframe. These reservoir levels would remain lower with the transfers than without, until refilling to normal levels, as described in Section 3.1.2 of the 2019 LTWT Final EIS/EIR and impacts would remain less than significant.

Compared to the reservoir levels analyzed in the 2019 LTWT Final EIS/EIR, the Proposed Project refinements could result in reservoir levels in downstream CVP reservoirs (Shasta and Folsom) or the downstream SWP reservoir (Oroville) being higher during dry and critical water years in July through September, when water would otherwise be transferred. While this increase in water levels would offset the decrease in water levels anticipated in 2019 LTWT Final EIS/EIR, overall, stored reservoir release transfers are expected to decrease reservoir levels until refilling to normal levels. As previously mentioned and described in Chapter 2 of the 2019 LTWT Final EIS/EIR, each stored reservoir release transfer would include a refill agreement which specifies that the reservoir could only be refilled when it would not adversely affect downstream water users. Therefore, the impact of reservoir release transfers on downstream water users would remain less than significant.

In the 2019 LTWT Final EIS/EIR, water would be pumped through the Delta at Banks and/or Jones pumping plants during the period of July through September. and Banks and Jones pumping plants would pump more water than they would compared to the No Action/No Project conditions. Decreased Delta water levels could have the potential to affect water supplies in this area because the local users' diversion pumps may not remain submerged. Modeling in the 2019 LTWT Final EIS/EIR estimated that surface water levels would be the same under the No Action Alternative and Proposed Project and impacts to Delta water levels were concluded to be less than significant.

The extension of the transfer window analyzed in this Addendum would extend the pumping of water through the Delta into October and November, rather than through September. However, the maximum quantity of potential transfer water evaluated in the 2019 LTWT Final EIS/EIR would be the same. Therefore, decreased Delta water levels would be similar to the levels evaluated in the 2019 LTWT Final EIS/EIR, and impacts to Delta water levels would remain less than significant. In addition, during October and November, impacts to Delta water users will likely be even less than what would be experienced during the July through September transfer period as most irrigation would have concluded by this time.

3.2.3 Findings

There are no substantial changes to the circumstances under which the range of potential water transfers evaluated in the 2019 LTWT Final EIS/EIR would be undertaken, and there is no new information of substantial importance that has become available relative to water supply. No substantial changes in the water supply environment have occurred since certification of the 2019 LTWT Final EIS/EIR, which retains its relevance as to the evaluation of potential impacts, identification of mitigation measures, and consideration of alternatives for the Proposed Project.

Based on the above, no new significant water supply impacts or a substantial increase in previously identified water supply impacts would occur as a result of refinements to the Proposed Project. Therefore, impacts to water supply do not meet the standards for preparation of either a subsequent or a supplemental EIR pursuant to CEQA Guidelines, Section 15162.

3.3 Water Quality

3.3.1 Existing Environmental Setting

Section 3.2.1 of the 2019 LTWT Final EIS/EIR provides a summary of the environmental setting for water quality analysis at the time the EIS/EIR was prepared. The setting includes a description of existing water quality for each of the water bodies with the potential to be affected by the range of potential water transfers evaluated in the 2019 LTWT Final EIS/EIR. Since the 2019 LTWT Final EIS/EIR, the State Water Resources Control Board (SWRCB) released the *2014 and 2016 California Integrated Report*, which included an update to the 2012 303(d) listed water bodies, presented in Table 3.2-1 in the 2019 LTWT Final EIS/EIR. No additional water bodies within the area of analysis were identified as impaired by certain constituents of concern, and none were delisted (SWRCB 2018). The environmental setting for water quality has remained primarily the same for the Seller Service Area.

3.3.2 Evaluation of Impacts

Section 3.2.2 in the 2019 LTWT Final EIS/EIR concluded stored reservoir release, groundwater substitution, and cropland idling water transfers under the Proposed Project would have a less than significant impact on water quality. The analysis assessed the potential for cropland idling transfers to increase runoff of sediment and constituents of concern into area waterways but found that soil types in the area and farming practices would result in minimal erosion of idled fields. The refinements to the Proposed Project would not result in additional cropland idling and the impacts would remain less than significant for the same reasons as the existing cropland idling transfers.

The 2019 LTWT Final EIS/EIR also considered impacts to reservoirs, rivers, and the Delta associated with changing water flow patterns and concluded that changes in flows and reservoir storage would not be of significant frequency and magnitude to affect water quality. Therefore, water quality impacts associated with changes in flow in the Seller Service Area are expected to be less than significant.

The refinements to the Proposed Project would extend the transfer window, and while the overall transfer amount would not increase, the timing of conveying the transfer water would change. Compared to the reservoir levels analyzed in the 2019 LTWT Final EIS/EIR, water levels could increase in downstream CVP reservoirs (Shasta and Folsom) and the downstream SWP reservoir (Oroville) during dry and critical water years in July through September. These changes are caused by the CVP and SWP storing the transfer water, when possible, until the transfer water can be released for pumping in October rather than July. As shown in Table A-1 through Table A-6 in Appendix A, there would be no change to groundwater substitution transfers and decreases in storage from streamflow depletion during other times of the year, similar to what is presented in the 2019 LTWT Final EIS/EIR, Overall, reservoirs would experience only insubstantial changes in storage, which would not be of sufficient magnitude and frequency to result in substantive changes to water quality. In addition, backing up water in reservoirs for release in October and November could improve temperature management in associated rivers. Therefore, the impact of reservoir storage on water quality would remain less than significant.

The 2019 LTWT Final EIS/EIR also considered impacts to non-Project reservoirs participating in reservoir release transfers and found that the short-term changes in reservoir levels would have a less than significant impact on water quality. Under the refined Proposed Project, storage in non-Project reservoirs would remain largely the same as analyzed in the 2019 LTWT Final EIS/EIR (see Tables A-11 through A-16 in Appendix A) and water quality impacts to non-Project reservoirs from reservoir release transfers would remain less than significant.

The refinements to the Proposed Project would not substantially change flow rates compared to the 2019 LTWT Final EIS/EIR and changes in river flows would extend from July through September into October and November. Compared to the 2019 LTWT Final EIS/EIR, average monthly flow rates in the Sacramento River, Feather River, and American River would decrease slightly from July through September and increase slightly in October and November, as shown in Table A-17 through Table A-26 in Appendix A. These insubstantial decreases during July through September and insubstantial increases during October and November would not be of significant frequency or magnitude as to affect water quality and impacts would remain less than significant.

The refinements to the Proposed Project would extend Delta inflows and outflows compared to the 2019 LTWT Final EIS/EIR. Delta inflows and outflows would decrease in July through September and increase in October and November in dry and critical water years compared to the 2019 LTWT Final EIS/EIR, as shown in Table A-27 through Table A-30 in Appendix A. Impacts during transfers would remain similar to those described in the 2019 LTWT Final EIS/EIR. During all other times, Delta inflows and outflows would be similar to the No Action/No Project Alternative. Therefore, the impact of Delta inflows and outflows on water quality would remain less than significant.

The refinements to the Proposed Project would result in insubstantial changes in Delta salinity conditions compared to the 2019 LTWT Final EIS/EIR. Updated modeling shows slight variations in the estimated X2 location during transfer years, as shown in Table A-31 and Table A-32 in Appendix A. Carriage water is a required component of water transfers that is used to maintain water quality in the Delta. See Section 2.2.2.3 of the 2019 LTWT Final EIS/EIR for detailed discussion of carriage water. Using the SWRCB criteria described in the 2019 LTWT Final EIS/EIR, all monthly changes in X2 would be insignificant and impacts would remain less than significant.

3.3.3 Findings

There are no substantial changes to the circumstances under which the range of potential water transfers evaluated in the 2019 LTWT Final EIS/EIR would be undertaken, and there is no new information of substantial importance that has become available relative to water quality. No substantial changes in water quality parameters have occurred since certification of the 2019 LTWT Final EIS/EIR, which retains its relevance as to the evaluation of potential impacts, identification of mitigation measures, and consideration of alternatives for the Proposed Project.

Based on the above, no new significant water quality impacts or a substantial increase in previously identified water quality impacts would occur because of refinements to the Proposed Project. Therefore, impacts to water quality do not meet the standards for preparation of either a subsequent or a supplemental EIR pursuant to CEQA Guidelines, Section 15162.

3.4 Fisheries

3.4.1 Existing Environmental Setting

Section 3.7.1 of the 2019 LTWT Final EIS/EIR provides a summary of the environmental setting for fisheries resources in the area of analysis at the time the EIS/EIR was prepared. The 2019 LTWT Final EIS/EIR details habitat conditions present within the different regions of the area of analysis including: Shasta, Oroville, and Folsom Reservoirs; the portions of the Sacramento River, Feather River, and American River that flow from these reservoirs into the Delta; the Merced River and the portion of the San Joaquin River from the intersect of the Merced River to the Delta; and the Sacramento-San Joaquin River Delta. Habitat conditions have remained largely the same as presented in the 2019 LTWT Final EIS/EIR. See Appendix B of this Addendum for a full description of the existing habitat conditions.

The 2019 LTWT Final EIS/EIR provides a description of the special-status fish species analyzed, which include: Central Valley steelhead (*Oncohynchus mykiss*) distinct population segment (DPS), Sacramento River winter-run Chinook salmon (*O. tshawytscha*), Central Valley spring-run Chinook salmon (*O. tshawytscha*), Central Valley fall and late-fall-run Chinook salmon (*O. tshawytscha*), the southern DPS of green sturgeon (*Acipenser medirostris*), longfin smelt (*Spirinchus thaleichthys*), and delta smelt (*Hypomesus transpacificus*). Special-status fish species descriptions have largely remained the same as presented in the 2019 LTWT Final EIS/EIR. See Appendix B of this Addendum for legal status, life history, and the status in the area of analysis for each special-status species.

3.4.2 Evaluation of Impacts

For this Addendum analysis, potential impacts on fisheries resources were assessed by evaluating the potential environmental changes that could result from the refined Proposed Project relative to the Proposed Project. To evaluate potential flow-related impacts, outputs from CalSim II—a hydrological planning scenario tool that provides monthly average flows for the entire SWP and CVP system—were used to either directly assess potential effects or as inputs for additional analytical tools. A ten percent difference in modeled flow between the Proposed Project and the refined Proposed Project flow scenarios was used as the threshold for determining measurable flow changes—consistent with the 2019 LTWT Final EIS/EIR (Section 3.7.2.1.3), which was based on several major, legally certified environmental documents in the Central Valley related to fisheries (Trinity River Mainstem Fishery Restoration Record of Decision, December 19, 2000; San Joaquin River Agreement Record of Decision in March 1999; Freeport Regional Water Project Record of Decision, January 4, 2005; Lower Yuba Accord EIR/EIS). In these documents, there is consensus that differences in modeled flows of less than ten percent would be within the noise of the model outputs, and thus, beyond the ability of the model to measure. Therefore, CalSim II analytical results of less than 10 percent between the Proposed Project and the refined Proposed Project were deemed as being attributable to noise associated with the flow model outputs and the impacts assumed to be within the range of impacts evaluated and disclosed in the 2019 LTWT Final EIS/EIR. If the CalSim II analysis resulted in a difference of greater than 10 percent between the Proposed Project and the refined Proposed Project, a closer evaluation of this difference was conducted to determine whether the predicted change in conditions would have a significant biological effect on focal fisheries resources. The effects analyses summarized herein evaluated potential flow-related effects on relevant life stages—egg, alevin, fry, juvenile, and adult—of each focal species based on analytical tools, including species-specific conceptual models summarized in subsequent sections and detailed in Attachment 1 of Appendix B. These further biological analyses included consideration of the magnitude, frequency, and timing of differences in flows that were greater than 10 percent.

The limitations of species-specific conceptual models used to analyze potential effects of each alternative on focal fish species are described in Appendix B and where warranted below. Despite these limitations, the analytical tools used to inform the analyses summarized herein are believed to represent the best options available and are consistent with methods used to analyze similar effects in the 2019 National Marine Fisheries Service (NMFS) biological opinion (BO) (NMFS 2019) and the 2019 USFWS BO (USFWS 2019).

The sub-section for each water body considers the exposure of applicable life stages of focal species to the refined Proposed Project flow scenarios, largely based on species timing summaries included in Appendix B. Consideration of exposure focuses on the extent to which the expected effects of predicted changes in flow overlap in time and location with the species and life stage being considered. Potential effects of exposure to the refined Proposed Project flow scenarios on individuals of each species are summarized below by species and life history stage.

3.4.2.1 Analytical Approach - Effects on Salmonid Spawning and Rearing Habitat

The potential effects of each refined Proposed Project flow scenario on the availability of salmonid spawning and rearing habitat were evaluated using weighted usable area (WUA) predictions based on WUA curves developed by USFWS (USFWS 2006). The WUA is an index of the surface area of physical habitat available, weighted by the suitability of that habitat for specific species and/or specific life history stages. Habitat suitability is based on habitat suitability criteria (HSC) informed by habitat conditions known to support the species/life stage of interest. Hydraulic modeling is then used to estimate the amount of suitable habitat available for different HSC levels at different river flows, and the results are used to develop WUA curves and tables (Bovee et al. 1998). These curves and tables can then be used to estimate the amount of rearing and spawning WUA available under different flow scenarios, as further described in Appendix B.

3.4.2.2 Analytical Approach - Effects on Salmonid Redds

The potential for each alternative to cause redd dewatering—resulting in adverse effects to incubating eggs and/or alevins—during the spawning period for each focal salmonid species was analyzed based on the maximum reduction in flow predicted to occur over the duration of an egg cohort. Cohort duration was estimated as being 3 months for all salmonid species being considered based on input from NMFS. If flows during the 3 months subsequent to egg deposition (i.e., cohort duration) are all predicted to be greater than the flow at the time of egg deposition, it is assumed that no redd dewatering would occur. The analysis also assumes that, for each species considered, a new egg cohort begins each month of the spawning period and that egg deposition ceases 3 months prior the end of the overall spawning and incubation period. The percentage of redds in the Sacramento River that may be affected by dewatering was estimated using tables that relate spawning flows (flow level at the time of egg deposition) and dewatering flows (the minimum flow predicted during the egg cohort duration) to percent reductions in species-specific spawning WUA, as described in Appendix B.

3.4.2.3 Evaluation of Impacts

Section 3.7.2.4 of the 2019 LTWT Final EIS/EIR identifies and assesses the potential environmental impacts on fisheries resources, including fish species of management concern and their habitat, that could result from implementation of the potential range of transfer actions included under the Proposed Project. Impacts from transfer actions under the Proposed Project may include: (1) impacts on rivers and creeks from groundwater/surface water interaction due to groundwater substitution pumping, (2) stored reservoir releases, (3) changes to flows in rivers and creeks from transfer conveyance, and (4) changes to Delta flows resulting from transfer conveyance.

As discussed above, the refinements to the Proposed Project would only impact water conveyance; therefore, this fisheries analysis focuses on changes to flows in river and creeks and changes to Delta flows that would result from transfer water conveyance.

Central Valley Steelhead

Sacramento River

Effects on Central Valley steelhead that could result from refinements to the Proposed Project could be temperature- or flow-based in nature. Water temperature management for Chinook salmon, as described in the 2019 NMFS BO (NMFS 2019), would maintain water temperatures suitable for steelhead spawning and egg incubation, rearing, and migration. Cold water pool management is required by the SWRCB and will take precedent over backing up water for transfers, such as the refined Proposed Project, if necessary. Previously, in critical dry years such as 2014, 2015, and 2021, Reclamation has backed up and held transfer water over the summer months to maintain the cold water pool in Shasta and Folsom Reservoir. Under such conditions, the refined Proposed Project would help maintain the cold water pool and would be beneficial to all special-status species evaluated in this Addendum. As such, temperature-related effects from the refined Proposed Project to special-status fish species are anticipated to be beneficial. Thus, temperature-related impacts on the Sacramento River, and associated special-status fish species, are not discussed further in this Addendum.

Flow differences in the Sacramento River at Keswick that would result from refinements to the Proposed Project would primarily occur in summer and fall of dry and critically dry water years. Based on CalSIM II modeling, Alternative 1 of the refined Proposed Project in comparison to the Proposed Project shows flows decreasing in dry and critically dry water years by up to 14 percent during July and September and increasing by up to 27 percent during October. Under Alternative 2 of the refined Proposed Project flows would decrease in critically dry water years by 14 percent during July and would increase by up to 21 percent in October and November. Although steelhead are known to spawn in the section of the Sacramento River between Keswick Dam and the Red Bluff Diversion Dam, Central Valley steelhead typically spawn from December through April. Thus, the steelhead spawning season corresponds to a period when changes in flow under the refined Proposed Project (Alternative 1 and Alternative 2 flow scenarios) relative to the Proposed Project would be negligible (less than 1 percent). Therefore, changes in flows under the refined Proposed Project are not expected to affect the availability of suitable spawning habitat for steelhead.

In the Sacramento River below Keswick Dam, steelhead redd dewatering risks under the refined Proposed Project (Alternative 1 and Alternative 2 flow scenarios) and Proposed Project are expected to be similar during all months of spawning (see Table 13 and Table 43 in Appendix B). The 2019 NMFS BO (NMFS 2019) details measures that will be implemented by Reclamation to minimize redd dewatering risks associated with storage releases. The implementation of these measures would continue similar to the Proposed Project evaluated in the 2019 LTWT Final EIS/EIR. As a result, effects of refinements to the Proposed Project on steelhead redd dewatering risks are expected to be less than significant. However, under Alternative 2 flow scenarios the dewatering risk to steelhead redds would be slightly higher than the risk under Alternative 1 flow scenarios.

Flow changes under the refined Proposed Project (Alternative 1 and Alternative 2 flow scenarios) could affect the availability of juvenile steelhead rearing habitat in the Sacramento River, measured as WUA (see Table 14 and Table 44 in Appendix B). Under both refined Proposed Project flow scenarios, rearing WUA would increase in some areas under some water year types in July and August and would decrease in some areas under some water year types in October. However, given the isolated temporal and spatial incidence and generally low magnitude of expected changes in rearing habitat availability (as described in Section 3.2.1.1 of Appendix B), and the insubstantial number of individuals these changes would affect (juvenile steelhead generally migrate to the ocean in spring and early summer), effects on steelhead rearing habitat under the refined Proposed Project are expected to be less than significant. For these same reasons, the effect of the refined Proposed Project on juvenile stranding is also expected to be less than significant.

Based on observations at the Red Bluff Diversion Dam, peak adult steelhead migration in the upper Sacramento River typically occurs during September and October. During September, attraction flows from Keswick Dam are predicted to be somewhat lower under the refined Proposed Project (both Alternative 1 and Alternative 2) compared to the Proposed Project evaluated in the 2019 LTWT Final EIS/EIR (see Table 11 in Appendix B). During October, flows are expected to be higher under refined Proposed Project flow scenarios. As such, the refined Proposed Project would likely have insubstantial negative effects on adult migration in the Sacramento River during September and larger beneficial effects during October. Owing to the insubstantial magnitude of predicted flow reductions in September during peak adult steelhead migration in the upper Sacramento River, the refined Proposed Project is expected to have less than significant effects on adult steelhead migration.

The primary juvenile steelhead outmigration period in the Sacramento River is February through May (see Table 1 in Appendix B), which coincides with a period of negligible (less than 1 percent) predicted flow changes in the Sacramento River under refined Proposed Project flows scenarios compared to the Proposed Project evaluated in the 2019 LTWT Final EIS/EIR (see Table 11 in Appendix B). Therefore, the refined Proposed Project would have less than significant effects on juvenile outmigration in the Sacramento River.

Feather River

Flows in the Low Flow Channel of the Feather River (Low Flow Channel), where a large majority of steelhead spawning and rearing occurs, have been optimized for salmonids. These flows would not change under the refined Proposed Project flow scenarios relative to the Proposed Project. Therefore, less than significant effects on steelhead spawning and rearing in the Low Flow Channel are expected under the refined Proposed Project.

The High Flow Channel of the Feather River (High Flow Channel) is used primarily as a migration corridor for juveniles (typically July through March) and adults (typically February through September). Under the assumption that higher flows would be better for migration, flow modeling results indicate that both juvenile and adult migration in the High Flow Channel would not be significantly impacted under the refined Proposed Project flow scenarios.

The California Department of Water Resources' (DWR's) commitment to meet year-round water temperature targets for salmonids in the Low Flow and High Flow channels of the Feather River would continue to be implemented under the refined Proposed Project. As such, no temperature-related effects on steelhead occurring in the Feather River are anticipated under the refined Proposed Project.

American River

Flows in the American River under the refined Proposed Project flow scenarios would be similar to those expected under the Proposed Project, with some exceptions. During July of dry and critically dry water years and August of critically dry water years, flows would be 11 to 20 percent lower under both of the refined Proposed Project flow scenarios. These flow reductions would coincide with the juvenile steelhead rearing period. During October in critically dry water years, flows would be 26 percent higher under the Alternative 1 flow scenario and 14.8 percent higher under the Alternative 2 flow scenario (see Table 16 of Appendix B), resulting in a negligibly positive effect on adult migration cues associated with increased flows. Spawning and juvenile emigration occur during periods of little to no difference in modeled flows between the refined Proposed Project and the Proposed Project, and thus, would be unaffected. Owing to the relatively low magnitude and limited duration of predicted flow reductions, steelhead would not be significantly affected by flow changes under the refined Proposed Project.

Reclamation's requirement to maintain cold water pool for salmon and steelhead in downstream reservoirs under SWRCB's 2021 TUCP Order[3] would continue to be implemented under the refined Proposed Project. Under the assumption that lower flows would result in increased water temperatures, July and August would be the only months that temperatures under refined Proposed Project (Alternative 1 and Alternative 2 flow scenarios) could be higher than under the Proposed Project. However, because of Reclamation's commitment to maintain suitable water temperatures, no significant temperature-related effects on steelhead in the American River are expected under the refined Proposed Project

Merced River

Under both of the refined Proposed Project flow scenarios, flows at the Merced River mouth would be similar to those expected under the Proposed Project in all months and water years, with some exceptions (See Table 17 in Appendix B). Under the refined Proposed Project flow scenarios flows would be 49.5 percent and 34.7 percent lower during July of dry and critically dry water years, respectively. Little is known about steelhead habitat use in the Merced River, but these reductions would likely coincide with the juvenile steelhead rearing period. Flows are expected to increase under both flow scenarios included in the refined Proposed Action. During October and November of some water year types—up to 60.8 percent increase is expected under the refined Proposed Project relative to the Proposed Project. Predicted flow increases would likely coincide with the adult migration and juvenile rearing periods and it is assumed that any changes in habitat conditions resulting from higher flows would be beneficial in nature. Given the limited temporal occurrence of predicted flow decreases, it is anticipated that changes in flow under the refined Proposed Project would have less than significant impacts on Central Valley steelhead in the Merced River.

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the Merced River. Under this assumption, water temperature results would be similar to flow results (seesee Table 17 in Appendix B) in that, because of the low frequency of differences between the refined Proposed Project and the Proposed Project, temperature-related effects on steelhead are expected to be less than significant.

San Joaquin River

Under the refined Proposed Project flows in the San Joaquin River at Vernalis would be similar to those under the Proposed Action in all months and water year types, with one exception (see Table 18 in Appendix B). During July of dry water years, flows would be 11.8 percent lower under both refined Proposed Project flow scenarios relative to the Proposed Action. Based on known steelhead habitat use in neighboring rivers, it is expected that these reductions would coincide with the juvenile steelhead rearing period in the San Joaquin River. Given the limited temporal occurrence of predicted flow decreases, it is anticipated that changes in flow under the refined Proposed Project would have less than significant impacts on Central Valley steelhead in the San Joaquin River.

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[3] TUCP Orders provide relief in drought conditions. These orders last up to 180 days but are renewable (SWRCB 2009).

As described for the Merced River, it is assumed that there is an inverse relationship between flow and water temperature in the San Joaquin River. Under this assumption, water temperature results would be similar to flow results (seesee Table 18 in Appendix B) in that, because differences between the refined Proposed Project and the Proposed Project are expected to be insubstantial, temperature-related effects on steelhead are expected to be less than significant.

Delta

This analysis assumes that modeled flows in the Sacramento River at Freeport are representative of flows in the Delta (see Table 19 in Appendix B). Flow modeling results show a decrease in flow at Freeport under the refined Proposed Project compared to the Proposed Project during July and August of critically dry water years and an increase during October of above normal and critically dry water years. These flow changes would not be large or persistent enough to have biologically meaningful effects on steelhead adult migration. Therefore, the refined Proposed Action would have less than significant effects on adult steelhead migration.

During March and June (peak juvenile migration) flows at Freeport under the refined Proposed Project would be nearly identical to those under the Proposed Project, suggesting that changes in flow at Freeport would have a less than significant effect on juvenile migration.

South Delta export actions may result in entrainment of juvenile steelhead at export facilities (see Table 20 in Appendix B). Export rates under the refined Proposed Project would be lower in July through September of several water year types relative to the Proposed Project, when juvenile steelhead are present in very low numbers at salvage facilities and in the Delta. Assuming entrainment risk is a function of presence in the Delta and export rates, changes in export rates during these months would cause an insubstantial increase in salvage of steelhead juveniles as individuals in the Delta are present in such small numbers.

Winter-run Chinook Salmon

Sacramento River

Effects of the refined Proposed Project on winter-run Chinook salmon could be temperature-based or flow-based. As noted previously, requirements in the 2019 NMFS BO (NMFS 2019) should maintain water temperatures suitable for winter-run Chinook salmon spawning and egg incubation, rearing, and migration. The refined Proposed Project would help maintain the cold water pool in critical dry years and would be beneficial to all special-status species evaluated in this Addendum. As such, temperature-related effects from the refined Proposed Project to special-status fish species are anticipated to be beneficial. Thus, temperature-related impacts on the Sacramento River, and associated special-status fish species, are not discussed further in this Addendum.

Similar to effects described for Central Valley steelhead, flow differences in the Sacramento River at Keswick Dam under the refined Proposed Project (Alternative 1 and Alternative 2 flow scenarios) relative to the Proposed Project would occur primarily during summer and fall of dry and critically dry water years (see Table 11 of Appendix B). Results of analyses performed to predict how spawning WUA may change indicate that the refined Proposed Project would not have significant effects on winter-run Chinook salmon spawning habitat availability.

Similar to the potential for redd dewatering described for Central Valley steelhead, the refined Proposed Project (Alternative 1 and Alternative 2 flow scenarios) is expected to have a less than significant effect on the risk of dewatering winter-run Chinook salmon redds in the Sacramento River relative to the Proposed Project.

Based on WUA modeling results, flows under the refined Proposed Project (Alternative 1 and Alternative 2 flow scenarios) could affect winter-run Chinook salmon rearing habitat availability relative to the Proposed Project (see Table 23 and Table 47 in Appendix B). However, differences in WUA over 10 percent (up to 11.8 percent) were only predicted during July of dry and critically dry water years in one reach of the Sacramento River under both flow scenarios in comparison to the Proposed Project. Given the isolated temporal and spatial incidence and insubstantial magnitude of expected differences in rearing habitat availability, measured as WUA, such differences are considered less than significant.

Juvenile winter-run Chinook salmon are typically present upstream of Red Bluff from July through October. Flows under the refined Proposed Project would generally be similar to those under the Proposed Project during this period, except for reduced flows during July and September in critically dry water years and increased flows during October in above normal, dry, and critically dry water years (see Table 11 in Appendix B). Ramping rates presented in the 2019 NMFS BO that would be adhered to under both the Proposed Project and the refined Proposed Project would minimize the risk of juvenile stranding during future operations. Therefore, effects of refined Proposed Project on juvenile stranding risks relative to the Proposed Project are expected to be less than significant.

The migration period of adult winter-run Chinook salmon in the Sacramento River is typically November through July. During this period, adult attraction flows from Keswick Dam are expected to be similar under the refined Proposed Project Alternative 1 flow scenario, except for a 14 percent reduction in flow predicted during July of critically water years (see Table 11 in Appendix B). Under the Alternative 2 flow scenario, flows are expected to increase by up to 13 percent during November for above normal and critically dry water years, and to decrease by 14 percent in July of critically dry water years. Owing to the low frequency and small magnitude of predicted changes in flow under the refined Proposed Project, impacts on adult winter-run Chinook salmon migration are expected to be less than significant.

The primary juvenile winter-run Chinook salmon outmigration period in the Sacramento River above Red Bluff is typically August through December. During this period, flows under the refined Proposed Project would be higher during October and November of multiple water year types relative to the Proposed Project (see Table 11 in Appendix B). Because increased flows are expected to improve conditions for out-migrating juvenile winter-run Chinook salmon and owing to the insubstantial magnitude of predicted reductions in flow (less than 10 percent) under the refined Proposed Project flow scenarios relative to the Proposed Project, impacts on juvenile migration are expected to be less than significant.

Delta

Juvenile winter-run Chinook salmon are typically found in the Delta from approximately October through April. During this period, flows at Freeport would be nearly identical between the refined Proposed Project and the Proposed Project—except during October in above normal and critically dry water years when flows would be greater under the Alternative 1 flow scenario and during October and November of critically dry water years under the Alternative 2 flow scenario (see Table 19 in Appendix B). Similarly, from November through June, when adult winter-run Chinook salmon are found in the Delta, predicted flows at Freeport under the refined Proposed Project and

Proposed Project would be nearly identical—except during November in critically dry water years when flow would increase by 12 percent under the Alternative 2 flow scenario of the refined Proposed Project (see Table 19 in Appendix B). Since there are no significant decreases in flows under the refined Proposed Project compared to the Proposed Project, no significant impacts are expected to juvenile winter-run Delta migration and residence period or the adult winter-run Delta migration period.

Predicted increases in South-of-Delta export rates under the refined Proposed Project would be limited to the months of October and November (see Table 20 in Appendix B) when a small portion of the overall winter-run Chinook salmon population is expected to be present. Thus, it is expected that relatively few individuals would be exposed to potential entrainment risks associated with export facilities. Therefore, expected changes in export rates under the refined Proposed Project would have a less than significant impact on winter-run Chinook salmon.

Spring-run Chinook Salmon

Sacramento River

Similar to effects described under Section 1.1.2.3 *Central Valley Steelhead*, modeled flow differences in the Sacramento River at Keswick Dam under the refined Proposed Project relative to Proposed Project would occur primarily during summer and fall of dry and critically dry water years (see Table 11 of Appendix B). Spring-run Chinook salmon spawning normally occurs between mid-August and early October, peaking in September. The WUA modeling results (detailed in Appendix B) indicate that Alternative 1 and Alternative 2 flow scenarios under the refined Proposed Project would have insubstantial effects (10% or less change in WUA) on spring-run Chinook salmon spawning habitat availability during August and September. However, during October, spawning WUA is predicted to be lower in the section of the Sacramento River between Cow Creek and Battle Creek for both refined Proposed Project flow scenarios during most water year types (see Table 24 and Table 48 in Appendix B). Given the limited temporal and spatial extent of predicted flow reductions, and the trend toward greatly reduced spring-run Chinook salmon spawning in the mainstem Sacramento River observed over the last two decades, it is anticipated that both refined Proposed Project flow scenarios would have a less than significant impact on the availability of spring-run Chinook salmon spawning habitat.

The spring-run Chinook salmon redd dewatering risk associated with the refined Proposed Project relative to the Proposed Project is expected to be slightly lower in August and September and slightly higher in October under both flow scenarios (see Table 25 and Table 49 in Appendix B). However, in accordance with the 2019 NMFS BO (NMFS 2019), Reclamation will take steps to minimize the risk of dewatering redds during reservoir storage releases. Such actions would continue to be implemented under the refined Proposed Project. As a result, the effect of the refined Proposed Project on the risk of dewatering spring-run Chinook salmons redds relative to the Proposed Project is expected to be less than significant.

Based on WUA modeling results, flows under the refined Proposed Project would have a limited effect on spring-run Chinook salmon rearing habitat availability relative to the Proposed Project (see Table 26 and Table 50 in Appendix B). Given the isolated temporal incidence (changes are only predicted for the months of November and February) and insubstantial magnitude (less than 10 percent) of expected differences in juvenile rearing WUA under the refined Proposed Project, such differences are considered less than significant.

The period when juvenile spring-run Chinook salmon are most vulnerable to stranding risks—right after emergence from the gravel (typically November through February)—coincides with a period of insubstantial differences in modeled flow between the refined Proposed Project and the Proposed Project under the Alternative 1 flow scenario (see Table 11 in Appendix B). Although flows are predicted to increase slightly under the Alternative 2 flow scenario during November of above normal and critically dry water years, these insubstantial changes in flow are not expected to increase stranding risks because the ramping rate restrictions included in the 2019 NMFS BO—designed to minimize stranding risks—would be adhered to under both the Proposed Project and the refined Proposed Project. Therefore, the effect of the refined Proposed Project on juvenile spring-run Chinook salmon stranding is expected to be less than significant.

The primary migration period of adult spring-run Chinook salmon past the Red Bluff Diversion Dam is typically March through September. Flows under the refined Proposed Project are predicted to decrease by 14 percent during July of critically dry water years for both flow scenarios (Alternative 1 and Alternative 2) (see Table 11 of Appendix B). Given the limited incidence of expected reductions in modeled flows, it is anticipated that the refined Proposed Project would have less than significant effects on adult spring-run Chinook salmon migration in the Sacramento River. From November through January—the primary juvenile spring-run Chinook salmon outmigration period in the upper Sacramento River—changes in flow under the refined Proposed Project relative to the Proposed Project would be minimal, except during November of above normal and critically dry water years when flows are predicted to increase by a modest 13.3 percent and 10.4 percent, respectively (see Table 11 in Appendix B). Therefore, it is anticipated that the refined Proposed Project would have less than significant impacts on juvenile spring-run Chinook salmon migration.

Feather River

Effects on Chinook salmon from flow changes in the Feather River under the refined Proposed Project would be similar to the effects described for Central Valley steelhead.

San Joaquin River

Under the refined Proposed Project flows in the San Joaquin River at Vernalis would be similar to those under the Proposed Project in all months and water year types, except during July of dry water years when flows would be 11.8 percent lower under both flow scenarios (Alternative 1 and Alternative 2) relative to the Proposed Project (see Table 18 in Appendix B). Based on monitoring data for the experimental spring-run Chinook salmon population in the San Joaquin River, these reductions are expected to coincide with adult migration and holding life stages. Given the limited temporal occurrence of predicted flow decreases, it is anticipated that changes in flow under the refined Proposed Project would have less than significant impacts on spring-run Chinook salmon in the San Joaquin River.

As previously noted, it is assumed that there is an inverse relationship between flow and water temperature in the San Joaquin River. Under this assumption, water temperature results would be similar to flow results (seesee Table 18 in Appendix B) in that, because of the low frequency of differences between the refined Proposed Project and the Proposed Project, temperature-related effects on spring-run Chinook salmon are expected to be less than significant.

Delta

From December through May, when juvenile spring-run Chinook salmon are found in the Delta (see Table 6 in Appendix B), predicted flows at Freeport under the refined Proposed Project would be nearly identical to those expected under the Proposed Project (see Table 19 in Appendix B). Similarly, during January through June, when adult spring-run Chinook salmon are found in the Delta, flows at Freeport would be nearly identical between the refined Proposed Project and Proposed Project. Therefore, flow changes under the refined Proposed Project are expected to have insubstantial effects during the juvenile spring-run Delta migration and residence period and the adult spring-run Chinook salmon migration period in the Delta.

South-of-Delta export rates during the spring-run Chinook juvenile rearing and migration period in the Delta (December through May) would be nearly identical under the refined Proposed Project relative to the Proposed Project. Therefore, assuming that entrainment risk is a function of export rates, effects of the refined Proposed Project on spring-run Chinook salmon entrainment risk would be less than significant

Fall/Late Fall-Run Chinook Salmon

Sacramento River

Fall-run Chinook salmon typically spawn in upper reaches of the Sacramento River from October through March. Based on WUA modeling results, there would be insubstantial (less than 10 percent) differences in spawning WUA for fall-run Chinook salmon between the Proposed Project and refined Proposed Project Alternative 1 flow scenario in all months except October (see Table 27 in Appendix B). For Alternative 2 flow scenarios, changes in spawning WUA greater than 10 percent are expected in October of critically dry water years and in November of above normal and critically dry water years (see Table 51 in Appendix B). Given the limited temporal and spatial extent of predicted reductions in spawning WUA, it is anticipated that the refined Proposed Project would have a less than significant impact on fall-run spawning habitat availability. For late fall-run Chinook salmon, there would be negligible (less than 1 percent) differences in spawning WUA between the Proposed Project and the refined Proposed Project flow scenarios during the December through April spawning period (see Table 28 and Table 52 in Appendix B). Therefore, it is anticipated that effects of refined Proposed Project flow changes on late-fall run Chinook salmon spawning habitat availability would be less than significant.

Similar to the potential for redd dewatering described for Central Valley steelhead, effects of the refined Proposed Project on fall-run/late-fall run Chinook salmon redd dewatering risks is expected to be less than significant relative to the Proposed Project (see Table 29, 30, 53, and 54 in Appendix B).

Based on WUA modeling results, flows under the Alternative 1 flow scenario of the refined Proposed Project could have a limited negative effect on fall-run/late-fall run Chinook salmon rearing habitat availability relative to the Proposed Project (see Tables 31 and 32 in Appendix B). However, for both fall-run/late fall-run Chinook salmon, changes in rearing WUA under the Alternative 1 flow scenario relative to the Proposed Project are not expected to exceed 1.5 percent. The difference in WUA under the Alternative 2 flow scenario would be approximately 1.5 percent or less (see Tables 55 and 56 in Appendix B). Since the impacts of the refined Proposed Project flow scenarios on rearing WUA are within 10 percent of the impacts expected for the Proposed Project, effects on fall-run Chinook salmon rearing habitat are considered less than significant.

Juvenile fall-run Chinook salmon are typically present in the upper Sacramento River from December through April and late fall-run juvenile Chinook salmon may be present year-round. Adherence to ramping rates included in the 2019 NMFS BO (NMFS 2019) would minimize stranding risks during future operations and would continue to occur under the refined Proposed Project. Therefore, effects on fall-/late fall-run juvenile Chinook salmon stranding risks that may result from the refined Proposed Project are expected to be less than significant relative to the Proposed Project.

The migration period of adult fall-run Chinook salmon in the Sacramento River is typically June through December. For late fall-run Chinook salmon, the adult migration period is October through April. Sacramento River flows during the overall fall-run Chinook salmon migration period would be similar between the Proposed Project and the refined Proposed Project, with some exceptions. Under Alternative 1 flow scenarios, a 14 percent decrease in flow is predicted during July of critically dry water years and increased flows are predicted during October of above normal, dry, and critically dry water years—22.6 percent, 15.6 percent, and 27.2 percent, respectively (see Table 11 in Appendix B). Under Alternative 2 flow scenarios, flows are predicted to decrease by 14 percent during July of critically dry water years and to increase during October and November of multiple water year types—up to 21 percent (see Table 11 in Appendix B). Because of the limited temporal occurrence and insubstantial magnitude of expected reductions in flow under refined Proposed project flow scenarios relative to the Proposed Project, effects on adult fall-/late fall-run Chinook salmon migration are expected to be less than significant.

The juvenile fall-run outmigration period in the Sacramento River generally occurs from November through May. For late fall-run, this period is April through June. During both the fall-run and late fall-run Chinook salmon outmigration period Sacramento River flows under the refined Proposed Project flow scenarios would be similar to those under the Proposed Project. However, flows would be higher under the Alternative 2 flow scenario in November of above normal and critically dry water years (see Table 11 in Appendix B). Since flows would be similar or higher under the refined Proposed Project compared to the Proposed Project, effects on juvenile fall-run Chinook salmon migration are expected to be less than significant.

Feather River

Effects on Chinook salmon from flow changes in the Feather River under the refined Proposed Project would be similar to the effects on Central Valley steelhead.

American River

Effects on Chinook salmon from flow changes in the American River under the refined Proposed Project would be similar to the effects on Central Valley steelhead.

Merced River

As previously noted, predicted flows at the Merced River mouth would be similar for both of the alternatives included under the refined Proposed Project relative to those expected under the Proposed Project in all months and water years, with some exceptions (See Table 17 in Appendix B). Under both flow scenarios flows would be 49.5 percent and 34.7 percent lower during July of dry and critically dry water years, respectively. Based on fall-run Chinook salmon habitat use patterns observed in neighboring rivers, it is expected that these flow reductions would not coincide with fall-run Chinook salmon presence in the Merced River. Flows are expected increase under both refined Proposed Action flow scenarios during October and November of some water year types—by up to 60.8 percent relative to the Proposed Project. This increase would likely coincide with the adult fall-run Chinook salmon migration and spawning periods. However, given the limited temporal occurrence of predicted flow changes, it is anticipated that such changes would have a less than significant impact on fall-run Chinook salmon in the Merced River.

San Joaquin River

Under the refined Proposed Action flows in the San Joaquin River at Vernalis would be similar to those under the Proposed Action in all months and water year types, except for an 11.8 decrease predicted for both alternatives during July of dry water years (see Table 18 in Appendix B). Based on fall-run Chinook salmon habitat use patterns observed in neighboring rivers, it is expected that these reductions would not coincide with fall-run Chinook salmon presence in the San Joaquin River. Therefore, it is anticipated that changes in flow under the refined Proposed Project relative to the refined Proposed Project would have insubstantial effects on fall-run Chinook salmon in the San Joaquin River.

As previously described, it is assumed that there is an inverse relationship between flow and water temperature in the San Joaquin River. Under this assumption, water temperature results would be similar to flow results (see Table 18 in Appendix B) in that, owing to the lack of differences between the refined Proposed Project and the proposed project when fall-run Chinook salmon are expected to be present, effects are expected to be insubstantial.

Delta

From December through June, when juvenile fall-run and late fall-run Chinook salmon are found in the Delta, predicted flows at Freeport under the Proposed Project would be nearly identical to those expected for both refined Proposed Project flow scenarios (see Table 19 in Appendix B). Therefore, the refined Proposed Project is expected to have less than significant impacts on habitat conditions during the juvenile fall-run/late fall-run Chinook salmon Delta migration and residence period.

From June through November, when adult fall-run Chinook salmon are typically found in the Delta, flows at Freeport would be similar under the Proposed Project relative to the refined Proposed Project, except for flow reductions of greater than 10 percent in July and August of critically dry water years and increases of greater than 10 percent in October and November of multiple water year types (see Table 19 in Appendix B). From October through May, when adult late fall-run Chinook salmon are typically found in the Delta, flows at Freeport would be similar under the Proposed Project relative to the refined Proposed Project, except for increases in October and November, which would likely improve migration conditions (see Table 19 in Appendix B). Because flow reduction under the refined Proposed Project would be temporary in nature (isolated to July and August of critically dry water years), resultant effects on adult fall-run Chinook salmon migration in the Delta are expected to be less than significant.

South-of-Delta export rates from June through November—coincident with the fall-run Chinook salmon juvenile rearing and migration period in the Delta—would be lower during July and August in dry and critically dry water years, lower during September in critically dry water years, and higher during October and November of above normal, and critically dry water years (see Table 20 in Appendix B). Overall, owing to the isolated incidence of higher export rates and the higher frequency of reduced export rates, effects to fall-run Chinook salmon would be less than significant.

South-of-Delta export rates from October through May, when late fall-run juvenile rearing and migration occurs in the Delta, would be higher during October and November (see Table 18 in Appendix B). Given the limited temporal extent of expected increases in export rates, effects of the refined Proposed Project on late fall-run Chinook salmon entrainment risk are anticipated to be less than significant.

Green Sturgeon

Sacramento River

Based on a recent study of the effects of flow on green sturgeon spawning in the Sacramento River (Wyman et al. 2018), this analysis assumes that optimal flows for green sturgeon spawning are between 7,500 ft^3/s and 12,360 ft^3/s. Therefore, for the purposes of this analysis, Sacramento River flows that fall outside this range during the spawning period (March–June) are considered to adversely affect green sturgeon spawning. Analysis results indicate that the occurrence of flows outside of the range indicated above would be similar between the Proposed Project and refined Proposed Project, except in July of dry and critically dry water years when fewer incidences of sub-optimal flow would occur under the refined Proposed Project (see Table 33 in Appendix B). These results indicate that the effect of refined Proposed Project on green sturgeon spawning would be less than significant.

To determine the potential effects of the refined Proposed Project on green sturgeon larvae and juveniles, flow rates at Wilkins Slough from April through December—when green sturgeon are likely to be present—were evaluated for the Proposed Project and the refined Proposed Project (Alternative 1 and Alternative 2 flow scenarios) (see Table 34 in Appendix B). The effects of flow on juvenile and larval abundance are poorly understood. However, there appears to be a positive relationship between annual outflow and downstream movement of green sturgeon larvae and juveniles (Heublein et al. 2017). Thus, increased flows may benefit green sturgeon larvae and juveniles by facilitating the dispersal of individuals to areas with greater food and habitat availability. Flow modeling results indicate that flows under both of the refined Proposed Project flow scenarios would generally be similar to those under the Proposed Project from April through June, November through December, and in wetter water years from July through September; lower in drier water years from July through September; and higher in most water year types during October. Given the limited incidence of expected flow reductions during their period of presence, the effect of the refined Proposed Project on green sturgeon larvae and juveniles is expected to be less than significant.

Adult green sturgeon enter the Delta between mid-February and early May and rapidly migrate up the Sacramento River. Low flows (less than 3,250 ft^3/s) potentially create difficult upstream passage conditions. However, modeled flows at Wilkins Slough during the February through June migration period all exceed 3,250 ft^3/s (see Table 35 in Appendix B). These results indicate that there would be no risk of additional passage limitations under the refined Proposed Project. Therefore, the refined Proposed Project is anticipated to have less than significant effects on adult green sturgeon migration.

Feather River

Green sturgeon irregularly spawn in the Feather River—likely only during wet water years characterized by high flows. Flow changes under the refined Proposed Project are not expected to occur in wet water years. Therefore, flow-related effects of the refined Proposed Action on green sturgeon spawning would be less than significant.

As previously noted, DWR's commitment to meet year-round water temperature targets for salmonids in the Low-Flow and High Flow channels of the Feather River would continue to be implemented under the refined Proposed Project. These temperature targets are generally protective of green sturgeon as well. Therefore, no temperature-related effects on green sturgeon occurring in the Feather River are anticipated under the refined Proposed Project.

San Joaquin River

Because very little information regarding green sturgeon presence in the San Joaquin River is available, this analysis evaluates potential effects by comparing flows predicted at Vernalis for the Proposed Project with those predicted at Vernalis for the refined Proposed Project flow scenarios. Flows at Vernalis under both flow scenarios would be similar to those under the Proposed Project in all months and water years with one exception (see Table 18 of Appendix B). During July of dry water years, flows would be 11.8 percent lower under both refined Proposed Project flow scenarios relative to the Proposed Project. Given the low frequency of its occurrence, it is anticipated that this flow reduction would cause less than significant effects on green sturgeon in the San Joaquin River. Similarly, assuming flow and water temperature are inversely related, the low frequency of substantial flow differences between the refined Proposed Project and the Proposed Project indicates that water temperature-related effects on green sturgeon in the San Joaquin River would also be less than significant.

Delta

Because of the year-round presence of juvenile green sturgeon in the Delta, entrainment at export facilities has the potential to occur in most months of the year. However, salvage of green sturgeon at export facilities in the Delta has been very low since 2009, as described in Appendix B. Given the insubstantial changes in total exports under the refined Proposed Project flow scenarios relative to the Proposed Project (see Table 20 in Appendix B) less than significant effects on green sturgeon entrainment are expected.

As noted by NMFS (2018), there are statistically significant correlations between white sturgeon year class strength and Delta outflow during April through May and March through July, which have previously been used to infer potential effects on green sturgeon. Based on analyses described in Appendix B, results indicate that there would be insubstantial differences between the refined Proposed Project and the Proposed Project with regard to potential effects on green sturgeon year-class strength (see Tables 36 and 37 in Appendix B).

Delta Smelt

Adult delta smelt have the potential to be entrained at south Delta export facilities during dispersal prior to spawning, which typically occurs form December through March. Refined Proposed Project flow scenarios (Alternative 1 and Alternative 2) would not include any changes to measures currently being implemented—in accordance with the USFWS 2019 BO and CDFW State Water Project Incidental Take Permit (SWP ITP) (USFWS 2019, CDFW 2020)—to minimize the risk of adult delta smelt entrainment. Because these measures would remain in place, and since Delta exports and Delta outflow would generally be very similar under Alternative 1 and Alternative 2 relative to the Proposed Project (see Table 20 and Table 38 in Appendix B), it is anticipated that there would be little difference in entrainment risk for adult delta smelt between the Proposed Project and the refined Proposed Project.

South Delta entrainment of larval/early juvenile delta smelt generally occurs between March and June. As described in Appendix B, the risk of larval/early juvenile entrainment risk is expected to increase as Old and Middle River (OMR) flows decrease and X2 (an indicator of the downstream extent delta smelt habitat in the Delta measured as the distance from the Golden Gate to the 2 parts per thousand [ppt] salinity isohaline) increases. Flow modeling indicates that there would be no differences in X2 position or OMR flows between the Proposed Project and the refined Proposed Project flow scenarios (Alternative 1 and Alternative 2) throughout the March-June period (see Table 39 in Appendix B). Because neither X2 position nor OMR flows would change during the March through June period, effects of the refined Proposed Project on larval/early juvenile delta smelt entrainment are expected to be less than significant.

Spring (March–May) X2 position positively correlates with the density of the delta smelt zooplankton prey (*Eurytemora affinis)* (Kimmerer 2002a; Greenwood 2018), suggesting a potentially positive effect of Delta outflow on this prey species. The X2 position from March through May would be identical between the Proposed Project and the refined Proposed Project (see Table 39 in Appendix B). Therefore, the refined Proposed Project is anticipated to have a less than significant effect on delta smelt prey availability.

The Interagency Ecological Program Management, Analysis, and Synthesis Team (IEP MAST) conceptual model of delta smelt biology (IEP MAST 2015) suggests that the probability of egg/larval delta smelt surviving to the juvenile life stage is influenced by predation risk, which may involve different factors such as turbidity, water temperature, and abundance of predators—namely inland silversides (*Menidia beryllina*).The main factor influencing the probability of egg/larval delta smelt surviving to the juvenile life stage that would be affected by the refined Proposed Project would be abundance of the inland silverside—presently thought to be the most substantial predator of delta smelt larvae (IEP MAST 2015). Mahardja et al. (2017) showed that summer (June–September) Delta inflow and spring (March–May) South-of -Delta exports had the strongest correlations with inland silverside cohort strength (both relationships were negative). Only Sacramento River flows at Freeport would be affected under the refined Proposed Project, and therefore, characterize expected effects on Delta inflow. Under the refined Proposed Project, mean June-September flows at Freeport would generally be similar (within 10 percent) to those expected under the Proposed Project (see Table 40 in Appendix B). Additionally, mean March-May combined South Delta exports would be identical under both the Proposed Project and the refined ProposedProposed Project (see Table 41 in Appendix B). These results suggest that inland silverside abundance would remain similar under the Proposed Project and the refined Proposed Project. Therefore, it is anticipated that the refined Proposed Project would have a less than significant impact on the probability of egg/larval delta smelt surviving to the juvenile life stage.

The IEP MAST conceptual model of delta smelt biology suggests that the size and location of the low-salinity zone may affect subadult delta smelt survival (IEP MAST 2015). The X2 position—a measure of the low salinity zone—under the Proposed Project and the refined Proposed Project would be nearly identical in all months (see Table 39 in Appendix B). Therefore, effects of the refined Proposed Project on the low-salinity zone size and position, and related effects on delta smelt survival, would be less than significant.

Longfin Smelt

During the winter-spring months when adult, larval, and juvenile longfin smelt entrainment risks are expected to be highest (i.e., December through May), flow modeling indicates that there would be little difference in South Delta exports between the Proposed Project and the refined Proposed Project (see Table 20 in Appendix B). Because neither San Joaquin River flows nor southsouth Delta exports would change during this period, Old and Middle River flows would not change. As described in Appendix B, CDFW (2009) demonstrates that salvage of longfin smelt is positively correlated with higher mean December–March X2. However, flow modeling indicates that there would be insubstantial differences in mean December–March X2 between the Proposed Project and the refined Proposed Project (see Table 39 in Appendix B). Therefore, the effect of the refined Proposed Project on the risk of longfin smelt entrainment at South Delta export facilities is expected to be less than significant.

Two approaches to evaluate flow-based effects on longfin smelt abundance were considered. Both approaches indicate that the effect of the refined Proposed Project would be less than significant. The first approach is based on a study completed by Nobriga and Rosenfield (2016), which determined that December–May Delta outflow has a positive association with recruits per spawner. Under refined Proposed Project flow scenarios (Alternative 1 and Alternative 2), Delta outflow would be nearly identical to that under the Proposed Project (see Table 36 in Appendix B). Therefore, it is expected that the refined Proposed Project would have insubstantial effects on longfin smelt abundance if calculated using the Nobriga and Rosenfield (2016) approach detailed in Section 3.2.7 of Appendix B. A second approach is based on methods described in studies conducted by Kimmerer and Nobriga (2008) and Mount et al. (2013) and updated in DWR (2020). These studies use regression analyses to estimate longfin smelt as a function of mean January through June X2 position, as further described in Appendix B. Under the refined Proposed Project flow scenarios (Alternative 1 and Alternative 2), mean January through June X2 position would be identical to that expected under the Proposed Project (see Table 37 in Appendix B). Therefore, it is expected that the refined Proposed Project would have less than significant effects on longfin smelt abundance if calculated using the regression approach described in Section 3.2.7 of Appendix B.

3.4.3 Findings

There are no substantial changes to the circumstances under which the range of potential water transfers evaluated in the 2019 LTWT Final EIS/EIR would be undertaken. Based on the analyses summarized above, no new significant fisheries impacts or a substantial increase in previously identified fisheries impacts would occur as a result of the refinements to the Proposed Project. The 2019 LTWT Final EIS/EIR retains its relevance as to the evaluation of potential impacts, identification of mitigation measures, and consideration of alternatives for the Proposed Project. Therefore, impacts to fisheries as a result of refinements to the Proposed Project do not meet the standards for preparation of a subsequent or a supplemental EIR pursuant to CEQA Guidelines, Section 15162.

3.5 Power

3.5.1 Existing Environmental Setting

Section 3.16.1 of the 2019 LTWT Final EIS/EIR provides a summary of the environmental setting for the power analysis at the time the EIS/EIR was prepared. The environmental setting includes a description of the existing hydroelectric facilities with the potential to be affected by the range of potential water transfers evaluated in the 2019 LTWT Final EIS/EIR. The environmental setting for power has remained primarily the same for the Proposed Project.

3.5.2 Evaluation of Impacts

Section 3.16.2 of the 2019 LTWT Final EIS/EIR considered power generation impacts from changes in reservoir releases and elevations. As described in the 2019 LTWT Final EIS/EIR, in some years, sellers may start transferring water in April, May, or June, before Delta export capacity is available. If possible, Reclamation and DWR would back up this water in upstream reservoirs until export capacity becomes available in July, August and September. This "backing up" transfer water would decrease reservoir releases early in the season and increase releases later in the season. As noted in the 2019 LTWT Final EIS/EIR, if backing up of transfer water results in impacts to meet downstream standards and/or maintain exports when streamflow is decreased, Reclamation and DWR will release additional flows to meet these requirements. Reclamation and DWR would then capture additional flow during the eventual wetter periods, which would decrease releases. This backing up of water in storage and streamflow depletion could result in lower surface elevation at Shasta, Oroville and Folsom Reservoirs and would translate to reduced head and slightly decreased head component at the generation facilities. The 2019 LTWT Final EIS/EIR concluded that the loss of head pressure would reduce the efficiency of the turbines, and therefore the amount of electricity that can be produced. The power loss would be insubstantial because of the minimal difference between elevation at Shasta, Oroville, and Folsom Reservoir. Therefore, the impacts to power generation associated with transfers was considered to be less than significant.

Under the refined Proposed Project, Reclamation and DWR could store the backed up water during the summer months, i.e.,., July, August and September, for release in October and November. Similar to the evaluation presented in the 2019 LTWT EIS/EIR, backing up of water in Shasta, Oroville and Folsom Reservoirs under the refined Proposed Project could result in lower surface elevations at the three reservoirs. However, the difference in elevation would be minimal similar to the 2019 LTWT Final EIS/EIR. Additionally, comparison of releases from Keswick, Thermalito and Nimbus (power regulating facilities associated with Shasta, Oroville and Folsom Reservoir) show insubstantial changes under the refined Proposed Project in comparison to the Proposed Project (see Table A-7 through A-10 in Appendix A). Similar to the Proposed Project, Reclamation and DWR would consider increasing releases through the reregulating facilities to meet downstream standards and/or maintain exports when streamflow is decreased under the refined Proposed Project. As noted in Section 2, Project Description, if Reclamation or DWR were to reregulate flows through Keswich, Thermalito or Nimbus to meet downstream requirements which consequently impacts power generation and WAPA power users, a power letter of agreement would be developed to compensate for any power losses. Therefore, the impacts to power generation under the refined Proposed Project would be similar to that evaluated in the 2019 LTWT Final EIS/EIR and less than significant.

The 2019 LTWT Final EIS/EIR evaluated impacts to power generation from releasing water from non-Project reservoir for stored reservoir water transfers. The 2019 LTWT Final EIS/EIR concluded reservoir release transfers would increase power generation during the period when water is released and result in less power generation while the reservoir is refilling in subsequent wet seasons. This would reduce overall power supplies slightly, but it would primarily just change the timing of power generation and was considered to be less than significant. This operation would not change under the refined Proposed Project. The non-Project reservoirs could release transfer water earlier on the season (April through September) or water could be released in October and November, generating additional power during these months. After release, less power would be generated while the reservoir is refilling in subsequent wet seasons. Similar to the Proposed Project, in the long-term, the refined Proposed Project would not substantially reduce power supplies and impacts would remain less than significant.

3.5.3 Findings

There are no substantial changes to the circumstances under which the range of potential water transfers evaluated in the 2019 LTWT Final EIS/EIR would be undertaken, and there is no new information of substantial importance that has become available relative to power. No substantial changes in the power environmental setting have occurred since certification of the 2019 LTWT Final EIS/EIR, which retains its relevance as to the evaluation of potential impacts, identification of mitigation measures, and consideration of alternatives for the Proposed Project.

Based on the above, no new significant power-related impacts or a substantial increase in previously identified power impacts would occur as a result of refinements to the Proposed Project. Therefore, impacts to power do not meet the standards for preparation of either a subsequent or a supplemental EIR pursuant to CEQA Guidelines, Section 15162.

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Appendix A CalSim II Modeling Results

This appendix contains the changes to reservoir storage, river flow, Delta outflow and exports, and X2 location associated with each alternative. The changes are estimated using the CalSim II model.

3.1 Reservoir Storage

Based on modeling efforts, changes in CVP and SWP reservoir storage between the refinements to the Proposed Action and the 2019 Long-Term Water Transfers Final EIS/EIR (2019 LTWT Final EIS/EIR) are shown in Table A-1 through Table A-6. Compared to the reservoir levels analyzed in the 2019 LTWT Final EIS/EIR, water levels would increase in downstream CVP reservoirs (Shasta and Folsom) and the downstream SWP reservoir (Oroville) during dry and critical water years in July through September.

Table A-1. Changes in Shasta Reservoir Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
AN	0.9	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	-0.6	-0.6	-0.2	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	1.0	1.4	1.7
D	1.2	-0.1	-0.1	-0.1	-0.1	0.0	0.0	-0.1	-0.3	11.3	17.8	21.3
C	2.4	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.3	-0.8	13.6	19.0	22.7

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-2. Changes in Shasta Reservoir Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
AN	6.8	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	-0.6	-0.6	-0.2	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	1.0	1.4	1.7
D	1.7	-0.1	-0.1	-0.1	-0.1	0.0	0.0	-0.1	-0.3	11.3	17.8	21.3
C	5.4	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.3	-0.8	13.6	19.0	22.7

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-3. Changes in Oroville Reservoir Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3
AN	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	1.8	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	1.0	1.3	1.7
C	0.7	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	2.3	3.8	4.3

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-4. Changes in Oroville Reservoir Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3
AN	1.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	1.8	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	1.0	1.3	1.7
C	2.7	0.1	0.1	-0.2	0.1	0.1	0.1	0.1	0.1	2.6	4.0	4.6

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-5. Changes in Folsom Reservoir Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	1.1	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	1.8	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.0	4.6
C	2.1	0.8	0.8	0.7	0.6	0.6	0.6	0.6	0.6	3.3	4.9	5.7

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-6. Changes in Folsom Reservoir Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	1.9	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	1.8	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.0	4.6
C	3.3	2.0	2.0	0.7	0.8	0.8	0.8	0.8	0.8	3.5	5.0	5.8

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Based on modeling results, changes in reservoir releases from Keswick and Nimbus Reservoirs between the refinements to the Proposed Action and the 2019 LTWT Final EIS/EIR are shown in Table A-7 through Table A-10. Changes in releases from Thermalito Afterbay are shown in Table A-15 and A-16. Compared to the reservoir releases analyzed in the 2019 LTWT Final EIS/EIR, releases would increase in Keswick, Thermalito, and Nimbus in October and November and releases would decrease July through September of dry and critical water years.

Table A-7. Changes in Keswick Reservoir Releases between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
AN	12.9	1.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.6	0.0	-0.4	-0.2
BN	6.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.4	-0.4	-0.4	-0.2
D	9.6	1.3	0.0	0.0	0.0	-0.1	0.0	0.1	0.2	-11.6	-6.5	-3.5
C	13.3	2.4	0.0	0.0	0.0	0.0	0.0	0.3	0.4	-14.4	-5.3	-3.8

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-8. Changes in Keswick Reservoir Releases between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
AN	7.0	6.9	0.0	0.0	0.0	-0.1	0.0	0.0	0.6	0.0	-0.4	-0.2
BN	6.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.4	-0.4	-0.4	-0.2
D	9.1	1.8	0.0	0.0	0.0	-0.1	0.0	0.1	0.2	-11.6	-6.5	-3.5
C	10.3	5.4	0.0	0.0	0.0	0.0	0.0	0.3	0.4	-14.4	-5.3	-3.8

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-9. Changes in Nimbus Reservoir Releases between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.7	0.4	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	1.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	-2.5	-1.5	-0.6
C	2.5	1.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	-2.7	-1.6	-0.8

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-10. Changes in Nimbus Reservoir Releases between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	1.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	-2.5	-1.5	-0.6
C	1.5	1.3	0.0	0.1	0.4	0.0	0.0	0.0	0.0	-2.7	-1.6	-0.8

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

3.2 Non-Project Reservoir Storage

Based on modeling results, changes in reservoir storage in non-Project reservoirs participating in reservoir release transfers between the refinements to the Proposed Action and the 2019 LTWT Final EIS/EIR are shown in Table A-11 through Table A-16. Compared to the reservoir storage analyzed in the 2019 LTWT Final EIS/EIR, storage in non-Project reservoir would remain largely the same under the refined Proposed Project.

Table A-11. Changes in Camp Far West Reservoir Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-12. Changes in Camp Far West Reservoir Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4
C	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-13. Changes in Hell Hole and French Meadows Reservoirs Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-14. Changes in Hell Hole and French Meadows Reservoirs Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-15. Changes in Lake McClure Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.8	-0.8	-0.8	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
D	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.7	1.7
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-16. Changes in Lake McClure Storage between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	-0.8	-0.8	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
D	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.7	1.7
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

3.3 River Flow

Based on modeling results, Table A-17 through A-26 provides changes in river flows in between the refinements to the Proposed Action and the 2019 LTWT Final EIS/EIR. Average monthly flow rates in the Sacramento River, Feather River, and American River would decrease slightly from July through September and increase slightly in October and November

Table A-17. Changes in Sacramento River at Freeport Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	1.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
AN	15.4	1.4	0.0	0.7	0.0	0.0	0.0	-0.4	-0.1	-0.7	-1.1	-0.6
BN	17.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	9.6	4.6	0.5	0.1	0.0	0.0	0.0	0.0	0.0	-16.1	-8.7	-4.6
C	18.5	4.6	0.0	0.1	0.1	0.0	0.0	0.0	0.0	-21.0	-8.8	-5.5

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-18. Changes in Sacramento River at Freeport Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	1.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
AN	7.0	9.4	0.0	0.7	0.0	0.0	0.0	-0.4	-0.1	-0.7	-1.1	-0.6
BN	17.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	9.1	5.1	0.5	0.1	0.0	0.1	0.0	0.0	0.0	-16.1	-8.7	-4.6
C	12.2	9.9	0.0	0.1	0.4	0.0	0.0	0.0	0.0	-21.0	-8.8	-5.5

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-19. Changes in Sacramento River at Wilkins Slough Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
AN	12.9	1.0	0.0	0.0	0.0	-0.1	0.0	-0.4	0.0	-0.7	-1.1	-0.6
BN	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	9.6	1.3	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-11.8	-6.8	-3.6
C	13.3	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-14.8	-5.8	-4.1

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-20. Changes in Sacramento River at Wilkins Slough Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (in cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
AN	7.0	6.9	0.0	0.0	0.0	-0.1	0.0	-0.4	0.0	-0.7	-1.1	-0.6
BN	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	9.1	1.8	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-11.8	-6.8	-3.6
C	10.3	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-14.8	-5.8	-4.1

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-21. Changes in Feather River below Thermalito Afterbay Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
AN	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	-0.2	-0.3
C	2.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.4	-1.4	-0.5

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-22. Changes in Feather River below Thermalito Afterbay Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
AN	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	-0.2	-0.3
C	0.4	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.4	-1.4	-0.5

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-23. Changes in Lower Feather River Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep

W	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1
AN	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
BN	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.8	-0.5	-0.4
C	2.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.5	-1.5	-0.6

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-24. Changes in Lower Feather River Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1
AN	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
BN	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	2.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	-1.8	-0.5	-0.4
C	0.5	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.5	-1.5	-0.6

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-25. Changes in American River at H Street Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.7	0.4	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	1.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	-2.5	-1.5	-0.6
C	2.5	1.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	-2.7	-1.6	-0.8

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-26. Changes in American River at H Street Flows between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (cfs)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	1.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	-2.5	-1.5	-0.6
C	1.5	1.3	0.0	0.1	0.4	0.0	0.0	0.0	0.0	-2.7	-1.6	-0.8

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

3.4 Delta Outflow, Exports, and Salinity

Based on modeling efforts, changes in Delta outflow, exports, and X2 location between the refinements to the Proposed Action and the 2019 LTWT Final EIS/EIR are shown in Table A-27 through Table A-32. Delta outflows and exports would decrease in July through September and increase in October and November in dry and critical water years. The refinements to the Proposed Project would result in minor changes in Delta salinity conditions compared to the 2019 LTWT Final EIS/EIR.

Table A-27. Changes in Delta Outflow between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.4	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	3.2	0.3	0.0	0.7	-0.7	0.0	0.0	-0.5	-0.1	-0.1	-0.2	-0.1
BN	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	1.9	1.0	0.5	0.1	0.0	0.0	0.0	0.0	0.0	-3.8	-1.9	-0.7
C	3.7	0.9	0.0	0.1	0.1	0.0	0.0	0.0	0.0	-4.3	-1.8	-0.9

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-28. Changes in Delta Outflow between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.4	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	1.5	2.0	0.0	0.7	-0.7	0.0	0.0	-0.5	-0.1	-0.1	-0.2	-0.1
BN	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	1.8	1.1	0.5	0.1	0.0	0.1	0.0	0.0	0.0	-3.8	-1.9	-0.7
C	2.4	2.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	-4.3	-1.8	-0.9

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-29. Changes in Delta Exports between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
AN	13.8	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	-0.9	-0.5
BN	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4
D	7.7	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.8	-6.9	-3.9
C	14.8	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-17.3	-7.1	-4.7

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-30. Changes in Delta Exports between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (1,000 acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
AN	5.1	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	-0.9	-0.5
BN	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4
D	7.3	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.8	-6.9	-3.9
C	9.6	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-17.3	-7.1	-4.7

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-31. Changes in Delta X2 Position between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 1 (km change)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
C	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

Table A-32. Changes in Delta X2 Position between the 2019 LTWT Final EIS/EIR and the Proposed Project Refinements – Alternative 2 (km change)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
C	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1

Notes: AN – Above Normal; BN – Below Normal; C – Critical; D – Dry; Year Type – Sacramento River Water Year Type; W – Wet

ADDENDUM TO THE 2019 FINAL LONG-TERM WATER TRANSFERS EIS/EIR

APPENDIX B

SPECIAL-STATUS FISH IMPACT ANALYSIS FOR EXTENDED WATER TRANSFERS

September 2021

ICF

ICF. 2021. Addendum to the 2019 Long-Term Water Transfers Final EIS/EIR: Special Status Fish Impact Analysis for Extended Water Transfers. September. ICF 00568.18. Sacramento, CA. Prepared for CDM Smith.

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Chapter 1
Introduction

This technical report presents the results of additional information related to impacts on state and federally listed fish associated with changes in water transfer timing. This report is intended to supplement the analysis provided in the 2019 Long-Term Water Transfers Final Environmental Impact Statement/Environmental Impact Report (2019 LTWT Final EIS/EIR) to determine if new significant effects would occur by conducting water transfer actions in October and November.

1.1 Area of Analysis

For purposes of this analysis the area that will be evaluated includes the Shasta, Oroville, and Folsom Reservoirs, the portions of the Sacramento River, Feather River, and American River that flows from these reservoirs into the Delta, the Merced and San Joaquin Rivers, and the Sacramento-San Joaquin River Delta.

1.2 Proposed Action

Under the 2019 LTWT Final EIS/EIR, the upper limit for transfers in any one year would be 250,000 acre-feet and up to 60,693 acres of cropland could be idled. San Luis & Delta-Mendota Water Authority (SLDMWA) is proposing to refine the Proposed Project. The refinement would modify the water transfer window to extend the period for the transfers into October and November. The refined Proposed Project is presented below as two action alternatives, which attempt to maximize the volume of water conveyed across the Delta in individual months.

- **Alternative 1: Maximum October** – This alternative conveys as much transfer water as possible in October of each year with up to 209,000 acre-feet in a single month. Remaining transfer water is conveyed across the Delta in November.

- **Alternative 2: Maximum November** – This alternative conveys as much transfer water as possible in November of each year with up to 124,000 acre-feet in a single month. Remaining transfer water is conveyed across the Delta in October.

Chapter 2
Baseline Conditions

2.1 Data Sources Reviewed

Data sources used to develop baseline conditions in this document include peer-reviewed scientific literature, agency reports, and unpublished monitoring data.

2.2 Existing Habitat Conditions

Aquatic habitats included riverine, estuarine, reservoir habitats and the Sacramento-San Joaquin River Delta. It extends upstream within the channels of the Sacramento River to Keswick and Shasta Dams, including Shasta Reservoir, the American River to Nimbus and Folsom Dams, including Folsom Reservoir, the Feather River to Oroville Dam and including Oroville Reservoir. It also includes the legal Delta, Suisun Marsh and Suisun Bay which are connected to the Western Delta.

2.2.1 Shasta Reservoir and Sacramento River

Shasta Reservoir is formed by Shasta Dam, which is located on the Sacramento River just downstream of the confluence of the Sacramento, McCloud, and Pit rivers. Shasta Dam has no fish passage facilities, but it has a fish trapping facility that operates in conjunction with Livingston Stone National Fish Hatchery downstream of Shasta Dam to propagate winter-run Chinook salmon.

Shasta Reservoir fish species include native and introduced warm-water and cold-water species. The reservoir is typically thermally stratified from April through November, during which time the upper layer (epilimnion) can reach a peak water temperature of 80 degrees Fahrenheit (°F) (Bureau of Reclamation (Reclamation) 2003). The epilimnion supports warm-water game fish, while the lower layers (metalimnion and hypolimnion) support cold-water fishes. Nonnative, warm-water fish species in Shasta Reservoir include smallmouth bass, largemouth bass, spotted bass (*Micropterus punctulatus*), black crappie (*Pomoxis nigromaculatus*), bluegill, green sunfish, channel catfish (*Ictalurus punctatus*), white catfish, and brown bullhead (California Department of Water Resources (DWR) et al. 2013). Cold-water species include rainbow trout, brown trout, landlocked white sturgeon, landlocked coho salmon (Reclamation 2003), and landlocked Chinook salmon Reclamation 2013). Other fish species in Shasta Reservoir include golden shiner, threadfin shad, and common carp. Native fish species include hardhead (*Mylopharadon conocephalus*), Sacramento sucker (*Catostomus occidentalis*), and Sacramento pikeminnow (DWR et al. 2013; Reclamation 2013).

Water quality in Shasta Reservoir is generally considered good, largely because of the continual inflow of cool, high-quality water from the major tributaries to the reservoir. The primary water quality concern in the reservoir is turbidity, typically associated with heavy rainfall events that move soils and runoff from abandoned mines in the area into the reservoir.

Warm-water fish habitat in Shasta Reservoir is influenced primarily by fluctuations in the lake level and the availability of shoreline cover (Reclamation 2003). Water surface elevations in Shasta

Reservoir can fluctuate approximately 55 feet annually as a result of operation of Shasta and upper Sacramento River diversions (Reclamation 2003). Fluctuations in the surface elevation of the reservoir can disturb shallow, nearshore habitats, including spawning and rearing habitat for warm-water fish species. The shoreline of Shasta Reservoir is generally steep. This, with the large fluctuations in surface elevation, limits shallow, warm-water fish habitat, and the establishment of vegetation or other shoreline cover (Reclamation 2003).

Keswick Reservoir is a re-regulating reservoir for Shasta Reservoir. The water surface elevation is relatively constant. Residence time for water in Keswick Reservoir is about a day, compared with a residence time of about a year for water in Shasta Reservoir. Consequently, water temperatures tend to be controlled by releases from Shasta Dam and average less than 55°F. Despite the cool temperatures, the reservoir supports warm-water and cold-water fishes, including largemouth bass, crappie, catfish, and rainbow trout (Reclamation 2003).

Aquatic resources in the Sacramento River rely on the habitat in and along the river and along the tributaries that connect to the river. Habitat along the river ranges from artificial structures used for water supply and flood management to open spaces that provide more natural types of habitat. The flow regime of the Sacramento River is managed for water supply and flood management.

The upper Sacramento River extends from Keswick Dam for approximately 240 miles to the Delta. The Sacramento River is the largest river in California. The river and its tributaries provide spawning, rearing, and migratory habitat for four races of Chinook salmon, steelhead, and two species of sturgeon. Winter-run and spring-run Chinook salmon are federally- and state-listed species and Central Valley steelhead and the southern distinct population segment of green sturgeon are federally-listed. These species are described further in Section 2.3, Special Status Fish

The level of flow in the upper Sacramento River below Keswick Dam result from controlled releases from Shasta and Keswick reservoirs, as well as transfers from the Trinity River and natural accretions. The releases and transfers are determined by a suite of laws, regulations, contracts, and agreements to address demands of water users, requirements for water quality, and needs of fish populations throughout the river and the Delta. In particular, operations are regulated by the State Water Resources Control Board's (SWRCB) D-1641 decision, which requires flow releases to meet Delta standards, the WRO 90-5 decision, which requires cold water releases to meet temperature targets at compliance points in the upper Sacramento River, as modified by the 2019 National Marine Fisheries Service (NMFS) BiOp, which prescribes a tiered operational approach that allows for variable water temperature objectives for egg incubation based on water-year and cold water pool conditions.

The upper Sacramento River's water temperatures are controlled by selective withdrawal through the temperature control device (TCD) in Shasta Reservoir and by balancing releases between Lewiston (Trinity River) and Shasta Reservoirs. The water temperature operations have three principal objectives: (1) provide enough cold water to optimize survival of the current year's winter-run Chinook salmon eggs and alevins and those of other salmonids (Chinook Salmon and steelhead), (2) stabilize water levels through the fall to avoid dewatering redds and stranding juveniles of winter-run and other salmonids, and (3) conserve and rebuild Shasta storage in the fall and winter to provide the coldwater pool resources needed to optimize survival of the next year's winter-run eggs and alevins and those of other salmonids. Protection of other salmonids, especially spring-run Chinook salmon and steelhead, is an important objective, but winter-run Chinook salmon is the principal target of operations, as primary spawning habitat for winter-run Chinook salmon is the upper Sacramento River.

The mainstem Sacramento River provides habitat for native and introduced (nonnative) fish and other aquatic species. The diversity of aquatic habitats ranges from fast-water riffles and glides in the upper reaches to tidally influenced slow-water pools and glides in the lower reaches (Vogel 2011).

A few miles downstream of Keswick Dam, the river enters the Central Valley, and the floodplain broadens. Historically, this area had wide expanses of riparian forests, but the riparian zone now has a great deal of urban encroachment. In the middle Sacramento River between Red Bluff and Chico Landing, the mainstem channel is flanked by broad floodplains (The Nature Conservancy 2007). In the lower reaches downstream of Verona, much of the Sacramento River is constrained by levees. Dredging, dams, levee construction, urban encroachment, and other human activities in the Sacramento River have modified aquatic habitat, altered sediment dynamics, simplified stream bank and riparian habitat, reduced floodplain connectivity, and modified hydrology (NMFS 2009a). However, some complex floodplain habitats remain in the system such as reaches with setback levees and the Yolo and Sutter Bypasses.

An abundance of deep, cold-water pools in the upper mainstem Sacramento River provide habitat for holding adult anadromous salmonids during all months of the year (Vogel 2011). Green sturgeon also use deep pools for holding and spawning, but can tolerate warmer water temperatures than salmon, so the species can hold farther downstream.

Shasta and Keswick Dams substantially influence sediment transport in the upper Sacramento River because they block sediment that would normally be transported downstream (The Nature Conservancy 2007; DWR 1985). The result has been a net loss of coarse sediment, including gravel particle sizes suitable for salmon spawning, in the Sacramento River downstream of Keswick Dam (Reclamation 2013). To address the issue of spawning gravel loss downstream of Keswick Dam, Reclamation has placed approximately 5,000 tons of washed spawning gravel into the Sacramento River downstream of Keswick about every other year since 1997 (Reclamation 2010).

The suitability of physical habitat for salmonid spawning (i.e., not including water quality parameters such as temperature and DO) is largely a function of the availability of clean, coarse gravel for constructing redds, favorable depths, and suitable flow velocities. Instream flow potentially affects all three of these habitat characteristics and often affects the availability of suitable habitat.

Most winter-run Chinook salmon spawn in the uppermost reach of the Sacramento River, from Keswick Dam to the confluence with Clear Creek. Operations of Shasta and Keswick Dams generally determine flow and temperature in this area and largely determine spawning habitat availability.

Like winter-run Chinook salmon, the spawning distributions of spring-run, fall-run, and late fall–-run Chinook salmon populations that spawn in the Sacramento River are primarily upstream of RBDD, the Red Bluff Diversion Dam, with fall-run spawning the farthest downstream. About 15% of fall-run redds are constructed downstream of the RBDD. Spring-run spawning locations are generally between those of winter-run and fall-run Chinook salmon, and late fall–-run spawning distribution is most similar to that of winter-run Chinook salmon (NMFS 2017). The spawning substrate, depth, and flow velocity requirements of the four Chinook salmon runs are generally similar, so differences in spawning habitat availability among the runs are most strongly related to differences in their spawning distributions and in the prevailing flow and temperature levels during the time of year that they spawn.

Variations in flow can also have major effects on spawning habitat. Reductions in flow following spawning may result in dewatering of the redds and mortality of incubating eggs and alevins (USFWS 2006). Large increases in flow may result in scouring of riverbed sediments, including any redds present, or entombment in deposited sediments.

The spawning distribution of steelhead in the upper Sacramento River is poorly known, but the suitability of spawning habitat is largely determined by the same physical habitat and water quality parameters that affect the Chinook salmon runs, although preferred depths, flow velocities, and spawning substrates are somewhat different than those for Chinook salmon. As for the salmon runs, the availability of suitable spawning habitat for steelhead is strongly affected by instream flow (USFWS 2011).

Rearing habitat suitability for juvenile salmonids is generally related to flow much as described above for spawning habitat suitability, although important habitat features for rearing include cover, and the suitability of specific depths and flow velocities differ from those for spawning (USFWS 2005).

Historically, anadromous salmonids had access to a minimum of about 493 miles of habitat in the Sacramento River (Yoshiyama et al. 1996). After completion of Shasta Dam in 1945, access to approximately 207 miles was blocked. Keswick Dam, just downstream of Shasta Dam, is now the upstream extent of available habitat for anadromous fish in the Sacramento River.

Several endemic salmonid-specific pathogens occur in the Sacramento River: *Ceratonova shasta* (salmonid ceratomyxosis), *Parvicapsula minibicornis*, *Flavobacterium columnare* (columnaris), Infectious Hematopoietic Necrosis (IHN) virus, *Renibacterium salmoninarum* (bacterial kidney disease), *Flavobacterium psychrophilum* (cold-water disease), *Ichthyophthirius multifiliis* (white spot disease or Ich), and *Aeromonas salmonicida* (Furunculosis) (DWR 2004; Foott 2014). Of these, salmonid *Ceratonova shasta* and *Parvicapsula minibicornis* are of most concern for fisheries management in the region (Foott 2014; Foott et al. 2017). The Coleman National Fish Hatchery (NFH) on Battle Creek employs best management practices and protocols to minimize the spread of diseases to Battle Creek and the Sacramento River (Cramer Fish Sciences 2016).

On the mainstem Sacramento River, high rates of predation have been known to occur at the diversion facilities and areas where rock revetment has replaced natural riverbank vegetation (NMFS 2009a). Chinook salmon fry, juveniles, and smolts may be more susceptible to predation at these locations because Sacramento pikeminnow and striped bass congregate in areas that provide predator refuge (Williams 2006; Tucker et al. 1998). A recent study by Stompe et al. (2020) comparing angling catch per unit effort (CPUE) at engineered (water diversions or beam bridges), rip-rap, and natural locations found no statistically significant difference for striped bass and a marginally significant difference for Sacramento pikeminnow (greater CPUE catch per unit effort at engineered sites compared to natural sites), with no significant difference in diet composition between sites.

2.2.2 Oroville Reservoir and Feather River

The Feather River contributes approximately 25% of the total flow in the Sacramento River (Federal Energy Regulatory Commission (FERC) 2007). The lower Feather River extends about 67 miles from the Fish Barrier Dam below Oroville Dam to its confluence with the Sacramento River. There are two reaches where Chinook salmon, steelhead and green sturgeon spawn: the low-flow channel, which extends about 8 miles from the Fish Barrier Dam to the Thermalito Afterbay outlet, and the high-flow channel, which extends about 15 miles from the Thermalito Afterbay outlet to Honcut Creek (Vogel 2011). Most of the in-river spawning and rearing by salmon and steelhead occurs in the low-flow channel (FERC 2007; DWR 2007).

The Oroville Facilities include Oroville Dam, the Thermalito Diversion Dam, the Thermalito Complex, and the Feather River Fish Hatchery. The hatchery, which is managed by CDFW, raises spring and fall-run Chinook salmon and steelhead. A special fish barrier dam leads adults returning to spawn in the Feather River into the Feather River Fish Hatchery (DWR 2007). Central Valley spring-run and Central Valley fall-run Chinook salmon and California Central Valley steelhead are reared at the Feather River Hatchery, using cold water diverted from Oroville Reservoir. The capacity of this facility is 2.5 million fingerlings a year. Approximately 20 percent of the salmon and steelhead returning to spawn use the hatchery and 80 percent spawn in the Feather River (ICF International 2015). Hatchery operations are discussed in more detail below.

Oroville Dam impounds Oroville Reservoir, which is the principal water storage facility of the SWP. The reservoir has a storage capacity of 3.5-million-acre-feet (AF) and a surface area of 15,810 acres. The surface elevation of Oroville Reservoir is reduced through the summer season as releases from storage are required to meet downstream requirements, including instream flow, environmental requirements, in-basin uses, and urban and agricultural demand. In wetter years, the maximum total release from Oroville Reservoir typically occurs in February and March, due primarily to the requirement for large releases to meet flood control criteria and maintain adequate flood storage in the reservoir. In drier years, the highest releases from Oroville Reservoir typically occur in July (DWR 2007).

Releases from Oroville Reservoir are made into the Diversion Pool below Oroville Dam, where water can be released through the Thermalito Diversion Dam Power Plant to the low- flow channel (LFC) of the Feather River, or diverted through the Thermalito Power Canal Forebay and into Thermalito Afterbay. Flows can be diverted from Thermalito Afterbay into agricultural canals to meet local Feather River Service Area requirements (including WCWD and RID) or released through the Thermalito Afterbay outlet back into the Feather River, where they combine with flows passing through the LFC to produce the high-flow channel. Flows in the LFC are currently required to be at least 800 cfs from September 9 to March 31 of each water year, to accommodate spawning by anadromous salmonids, and at least 700 cfs the remainder of the year. Water temperatures in the LFC are required to meet stringent standards for protection of all life stages of the anadromous salmonids.

Oroville Reservoir typically thermally stratifies beginning in the spring, begins to de-stratify in the fall, and remains relatively uniform throughout the winter. Because of this stratification regime, Oroville Reservoir supports both coldwater and warmwater fisheries that are thermally segregated for much of the year. The coldwater fish use the deeper, cooler, well-oxygenated hypolimnion and thermocline, whereas the warmwater fish are found in the warmer, shallower, epilimnetic and littoral zones (DWR 2007).

Oroville Reservoir's coldwater fishery is primarily composed of coho salmon, although rainbow trout, brown trout, and lake trout (*Salvelinus namaycush*) are periodically caught. The coldwater fishery for coho salmon is sustained by hatchery stocking. The Oroville Reservoir warmwater fishery is a self-sustaining fishery. Spotted bass are the most abundant bass species in Oroville Reservoir, followed by largemouth, redeye (*Micropterus coosae*), and smallmouth bass. Catfish species and, white crappie (*Pomoxis annularis*), and black crappie are also present. Resident native species include white sturgeon, Sacramento sucker, Sacramento pikeminnow, and hardhead (DWR 2007).

Project operations influence fish habitat in Oroville Reservoir through manipulation of the amount of cold water released into the Feather River and changes in Oroville Reservoir's water surface elevation that result from flood control, power generation, and water releases downstream. Cold water is taken from Oroville Reservoir's hypolimnion for releases to the downstream fishery in the main channel of the Feather River, thereby potentially limiting the amount of cold water available for salmonids in Oroville Reservoir. Water surface elevation fluctuations in Oroville Reservoir occur on a seasonal basis, resulting from seasonal variations in upstream tributary inflows into the reservoir, as well as seasonal variations in Oroville Facilities reservoir releases. Reservoir stage reductions can reduce the amount of littoral fish habitat, bass nest survival, invertebrate food supply, and coldwater pool volume (DWR 2007).

Thermalito Afterbay provides habitat for both coldwater and warmwater fishes. This 4,300 surface-acre reservoir has gently sloping banks with large areas of rooted aquatic vegetation along its upper margins. Depths rarely exceed 20 feet. Changes in flow rates, pumpback operations, and water surface elevations resulting from project operations affect water temperatures and the quality, quantity, and distribution of fish habitat in the afterbay. Water temperatures can vary widely around the afterbay in the summer, from the low 60s (°F) near the tailrace channel that feeds the afterbay to the mid-80s (°F) in the backwater areas that do not readily circulate (DWR 2007). The operational range of surface elevation fluctuations is 12 feet, although the normal fluctuation range is between 4 and 8 feet. The water surface elevation can fluctuate rapidly and frequently, resulting in a high degree of variability in water levels from day -to -day and week -to week, depending on project operation (DWR 2007).

Fish species observed in Thermalito Afterbay include largemouth bass, smallmouth bass, rainbow trout, brown trout, sunfish species, black crappie, channel catfish, carp, and large schools of wakasagi (*Hypomesus nipponensis*). The rainbow and brown trout that occur in the afterbay likely are washed in from the smaller and colder Thermalito Forebay. The Thermalito Afterbay likely provides good habitat for largemouth and smallmouth bass, except that nest dewatering from reservoir fluctuations likely limits juvenile recruitment. Large schools of wakasagi provide a plentiful source of prey (DWR 2007).

At least 22 fish species have been found in the lower Feather River, although some of these may be non-residents washed down from Oroville Reservoir. Fish Species of Management Concern present in the lower Feather River include Central Valley spring-run Chinook salmon, Central Valley fall-run Chinook salmon, California Central Valley steelhead, southern DPS green sturgeon, Pacific lamprey, river lamprey (*Lampetra ayresii*), hardhead, and Sacramento splittail. Chinook salmon are abundant in the Feather River, with an estimated 30,000 to 170,000 Chinook salmon spawning in the Feather River annually (FERC 2007). There is substantial introgression between Feather River spring-run and fall-run Chinook salmon, likely a result of past hatchery practices and loss of geographic separation when Oroville Dam was built (Williams 2006; NMFS 2009a; Vogel 2011).

Oroville Dam releases are managed to benefit coldwater fisheries. Most Feather River spring-run Chinook salmon, fall-run Chinook salmon, and steelhead natural spawning occurs in the low-flow channel (LFC), which has flow and water temperature restrictions (FERC 2007:122). Flows in the LFC are currently required to be at least 800 cfs from September 9 to March 31 of each water year, to accommodate spawning by anadromous salmonids, and at least 700 cfs the remainder of the year. Water temperatures in the channel LFC range from 47°F in the winter to 65°F in the summer (Vogel 2011). The summer water temperatures can limit salmon production. Gravel recruitment is also an issue for the LFC of the river (Vogel 2011).

The flow regime in the reach of the Feather River extending from the Thermalito Afterbay outlet (RM 59) to the confluence of the Feather and Sacramento Rivers varies depending on runoff and month. Flows in this reach of the Feather River typically vary from the minimum flow requirement up to a flow of 7,500 cfs (FERC 2007). Spawning by southern DPS green sturgeon was documented in 2011, a wet year, at the Thermalito Afterbay outlet (Seesholtz et al. 2015).

The lower Feather River contained at least 71 miles of suitable spawning habitat for winter-run and spring-run Chinook salmon, steelhead, and green sturgeon prior to the installation of the Oroville Complex on the Feather River (Yoshiyama et al. 2001; Schick et al. 2005). Extensive mining, irrigation, and other dams significantly reduced the amount of suitable habitat for these species (Yoshiyama et al. 2001). Currently, most spawning for these fishes is concentrated in the uppermost 3 miles of accessible habitat downstream of the Feather River Fish Hatchery (FERC 2007). As a result, spawning is concentrated at unnaturally high levels directly downstream of Oroville Dam and the Fish Barrier Dam in the LFC.

The lower Feather River is almost entirely contained within a series of levees. Streamflow is regulated by the Oroville Complex (composed of the Oroville Dam, Thermalito Diversion Dam, and Thermalito Afterbay outlet), and releases from the Oroville Complex are planned weekly to accommodate water deliveries, Sacramento Valley in-basin demands such as Delta requirements, instream flow requirements in the Feather River, and minimum flood management space requirements. The lower Feather River's modified flow regime has reduced the frequency of channel- forming flows, which, along with levees, has reduced the lateral movement of the Feather River and resulted in a more channelized river with reduced sinuosity.

Natural channel processes have also been affected by flow fluctuations, including the interruption of the downstream movement of gravel and wood, lateral river movement forming side channels, and a reduction in the frequency of inundated flood plains. An estimated 97% of the sediment from the upstream watershed has been trapped behind Oroville Dam, only allowing the discharge of fine sediment into the lower Feather River (FERC 2007). As a result, optimum habitat features such as gravel and large woody materials from upstream reaches are now limited in the lower Feather River, and the median gravel diameter (D50) in the LFC may generally be too large for successful redd construction by native salmonids (FERC 2007). However, the lower Feather River watershed encompasses approximately 803 square miles, with approximately 190 miles of major streams and 695 miles of minor streams, which contribute to the sediment load of the lower Feather River. The FERC (2007) noted that the suitability of gravel sizes for spawning Chinook salmon increased with distance downstream of Oroville Dam.

DWR currently operates the Oroville Complex consistent with the applicable NMFS and USFWS BiOps. When Lake Oroville surface elevation is greater than 773 feet, minimum instream flow releases downstream of the Thermalito Afterbay outlet range from 1,000 to 1,700 cfs, depending on water year type and season.

Mean daily flow in the Feather River ranged from approximately 2,000 cfs in Critically Dry Water Years to 18,000 cfs in Wet Water Years prior to the completion of Oroville Dam (Oroville gage 1906–1965), and from approximately 1,000 cfs during Critically Dry Water Years to 12,000 cfs during Wet Water Years after the completion of the Oroville Dam (Gridley gage 1969–2012) (NMFS 2016).

Modeling and surveys have been conducted to inform management decisions by identifying optimum water flow for native salmonids. According to DWR(2002), optimum Chinook salmon flow suitability for spawning is about 800–825 cfs in the LFC and 1,200 cfs in the high-flow channel. Steelhead appeared to have no optimum flow for spawning in the LFC; however, optimum flow was just under 1,000 cfs in the high-flow channel (DWR 2004).

In addition to the Oroville Complex, two other potential/partial upstream migration barriers exist in the lower Feather River during low-flow or high-flow conditions (approximately 2,074 cfs or 9,998 cfs, respectively). These are the Sunset Pumps Diversion Dam and Steep Riffle (FERC 2007). The Sunset Pumps Diversion Dam is a rock weir structure approximately 27 miles downstream of the Fish Barrier Dam that may impede or delay passage under certain flow conditions. Planning efforts are underway to resolve/correct this feature. Steep Riffle is located approximately 2 miles upstream of the Thermalito Afterbay outlet but is generally considered passable under both low and high flows (Beamesderfer et al. 2004).

The Feather River Fish Hatchery is part of the SWP Oroville Complex. The hatchery is operated as part of a mitigation measure established to address anadromous fish decline as a result of loss of habitat upstream of Oroville Dam (NMFS 2009a). This facility produces fall-run Chinook salmon, spring-run Chinook salmon, and steelhead and is the sole contributor of hatchery-raised spring-run Chinook salmon found within the Central Valley (California Hatchery Scientific Review Group 2012). The hatchery-raised spring-run Chinook salmon are included in the federal designation of Central Valley spring-run Chinook salmon evolutionarily significant unit (ESU) (70 Federal Register [FR] 37160).

Several endemic salmonid-specific pathogens and diseases occur in the Feather River Basin: *Ceratomyxa shasta* (salmonid ceratomyxosis), *Flavobacterium columnare* (columnaris), Infectious Hematopoietic Necrosis (IHN) virus, *Renibacterium salmoninarum* (bacterial kidney disease), and *Flavobacterium psychrophilum* (cold-water disease) (DWR 2004). Each of these diseases has been shown to infect stocked and native salmonids in the Feather River (Federal Energy Regulatory Commission 2007). Of these, salmonid ceratomyxosis and IHN are of most concern for fisheries management in the region because of the associated fish mortality rates at the hatchery (DWR 2004).

Sufficient information is not available to estimate the current rate of predation on juvenile salmonids in the lower Feather River. As reported by FERC (2007), the Fish Barrier Dam concentrates most anadromous salmonid spawning within the low-flow channel LFC. Reported counts of known predators on juvenile anadromous salmonids in the low-flow channel LFC were low. However, significant numbers of predators reportedly do exist throughout the lower Feather River and have been known to congregate at passage impediments, such as the Sunset Pumps Diversion Dam (Seesholtz et al. 2004; Windell et al. 2017). Passage impediments increase the risk of predation by providing habitat for predator fishes that feed on out-migrating juvenile salmonids that become disoriented in the turbulent water below the dam, and by increasing the exposure to predation by delaying passage.

2.2.3 Folsom Reservoir and American River

The American River watershed includes nearly 2,100 square miles (USACE 2015). Three forks of the American River (north, middle, and south forks) meet upstream of Folsom Dam, and the collective flow is transported through Lake Natoma and the 23-mile lower American River before converging with the Sacramento River just north of the city of Sacramento. Access to the upper reaches of the American River by anadromous fish is blocked at Nimbus Dam.

Folsom Reservoir has a capacity of approximately 977 thousand acre-feet (TAF) (USACE 2002). Thermal stratification occurs in Folsom Reservoir from April until November which results in a thermocline with warmer, less dense water at the surface and colder, denser water underneath (USACE et al. 2012). This thermal stratification allows both cold-water and warm water fish species to coexist in the reservoir. Warm water fish species include native hardhead, California roach, Sacramento pikeminnow, and Sacramento sucker, as well as nonnative largemouth bass, smallmouth bass, spotted bass, sunfish, black crappie, and white crappie (Reclamation 2007). Cold-water fish species include native rainbow trout and planted Chinook salmon, as well as nonnative brown trout (Bureau of Reclamation 2007).

Formed by Nimbus Dam, Lake Natoma is a regulating afterbay to the Folsom Power plant and provides more uniform releases into the lower American River. Lake Natoma also serves as a forebay for diversions to the Folsom South Canal. Surface water elevations in Lake Natoma may fluctuate daily between 4 and 7 feet (USACE et al. 2012). Owing to the high fluctuation in surface water elevations and water temperatures, the lake has relatively low productivity as a fishery. The fish species present in Lake Natoma are generally similar to those found in Folsom Lake (Reclamation 2007).

Reclamation operates the CVP American River Division for flood control, municipal, industrial, and agricultural water supplies, hydroelectric power generation, fish and wildlife protection, recreation, and Delta water quality. Many other small reservoirs above Folsom Reservoir with a combined reservoir storage of approximately 820 TAF provide hydroelectric generation and water supply without specific flood control responsibilities. Because Folsom Reservoir is the closest reservoir among SWP/CVP reservoirs to the Delta, operators can use releases from Folsom to address any Delta regulatory requirements, such as water quality or flow requirements more quickly than upstream reservoirs.

Reclamation currently operates the reservoir to meet downstream regulatory requirements.

Water temperatures in the lower American River are managed primarily by the timing, magnitude, and temperature of water releases from Folsom and Nimbus Dams.

As a result of the recent reinitiation of consultation on coordinated SWP/CVP/SWP operations, the following refinements for American River operations have been made relative to the 2009 NMFS BiOp RPA, as summarized by USFWS (2019) and NMFS (2019:20):

> *"The proposed action is consistent with the approach under the 2009 RPA with a modified flow management standard that targets preserving coldwater pool in the drier years to improve temperature management and reduce the magnitude and frequency of the high temperatures seen under the 2013-2016 drought. A commitment to modify the shutters in drought conditions is also included to improve temperature management (USFWS 2019 and NMFS 2019:20)."*

Completion of Nimbus Dam in 1955 blocked upstream passage by anadromous fish and restricted available habitat in the lower American River to the approximately 23- river- mile reach below the dam to the confluence with the Sacramento River. Additionally, completion of Folsom Dam has blocked downstream transport of sediment that contributes to the formation and maintenance of habitat for aquatic species in the American River and further downstream.

Historically, more than 125 miles of riverine habitat was available for anadromous salmonids in the American River watershed (Yoshiyama et al. 1996). Access to the upper reaches of the river has been blocked by a series of impassable dams, which preceded the construction of Folsom Dam, including Old Folsom Dam, first constructed in the American River between 1895 and 1939.

The Nimbus Salmon and Steelhead Hatchery and American River Trout Hatchery (collectively, Nimbus Fish Hatchery) is located immediately downstream from Nimbus Dam. Facilities for the hatchery include a fish weir, fish ladder, gathering and handling tanks, hatchery-specific buildings, and rearing ponds. Nimbus Fish Hatchery was constructed primarily to mitigate the loss of spawning habitat for Chinook salmon and Central Valley steelhead (regardless of unintended genetic differences) that were blocked by the construction of Nimbus Dam (Reclamation and California Department of Fish and Game (CDFG) 2011). It does not address lost habitat upstream from Folsom Dam (California Hatchery Scientific Review Group 2012). Under contract with Reclamation, CDFW operates the hatchery (Lee and Chilton 2007). Operations include trapping, artificially spawning, rearing, and releasing steelhead and fall- /late fall–-run Chinook salmon. The Nimbus Fish Hatchery Winter-Run Steelhead Program is an isolated-harvest program, meaning it does not include natural-origin steelhead in the broodstock, and is designed and implemented to artificially spawn the adipose fin-clipped adult steelhead that seasonally enter the trapping facilities (California Hatchery Scientific Review Group 2012). These fin-clipped fish are not considered part of the Central Valley steelhead DPS by NMFS. The Nimbus Fish Hatchery Winter-Run Steelhead Program propagates fish for recreational fishing opportunities and harvest (California Hatchery Scientific Review Group 2012).

Beginning in 2008, in coordination with USFWS and the Sacramento Water Forum, Reclamation implemented a salmonid habitat improvement program in the lower American River. Since 2008, approximately 30,000 cubic yards of gravel and cobble have been placed in the American River.

CDFW has observed the occurrence of a bacterial-caused inflammation of the anal vent (commonly referred to as “rosy anus”) of steelhead in the lower American River. The inflammation has been linked to relatively warm water temperatures (Water Forum 2005). Disease transmission may be exacerbated by crowding under conditions when water flows are reduced (Water Forum 2005).

Several predatory fish are present in the lower American River, including black basses (largemouth bass, smallmouth bass, and spotted bass) and striped bass, that exert predatory pressure on salmonids and other native fish species. Two factors, reduced cold-water storage in Folsom Reservoir and using Folsom Reservoir to meet Delta water quality objectives and demands, influence habitat conditions in the lower American River for warm-water predator species that feed on juvenile salmonids and potentially alter predation pressure (Water Forum 2005). Additionally, isolation of redds in side channels resulting from fluctuations in Folsom Reservoir releases may increase predation of emergent fry (Water Forum 2005).

2.2.4 Merced River

The Merced River drains an area of approximately 1,276 square miles within the western Sierra Nevada Mountain Range, originating in Yosemite National Park at ~4,000 m elevation and draining into the San Joaquin River at 15 m elevation (NMFS 2014). The river is regulated by several dams, including New Exchequer, McSwain, Merced Falls, and Crocker-Huffman, which are used for flood protection, power generation, and agricultural and municipal water (Montgomery et al. 2008). New Exchequer Dam is the largest dam and created Lake McClure with a storage capacity near 1 million acre-feet (SWRCB 2018).

The Merced River supports the southern-most fall-run Chinook salmon population. Between 2011 and 2020, annual fall-run in-river escapement ranged from 426 to 3,191 adults with an average of 1,782 adults (CDFW unpubl. data). Spawning occurs between Crocker-Huffman Dam and the town of Cressy, although primary spawning habitat occurs between RM32 and RM52 (NMFS 2014). Juvenile rearing for fall-run Chinook salmon occurs from Crocker-Huffman Dam to the mouth of the Merced River.

The Merced River also supports the southernmost Central Valley steelhead population, but little is known about population size or habitat use (NMFS 2014). NFMS considers the steelhead population in the Merced River to be nonviable due to significant alternations in habitat from land and water use (Lindley et al. 2007). Suitable spawning habitat for steelhead in the Merced River is currently located from Crocker Huffman Dam (RM 52) to the Highway J59 Bridge Crossing (RM 42; NMFS 2014).

Stressors of salmonids inhabiting the Merced River include reduction and modification of seasonal flows, lack of suitable spawning gravels, and poor water quality (Lindley et al. 2007).

2.2.5 San Joaquin River

The San Joaquin River begins in the Sierra Nevada mountains and emerges from the foothills at Friant Dam (USACE and SJAFCA 2015). The river flows west to the Central Valley, where it runs northward and is joined by the Fresno, Chowchilla, Merced, Tuolumne, Stanislaus and Calaveras Rivers, and smaller tributaries as it flows north to the Sacramento-San Joaquin Delta. Altered flow regimes, flood control, and bank protection efforts along much of the San Joaquin River have reduced riparian vegetation and degraded habitat for native fish.

The San Joaquin River Restoration Program (SJRRP) stemmed from the October 2006 settlement of the case *NRDC et al. v. Kirk Rodgers et al*. The program has two objectives: (1) to restore and maintain fish populations in "good condition" in the mainstem San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish; and (2) to reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement (NFS 2014). Spring-run juveniles were first reintroduced in 2014 and adults first returned in 2019 (Sutphin et al 2019).

The reach of the San Joaquin River upstream (south) of the Merced River was historically occupied by fall-run Chinook salmon, spring-run Chinook salmon, and Central Valley steelhead. However, this reach has been significantly altered by land and water use over the past century and no longer supports these species (NMFS 2014). Fall-run Chinook salmon and steelhead historically and presently inhabit the reach downstream of the Merced River. Spring-run were extirpated from the entire San Joaquin River but have been reintroduced as an experimental population as part of the San Joaquin River Restoration Program. Green sturgeon have been reported by anglers in the San Joaquin River, although there is no evidence that they spawn in the river.

2.2.6 Sacramento-San Joaquin Delta

The Delta is a series of interconnected channels and islands lying near and upstream of the confluence of the Sacramento and San Joaquin rivers, near Antioch. The legal Delta is a triangular area extending from Freeport in the north to Vernalis in the south, to Antioch in the west. The waterways within the Delta are highly channelized by the levees protecting farms, homes, and towns on the islands. The Delta is strongly influenced by the tides, with water elevations and current direction being determined by the interaction of inflow, exports and tides. It serves as the hub of the State's water system and flow patterns through the Delta have been highly altered from historical patterns. The Delta includes a variety of habitats for fish including the mainstem rivers, sloughs, canals, natural and managed wetlands, and flooded islands. These habitats are affected by water diversions (both by the CVP and SWP as well as thousands of smaller local diversions), introduced fish, invertebrates, and plants, and environmental toxins from urban, municipal and farms.

Dozens of fish species use the Delta during some portion of their life. Six of these species are listed under federal or state ESAs. These include winter-run and spring-run Chinook salmon, Central Valley steelhead, and southern DPS green sturgeon green sturgeon, all of which migrate through the Delta on their way to upstream spawning and rearing habitats, and when their offspring migrate to the ocean from these upstream habitats. Most of these species may rear for some period of time in the Delta on their way to the ocean, with this duration depending on the species and conditions in the Delta. Delta smelt (*Hypomesus transpacificus*) are endemic (they are not found anywhere else) to the Delta and spend their entire lives in the Delta or Suisun Bay. Longfin smelt (*Spirinchus thaleichthys*) spawn in the Delta and rear in Suisun, San Pablo and San Francisco bays and nearshore marine ecosystems. A few of the non-listed native species that use the Delta include fall-run Chinook salmon, white sturgeon, and Sacramento splittail. A large number of non-native species also live in the Delta, including striped bass, largemouth bass, various sunfish and catfish, inland silversides, and threadfin shad.

Salinity is a critical factor influencing the distribution of aquatic communities in the Delta. Although estuarine fish species are generally tolerant of a range of salinities, this tolerance varies by species and life stage. Some species can be highly sensitive to excessively low or high salinity during physiologically vulnerable periods, such as reproductive and early life stages. While most of the Delta contains fresh water year-round due to inflows from rivers, the south Delta can have low salinity because of agricultural return water and the west Delta contains a fresh water/salt water prism typical of estuaries. This tidal prism moves east and west in the delta with the tides and the distance it moves may be influenced by the volume of fresh water inflow from tributary rivers, primarily the Sacramento River.

X2, which represents the location of the 2 parts per thousand (ppt) isohaline and is measured in kilometers as the distance to the Golden Gate Bridge, has been used to determine the location of the low salinity zone and the extent of habitat for oligohaline fish species and their habitat.

Several researchers (e.g., Feyrer et al. 2007, 2011; Kimmerer 2002a, 2002b; Kimmerer et al. 2009, Jassby et al. 1995) have explored the relationship between X2 and population status of delta smelt, longfin smelt, and other pelagic fishes in the Delta. The USFWS (2008 and 2019) and the California

State Water Resources (Decision D 1641) have relied on this work to establish the location of X2 as a factor in regulating the effect of the State and Federal water projects on habitat quantity and quality for these species.

More recent research (e.g., Hutton et al. 2015, Mac Nally et al. 2010, Murphy and Weiland 2019) has demonstrated the limitations of using a single location for evaluating salinity trends in the estuary, questioned the appropriateness of a single measure (X2) as a surrogate for regulating the complexity between flow, salinity, habitat quality, and population response of delta pelagic fishes in the estuary. Nevertheless, X2 remains a regulatory standard for maintenance of fall habitat for delta smelt (CWQCB D-1641).

Turbidity is an important water quality component in the Delta that affects physical habitat through sedimentation and foodweb dynamics by means of attenuation of light in the water column. Light attenuation, in turn, affects the extent of the photic zone where primary production can occur and the ability of predators to locate prey and for prey to escape predation.

Turbidity has been declining in the Delta, as indicated by sediment data collected by the U.S. Geological Survey since the 1950s (Wright and Schoellhamer 2004), and the decline has important implications for foodweb dynamics, nonnative submerged aquatic vegetation growth, and predation. Higher water clarity is at least partially caused by increased water filtration and plankton grazing by highly abundant overbite clams and other benthic organisms (Kimmerer 2004; Greene et al. 2011) and potentially by filtration by high densities of aquatic vegetation (Hestir et al. 2016). High nutrient loads coupled with reduced sediment loads and higher water clarity could contribute to plankton and algal blooms and overall increased eutrophic conditions in some areas (Kimmerer 2004).

2.3 Special-Status Fish

This addendum evaluates the following special-status species: Central Valley steelhead DPS, winter-run, spring-run, and fall-/late fall-run Chinook salmon, southern DPS of green sturgeon. longfin smelt, and delta smelt.

2.3.1 Central Valley Steelhead DPS

2.3.1.1 Legal Status

The California Central Valley (CCV) steelhead (*Oncorhynchus mykiss irideus*) ESU was listed as a threatened species under ESA on March 19, 1998. This ESU includes all naturally spawned populations of steelhead in the Sacramento and San Joaquin Rivers and their tributaries, including Bay-Delta (63 FR 13347).

CCV steelhead is not listed under CESA but is designated as a California Species of Special Concern.

2.3.1.2 Life History

Steelhead are broadly divided into two life history types, summer-run steelhead and winter-run steelhead, based on their state of sexual maturity at the time of river entry. Only winter-run steelhead are currently found in Central Valley rivers and streams. Historically, CCV steelhead were distributed from the upper Sacramento and Pit River systems (upper Sacramento, McCloud, Pit, and Fall Rivers) south to the Kings River (and possibly Kern River system in wet years) (McEwan 2001).

Presently, CCV steelhead are found in the Sacramento River downstream of Keswick Dam, in major tributary rivers and creeks in the Sacramento River watershed, and in major tributaries of the San Joaquin River (Stanislaus, Tuolumne, and Merced Rivers) and Delta (Mokelumne and Calaveras River). The populations in the Feather and American Rivers are supported primarily by the Feather River and Nimbus Fish Hatcheries, respectively. Other major steelhead populations in the Sacramento River watershed are found in Battle, Mill, Deer, Clear, and Butte Creeks.

Juvenile steelhead can be found in all waterways of the Delta, but particularly in the main channels leading from their natal river systems (NMFS 2009). Outmigrating steelhead smolts enter the Delta primarily from the Sacramento or San Joaquin Rivers. Juvenile steelhead are recovered in trawls from October through July at Chipps Island and at Mossdale. Steelhead are salvaged annually at the project export facilities (e.g., 4,631 fish were salvaged in 2010, and 1,648 in 2011) (Aasen 2011, 2012). Steelhead use the San Francisco and San Pablo Bays as a migration corridor to and from the ocean. The juveniles move quickly through the bays on their way to the ocean, preying on a variety of macroinvertebrates and small fish.

Adult steelhead migrate upstream past the Fremont Weir between August and March, but primarily from August through October, and they migrate upstream past RBDD during all months of the year, but primarily during September and October (NMFS 2009). The primary spawning area used by steelhead in the Sacramento River is the area from Keswick Dam downstream to RBDD. Unlike Pacific salmon, steelhead may live to spawn more than once and generally rear in freshwater streams for 2 to 4 years before outmigrating to the ocean. Both spawning areas and migratory corridors are used by juvenile steelhead for rearing prior to outmigration. The Sacramento River functions primarily as a migration channel, although some rearing habitat remains in areas with setback levees (primarily upstream of Colusa) and flood bypasses (e.g., Yolo Bypass) (National Marine Fisheries Service 2009a).

CCV steelhead adults migrate into the Feather River between July and March, and redd construction occurs from late December to March, peaking in late January (FERC 2007; McEwan 2001). The large majority of spawning in the Feather River (>98% between 2003-2011; DWR unpubl. redd survey data) occurs within the low-flow channel between the Fish Barrier Dam and the Thermalito Afterbay outlet. Fry begin to outmigrate in February, soon after emerging, with the majority outmigrating between March and mid-April. The large majority of juveniles (>99%) have been observed rearing the low flow channel (DWR 2012). Most juveniles outmigrate by September, but a small portion of juveniles that do not outmigrate rear in the river for up to 1 year, most often in secondary channels of the low-flow channel (FERC 2007).

Adult steelhead migrate up the American River from October through April with a peak occurring from December through March (Surface Water Resources 2001). Adult steelhead have been caught in the Nimbus Fish Hatchery trap as early as the first week of October. Spawning typically occurs in the lower American River between late December and early April, with the peak occurring in late February to early March (Hannon and Deason 2008). Spawning occurs between Nimbus Dam and Paradise Beach, although approximately 90% of spawning occurs upstream of the Watt Avenue Bridge (Hannon and Deason 2008). Embryo incubation occurs shortly after spawning in late December and generally extends through May, although incubation can occur into June in some years (Surface Water Resources 2001). Although steelhead embryo and alevin mortality from high flows in the American River has not been documented, flows high enough to mobilize spawning gravels and scour or entomb redds have been recorded during the spawning and embryo incubation periods (National Marine Fisheries Service 2009a). Juvenile *O. mykiss* are present year-round throughout the lower American River, with rearing generally upstream of spawning areas. Juveniles can rear in the lower American River for a year or more before outmigrating as smolts from January through June (Snider and Titus 2000a; Surface Water Resources 2001), although it is rare to find individuals older than YOY fry and parr (Snider and Titus 2002; Pacific States Marine Fisheries Commission 2014). Peak juvenile steelhead outmigration occurs from March through May (McEwan and Jackson 1996; Surface Water Resources 2001; Pacific States Marine Fisheries Commission 2014). Juvenile steelhead rear in the lower American River from Nimbus Dam to Paradise Beach. During summer months, juveniles occur in most major riffle areas, with the highest densities near the higher density spawning areas (Reclamation 2008). The number of juveniles in the American River decreases throughout summer (Reclamation 2008). Juveniles experience water temperature-related stress during summer and early fall (Lower American River Task Force 2002; Water Forum 2005; NMFS 2014) despite laboratory studies indicating that American River steelhead may be more tolerant of high temperatures than steelhead from other rivers (Myrick and Cech 2004).

Steelhead entering the San Joaquin River Basin appear to have a later spawning run, with adults entering the system starting in late October through December, indicating that migration up through the Delta may begin a few weeks earlier. During fall, warm water temperatures in the south Delta waterways and water quality impairment because of low dissolved oxygen at Stockton have been suggested as potential barriers to upstream migration (National Marine Fisheries Service 2009a). Reduced water temperatures, as well as rainfall runoff and flood control release flows, provide the stimulus to adult steelhead holding in the Delta to move upriver toward their spawning reaches in the San Joaquin River tributaries. Adult steelhead may continue entering the San Joaquin River Basin through winter.

General life stage timing for CCV steelhead is summarized in Table 1 and Table 2.

Table 1. Temporal Occurrence of Central Valley Steelhead by Life Stage

Relative Abundance	High (▼)								Medium (⊠)							Low (#)					None (-)			
Migration Life Stage: (a) Adult	Month																							
Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
[1]Sacramento R. at Fremont Weir	#	#	#	#	#	-	-	-	-	-	-	#	#	#	#	⊠	▼	▼	▼	⊠	#	#	#	#
[2]Sacramento R. at Red Bluff Diversion Dam	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	⊠	⊠	▼	⊠	#	#	#	#
[3]San Joaquin River	▼	▼	⊠	⊠	#	#	-	-	-	-	-	-	#	#	#	#	⊠	⊠	⊠	⊠	⊠	⊠	▼	▼
Migration Life Stage: (b) Juvenile	Month																							
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 et al. (1957); [2]McEwan (2001); [3]California Department of Fish and Game (2007); [4]NMFS analysis of 1998-2018 CDFW data; [5]NMFS analysis of 1998-2018 USFWS data; [6]NMFS analysis of 2003-2018 USFWS data.

Source: NMFS (2019).

Table 2. Temporal Occurrence of Central Valley Steelhead by Life Stage in the Delta

Relative Abundance	High (▼)			Medium (☒)			Low (#)			None (-)		
Life Stage	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult [1]	☒	☒	☒	☒	▼	-	#	☒	▼	☒	☒	☒
Juvenile [2]	#	☒	☒	▼	▼	#	#	-	#	-	-	#
Salvaged [3]	☒	▼	▼	☒	#	#	-	-	-	-	#	#

1Adult presence was determined using information in Moyle (2002), Hallock et al. (1961), and California Department of Fish and Wildlife (2015b).
2Juvenile presence in the Delta was determined using Delta Juvenile Fish Monitoring Program data.
3Months in which salvage of wild juvenile steelhead at State and Federal pumping plants occurred; values in cells are salvage data reported by the facilities (He and Stuart 2016).

Source: NMFS (2019)

2.3.1.3 Current Status in Area of Analysis

Recent steelhead monitoring data are scarce for the upper portion of the Sacramento River system. Hallock (1989) reported that steelhead had declined drastically in the Sacramento River upstream of the Feather River confluence. In the 1950s, the average estimated spawning population size upstream of the Feather River confluence was 20,540 fish (McEwan and Jackson 1996). In 1991–1992, the annual run size for the total Sacramento River system was likely fewer than 10,000 adult fish (McEwan and Jackson 1996). From 1967 to 1993, the estimated number of steelhead passing the Red Bluff Pumping Plant ranged from a low of 470 to a high of 19,615 (California Hatchery Scientific Review Group 2012). Steelhead escapement surveys at Red Bluff ended in 1993.

Although some spawning by steelhead in the American River occurs naturally (Hannon and Deason 2008), the population is supported primarily by the Nimbus Fish Hatchery. The total estimated steelhead return to the river (spawning naturally and in the hatchery) has ranged from 946 to 3,426 fish, averaging 2,184 fish per year from 2002 to 2010 (California Hatchery Scientific Review Group 2012). Steelhead spawning surveys have shown approximately 300 steelhead spawning in the river each year (Hannon and Deason 2008). Lindley et al. (2007) classifies the listed (i.e., naturally spawning) population of American River steelhead at a high risk of extinction because it is reportedly mostly composed of winter-run steelhead originating from Nimbus Fish Hatchery; possibly up to 90% of spawners are of hatchery origin (Hannon and Deason 2008). NMFS considers the American River population to be important to the survival and recovery of the species (NMFS 2009).

2.3.2 Winter-Run Chinook Salmon

2.3.2.1 Legal Status

On May 16, 1989, the California Fish and Game Commission listed the Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) ESU as endangered under CESA due to persistent long-term declines (Figure 1). The National Marine Fisheries Service (NMFS), under an emergency interim rule, listed the Sacramento River winter-run Chinook salmon ESU as a threatened species under the federal ESA in August 1989 (54 FR 32085). In 1994, NMFS reclassified the ESU as endangered due to several factors: the continued decline and increased variability of run sizes including expected weak returns due to small year classes in 1991 and 1993, and continuing threats to the species (59 FR 440). The ESU consists of one population in the mainstem of the upper Sacramento River in California's Central Valley below Keswick Dam, though efforts to reintroduce the run in Battle Creek have had success in recent years with at least 700 subadults and adults returning in 2020 as a result of juvenile releases undertaken in 2018 and 2019 (Figure 2; USFWS 2020). NMFS reaffirmed the listing of the Sacramento River winter-run Chinook salmon ESU as endangered on June 28, 2005 (70 FR 37160), and expanded the ESU to include winter-run Chinook salmon produced by the Livingston Stone National Fish Hatchery (LSNFH) artificial propagation program in the ESU.

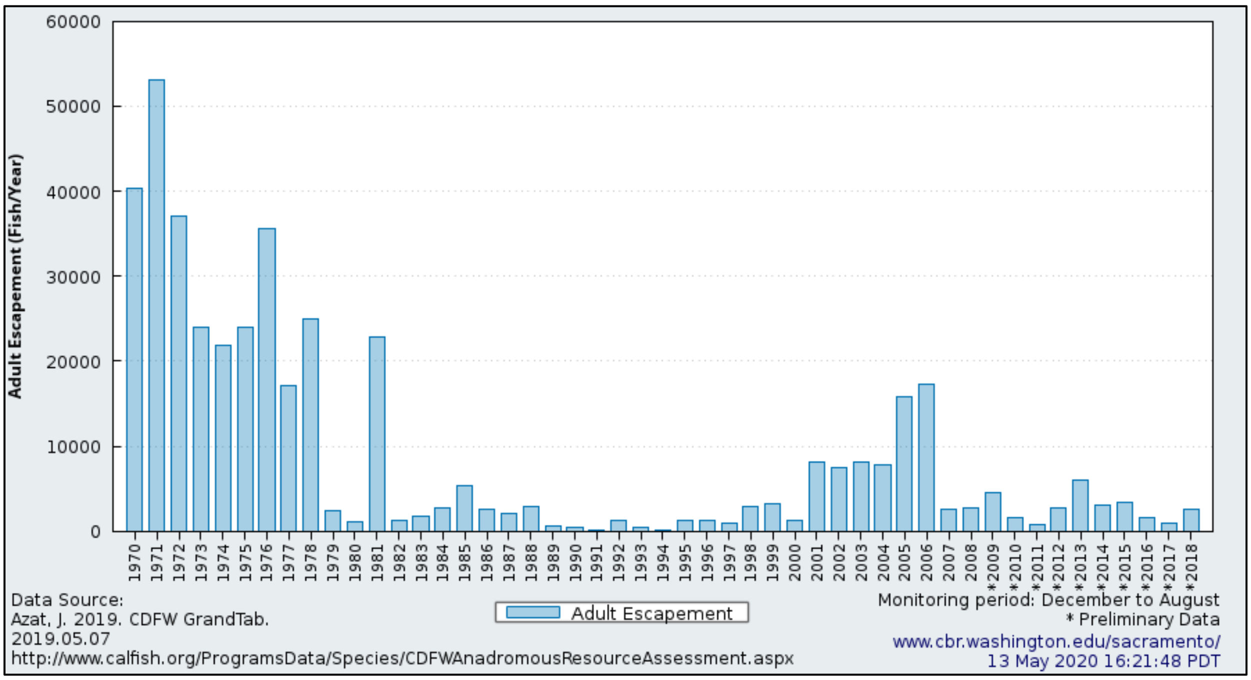


Figure 1. Winter-Run Chinook Salmon Adult Escapement in the Sacramento River, 1970-2018.

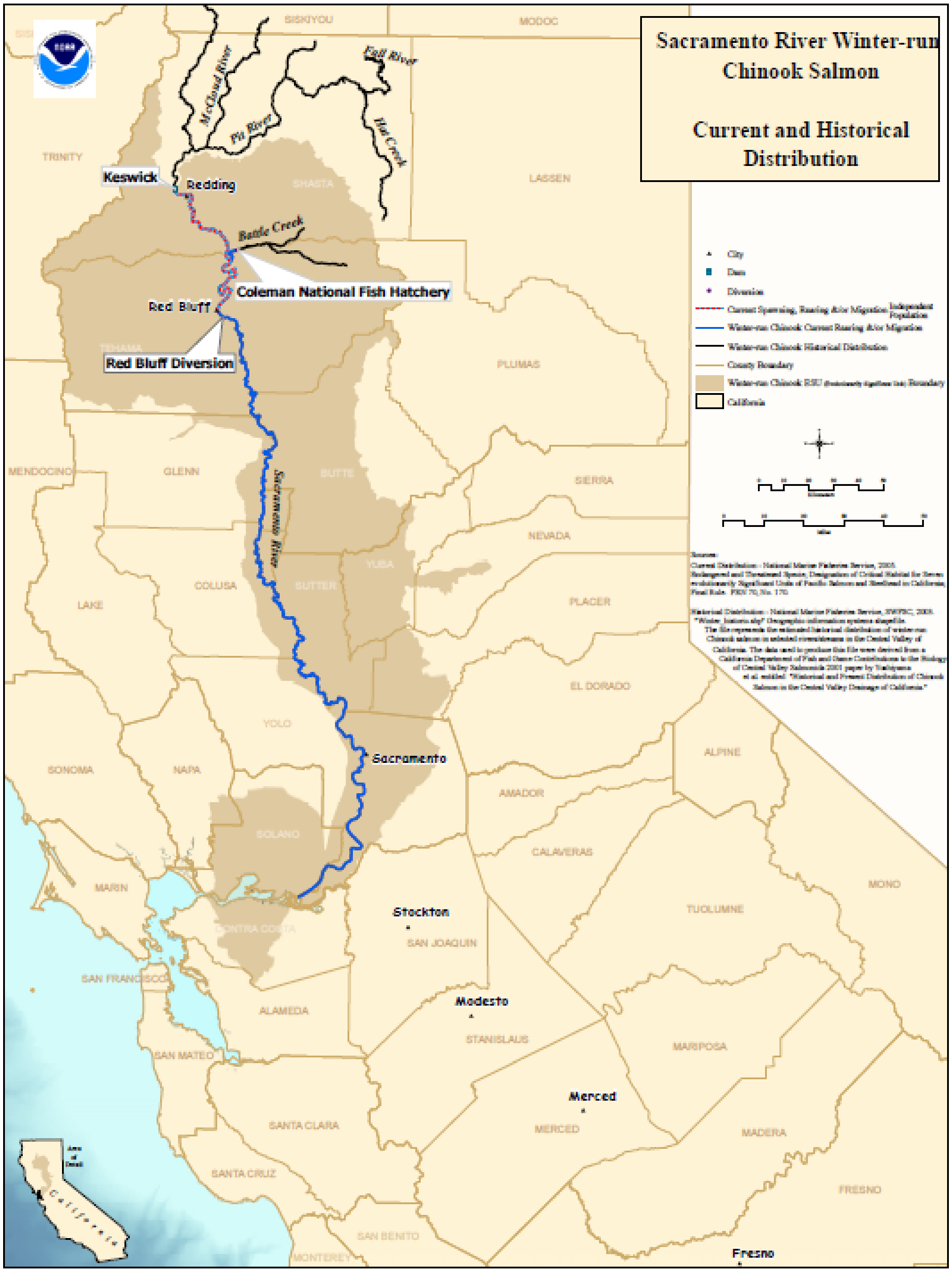


Figure 2. Current and Historical Sacramento River Winter-Run Chinook Salmon Distribution

2.3.2.2 Life History

Adult Sacramento River winter-run Chinook salmon enter the San Francisco Bay in November to begin their spawning migration and continue upstream from December through early August to the extent of anadromy at the base of Keswick Dam (Figure 2). Winter-run Chinook salmon spawn in the upper mainstem Sacramento River from mid-April through August, peaking in June and July. All known winter-run Chinook salmon production currently occurs either in the mainstem Sacramento River or LSNFH (CDFG 2004) although a nascent reintroduction effort in Battle Creek led to the return of at least 700 subadults and adults in 2020 (USFWS 2020). Current spawning is confined to the mainstem of the Sacramento River above Red Bluff Diversion Dam (RBDD) (River Mile [RM] 243) and below Keswick Dam (RM 302) (NMFS 2014). Until recent years, salmon passage was not possible above the Coleman Hatchery barrier weir located on Battle Creek.

2.3.2.3 Current Status in Area of Analysis

In addition to the Sacramento River, juveniles have also been found to rear in areas such as the lower American River, lower Feather River, Battle Creek, Mill Creek, Deer Creek, and the Delta (Phillis et al. 2018). Phillis et al. (2018) found with isotope data that 44% to 65% of surviving adults reared in non-natal habitats as juveniles. There may be other streams in which non-natal rearing occurs. The lower reaches of the Sacramento River, the Delta, and San Francisco Bay serve as migration corridors for both smolts and adults and are thought to serve as juvenile rearing habitat. Juvenile winter-run Chinook salmon begin to enter the Delta in October and smolt outmigration continues typically until April. Timing of smolt movement is thought to be strongly correlated with winter rain events that result in pulse flows in the Sacramento River (del Rosario et al. 2013). Fry and smolts are known to use the San Francisco Estuary as rearing habitat before entering the ocean (Phillis et al. 2018). In addition to monitoring salvage of winter-run Chinook salmon at the Tracy Fish Collection Facility (TFCF) and the John E. Skinner Delta Fish Protective Facility (Skinner Fish Facility) in the south Delta, temporal occurrence of each life stage in the project area is monitored using screw trapping data in the rivers, trawls, and beach seines in the estuary and, more recently, acoustic tagging using a network of receivers located throughout the extent of their range, from Keswick Dam to the Golden Gate Bridge (e.g., Klimley et al. 2017). General life stage timing for winter-run Chinook salmon is summarized in Table 3 and Table 4.

Table 3. Temporal Occurrence of Sacramento River Winter-Run Chinook Salmon by Life Stage in the Sacramento River

Relative Abundance	High (▼)			Medium (☒)			Low (#)			None (-)	
Adults Freshwater	Month											
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento River basin [a,b]	☒	☒	☒	☒	☒	☒	☒	-	-	-	☒	☒
Upper Sacramento River spawning [c]	-	-	-	-	#	▼	▼	☒	-	-	-	-
Juvenile Emigration	Month											
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 [f]	☒	☒	▼	▼	#	-	-	-	-	-	-	#

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 (1999-2019); [f] Delta Juvenile Fish Monitoring Program, USFWS (1995-2019), del Rosario et al. (2013).

Source: NMFS (2019)

Table 4. Temporal Occurrence of Sacramento River Winter-Run Chinook Salmon by Life Stage in the Delta

Relative Abundance	High (▼)			Medium (☒)			Low (#)			None (-)	
Life-Stage	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult [1]	☒	▼	▼	▼	☒	☒	-	-	-	-	☒	☒
Juvenile [2]	#	☒	▼	☒	-	-	-	-	-	#	#	☒
Salvaged [3]	☒	▼	▼	#	#	#	-	-	-	-	-	#

[1] Adults enter the Bay November to June (Hallock and Fisher 1985) and are in spawning ground at a peak time of June to July (Vogel and Marine 1991).
[2] Juvenile presence in the Delta was determined using Delta Juvenile Fish Monitoring Program data.
[3] Months in which salvage of wild juvenile winter-run at State and Federal pumping plants occurred (National Marine Fisheries Service 2016c).

Source: NNMFS (2019)

Stressors thought to be of very high importance to winter-run Chinook salmon by NMFS (2014:27) include blockage of historical staging and spawning habitat by Shasta and Keswick Dams; flow fluctuations, water pollution, and water temperature impacts in the upper Sacramento River during embryo incubation; loss of juvenile rearing habitat in the form of lost natural river morphology and function, and lost riparian and instream cover; predation during juvenile rearing and outmigration; ocean harvest; and south Delta entrainment. A very recent potential threat identified for winter-run is Thiamine Deficiency Complex, possibly the result of the oceanic diet of adults transferring negative effects to juveniles (NOAA Fisheries 2020a). Recent temperature modeling shows higher sensitivity to increases in water temperature because it leads to exponential increases in oxygen demand with a rise in temperature during the final weeks of egg-embryo maturation before the alevin stage (Martin et al. 2017; Anderson 2018).

2.3.3 Spring-Run Chinook Salmon

2.3.3.1 Legal Status

Spring-run Chinook salmon (*Oncorhynchus tshawytscha*), which were historically the most abundant run in the Central Valley, are now remnant in Butte, Mill, Deer, Antelope, Beegum, Battle, Big Chico, Clear, and Cottonwood Creeks, and the Yuba River, which are all tributaries of the Sacramento River. Spring-run Chinook salmon were extirpated from most rivers by mining or dam construction (Williams 2006). Due to the small number of these populations remaining and the significant hybridization with fall-run Chinook salmon that has occurred in the mainstem of the Sacramento (Moffett 1949) and Feather Rivers (Lindley et al. 2004), spring-run Chinook salmon were listed as threatened under CESA in 1999. Native spring-run Chinook salmon have been extirpated from the San Joaquin River watershed, which represented a large portion of their historical range, although reintroduction efforts in the San Joaquin River have been ongoing. The Central Valley spring-run Chinook salmon ESU was listed as threatened under the ESA in 1999 because of the reduced range and small size of remaining spring-run Chinook salmon populations (64 FR 50393). On June 28, 2005, NMFS published the final hatchery listing policy (70 FR 37204) and reaffirmed the threatened status of the ESU (70 FR 37160). The ESU consists of naturally spawned spring-run Chinook salmon originating from the Sacramento River and its tributaries, and also from the Feather River Fish Hatchery Spring-Run Chinook Program (National Marine Fisheries Service 2016).

2.3.3.2 Life History

Spring-run Chinook salmon share some similar life history and habitat requirements as those described for winter-run Chinook salmon, with differences primarily in the duration and time of year that the spring-run Chinook salmon ESU occupies freshwater habitat. Adult spring-run Chinook salmon enter fresh water as sexually immature fish between mid-February and July and remain in deep cold pools in proximity to spawning areas until late summer and early fall, when they are sexually mature and ready to spawn, depending on water temperatures (CDFG 1998; NMFS 2009a).

Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water, which promotes higher oxygen levels and reduced deposition of fines. Adult spawning conditions, incubation, and emergence from gravel is dependent on cold water temperatures (Myrick and Cech 2004). Fry emerge from gravels from November to March (Williams 2006). Post-emergent fry inhabits calm, shallow waters with fine substrates; fry depend on fallen trees, undercut banks, and overhanging riparian vegetation for refuge (Healey 1991).

Juvenile spring-run Chinook salmon can have highly variable outmigration timing based on various environmental factors (NMFS 2009a). Some juveniles begin outmigrating soon after emergence from gravel, whereas others oversummer and outmigrate as yearlings with the onset of intense fall storms (CDFG 1998). The outmigration period for spring-run Chinook salmon can extend from November to early May (National Marine Fisheries Service 2009:94) or June (CDFG 1998:III-9), with residency in the Delta probably lessening as the season progresses into the late spring months (CDFG 1998:III-9). Peak movement of yearling spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December and again in March and April (NMFS 2009a:94).

Juveniles prefer stream margin habitats with enough depth and velocities to provide suitable cover and foraging opportunities during rearing and downstream movement. Off-channel areas and floodplains can provide important rearing habitat. A greater availability of prey and favorable rearing conditions in floodplains increases juvenile growth rates compared with conditions in the mainstem Sacramento River, which can lead to improved survival rates during both their migration through the Delta and later in the marine environment (Sommer et al. 2001).

General life stage timing for spring-run Chinook salmon is summarized in Table 5 and Table 6.

Table 5. Temporal Occurrence of Central Valley Spring-Run Chinook Salmon by Life Stage in the Sacramento River

Relative Abundance	High (▼)								Medium (☒)							Low (#)						None (-)		
(a) Adult Migration	Month																							
Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac. River Basin [a,b]	-	-	-	-	☒	☒	☒	☒	▼	▼	▼	▼	☒	☒	☒	☒	☒	☒	#	-	-	-	-	-
Sac. River Mainstem [b,c]	-	#	#	#	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	#	#	-	-	-	-	-	-	-	-
Adult Holding [a,b]	-	-	#	#	☒	☒	▼	▼	▼	▼	▼	▼	▼	▼	▼	☒	☒	#	#	-	-	-	-	-
Adult Spawning [a,b,c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#	☒	▼	▼	☒	#	-	-	-	-
(b) Juvenile Migration	Month																							
Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac. River at Red Bluff Diversion Dam [c]	▼	▼	#	#	#	#	#	#	#	-	-	-	-	-	-	-	-	-	-	-	▼	▼	▼	▼
Sac. River at Knights Landing[h]	☒	☒	☒	☒	▼	▼	▼	▼	☒	☒	-	-	-	-	-	-	-	-	-	-	☒	☒	▼	▼

Sources: [a] *Yoshiyama et al. (1998);* [b] *Moyle (2002);* [c] *Myers et al. (1998);* [d] *Lindley et al. (2004);* [e] *California Department of Fish and Game (1998);* [f] *McReynolds et al. (2007);* [g] *Ward et al. (2003);* [h] *Snider and Titus (2000b)*

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.

Source: NMFS (2019)

Table 6. Temporal Occurrence of Central Valley Spring-Run Chinook Salmon by Life Stage in the Delta

Relative Abundance	High (▼)			Medium (☒)		Low (#)			None (-)			
Life Stage	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult [1]	☒	▼	▼	▼	☒	☒	-	-	-	-	-	-
Juvenile [2]	#	#	#	▼	☒	-	-	-	-	-	-	#
Salvaged [3]	#	#	☒	▼	☒	-	-	-	-	-	-	-

[1]*Adults enter the Bay late January to early February* (California Department of Fish and Game 1998) *and enter the Sacramento River in March* (Yoshiyama et al. 1998). *Adults travel to tributaries as late as July* (Lindley et al. 2004). *Spawning occurs September to October* (Moyle 2002).
[2]*Juvenile presence in the Delta based on Delta Juvenile Fish Monitoring Program data.*
[3]*Juvenile presence in the Delta based on salvage data* (National Marine Fisheries Service 2016a).

Source: NMFS (2019)

2.3.3.3 Current Status in Area of Analysis

Spring-run Chinook salmon were historically the dominant run of salmon in the Central Valley. Today, the mainstem Sacramento and Yuba Rivers and Butte, Mill, Deer, Clear and Battle Creeks maintain wild spring-run Chinook salmon populations (Figure 3). In most years, some adults return to Antelope, Big Chico, Little Chico, and Beegum Creeks, but these populations are not considered self-sustaining.

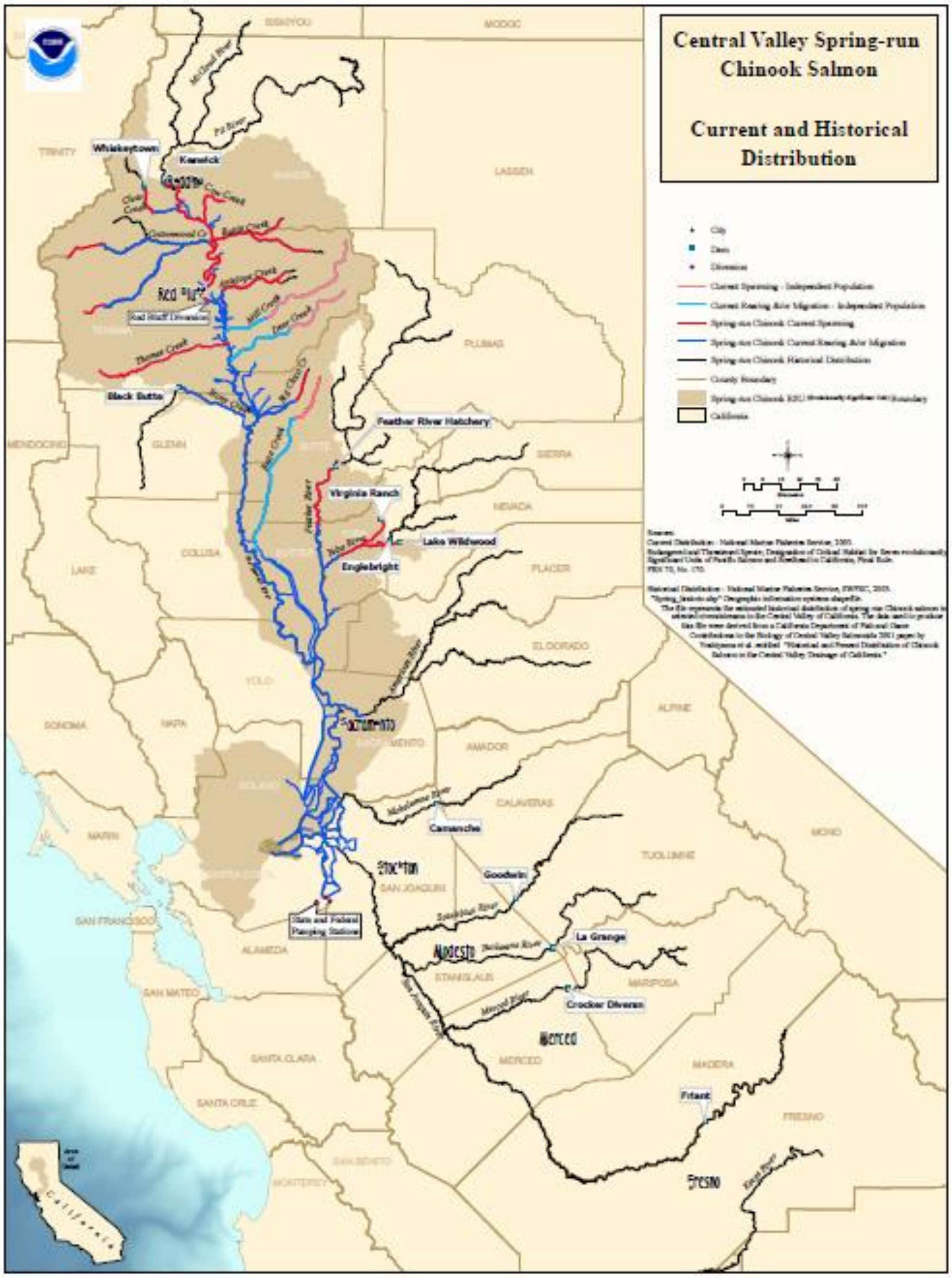


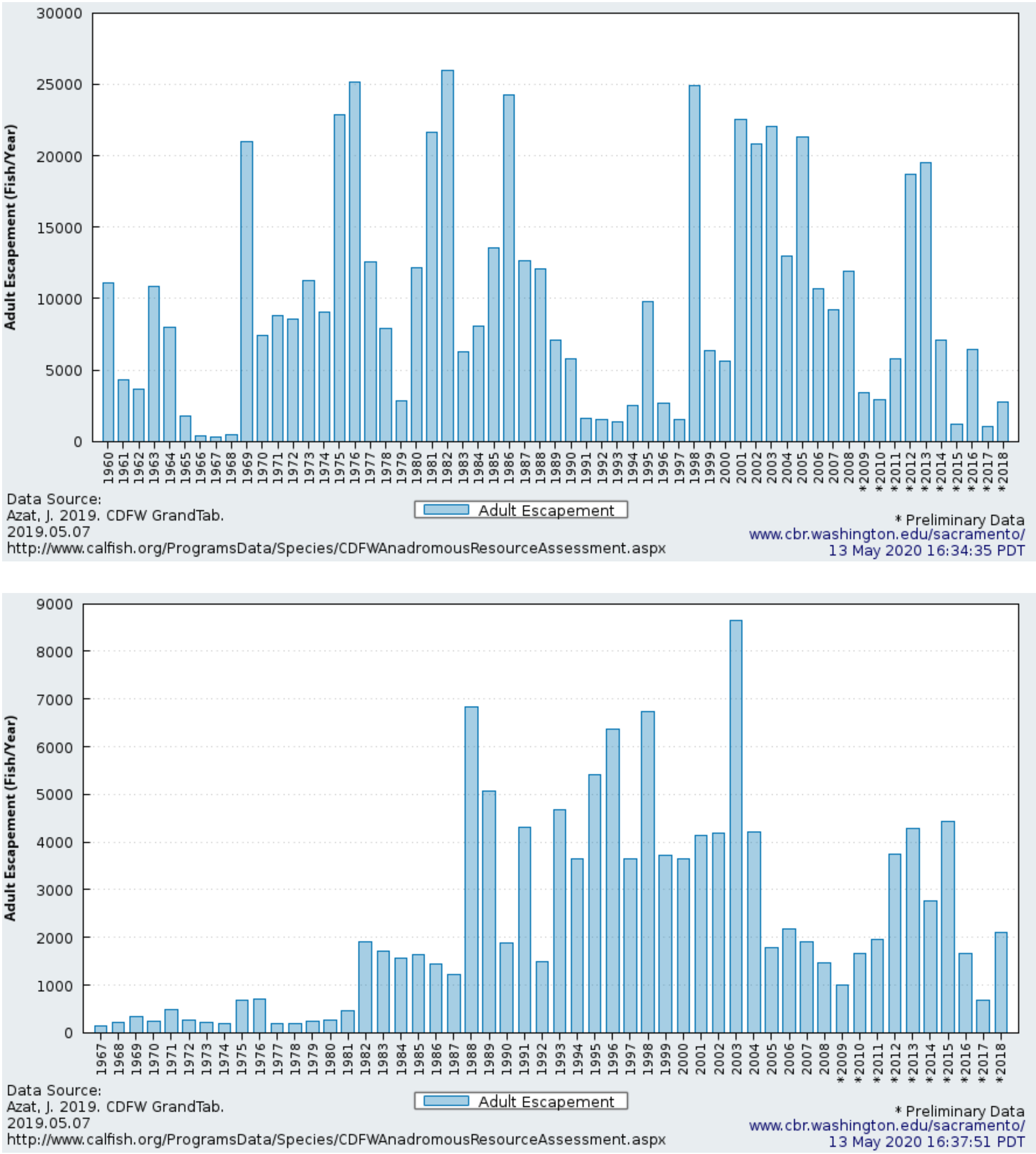
Figure 3. Current and Historical Central Valley Spring-Run Chinook Salmon Distribution. Source: NMFS(2014).

Since 1995, spring-run Chinook salmon annual run size estimates typically have been dominated by Butte Creek returns. Among Mill, Deer, and Butte Creeks, Butte Creek has produced an average of two-thirds of the total production between 2007-2017 (DWR and Reclamation 2017; California Department of Fish and Wildlife (CDFW) 2018a). During recent years, spring-run Chinook salmon escapement estimates (excluding in-river spawners in the Yuba and Feather Rivers) have ranged from 23,696 in 2013 to 1,796 in 2017 throughout the tributaries to the Sacramento River surveyed (CDFW 2018b).

Spring-run Chinook salmon population estimates remain low. In-river escapement was estimated to be 6,453 in 2016; 1,059 in 2017; and 2,774 in 2018 (Figure 4). During these years, escapement to hatcheries ranged from 691 (2017) to 2,110 (2018). In addition, fish monitoring is conducted throughout the year at the TFCF and the Skinner Fish Facility. Based on length-at-date criteria, during water year 2017, 26,551 wild (non-fin-clipped) juvenile spring-run and 963 hatchery (fin-clipped) spring-run Chinook salmon were observed at the TFCF and Skinner Fish Facility, and 9,487 wild juvenile spring-run and 1,010 hatchery spring-run were observed during water year 2018. Note, however, that length-at-date criteria for spring-run Chinook salmon are particularly prone to error because of the high overlap in lengths with the more abundant fall-run Chinook salmon, suggesting that actual spring-run entrainment is considerably lower than length-at-date criteria (Harvey et al. 2014).

In the Feather River in recent years, over 95% of Chinook salmon (fall-run ad spring-run combined) spawners (Hartwigsen 2009) and over 99.5% of juvenile rearing (DWR 2012) have been observed in the low flow channel during snorkel surveys. Potential reasons for the lack of salmonids in the high flow channel include low quality habitat and inhospitable predator abundance in the high flow channel and a large hatchery influence in the low flow channel.

Spring-run Chinook salmon are being reintroduced to the San Joaquin River as part of restoration efforts. In 2013, NMFS designated the Central Valley spring-run Chinook salmon reintroduced to the San Joaquin River as an experimental nonessential population in accordance with Section 10(j) of the ESA (78 FR 79622). This allows for the release of threatened California Central Valley spring-run Chinook salmon outside their current range. The population is considered an experimental, nonessential population (meaning that if the population does not survive, it will not threaten the whole ESU), because the population is geographically separate from the protected population of the same species (National Oceanic and Atmospheric Administration Fisheries 2020b). NMFS accounts for south Delta salvage of these reintroduced juveniles so that the reintroduction does not impose more than *de minimus* effects on water users (e.g., Strange 2020).



Source: Columbia Basin Research, University of Washington 2020.

Note: Vertical axis scale differs between upper and lower panel.

Figure 4. Spring-Run Chinook Salmon Adult In-River (Upper) and Hatchery (Lower) Annual Escapement in the Central Valley, 1970–2018

Stressors to spring-run Chinook salmon include access to habitat, degradation of habitat, exports, migration barriers, genetic introgression from hatchery-produced and overlapping fall-run individuals, and climate change.

2.3.4 Fall-/Late Fall-Run Chinook Salmon

2.3.4.1 Legal Status

The Central Valley fall- and late fall–run Chinook salmon (*Oncorhynchus tshawytscha*) ESU includes all naturally spawned populations of fall- and late fall–run Chinook salmon in the Sacramento and San Joaquin River basins and their tributaries east of Carquinez Strait, California (64 FR 50394). On April 15, 2004, the Central Valley fall- and late fall–run Chinook salmon ESU was identified by NMFS as a Species of Concern (69 FR 19975).

The Central Valley fall- and late fall-run Chinook salmon ESU is not listed under CESA. Fall- and late fall–run Chinook salmon is designated as a California species of special concern (Moyle et al. 1995).

2.3.4.2 Life History

Adult fall-run Chinook salmon migrate through the Delta and into Central Valley rivers from June through December. Adult late fall–run Chinook salmon migrate through the Delta and into the Sacramento River from October through April. Adult Central Valley fall-run and late fall–run Chinook salmon migrating into the Sacramento River and its tributaries primarily use the western and northern portions of the Delta, whereas adults entering the San Joaquin River system to spawn use the western, central, and southern Delta as a migration pathway.

Most fall-run Chinook salmon fry rear in fresh water from December through June, with outmigration as smolts occurring primarily from January through June. In general, fall-run Chinook salmon fry abundance in the Delta increases following high winter flows. Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. A small number of juvenile fall-run Chinook salmon spend over a year in fresh water and outmigrate as yearling smolts the following November through April. Late fall–run fry rear in fresh water from April through the following April and outmigrate as smolts from October through February (Snider and Titus 2000). Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay (MacFarlane and Norton 2002).

For fall–run Chinook salmon generally, peak spawning time is typically from October to November, but can continue through December and into January. Juveniles typically emerge from the gravel in December through March and rear in fresh water for 1 to 7 months (Moyle et al. 2015:543–552). Fall- and late fall–run Chinook salmon generally outmigrate as age-0 fish, although some (8.3% in 2011) late fall–run Chinook salmon juveniles outmigrate in their second year. Outmigration is generally from April to June for late fall–run and November to May for fall-run Chinook salmon.

Juvenile fall-run and late fall–run Chinook salmon migrating through the Delta toward the Pacific Ocean use the Delta, Suisun Marsh, and the Yolo Bypass for rearing to varying degrees, depending on their life stage (fry versus juvenile), size, river flows, and time of year. Movement of juvenile Chinook salmon in the estuarine environment is driven by the interaction between tidally influenced saltwater intrusion through San Francisco Bay and freshwater outflow from the Sacramento and San Joaquin Rivers (Healey 1991).

The fall-run Chinook salmon has an ocean-maturing type of life history adapted for spawning in lowland reaches of big rivers, including the mainstem Sacramento River. The late fall–run Chinook salmon has a stream-maturing type of life history (Moyle 2002). Similar to spring-run, adult late fall–run Chinook salmon typically hold in the river for 1 to 3 months before spawning, while fall-run

Chinook salmon generally spawn shortly after entering fresh water. Fall-run Chinook salmon migrate upstream past RBDD on the Sacramento River between July and December, typically spawning in upstream reaches from October through March. Late fall–run Chinook salmon migrate upstream past RBDD from August to March and spawn from January to April (NMFS 2009a; Tehama-Colusa Canal Authority 2008). The majority of young fall-run Chinook salmon migrate to the ocean during the first few months following emergence, although some may remain in fresh water and migrate as yearlings. Late fall–run Chinook salmon juveniles typically enter the ocean after 7 to 13 months of rearing in fresh water, at 150- to 170-mm in fork length, considerably larger and older than fall-run Chinook salmon (Moyle 2002). The primary spawning area used by fall-run and late fall–run Chinook salmon in the Sacramento River is the area from Keswick Dam downstream to RBDD. Spawning densities for all of the Chinook salmon runs are highest in this reach, but fall-run Chinook salmon generally spawn farther downstream in the reach than the other Chinook salmon runs (Gard 2013).

Feather River fall-run Chinook salmon are partially hybridized with Feather River spring-run Chinook salmon, but they largely maintain separate fall and spring upstream adult migrations. Fall-run adults return to the Feather River as sexually mature fish and spawn from September into December. The fall-run spawning period begins after the spring-run spawning period, but the spawning periods overlap considerably, leading to superimposition of spring-run redds by subsequently spawning fall-run adults. For this reason, a separation weir has been proposed to physically separate Central Valley spring-run and fall-run Chinook salmon in the river. Suitable water temperatures for Chinook salmon spawning in the Feather River are 42°F (5.5°C) to 58°F (14.4°C). Incubation may extend through March with suitable incubation temperatures between 48°F (8.9°C) and 58°F (14.4°C) (DWR 2007). Studies have confirmed that juvenile rearing and probably some adult spawning are associated with secondary channels within the Feather River low-flow channel. The lower velocities, smaller substrate size, and greater amount of cover (compared to the main river channel) likely make these side channels more suitable for juvenile Chinook salmon rearing. Currently, this type of habitat comprises less than 1% of the available habitat in the low-flow channel (DWR 2007). Juvenile Chinook salmon in the Feather River have been reported to outmigrate as young-of-the-year (YOY) (Seesholtz et al. 2004) and most appear to migrate out of the Feather River within days of emergence (National Marine Fisheries Service 2016). Juvenile outmigration from the Feather River is generally from mid-November through June, with peak outmigration occurring from January through March (NMFS 2016).

The American River historically supported fall-run and perhaps late fall–run Chinook salmon (Williams 2001). Both natural-origin and hatchery-produced Chinook salmon spawn in the lower American River. An analysis by Palmer-Zwahlen et al. (2018) found that constant fractional marking results from 2013 show that approximately 86% of the fall-run Chinook salmon spawners returning to Nimbus Hatchery were hatchery-origin. Further, 71% of fall-run Chinook salmon recorded at the Hatchery Weir and 65% of carcasses were identified as hatchery fish. Adult fall-run Chinook salmon enter the lower American River from about mid-September through January, with peak migration from approximately mid-October through December (Williams 2001). Spawning in the American River occurs from about mid-October through early February, with peak spawning from mid-October through December. Chinook salmon spawning occurs within an 18-mile (29 km) stretch from Paradise Beach to Nimbus Dam; however, most spawning occurs in the uppermost 3 miles (4.8 km) (California Department of Fish and Game 2012a). Chinook salmon egg and alevin incubation occurs in the lower American River from about mid-October through April. This period varies widely from year to year, although most incubation occurs from about mid-October through January.

Chinook salmon juveniles rear in the American River from about January to May (Snider and Titus 1995, 2002). Most Chinook Salmon outmigrate from the lower American River as fry between December and July; outmigration peaks February to March (Snider and Titus 2002; Pacific States Marine Fisheries Commission 2014).

General life stage timing for Central Valley fall-run and late fall–run Chinook salmon is summarized in Table 7 and Table 8.

Table 7. Temporal Occurrence of Central Valley Fall-Run Chinook Salmon by Life Stage

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Delta[1]												
Sacramento River Basin[2]												
San Joaquin River[2]												
Juvenile												
Sacramento River at Red Bluff[3]												
Delta (beach seine)[4]												
Mossdale (trawl)[4]												
West Sacramento River (trawl)[4]												
Chipps Island (trawl)[4]												
Knights Landing (trap)[5]												
Relative Abundance:		= High			= Medium				= Low			

Note: Darker shades indicate months of greatest relative abundance.

Sources:

[1] State Water Project and Federal Water Project fish salvage data 1981–1988.

[2] Yoshiyama et al. 1998; Moyle 2002; Vogel and Marine 1991.

[3] Martin et al. 2001.

[4] U.S. Fish and Wildlife Service 2001.

[5] Snider and Titus 2000.

Table 8. Temporal Occurrence of Central Valley Late Fall–Run Chinook Salmon by Life Stage.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Delta[1]	High	High	High	Medium	Medium					Medium	Medium	Medium
Sacramento River Basin[2]	High	High	High	Medium						Medium	Medium	Medium
Juvenile												
Sacramento River at Red Bluff[3]	High	High	High	High	Medium	Low	Low	High	High	High	High	Medium
West Sacramento River (trawl)[4]	Medium	Low		Low		Low	Low	Low	Low	Low	High	High
Delta (beach seine)[4]	High	Medium		High	High	Medium	Low				Low	High
Chipps Island (trawl)[4]	Medium	Low			Low	Low	Low	Low	Low	Low	Medium	High
Knights Landing (trap)[5]	Medium	Low		Medium	Medium	Low				Low	Medium	High

Relative Abundance: = High; = Medium; = Low

Note: Darker shades indicate months of greatest relative abundance.

Sources:

[1] Moyle 2002.

[2] Yoshiyama et al. 1998; Moyle 2002; Vogel and Marine 1991.

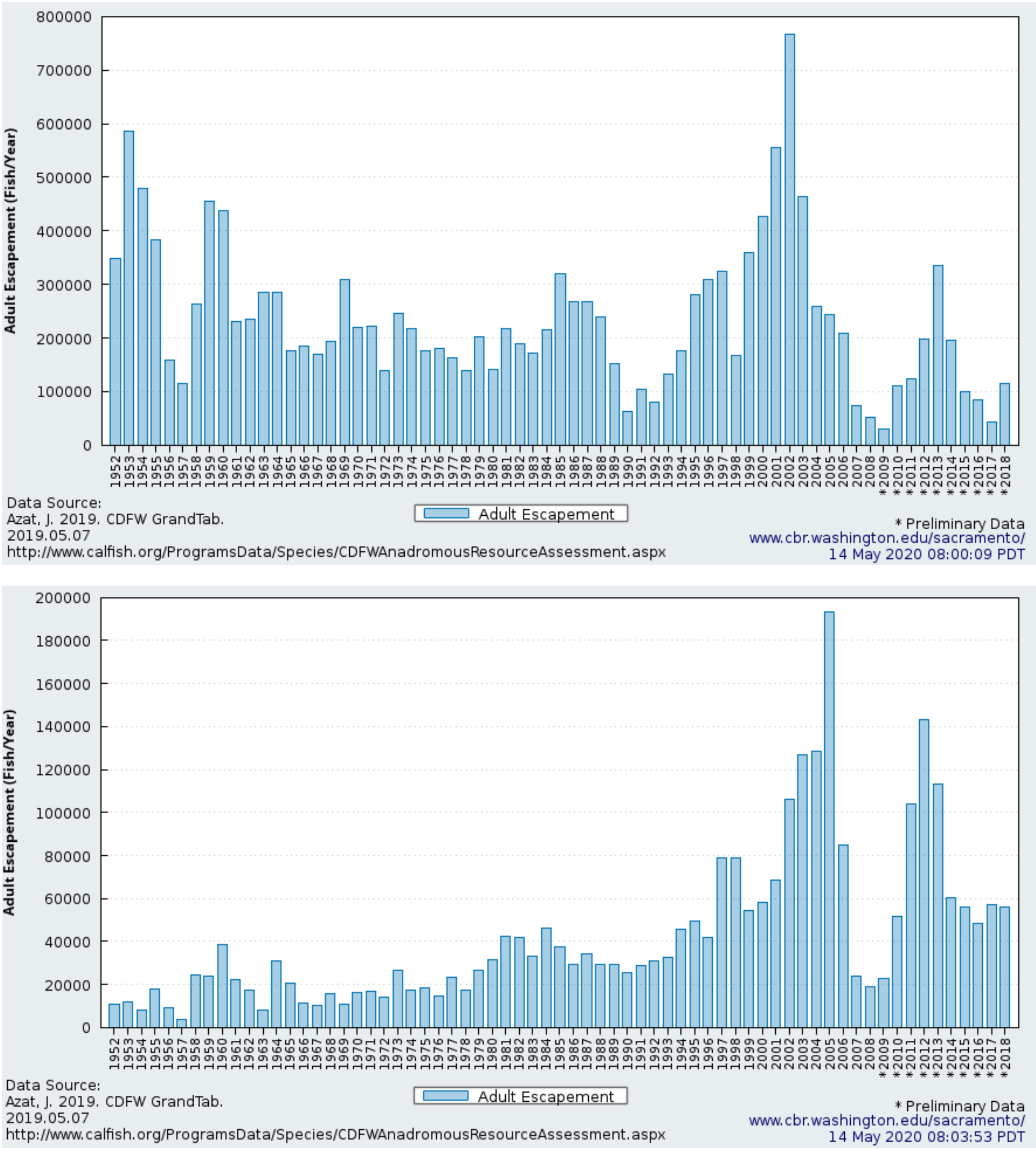
[3] Martin et al. 2001.

[4] U.S. Fish and Wildlife Service 2001.

[5] Snider and Titus 2000.

2.3.4.3 Current Status in Area of Analysis

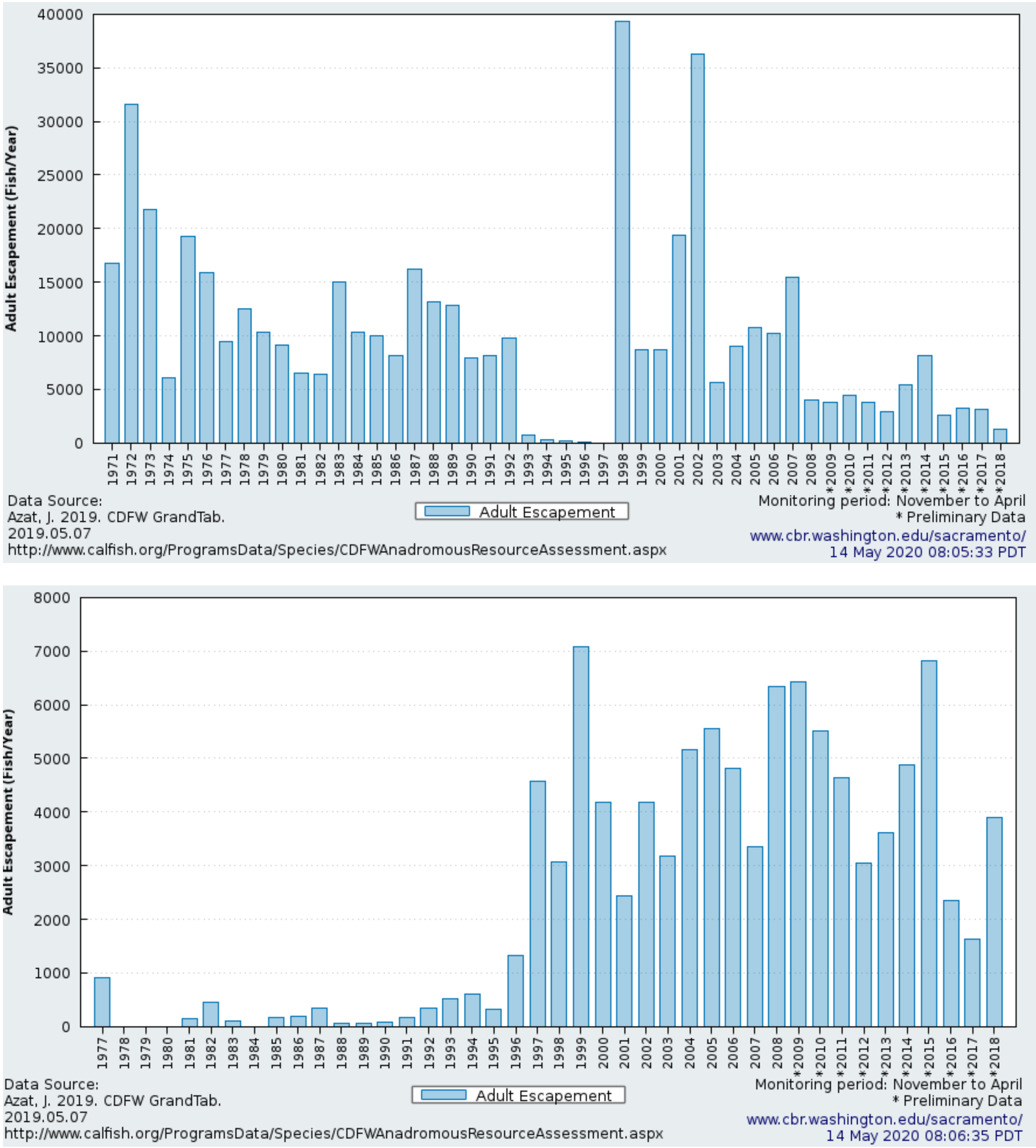
Annual fall-run and late fall–run Chinook salmon escapement to the Sacramento River and its tributaries has generally been lower in the last decade than historically, following peaks in the late 1990s to early 2000s (CDFW 2018a) (Figures 5 and Figure 6). Hatchery fall-run escapement was relatively consistent at approximately 50,000–60,000 fish during 2014–2018 (Figure 5), with hatchery escapement of late fall–run in recent years estimated to be greater than in-river numbers (Figure 5). Studies have suggested that hatchery-produced Chinook salmon may contribute large (approximately 90%) proportions of Chinook salmon to the mixed-stock fishery along the central California coast (Barnett-Johnson et al. 2007). Sturrock et al. (2019) found that transport distance of hatchery-origin juvenile Chinook salmon to release sites had increased over time (particularly during droughts) and was strongly associated with straying rate (averaging 0–9% compared to 7–89% for salmon released on site versus in the bay upstream of Golden Gate Bridge, respectively), increasing the effects of hatchery releases on natural spawners. The authors suggested that decreasing variation in release location and timing could reduce spatiotemporal buffering, narrowing ocean arrival timings and increasing risk of mismatch with peak prey production. The percentage of hatchery-origin fish released downstream of the Delta has been variable over time. For example, from the mid-1980s to 2012, the proportion of hatchery fall-run Chinook salmon juveniles released downstream of the Delta by state and federal hatcheries varied from around 20% to 60% (Huber and Carlson 2015). Similarly, from 2013 to 2017, the percentage of juvenile fall-run and spring-run Chinook salmon released by state Central Valley hatcheries downstream of the Delta varied between 24% (2016) and 60% (2013) (CDFW 2018c).



Source: Columbia Basin Research, University of Washington 2020.

Note: Vertical axis scale differs between upper and lower panel.

Figure 5. Fall-Run Chinook Salmon Adult In-River (Upper) and Hatchery (Lower) Annual Escapement in the Central Valley, 1970–2018



Source: Columbia Basin Research, University of Washington 2020.

Note: Vertical axis scale differs between upper and lower panel.

Figure 6. Late Fall–Run Chinook Salmon Adult In-River (Upper) and Hatchery (Lower) Annual Escapement in the Central Valley, 1970–2018

Stressors to fall-/late fall-run Chinook salmon include access to habitat, degradation of habitat, exports, migration barriers, genetic introgression from hatchery-produced and overlapping fall-run individuals, and climate change.

2.3.5 Green Sturgeon

2.3.5.1 Legal Status

The southern DPS of North American green sturgeon (*Acipenser medirostris*) was listed as threatened under the ESA by NMFS on April 7, 2006 (71 FR 17757). Included in the listing are the spawning population in the Sacramento River and fish living in the Sacramento River, the Delta, and the San Francisco Estuary.

Green sturgeon is not listed under the California ESA.

2.3.5.2 Life History

Green sturgeon reach maturity around 14 to 16 years of age and can live to be 70 years old, returning to their natal rivers every 3 to 5 years for spawning (Van Eenennaam et al. 2005). Adult green sturgeon move through the Delta from February through April, arriving at holding and spawning locations the upper Sacramento River between April and June (Heublein 2006; Kelly et al. 2007). Following their initial spawning run upriver, adults may hold for a few weeks to months in the upper river before moving back downstream in fall (Vogel 2008; Heublein et al. 2009), or they may migrate immediately back downstream through the Delta. Radio-tagged adult green sturgeon have been tracked moving downstream past Knights Landing during summer and fall, typically in association with pulse flows in the river (Heublein et al. 2009), similar to behavior exhibited by adult green sturgeon on the Rogue River and Klamath River systems (Erickson et al. 2002; Benson et al. 2007).

Similar to other estuaries along the West Coast of North America, adult and subadult green sturgeon frequently congregate in the San Francisco Estuary during summer and fall (Lindley et al. 2008). Specifically, adults and subadults may reside for extended periods in the central Delta as well as in Suisun and San Pablo Bays, presumably for feeding, because bays and estuaries are preferred feeding habitat rich in benthic invertebrates (e.g., amphipods, bivalves, and insect larvae). In part because of their bottom-oriented feeding habits, sturgeon are at risk of harmful accumulations of toxic pollutants in their tissues, especially pesticides such as pyrethroids and heavy metals such as selenium and mercury (Israel and Klimley 2008; Stewart et al. 2004). Subadult and adult green sturgeon occupy a diversity of depths within bays and estuaries for feeding and migration. Tagged adults and subadults within the San Francisco Estuary and Delta occupy waters over shallow depths of less than 33 feet (10 m), either swimming near the surface or foraging along the bottom, although recent studies suggested adults tend to be benthically oriented in the San Francisco Estuary and Delta (Chapman et al. 2019). Juvenile green sturgeon are largely oriented at or near the bottom (Thomas et al. 2019).

Green sturgeon larval distribution is estimated to extend at least 62 miles downstream from spawning habitats on the Sacramento and Feather Rivers in high-flow years. This estimated downstream distribution corresponds with the Colusa area on the Sacramento River (RM 157) and the confluence of the Sacramento and Feather Rivers near Verona (RM 80) for larvae originating in the Sacramento River and Feather River, respectively (Heublein et al. 2017:14). Juveniles are believed to use the Delta for rearing for the first 1 to 3 years of their lives before moving out to the ocean and are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, especially within the central Delta and Suisun Bay and Suisun Marsh. Project operations at the DCC have the potential to reroute green sturgeon as they outmigrate through the lower Sacramento River to the Delta (Israel and Klimley 2008; Vogel 2011). When the DCC is open, there is no passage delay for adults, but juveniles could be diverted from the Sacramento River into the interior Delta. This has been shown to reduce the survival of juvenile Chinook salmon (Brandes and McLain 2001; Newman and Brandes 2010; Perry et al. 2012), but it is unknown whether it has similar effects on green sturgeon.

The Sacramento River provides habitat for green sturgeon spawning, adult holding, foraging, and juvenile rearing. Sturgeon spawn in deep pools (averaging about 28 feet or 8.5 m deep) (NMFS 2018). Suitable spawning temperatures and spawning substrate exist for green sturgeon in the Sacramento River upstream and downstream of RBDD (Reclamation 2008). Although the upstream extent of historical green sturgeon spawning in the Sacramento River is unknown, the observed distribution of sturgeon eggs, larvae, and juveniles indicates that spawning occurs from Hamilton City to as far upstream as the Inks Creek confluence and possibly up to the Cow Creek confluence (Brown 2007; Poytress et al. 2013). Adult green sturgeon that migrate upstream in April, May, and June are completely blocked by the Anderson-Cottonwood Irrigation District (ACID) diversion dam (NMFS 2009b), rendering approximately 3 miles of spawning habitat upstream of the diversion dam inaccessible. Based on the distribution of sturgeon eggs, larvae, and juveniles in the Sacramento River, CDFG (2002) indicated that green sturgeon spawn in late spring and early summer, although they periodically spawn in late summer and fall (as late as October) (Heublein et al. 2009, 2017; NMFS 2018). Green sturgeon eggs are believed generally to hatch about a week after fertilization (Heublein et al. 2017). The number of green sturgeon accessing the upper Sacramento River appears to have increased following the decommissioning of RBDD (Steel et al. 2019).

Green sturgeon from the Sacramento River are genetically distinct from their northern counterparts, indicating a spawning fidelity to their natal rivers (Israel et al. 2004), even though individuals can range widely (Lindley et al. 2008). Larval green sturgeon have been regularly captured during their dispersal stage at about 2 weeks of age (24 to 34 mm fork length) in rotary screw traps at RBDD (CDFG 2002) and at about 3 weeks old when captured at the Glenn-Colusa Irrigation District (GCID) intake (Van Eenennaam et al. 2001). Young green sturgeon appear to rear for the first 1 to 2 months in the Sacramento River between Keswick Dam and Hamilton City (CDFG 2002).

Southern DPS North American green sturgeon are thought to have historically spawned in the Sacramento, Feather, and San Joaquin Rivers (Adams et al. 2007). Adults enter San Francisco Bay around late winter through early spring and generally migrate to spawning areas from late February through April. Spawning mainly occurs April through late July, with some occurring in late summer and early fall (Heublein et al. 2017). A significant portion of the spawning habitat was lost with the construction of Oroville Dam (FERC 2007; Yoshiyama et al. 2001; Schick et al. 2005). While regular occurrence of green sturgeon has been verified in the Sacramento River, only intermittent observations of spawning, at the Thermalito Afterbay outlet, have been reported in the lower Feather River (Beamesderfer et al. 2007; Seesholtz and Manuel 2012). After hatching, green sturgeon larvae possess limited swimming ability and generally seek refuge in low-velocity and complex habitats, such as large cobble substrate (Kynard et al. 2005). While little is known about green sturgeon rearing, it is likely that juveniles rear near spawning habitat for a few months or more before migrating to the Delta (Heublein et al. 2017:15).

Green sturgeon is also present in the San Joaquin River, but at considerably lower numbers than white sturgeon (*Acipenser transmontanus*). Between 2007 and 2012, anglers reported catching six green sturgeon in the San Joaquin River (Jackson and Van Eenennaam 2013). In 2017, environmental DNA testing confirmed the identity of a green sturgeon observed in the Stanislaus

River at Knights Ferry. Although the reported presence of green sturgeon in the San Joaquin River coincides with the spawning migration period of green sturgeon within the Sacramento River, no evidence of spawning has been detected (Jackson and Van Eenennaam 2013).

General life stage timing for southern DPS green sturgeon is summarized in Table 9 and Table 10.

Table 9. Temporal Occurrence of Southern Distinct Population Segment Green Sturgeon by Life Stage

Relative Abundance	High (▼)						Medium (⊠)						Low (#)						None (-)					
Life-Stage: (a) Adult-sexually mature[1]	Month																							
Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac River (river mile 332.5-451)	#	#	#	#	⊠	⊠	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	⊠	⊠	⊠
Sac River (<river mile 332.5)	#	#	#	⊠	⊠	⊠	⊠	⊠	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
Sac-SJ-SF Estuary	#	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	#	#
(b) Larva	Month																							
Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac River (<river mile 332.5)	-	-	-	-	-	#	⊠	⊠	▼	▼	▼	▼	▼	▼	⊠	⊠	⊠	⊠	#	#	-	-	-	-
(c) Juvenile (≤5 months old)	Month																							
Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac River (<river mile 332.5)	-	-	-	-	-	-	-	#	⊠	⊠	⊠	⊠	▼	▼	▼	▼	▼	▼	▼	⊠	⊠	⊠	⊠	⊠
(d) Juvenile (≤5 months old)	Month																							
Sac River (<river mile 391)	⊠	⊠	⊠	⊠	#	#	#	#	#	#	#	⊠	⊠	⊠	⊠	▼	▼	▼	▼	▼	▼	▼	▼	#
(e) Sub-Adults and Non-spawning adults	Month																							
Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac-SJ-SF Estuary	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	⊠	⊠
Pacific Coast	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠
Coastal Bays & Estuaries	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	▼	▼	▼	▼	▼	▼	▼			▼	▼ ▼	▼	▼ ⊠	⊠

[1] *Sexually mature adults (≥4.8 feet TL females, ≥ 3.9 feet TL males including pre- and post- spawning individuals)*

Sources: (a) (Heublein et al. 2009); (DuBois and Danos 2018; Klimley et al. 2015a; Mora et al. 2018; Poytress et al. 2015); (b) (Heublein et al. 2017; Poytress et al. 2015); (c) (Heublein et al. 2017; Poytress et al. 2015); (d) (California Department of Fish and Game 2002; Heublein et al. 2017; Poytress et al. 2015; Radtke 1966); (e) (DuBois and Danos 2018; Erickson and Webb 2007; Huff et al. 2011; Lindley et al. 2011; Lindley et al. 2008; Moser and Lindley 2007). Outside of Sac-SJ-SF estuary (e.g. Columbia R., Grays Harbor, Willapa Bay).

Source: NMFS (2019)

Table 10. Temporal Occurrence of Southern Distinct Population Segment Green Sturgeon by Life Stage in the Delta

Relative Abundance	High (▼)	Medium (⊠)	Low (#)	None (-)

Life Stage	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult [1]	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠
Juvenile [2]	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠
Salvaged [3]	#	#	#	#	#	-	⊠	▼	#	#	#	#

[1]Adult presence was determined to be year round according to information in (California Department of Fish and Game 2008; California Department of Fish and Game 2009; California Department of Fish and Game 2010a; California Department of Fish and Game 2011; California Department of Fish and Game 2012; California Department of Fish and Wildlife 2013a; California Department of Fish and Wildlife 2014a; Lindley et al. 2008; Moyle 2002).
[2]Juvenile presence in the Delta was determined to be year round by using information in (USFWS Delta Juvenile Fish Monitoring Program data), (Moyle et al. 1995; Radtke 1966).

Source: NNMFS (2019)

2.3.5.3 Current Status in Area of Analysis

A genetic analysis of green sturgeon larvae captured in the Sacramento River resulted in an estimate of the number of adult spawning pairs upstream of RBDD ranging from 32 to 124 between 2002 and 2006 (Israel 2006). Using results from acoustic telemetry and dual-frequency identification sonar (DIDSON) studies to locate green sturgeon in the Sacramento River to derive an adult spawner abundance estimate of 2,106 fish (95% confidence interval = 1,246–2,966), Mora et al. (2018) applied a conceptual demographic structure to the adult population estimate and generated a subadult southern Distinct Population Segment (sDPS) green sturgeon population estimate of 17,548 individuals (95% confidence interval = 12,614-22,482 individuals), together with an estimate of 4,387 juveniles (95% confidence interval = 2,595–6,179). It should be noted that the estimate does not include spawning adults in the lower Feather or Yuba Rivers (NNMFS 2019), with spawning confirmed in the Feather River (Seesholtz et al. 2015). Mora et al. (2018) cautioned that their juvenile and subadult green sturgeon estimates are less reliable than their adult estimates because the former were based on the ratios from a modeling study; the percentage of juvenile sturgeon is particularly uncertain because so little is known about this life stage. Additionally, the modeling study upon which the juvenile and subadult estimates are based requires four assumptions that Mora et al. (2018) admitted are rarely met: (1) constant recruitment, (2) population equilibrium, (3) stable size and age structure, and (4) a lack of density dependence. Mora et al. (2018) suggested, however, that their study provided a rough estimate of total abundance that is suitable for assessing the impacts of take, such as that observed in coastal trawl fisheries and at large water diversions.

Juvenile green sturgeon are periodically (although rarely) collected from the lower San Joaquin River at south Delta water diversion facilities and other sites (NMFS 2009b; Aasen 2011, 2012). Green sturgeon are salvaged from the south Delta diversion facilities and are generally juveniles greater than 10 months but less than 3 years old (Reclamation 2008). NMFS (2005) suggested that the high percentage of San Joaquin River flows contributing to the TFCF could mean that some entrained green sturgeon originated in the San Joaquin River Basin. Anglers have reported catching a few green sturgeon in recent years in the San Joaquin River (CDFG 2012b).

Stressors to green sturgeon include habitat loss, habitat modification, toxins, and climate change.

2.3.6 Delta Smelt

2.3.6.1 Legal Status

Delta smelt (*Hypomesus transpacificus*) was listed as a threatened species under the federal ESA and CESA in 1993. On March 4, 2009, the California Fish and Game Commission elevated the status of delta smelt to endangered under CESA. On 12/2/2016, the USFW) determined that reclassifying the delta smelt from threatened to endangered was warranted but was precluded by other higher priority listing actions . Therefore, delta smelt is currently listed as threatened under the federal ESA and endangered under CESA.

2.3.6.2 Life History

Delta smelt are endemic to the San Francisco Estuary and Sacramento–San Joaquin Delta (Delta) where the species primarily occupies open-water habitats in Suisun Bay, Suisun Marsh, and the Delta. On occasion, delta smelt distribution can extend up the Sacramento River to about Garcia Bend in the Pocket-Greenhaven neighborhood of Sacramento, up the San Joaquin River from Antioch to areas near Stockton, up the lower Mokelumne River system, and west throughout the Napa River and San Francisco Bay. Delta smelt is primarily an annual species, completing its life cycle in 1 year, which typically occurs from April to the following April. In captivity, delta smelt can survive to spawn at 2 years of age (Lindberg et al. 2013), but age-2 delta smelt are now rare in the wild (Bennett 2005; Damon et al. 2016).

Delta smelt complete their entire life cycle within the low-salinity zone of the Upper San Francisco Estuary, in the tidal freshwater region of the Cache Slough Complex or move between the two regions of fresh water and low salinity (Bennett 2005; Sommer and Mejia 2013; Hobbs et al. 2019).[1] Komoroske et al. (2016) found that delta smelt can acclimate to salinities greater than 6 parts-per-thousand (ppt) in the laboratory, but observations of delta smelt presence in waters having salinities exceeding 6 ppt in the wild are comparatively rare (92% of fish caught are at salinity < 6 ppt; Komoroske et al. 2016). This could be because the osmoregulatory costs at such high salinities are too high to support growth and survival (Komoroske et al. 2016), or the discrepancy between field observations and laboratory observations may be evidence that delta smelt's distribution in the wild is due to a factor or factors other than salinity per se (USFWS 2019:122).

Although delta smelt are physiologically euryhaline (i.e., are able to tolerate 0.4 – 34.0 ppt), the cumulative costs associated with physiological adjustments required to achieve homeostasis across a large, fluctuating salinity gradient may be higher than the continual maintenance cost for homeostasis within the low salinity zone (Komoroske et al. 2016).

Delta smelt spawning may occur at night with several males attending a female that broadcasts her eggs onto bottom substrate (Bennett 2005; Lindberg et al. 2020). Although preferred spawning substrate is unknown, spawning habits of the delta smelt's closest relative, surf smelt (*Hypomesus pretiosus*), in addition to experimental trials, suggest that sand or small pebbles may be the preferred substrate (Bennett 2005; Lindberg et al. 2020). Hatching success peaks at water

[1] The low-salinity zone is frequently defined as waters with a salinity range of about 0.5 to 6 parts per thousand (Kimmerer 2004).

temperatures of 15°C to 16°C (59.0 °F to 60.8°F), ceasing when water temperatures exceed 20°C (68.0°F) (Bennett 2005). Water temperatures suitable for spawning occur most frequently from March to May, but ripe female delta smelt have been observed as early as January and larvae have been collected as late as July (Damon et al. 2016). Most spawning occurs at 9°C to 18°C (48.2°F to 64.4°F) (Damon et al. 2016). Delta smelt appear to have one spawning season for each generation, which makes the timing and duration of the spawning season important every year. Damon et al. (2016) found all pre-spawn females achieved spawning size around April, which would result in only one spawn per female, with subsequent spawning events being rare except in exceptional years when the thermal spawning window extends past May. Prior studies suggested that spawning locations change based on hydrological conditions (reviewed by Bennett 2005:13). However, a more recent study indicated that the majority of regional movement from juvenile and subadult rearing locations to spawning areas occurs by January, spawning habitat locations are relatively constant within and between years, and no substantial further restructuring of the population at regional scales occurs after fish move to spawning locations (Polansky et al. 2018). The main spawning locations are in the lower Sacramento and San Joaquin Rivers, as well as the north Delta including the Cache Slough complex and Sacramento Deep Water Ship Channel (Polansky et al. 2018).

Although adult delta smelt can spawn more than once, as noted above, most spawning is complete by the time water temperature reaches 18°C (64.4°F) (Damon et al. 2016). The egg stage averages about 10 days before the embryos hatch into larvae (Bennett 2005). The larval stage averages about 30 days. Metamorphosing post-larvae appear in monitoring surveys from April into July of most years (Bennett 2005). By July, most delta smelt have reached the juvenile life stage. Delta smelt collected during the fall are considered subadults. Sampling for adult delta smelt by the Spring Kodiak Trawl survey begins in January, which generally aligns with the time period at which maturity is reached (Kurobe et al. 2016). Many delta smelt disperse to landward[2] habitats sometime after the first significant precipitation event of the winter for staging while sexual maturity is completed (Grimaldo et al. 2009; Sommer et al. 2011; Polansky et al. 2018). Some adult delta smelt exhibit very limited dispersal during the spawning season (Murphy and Hamilton 2013; Polansky et al. 2018).

In the wild, larval delta smelt are presumed to be surface-oriented, exhibiting greater dispersion during the night (Bennett 2005). In laboratory experiments, newly hatched larval delta smelt are able to manipulate their position in tanks, but there is no evidence to suggest that they can swim against prevailing currents. Juvenile delta smelt vary their position in the water column with respect to tides, water quality, and bathymetry; presumably these movements facilitate maintenance in favorable habitats (Feyrer et al. 2013). Adult delta smelt appear to use tidal migration and/or move horizontally toward shore during spawning migrations to upstream habitats (Bennett and Burau 2015). Laboratory studies of delta smelt of 32–68 millimeters (mm) standard length (SL) gave mean critical swimming velocity of around 28 centimeters (cm) per second, generally comparable to other fishes of similar size (Swanson et al. 1998).

From March through June, larval delta smelt rely heavily first on juvenile and then adult stages of the calanoid copepods *Eurytemora affinis* and *Pseudodiaptomus forbesi*, as well as cladocerans (Nobriga 2002; Hobbs et al. 2006; Slater and Baxter 2014) and *Sinocalanus doerrii*. Nobriga (2002) found that delta smelt larvae expressed positive selection for *E. affinis* and *P. forbesi*, consuming these prey species in greater proportion than available in the environment. Such selection was not

[2] Note that 'landward' in this context does not necessarily mean 'upstream', as there could be lateral movements (Murphy and Hamilton 2013).

noted for other zooplankton prey. Regional differences in food use occur, with *E. affinis* and *P. forbesi* being major prey items downstream in the low-salinity zone with a transition to *S. doerrii* and cyclopoid copepods as major prey items upstream into the Cache Slough Complex. Juvenile delta smelt (June through September) rely extensively on calanoid copepods such as *E. affinis* and *P. forbesi*, especially in fresh water (salinity < 1 ppt) and the Cache Slough Complex, but there is great variability among regions (Interagency Ecological Program 2015). Larger fish are also able to take advantage of mysids, cladocerans, and amphipods (Moyle et al. 1992; Lott 1998; Feyrer et al. 2003; Slater et al. 2019). The presence of several epibenthic species in diets therefore indicates that food sources for this species are not solely connected to pelagic pathways.

2.3.6.3 Current Status in Area of Analysis

The California Department of Fish and Wildlife (CDFW) conducts four fish surveys from which it develops indices of delta smelt's relative abundance. Each survey has variable capture efficiency (Mitchell et al. 2017) and the frequency of zero catches of delta smelt is very high, largely due to the species' rarity (Latour 2016; Polansky et al. 2018) or because the surveys are carried out independent of other factors that affect catch, such as tide (Bennett and Burau 2015) and channel location (Feyrer et al. 2013). In addition, detection probability decreases with increasing water clarity (Peterson and Barajas 2018) and relatively high numbers of delta smelt may occur in areas without long-term sampling stations (Murphy and Weiland 2019).

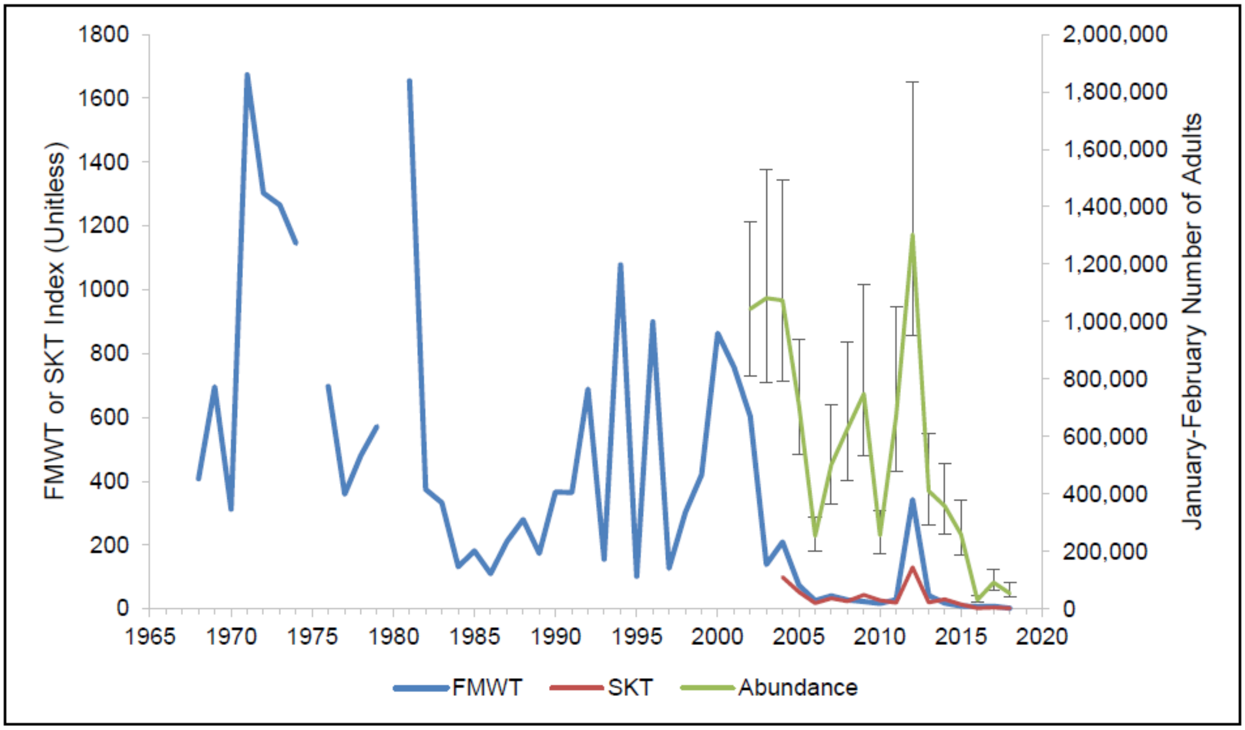
Information for delta smelt distribution and abundance can also be ascertained from other surveys that target salmonids. USFWS implemented a new smelt monitoring program in 2016 called the Enhanced Delta Smelt Monitoring (EDSM) program. This program measures the abundance and distribution of all life stages of delta smelt using a generalized random tessellation stratified design. Delta smelt population abundance estimates are derived from this monitoring.

The distribution of the delta smelt population varies with life stage, season, and environmental conditions (Bennett 2005; Sommer and Mejia 2013; Murphy and Hamilton 2013; Hobbs et al. 2019). Subadult and adult delta smelt typically make landward movements soon after "first flush" periods of initial winter precipitation and runoff, when turbidities elevate over 10 Nephelometric Turbidity Units (NTU) (Grimaldo et al. 2009). Larval delta smelt can be broadly distributed depending on hydrologic conditions during March and April. During wet years, larval delta smelt are generally distributed seaward than in drier years. In contrast, during drier years, larval delta smelt are concentrated in the Delta. Juvenile delta smelt distribution is generally centered in the "North Delta Arc," which extends from Cache Slough to Suisun Bay and Suisun Marsh (Merz et al. 2011; Murphy and Hamilton 2013).

Trawl abundance indices indicate that the relative abundance of delta smelt has declined substantially since the 1980s. The decline in abundance reflects decades of habitat change and marginalization by nonnative species that prey on and outcompete delta smelt. The observed decline in delta smelt abundance is consistent with declines of other pelagic species in the Delta (Sommer et al. 2007; Baxter et al. 2010).

Data derived from the CDFW Fall Midwater Trawl (FMWT) surveys are used for detecting and roughly scaling interannual trends in delta smelt abundance. The abundance indices derived from the FMWT closely mirror trends in catch per unit effort (Kimmerer and Nobriga 2008; Polansky et al. 2019), but do not presently support statistically reliable population abundance estimates, though substantial progress has been made in this regard (Newman 2008). The FMWT indices have ranged from 1,673 in 1970 to 0 in 2018, 2019, and 2020. The Summer Townet (STN) survey index was 0 in all but one year (2017) during 2015–2020. Indices from the two surveys show a similar pattern of delta smelt relative abundance that is higher prior to the mid-1980s and very low in the past decade. A recent analysis combining these and several other surveys into an 8-survey index suggested that the decline in delta smelt, as well as longfin smelt and striped bass, occurred in the early- to mid-1980s rather than the early 2000s as previously thought (Stompe et al. 2020).

The CDFW Spring Kodiak Trawl (SKT) survey monitors the adult spawning stock of delta smelt and serves as an indication for the relative number and distribution of spawners in the system. The 2019 SKT abundance index was 0.4, the second lowest on record; the 2020 SKT abundance index was 0.3, the lowest on record). All CDFW relative abundance indices show a declining trend since the early 2000s (Figure 7).



Source: Reclamation 2019:2–70.

Figure 7. Delta Smelt Fall Midwater Trawl Index, Spring Kodiak Trawl Index, and January–February Spring Kodiak Trawl Abundance Estimate (with 95% Confidence Interval), Water Years 2002–2018

Delta smelt are believed to be limited by a number of stressors, including water temperature, water quality, prey availability, entrainment at water diversions, increasing frequency and duration of droughts; and contaminants (Sommer et al. 2007; Miller et al. 2012; Wagner et al. 2011; Interagency Ecological Program Management Analysis and Synthesis Team 2015; Fong et al. 2016; Hamilton and Murphy 2020). Since 2010, several conceptual models (Interagency Ecological Program Management Analysis and Synthesis Team 2015) and empirical models (Thomson et al. 2010; Maunder and Deriso 2011; Miller et al. 2012; Rose et al. 2013; Hamilton and Murphy 2018) have explored life cycle models for the delta smelt to identify and describe the reasons for the population decline. Some of these models have recreated a trend observed in abundance indices, but each model has applied different methodology and predictive covariates. Collectively, these modeling efforts generally support water temperature, water clarity, and prey availability as key factors that limit delta smelt populations, but water diversions and predation may also have substantial impacts as well.

2.3.7 Longfin Smelt

2.3.7.1 Legal Status

On June 26, 2009, the California Fish and Game Commission ruled to list the status of longfin smelt as threatened under CESA. Longfin smelt is not listed under the ESA, but listing has been found to be warranted for the San Francisco Bay/Sacramento–San Joaquin Delta (Bay-Delta) DPS (77 FR 19756).

2.3.7.2 Life History

The longfin smelt (*Spirinchus thaleichthys*) is a small, euryhaline, anadromous, and semelparous fish with a life cycle of approximately 2 to 3 years (Rosenfield 2010). Longfin smelt reach 90 to 110 mm SL, with a maximum size of 120 to 150 mm SL (Moyle 2002; Rosenfield and Baxter 2007). Longfin smelt reside and rear in San Francisco Bay and in the nearshore ocean outside the Golden Gate (Garwood 2017). They spawn in tidal fresh water in the estuary's low-salinity zone where brackish and fresh waters meet (Grimaldo et al. 2017) and in freshwater in tributaries to the Bay (Lewis et al. 2020). Populations of longfin smelt occur along the Pacific Coast of North America, from Hinchinbrook Island, in Prince William Sound, Alaska, to the San Francisco Estuary (Lee et al. 1980) and have been detected as far south as Monterey Bay (Garwood 2017).

Longfin smelt are periodically caught in the nearshore ocean, suggesting that some individuals disperse out into the Gulf of Farallones to feed and then return to the estuary (Rosenfield and Baxter 2007). Longfin smelt have been documented in Humboldt Bay, the Eel River estuary, the Klamath River estuary, Russian River, and in smaller river estuaries from the central and northern coast of California, including Pescadero Creek, Garcia River, Gualala River, and Mad River (Moyle 2002; Pinnix et al. 2004; Garwood 2017). It is not known what portion of ocean-bound fish return to San Francisco Bay each year or to other coastal streams north and south of San Francisco Bay (Rosenfield and Baxter 2007; Nobriga and Rosenfield 2016).

The Bay-Delta distinct population segment of longfin smelt occurs throughout the San Francisco Bay and the Delta, and in coastal waters west of the Golden Gate Bridge. Within the San Francisco Estuary and Central Valley watershed, they have been observed, north as far as the town of Colusa on the Sacramento River, east as far as Lathrop on the San Joaquin River, and south as far as Alviso and Coyote Sloughs in the southern San Francisco Bay as well as various tributaries in northern San Francisco Bay (Merz et al. 2013; Hobbs et al. 2015; Lewis et al. 2020).

In Lake Washington, longfin smelt spawn over sandy substrate, but spawning substrates are unknown in the San Francisco Estuary. Longfin smelt eggs are adhesive and demersal (Moyle 2002). Evidence from Grimaldo et al. (2017) suggests spawning habitats include open shallow water and tidal marshes. Longfin smelt produce between 1,900 and 18,000 eggs, with greater fecundity in fish with greater lengths (CDFG 2009). Incubation times for egg development range between 25 and 42 days (Rosenfield 2010). Evidence for individuals spawning multiple times in a season has not been investigated but given that longfin smelt have such a broad spawning window (5–6 months), some females may undergo repeated spawning events. Newly hatched larvae have been observed in salinities up to 12 practical salinity units (psu) with peak observations occurring between 2 and 4 psu (Grimaldo et al. 2017). Early juvenile longfin smelt (20–40 mm SL) are found in salinities up to 30 psu, but most are found in salinities between 2 and 18 psu (MacWilliams et al. 2016). By late summer, late juveniles can tolerate full seawater.

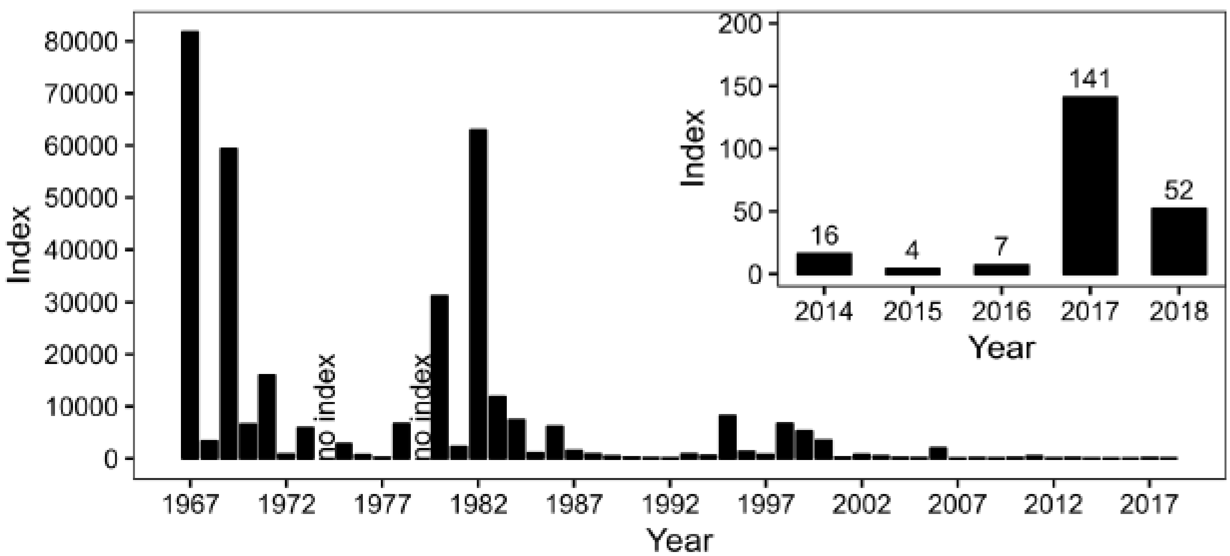
Longfin smelt are anadromous and semelparous, moving from saline to brackish or fresh water for spawning from November to May (Grimaldo et al. 2017; Lewis et al. 2020). Longfin smelt usually live for 2 years, spawn, and then die, although some individuals may spawn as 1-year-old or 3-year-old fish before dying (Rosenfield 2010). Age-2 adults appear to move into spawning areas during the late fall and early winter (Rosenfield and Baxter 2007). Spawning occurs at temperatures that range from 5°C (41.0°F) to 15°C (59.0°F) (Grimaldo et al. 2017). Peak spawning takes place in January and February of most years, when water temperatures are between 5°C (41.0°F) and 11°C (51.8°F). CDFW Smelt Larval Survey (SLS) data show that spawning appears to be centered in brackish water (2 to 4 psu), however, special studies that cover regions seaward of the SLS extent found newly hatched larvae in salinities up to 12 psu and concentrations of larvae peak between 2 and 4 psu (Grimaldo et al. 2017, 2020). Hobbs et al. (2010) provides evidence that larvae with the greatest recruitment success to later life stages are those that reared in salinities around 2 ppt.

Newly hatched longfin smelt larvae appear to be surface-oriented and probably have little ability to control their position in the water column before they develop their air bladder (Bennett et al. 2002). Once their air bladder is developed (approximately 12 mm SL), they can control their position in the water column by undergoing reverse diel vertical migrations or tidal vertical migration, depending on flow conditions (Bennett et al. 2002). Bennett et al. (2002) suggested that the ability of longfin smelt to undergo tidal vertical migrations allows them to maintain their position on the axis of the estuary. During the first few months of their lives (approximately January through May), longfin smelt primarily prey on calanoid copepods such as *P. forbesi* and *E. affinis* before switching to mysids as soon as they are large enough to feed on them (Slater 2008; Baxter et al. 2010). Mysid density is positively related to spring Delta outflow (negatively related to spring X2) (Mac Nally et al. 2010), although note that Kimmerer (2002b) found a changing relationship to X2 for the mysid *Neomysis mercedis* (negative prior to 1987; positive following 1987).

2.3.7.3 Current Status in Area of Analysis

During late summer and early fall, juvenile and adult longfin smelt within the San Francisco Estuary are more common throughout San Francisco Bay than in other landward areas (Rosenfield and Baxter 2007; MacWilliams et al. 2016), although the extent of marine migration has yet to be quantified. During the spawning period in late fall and early winter, adults are more commonly found in San Francisco Bay tributaries and marshes (Lewis et al. 2020; Grimaldo et al. 2020), Suisun Bay, and the Delta (Rosenfield and Baxter 2007). Larval longfin smelt are broadly distributed throughout San Francisco Bay and its associated tributaries during wet years (MacWilliams et al. 2016; Lewis et al. 2020; Parker et al. 2017; Grimaldo et al. 2020). Analyses of multiple surveys by Merz et al. (2013) found that larvae were more frequently detected in the Delta in drier years than in wet years; however, the limited extent of the SLS to landward regions does not account for potential spawning in tributaries of San Francisco Bay (Lewis et al. 2020). In long-term channel surveys, albeit limited to regions landward of San Pablo Bay, more than 50% of the measured larval abundance in any given year between 2009 and 2015 occurred in Suisun Bay and Suisun Marsh (Grimaldo et al. 2017). Some juveniles and adults are believed to move to the coastal ocean during the summer and fall (Rosenfield and Baxter 2007; MacWilliams et al. 2016).

Abundance indices for the longfin smelt population have undergone a decline over time. For example, there was an approximate thirty-fold reduction in the fall midwater trawl index since the early 1980s; although note that these indices do not sample large portions of the area occupied by the species (Figure 8) (Rosenfield and Baxter 2007; Sommer et al. 2007; Kimmerer et al. 2009) and an index of 2-year-olds based on the San Francisco Bay Study midwater and otter trawl went down from a mean of 1,931 in 1980–1986 (prior to the *Potamocorbula* invasion) to a mean of 918 during 1987–2002, with a further decline following the onset of the Pelagic Organism Decline to a mean of 422 during 2003–2013 (Nobriga and Rosenfield 2016). The rate of decline of the population suggested by abundance indices has been particularly steep, especially since the onset of the Pelagic Organism Decline (Sommer et al. 2007; Thomson et al. 2010), although a recent analysis of an integrated dataset featuring eight different surveys suggests that the original decline dates back to the early to mid-1980s (Stompe et al. 2020). Although the population has declined, the slope of the relationship between winter-spring flow and fall longfin smelt abundance indices remains unchanged, suggesting that flow or hydrological conditions are strong drivers of their population abundance (Kimmerer et al. 2009; Maunder et al. 2015; Nobriga and Rosenfield 2016). The intercept of this relationship has dropped nearly twofold, possibly because of declining food supply related to *Potamocorbula* (Kimmerer et al. 2009).



Source: White 2019.

Figure 8. Longfin Smelt Fall Midwater Trawl Abundance Index, 1967–2018

Chapter 3
Impact Analysis

3.1 Methods for Analysis

This impact analysis was conducted by evaluating the potential changes that could result for each alternative compared to the existing conditions without the alternatives. The analysis uses CalSim II outputs as the basis of the analysis. These CalSim outputs are either used directly to assess potential effects or are used as inputs to additional biological analytical tools. It is important to note that the model outputs for the American River below Nimbus Dam during the period of July 1976 through January 1978 were excluded from the analysis due to issues associated with PCWA water released into Folsom during the period (see surface water resources section for a full description). For most analytical tools, specific details and references are provided in Section 3.2, *Impacts from Alternative 1*, when the tool is first discussed. For analytical tools that require a more complex description, details are described in Attachment 1, *Additional Methods Description*. These analytical tools include: salmonid spawning weighted usable area (WUA), salmonid redd dewatering, and juvenile salmonid rearing (WUA). These analytical tools quantify the effects of flow on specific life stages and their habitats, making possible objective evaluation of flow effects on fish (Bovee et al. 1998). The tools have been used in many fish models, EIR/EIS reports and NMFS BiOps (Bartholow 2004, ESSA Technologies 2011, NMFS 2017, NMFS 2019).

For each analysis, comparisons were made between the Proposed Action in the 2019 LTWT Final EIS/EIR (hereafter, FEIS/R PA) and either Alternative 1 or Alternative 2. An alternative could have an adverse impact on fish if it substantially affected fish habitat or interfered with fish movement or access to or from spawning habitat. A ten percent difference between the FEIS/R PA and an alternative was used to determine measurable flow changes consistent with the 2019 LTWT Final EIS/EIR, Section 3.7.2.1.3, which was based on several major legally certified environmental documents in the Central Valley related to fisheries (Trinity River Mainstem Fishery Restoration Record of Decision, December 19, 2000; San Joaquin River Agreement Record of Decision in March 1999; Freeport Regional Water Project Record of Decision, January 4, 2005; Lower Yuba Accord EIR/EIS). In these documents, there is consensus that differences in modeled flows of less than ten percent would be within the noise of the model outputs and beyond the ability to measure actual changes. Because the inputs of all analyses in this document are modeled flow outputs, differences in results of these analyses of less than 10 percent were also deemed as being within the noise of the model. If an analysis resulted in a difference of >10% between the alternative and the FEIS/R PA, a closer biological evaluation of this difference was conducted because a >10% difference may not always translate into substantial biological effect on fisheries resources. These further biological analyses included consideration of the magnitude, frequency, and timing of >10% differences in the results.

It is important to note that Reclamation is required by SWRCB's 2021 TUCP Order to maintain cold water pool for salmon and steelhead in downstream reservoirs (Shasta and Folsom Reservoirs). Reclamation would review each transfer proposal to meet these requirements. Reclamation could consider reregulating flows through Folsom Reservoir to help meet SWRCB's 2021 TUCP Order.

3.2 Impacts from Alternative 1: Maximum October

3.2.1 Central Valley Steelhead

3.2.1.1 Sacramento River

Effects to steelhead as a result of Alt 1 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for steelhead spawning and egg incubation, rearing, and migration. Cold water pool management is required by the State Water Board and will take precedent over backing up water for transfers, if necessary. Previously, in critically dry water years—such as 2014, 2015, and 2021—Reclamation has backed up and held transfer water over the summer months to maintain the cold water pool in Shasta and Folsom Reservoirs. Under such conditions, Alt 1 would help maintain the cold water pool and would be beneficial to all special-status species evaluated in this Addendum. As such, temperature-related effects from Alt 1 on special-status fish species are anticipated to be beneficial. Therefore, no temperature-related effects from Alt 1 to steelhead in the Sacramento River are predicted.

Flow differences under Alt 1 relative to the FEIS/R PA in the Sacramento River at Keswick would occur primarily during summer and fall of dry and critical years (Table 11). Flows would decrease in dry and critical water years by up to 14 percent during July and September and increase by up to 27 percent during October.

Table 11. Mean Monthly Flows and Absolute (Percent) Differences in Flows between the FEIS/R PA and Alternative 1 and 2 (in cfs) in the Sacramento River below Keswick Dam. Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	18,657	18,657	18,657	0 (0%)	0 (0%)
	AN	10,628	10,628	10,628	0 (0%)	0 (0%)
	BN	3,704	3,704	3,704	0 (0%)	0 (0%)
	D	4,153	4,153	4,153	0 (0%)	0 (0%)
	C	4,051	4,051	4,051	0 (0%)	0 (0%)
Jan	All*	10,794	10,794	10,794	0 (0%)	0 (0%)
	W	19,298	19,298	19,298	0 (0%)	0 (0%)
	AN	16,368	16,368	16,368	0 (0%)	0 (0%)
	BN	4,186	4,186	4,186	0 (0%)	0 (0%)
	D	3,404	3,404	3,404	0 (0%)	0 (0%)
	C	3,627	3,627	3,627	0 (0%)	0 (0%)
Feb	All	11,861	11,861	11,861	0 (0%)	0 (0%)
	W	20,288	20,288	20,288	0 (0%)	0 (0%)
	AN	8,567	8,558	8,558	-8.8 (-0.1%)	-8.8 (-0.1%)
	BN	8,897	8,897	8,897	0 (0%)	0 (0%)
	D	4,061	4,055	4,055	-5.3 (-0.1%)	-5.3 (-0.1%)
	C	4,039	4,039	4,039	0 (0%)	0 (0%)
Mar	All	11,341	11,338	11,338	-2.5 (0%)	-2.5 (0%)
	W	6,555	6,555	6,555	0 (0%)	0 (0%)
	AN	5,517	5,517	5,517	0 (0%)	0 (0%)
Apr	BN	4,868	4,868	4,868	0 (0%)	0 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	D	4,108	4,108	4,108	0 (0%)	0 (0%)
	C	3,967	3,967	3,967	0 (0%)	0 (0%)
	All	5,308	5,308	5,308	0 (0%)	0 (0%)
	W	9,713	9,713	9,713	0 (0%)	0 (0%)
	AN	9,197	9,197	9,197	0 (0%)	0 (0%)
	BN	6,971	6,963	6,963	-8.1 (-0.1%)	-8.1 (-0.1%)
	D	9,085	9,098	9,098	13 (0.1%)	13 (0.1%)
	C	6,955	6,987	6,987	31.7 (0.5%)	31.7 (0.5%)
May	All	8,782	8,791	8,791	8.3 (0.1%)	8.3 (0.1%)
	W	9,885	9,885	9,885	0 (0%)	0 (0%)
	AN	9,988	10,051	10,051	62.2 (0.6%)	62.2 (0.6%)
	BN	11,841	11,829	11,829	-12.3 (-0.1%)	-12.3 (-0.1%)
	D	11,799	11,821	11,821	21.4 (0.2%)	21.4 (0.2%)
	C	9,563	9,611	9,611	48.1 (0.5%)	48.1 (0.5%)
Jun	All	10,290	10,314	10,314	23.9 (0.2%)	23.9 (0.2%)
	W	13,277	13,246	13,246	-31.2 (-0.2%)	-31.2 (-0.2%)
	AN	14,004	14,004	14,004	0 (0%)	0 (0%)
	BN	14,715	14,702	14,702	-13 (-0.1%)	-13 (-0.1%)
	D	13,733	12,601	12,601	-1132.1 (-8.2%)	-1132.1 (-8.2%)
	C	11,718	10,083	10,083	**-1634.7 (-14%)**	**-1634.7 (-14%)**
Jul	All	13,250	12,701	12,701	-549 (-4.1%)	-549 (-4.1%)
	W	11,064	11,064	11,064	0 (0%)	0 (0%)
	AN	10,088	10,045	10,045	-42.2 (-0.4%)	-42.2 (-0.4%)
	BN	9,511	9,498	9,498	-13 (-0.1%)	-13 (-0.1%)
	D	9,267	8,630	8,630	-636.8 (-6.9%)	-636.8 (-6.9%)
	C	8,381	7,773	7,773	-609 (-7.3%)	-609 (-7.3%)
Aug	All	9,931	9,685	9,685	-246 (-2.5%)	-246 (-2.5%)
	W	10,138	10,138	10,138	0 (0%)	0 (0%)
	AN	8,097	8,078	8,078	-18.6 (-0.2%)	-18.6 (-0.2%)
	BN	6,030	6,021	6,021	-8.4 (-0.1%)	-8.4 (-0.1%)
	D	4,836	4,486	4,486	-349.9 (-7.2%)	-349.9 (-7.2%)
	C	4,595	4,149	4,149	-446.2 (-9.7%)	-446.2 (-9.7%)
Sep	All	7,459	7,302	7,302	-157.4 (-2.1%)	-157.4 (-2.1%)
	W	7,095	7,390	7,390	294.9 (4.2%)	294.9 (4.2%)
	AN	5,555	6,813	6,236	**1257.8 (22.6%)**	**680.6 (12.3%)**
	BN	7,601	7,804	7,804	203 (2.7%)	203 (2.7%)
	D	5,993	6,929	6,882	**936.2 (15.6%)**	**888.8 (14.8%)**
	C	5,561	7,073	6,730	**1512 (27.2%)**	**1169 (21%)**
Oct	All	6,343	7,166	6,985	**823.2 (13%)**	**642.3 (10.1%)**
	W	8,784	8,784	8,784	0 (0%)	0 (0%)
	AN	5,204	5,300	5,897	96.8 (1.9%)	**693.3 (13.3%)**
	BN	5,666	5,666	5,666	0 (0%)	0 (0%)
	D	8,084	8,212	8,261	128.3 (1.6%)	177.3 (2.2%)
	C	6,140	6,425	6,779	284.4 (4.6%)	**638.8 (10.4%)**
Nov	All	7,301	7,399	7,586	98.3 (1.3%)	285.2 (3.9%)
	W	13,057	13,057	13,057	0 (0%)	0 (0%)
	AN	5,753	5,753	5,753	0 (0%)	0 (0%)
Dec	BN	3,588	3,588	3,588	0 (0%)	0 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	D	4,131	4,131	4,131	0 (0%)	0 (0%)
	C	4,257	4,257	4,257	0 (0%)	0 (0%)
	All	7,824	7,824	7,824	0 (0%)	0 (0%)

* "All" refers to all years in the CalSim record, irrespective of water year type.

Changes in flows under Alt 1 relative to the FEIS/R PA during fall months could affect the availability of suitable spawning habitat for steelhead, measured as weighted usable area (WUA).WUA is a useful and appropriate metric for assessing potential effects of flow on habitat because it is based on objective field measurements of major habitat attributes and their availability at different levels of flow (see Attachment 1). Results of the analysis predicting how spawning WUA changes under the FEIS/R PA and Alt 1 are presented in Table 12. These results indicate that there would be minimal effects of Alt 1 on steelhead spawning habitat availability.

Table 12. Spawning WUA Results for Steelhead in the Sacramento River for the FEIS/R PA and Alt 1 (in Weighted Usable Area Units).

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
Nov	W	53,052	53,052	0 (0%)	149,892	149,892	0 (0%)	56,164	56,164	0 (0%)
	AN	44,324	44,324	0 (0%)	120,662	120,662	0 (0%)	45,056	45,056	0 (0%)
	BN	59,132	59,132	0 (0%)	162,562	162,562	0 (0%)	61,495	61,495	0 (0%)
	D	54,074	53,590	-484 (-1%)	153,307	152,220	-1086 (-0.7%)	58,657	57,073	-1585 (-2.7%)
	C	62,961	62,073	-888 (-1%)	159,915	160,309	393 (0.2%)	62,544	63,502	958 (1.5%)
	All	54,346	54,078	-268 (0%)	149,005	148,894	-111 (-0.1%)	56,597	56,515	-82 (-0.1%)
Dec	W	44,925	44,925	0 (0%)	117,612	117,612	0 (0%)	46,566	46,566	0 (0%)
	AN	52,243	52,243	0 (0%)	133,411	133,411	0 (0%)	53,121	53,121	0 (0%)
	BN	60,573	60,573	0 (0%)	160,934	160,934	0 (0%)	56,518	56,518	0 (0%)
	D	49,569	49,569	0 (0%)	124,314	124,314	0 (0%)	47,275	47,275	0 (0%)
	C	64,710	64,710	0 (0%)	156,512	156,512	0 (0%)	62,377	62,377	0 (0%)
	All	51,815	51,815	0 (0%)	131,675	131,675	0 (0%)	51,496	51,496	0 (0%)
Jan	W	34,405	34,405	0 (0%)	85,882	85,882	0 (0%)	31,423	31,423	0 (0%)
	AN	35,875	35,875	0 (0%)	104,596	104,596	0 (0%)	32,712	32,712	0 (0%)
	BN	64,528	64,528	0 (0%)	157,864	157,864	0 (0%)	65,907	65,907	0 (0%)
	D	64,760	64,760	0 (0%)	154,759	154,759	0 (0%)	61,535	61,535	0 (0%)
	C	64,708	64,708	0 (0%)	157,336	157,336	0 (0%)	62,153	62,153	0 (0%)
	All	48,032	48,032	0 (0%)	120,284	120,284	0 (0%)	45,319	45,319	0 (0%)
Feb	W	35,556	35,556	0 (0%)	86,614	86,614	0 (0%)	33,207	33,207	0 (0%)
	AN	37,011	37,011	0 (0%)	86,491	86,491	0 (0%)	32,285	32,285	0 (0%)
	BN	63,224	63,224	0 (0%)	159,343	159,343	0 (0%)	58,449	58,449	0 (0%)
	D	66,280	66,280	0 (0%)	156,849	156,849	0 (0%)	64,950	64,950	0 (0%)
	C	65,115	65,115	0 (0%)	157,423	157,423	0 (0%)	63,664	63,664	0 (0%)
	All	48,948	48,948	0 (0%)	117,843	117,843	0 (0%)	46,402	46,402	0 (0%)

Salmonid redd dewatering can occur when water levels decrease after redd construction, exposing buried and otherwise submerged eggs or alevins to air. In the Sacramento River at Clear Creek, steelhead redd dewatering risk under the FEIS/R PA and Alt 1 are expected to be similar during all months of spawning (Table 13). In addition, as described in the 2019 NMFS BiOp (NMFS 2019), Reclamation attempts to minimize the risk redd dewatering from storage releases and this would continue under both the FEIS/R PA and Alt 1. There is low certainty in these results because the CalSim outputs used to conduct this analysis are at a monthly time step, yet flows can fluctuate and affect redd water levels at a shorter timestep.   However, if as expected, this limitation affects the FEIS/R PA and Alt 1 results similarly, the monthly time-step results should provide a relative index of dewatering probability. As a result of these considerations, effects of Alt 1 relative to the FEIS/R PA on steelhead redd dewatering risk is expected to be less than significant.

Table Results 13. Redd Dewatering Risk Results for Steelhead in the Sacramento River at Clear Creek for the FEIS/R PA and Alt 1 (in Percent of Redds Dewatered).

Month	WYT	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	W	18.2	18.2	0.0
	AN	6.2	6.8	0.6
	BN	14.6	14.6	0.0
	D	29.5	30.2	0.7
	C	15.6	17.2	1.6
Nov	All	17.3	17.9	0.6
	W	33.7	33.7	0.0
	AN	10.3	10.3	0.0
	BN	1.5	1.5	0.0
	D	5.1	5.1	0.0
	C	3.9	3.9	0.0
Dec	All	16.5	16.5	0.0
	W	45.1	45.1	0.0
	AN	41.6	41.6	0.0
	BN	0.7	0.7	0.0
	D	6.4	6.4	0.0
	C	4.2	4.2	0.0
Jan	All	26.6	26.6	0.0
	W	47.0	47.0	0.0
	AN	45.8	45.8	0.0
	BN	1.1	1.1	0.0
	D	1.8	1.8	0.0
	C	1.7	1.7	0.0
Feb	All	26.8	26.8	0.0

Differences in flows under Alt 1 relative to the FEIS/R PA during fall months could affect the availability of juvenile steelhead rearing habitat, measured as weighted usable area (WUA). In the first several months after emergence from the gravel (typically January through May) when individuals are most vulnerable, there would be negligible changes in rearing WUA (Table 14). For the small number of juveniles that remain in the river past May, rearing WUA would increase under Alt 1 relative to the FEIS/R PA in some segments and water years during July and August and would decrease in some segments and water years during October. Overall, given the isolated temporal and spatial incidence, and generally low magnitude of change, and small number of individuals these changes would affect, these differences under Alt 1 are considered less than significant.

Table 14. Juvenile Rearing WUA Results for Steelhead in the Sacramento River for the FEIS/R PA and Alt 1 (in Weighted Usable Area Units). Bold indicates >10% difference.

Month	WYT	Segment 6 FEIS/R PA	Segment 6 Alt 1	Segment 6 Alt 1 vs. FEIS/R PA	Segment 5 FEIS/R PA	Segment 5 Alt 1	Segment 5 Alt 1 vs. FEIS/R PA	Segment 4 FEIS/R PA	Segment 4 Alt 1	Segment 4 Alt 1 vs. FEIS/R PA
Jan	W	29,013	29,013	0 (0%)	349,507	349,507	0 (0%)	58,233	58,233	0 (0%)
	AN	25,460	25,460	0 (0%)	347,480	347,480	0 (0%)	44,267	44,267	0 (0%)
	BN	31,234	31,234	0 (0%)	459,473	459,473	0 (0%)	127,854	127,854	0 (0%)
	D	31,626	31,626	0 (0%)	447,530	447,530	0 (0%)	116,507	116,507	0 (0%)
	C	31,557	31,557	0 (0%)	448,832	448,832	0 (0%)	124,247	124,247	0 (0%)
	All	29,501	29,501	0 (0%)	393,365	393,365	0 (0%)	83,739	83,739	0 (0%)
Feb	W	29,197	29,197	0 (0%)	355,392	355,392	0 (0%)	59,081	59,081	0 (0%)
	AN	29,746	29,746	0 (0%)	362,813	362,813	0 (0%)	57,252	57,252	0 (0%)
	BN	30,747	30,747	0 (0%)	441,079	441,079	0 (0%)	85,367	85,367	0 (0%)
	D	32,041	32,041	0 (0%)	465,019	465,019	0 (0%)	118,232	118,232	0 (0%)
	C	31,505	31,505	0 (0%)	460,271	460,271	0 (0%)	128,537	128,537	0 (0%)
	All	30,362	30,362	0 (0%)	402,681	402,681	0 (0%)	85,043	85,043	0 (0%)
Mar	W	26,710	26,710	0 (0%)	319,342	319,342	0 (0%)	50,848	50,848	0 (0%)
	AN	25,939	25,943	4 (0%)	366,931	366,977	46 (0%)	60,057	60,101	44 (0.1%)
	BN	25,565	25,565	0 (0%)	371,035	371,035	0 (0%)	80,154	80,154	0 (0%)
	D	31,618	31,620	2 (0%)	447,156	447,317	161 (0%)	95,935	95,954	18 (0%)
	C	31,543	31,543	0 (0%)	449,724	449,724	0 (0%)	122,217	122,217	0 (0%)
	All	28,368	28,369	1 (0%)	380,180	380,216	37 (0%)	76,847	76,858	11 (0%)
Apr	W	39,400	39,400	0 (0%)	421,025	421,025	0 (0%)	95,731	95,731	0 (0%)
	AN	42,301	42,301	0 (0%)	411,906	411,906	0 (0%)	85,670	85,670	0 (0%)
	BN	42,483	42,483	0 (0%)	432,702	432,702	0 (0%)	111,173	111,173	0 (0%)
	D	41,951	41,951	0 (0%)	448,848	448,848	0 (0%)	125,087	125,087	0 (0%)
	C	41,582	41,582	0 (0%)	455,752	455,752	0 (0%)	135,223	135,223	0 (0%)
	All	40,993	40,993	0 (0%)	432,162	432,162	0 (0%)	108,175	108,175	0 (0%)
May	W	37,421	37,421	0 (0%)	337,197	337,197	0 (0%)	63,422	63,422	0 (0%)
	AN	39,073	39,073	0 (0%)	341,494	341,494	0 (0%)	62,042	62,042	0 (0%)
	BN	42,739	42,715	-24 (0%)	382,456	382,630	174 (0%)	80,577	80,699	123 (0.2%)
	D	40,602	40,579	-22 (0%)	337,698	337,430	-269 (0%)	62,842	62,710	-132 (-0.2%)
	C	42,162	42,098	-64 (0%)	380,168	379,511	-657 (0%)	91,554	91,270	-284 (-0.3%)
	All	39,563	39,544	-19 (0%)	349,553	349,381	-172 (0%)	69,877	69,803	-74 (-0.1%)
Jun	W	39,489	39,489	0 (0%)	336,909	336,909	0 (0%)	62,547	62,547	0 (0%)
	AN	37,880	37,833	-47 (-0.1%)	322,580	321,198	-1381 (-0.4%)	57,732	56,833	-899 (-1.6%)
	BN	32,429	32,469	40 (0%)	291,040	291,223	183 (0%)	51,159	51,201	42 (0.1%)
	D	33,415	33,395	-20 (0%)	300,912	300,851	-61 (0%)	54,350	54,347	-4 (0%)
	C	38,649	38,502	-147 (0%)	329,619	328,886	-732 (0%)	65,936	65,721	-215 (-0.3%)

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	All	37,545	37,505	-40 (0%)	323,829	323,434	-395 (0%)	60,279	60,078	-201 (-0.3%)
Jul	W	32,127	32,206	79 (0.2%)	287,853	288,234	381 (0.1%)	49,305	49,414	108 (0.2%)
Jul	AN	31,913	31,913	0 (0%)	284,345	284,345	0 (0%)	47,880	47,880	0 (0%)
Jul	BN	30,403	30,415	13 (0%)	278,461	278,384	-77 (0%)	45,947	45,925	-22 (0%)
Jul	D	30,312	31,910	1598 (5%)	279,572	288,736	9164 (3%)	46,804	50,679	3875 (8.3%)
Jul	C	33,387	37,261	**3874 (12%)**	299,429	322,103	22674 (8%)	55,325	64,861	**9536 (17.2%)**
Jul	All	31,927	33,038	1111 (3%)	287,603	294,030	6427 (2%)	49,654	52,341	2687 (5.4%)
Aug	W	35,360	35,360	0 (0%)	309,896	309,896	0 (0%)	58,212	58,212	0 (0%)
Aug	AN	37,855	37,979	124 (0%)	321,524	322,284	760 (0%)	62,208	62,432	224 (0.4%)
Aug	BN	39,316	39,354	38 (0%)	332,862	333,060	198 (0%)	69,752	69,821	69 (0.1%)
Aug	D	40,022	40,685	663 (2%)	337,633	351,389	13756 (4%)	71,813	81,240	**9428 (13.1%)**
Aug	C	40,725	41,689	964 (2%)	354,024	366,269	12245 (3%)	84,362	92,598	8236 (9.8%)
Aug	All	37,961	38,300	340 (1%)	327,279	332,373	5094 (2%)	67,380	70,783	3403 (5.1%)
Sep	W	36,569	36,569	0 (0%)	322,670	322,670	0 (0%)	64,463	64,463	0 (0%)
Sep	AN	41,250	41,306	56 (0.1%)	359,227	359,613	386 (0.1%)	84,722	84,888	167 (0.2%)
Sep	BN	42,960	42,919	-41 (0%)	401,585	401,808	223 (0%)	121,167	121,297	131 (0.1%)
Sep	D	41,161	40,703	-458 (-1%)	434,771	445,291	10519 (2%)	136,325	139,869	3544 (2.6%)
Sep	C	40,872	40,709	-163 (0%)	441,432	450,750	9318 (2%)	139,165	143,009	3844 (2.8%)
Sep	All	39,467	39,360	-107 (0%)	377,997	381,853	3856 (1%)	99,435	100,889	1454 (1.5%)
Oct	W	41,252	41,511	259 (0.6%)	377,233	369,250	-7983 (-2.1%)	92,531	88,112	-4419 (-4.8%)
Oct	AN	41,551	41,053	-498 (-1.2%)	412,671	385,835	-26836 (-6.5%)	119,281	96,440	**-22840 (-19.1%)**
Oct	BN	42,457	41,924	-533 (-1%)	366,718	362,513	-4204 (-1%)	86,972	85,156	-1816 (-2.1%)
Oct	D	41,956	40,668	-1289 (-3%)	400,778	381,743	-19036 (-5%)	111,304	98,682	**-12622 (-11.3%)**
Oct	C	40,676	40,898	222 (1%)	415,769	377,914	-37855 (-9%)	117,814	95,408	**-22407 (-19%)**
Oct	All	41,381	41,179	-202 (0%)	394,957	375,769	-19188 (-5%)	105,443	92,775	**-12668 (-12%)**
Nov	W	28,061	28,061	0 (0%)	370,766	370,766	0 (0%)	83,393	83,393	0 (0%)

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	AN	30,142	29,959	-184 (-1%)	419,263	416,973	-2290 (-1%)	109,963	108,994	-969 (-0.9%)
	BN	29,607	29,607	0 (0%)	407,884	407,884	0 (0%)	112,207	112,207	0 (0%)
	D	27,659	27,296	-363 (-1%)	356,462	353,531	-2931 (-1%)	73,285	71,619	-1666 (-2.3%)
	C	29,623	29,511	-112 (0%)	396,174	390,637	-5538 (-1%)	105,517	100,825	-4692 (-4.4%)
	All	28,770	28,650	-120 (0%)	384,215	382,153	-2062 (-1%)	92,548	91,117	-1431 (-1.5%)
	W	28,078	28,078	0 (0%)	356,472	356,472	0 (0%)	76,123	76,123	0 (0%)
	AN	29,226	29,226	0 (0%)	415,988	415,988	0 (0%)	96,136	96,136	0 (0%)
	BN	31,525	31,525	0 (0%)	460,928	460,928	0 (0%)	140,332	140,332	0 (0%)
	D	30,922	30,922	0 (0%)	446,876	446,876	0 (0%)	115,309	115,309	0 (0%)
	C	30,803	30,803	0 (0%)	445,706	445,706	0 (0%)	128,293	128,293	0 (0%)
Dec	All	29,546	29,546	0 (0%)	407,445	407,445	0 (0%)	101,088	101,088	0 (0%)

The primary migration period of adult steelhead past RBDD is typically September and October (Table 1). During September, adult attraction flows from Keswick are predicted to be somewhat lower under Alt 1 than the FEIS/R PA, although <10%, or within model noise (Table 11). During October, flows are expected to be higher under Alt 1. Due to the limited temporal occurrence and small frequency and magnitude of reduced flows under Alt 1, effects to juvenile migration are expected to be less than significant.

The primary juvenile steelhead outmigration period in the Sacramento River is February through May (Table 1). This coincides with a period of no flow changes in the Sacramento River (Table 11). Therefore, Alt 1 would have negligible effects on juvenile outmigration in the Sacramento River.

3.2.1.2 Feather River

The large majority of steelhead spawning (>98%) and rearing (>99%) occurs in the low-flow channel (DWR 2012). Low-flow channel flows would not change under Alt 1 compared to the FEIS/R PA. Monthly flows in the low-flow channel have been optimized for salmonids and these flows would remain under both the NAA and Alt 1. Therefore, no effects of Alt 1 to spawning and rearing steelhead in the low flow channel are expected.

The high flow channel is used primarily as a migration corridor for juvenile and adults. Adult migration typically occurs from July through March. The majority of juveniles typically emigrate from February through September, with a peak during March and April. Although no relationship between flow and migration is known for steelhead in the Feather River, it is generally thought that higher flows are better for migration. Predicted flows in the high flow channel are presented in Table 15. Flows in the high flow channel are predicted to be within 10% between Alt 1 and the FEIS/R PA in most months with one exception. During October of critical years, there would be a 16% increase in flows under Alt 1 relative to the FEIS/R PA, which could be beneficial to adult migration. Given this isolated flow change, these results indicate that both juvenile and adult migration in the high flow channel of the Feather River would be minimally impacted by Alt 1.

Table 15. Mean Monthly Flows and Absolute (Percent) Differences in Flows between the FEIS/R PA and Alternative 1 and 2 (in cfs) in the Feather River High Flow Channel below Thermalito Afterbay. Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	11,968	11,968	11,968	0 (0%)	0 (0%)
	AN	1,433	1,433	1,433	0 (0%)	0 (0%)
	BN	1,450	1,450	1,450	0 (0%)	0 (0%)
	D	1,491	1,491	1,491	0 (0%)	0 (0%)
	C	1,155	1,155	1,155	0 (0%)	0 (0%)
Jan	All	5,415	5,415	5,415	0 (0%)	0 (0%)
	W	12,150	12,150	12,150	0 (0%)	0 (0%)
	AN	4,928	4,928	4,928	0 (0%)	0 (0%)
	BN	1,450	1,450	1,450	0 (0%)	0 (0%)
	D	1,483	1,483	1,483	0 (0%)	0 (0%)
	C	1,151	1,151	1,151	0 (0%)	0 (0%)
Feb	All	6,099	6,099	6,099	0 (0%)	0 (0%)
	W	15,309	15,309	15,309	0 (0%)	0 (0%)
	AN	4,012	4,012	4,012	0 (0%)	0 (0%)
	BN	1,350	1,350	1,350	0 (0%)	0 (0%)
	D	1,433	1,433	1,433	0 (0%)	0 (0%)
	C	1,093	1,093	1,093	0 (0%)	0 (0%)
Mar	All	7,119	7,119	7,119	0 (0%)	0 (0%)
	W	5,307	5,307	5,307	0 (0%)	0 (0%)
	AN	1,319	1,317	1,317	-2.4 (-0.2%)	-2.4 (-0.2%)
	BN	1,000	1,000	1,000	0 (0%)	0 (0%)
	D	958	958	958	0 (0%)	0 (0%)
	C	892	892	892	0 (0%)	0 (0%)
Apr	All	2,673	2,673	2,673	-0.4 (0%)	-0.4 (0%)
	W	6,579	6,579	6,579	0 (0%)	0 (0%)
	AN	2,910	2,910	2,910	0 (0%)	0 (0%)
	BN	1,976	1,976	1,976	0 (0%)	0 (0%)
	D	1,980	1,980	1,980	0 (0%)	0 (0%)
	C	1,256	1,256	1,256	0 (0%)	0 (0%)
May	All	3,753	3,753	3,753	0 (0%)	0 (0%)
	W	5,226	5,226	5,226	0 (0%)	0 (0%)
	AN	2,510	2,507	2,507	-3.7 (-0.1%)	-3.7 (-0.1%)
	BN	3,444	3,444	3,444	0 (0%)	0 (0%)
	D	4,545	4,545	4,545	0 (0%)	0 (0%)
	C	3,813	3,813	3,813	0 (0%)	0 (0%)
Jun	All	4,231	4,230	4,230	-0.7 (0%)	-0.7 (0%)
	W	5,929	5,929	5,929	0 (0%)	0 (0%)
	AN	7,265	7,265	7,265	0 (0%)	0 (0%)
	BN	8,931	8,931	8,931	0 (0%)	0 (0%)
	D	6,638	6,550	6,550	-87.7 (-1.3%)	-87.7 (-1.3%)
	C	4,045	3,767	3,767	-278.4 (-6.9%)	-278.4 (-6.9%)
Jul	All	6,079	6,006	6,006	-72.8 (-1.2%)	-72.8 (-1.2%)
	W	3,854	3,823	3,823	-31.2 (-0.8%)	-31.2 (-0.8%)
	AN	6,038	6,038	6,038	0 (0%)	0 (0%)
Aug	BN	7,066	7,066	7,066	0 (0%)	0 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	D	1,989	1,966	1,966	-22.8 (-1.1%)	-22.8 (-1.1%)
	C	1,988	1,833	1,833	-155.2 (-7.8%)	-155.2 (-7.8%)
	All	3,715	3,667	3,667	-47.9 (-1.3%)	-47.9 (-1.3%)
	W	5,877	5,857	5,857	-20.2 (-0.3%)	-20.2 (-0.3%)
	AN	7,515	7,515	7,515	0 (0%)	0 (0%)
	BN	1,007	1,007	1,007	0 (0%)	0 (0%)
	D	960	929	929	-31.1 (-3.2%)	-31.1 (-3.2%)
	C	1,536	1,478	1,478	-58 (-3.8%)	-58 (-3.8%)
Sep	All	4,118	4,093	4,093	-25.1 (-0.6%)	-25.1 (-0.6%)
	W	3,308	3,346	3,346	38.6 (1.2%)	38.6 (1.2%)
	AN	1,988	2,103	1,988	114.1 (5.7%)	0 (0%)
	BN	3,765	4,126	4,126	360.6 (9.6%)	360.6 (9.6%)
	D	3,222	3,222	3,222	0 (0%)	0 (0%)
	C	1,563	1,812	1,613	**249.6 (16%)**	49.9 (3.2%)
Oct	All	2,728	2,835	2,774	107.5 (3.9%)	46.2 (1.7%)
	W	3,534	3,534	3,534	0 (0%)	0 (0%)
	AN	1,577	1,577	1,695	0 (0%)	117.9 (7.5%)
	BN	2,122	2,122	2,122	0 (0%)	0 (0%)
	D	1,887	2,074	2,074	187 (9.9%)	187 (9.9%)
	C	1,372	1,469	1,675	96.4 (7%)	**302.8 (22.1%)**
Nov	All	2,370	2,423	2,486	52.9 (2.2%)	116.1 (4.9%)
	W	6,444	6,444	6,444	0 (0%)	0 (0%)
	AN	2,018	2,018	2,018	0 (0%)	0 (0%)
	BN	3,442	3,442	3,442	0 (0%)	0 (0%)
	D	2,565	2,565	2,565	0 (0%)	0 (0%)
	C	2,155	2,155	2,155	0 (0%)	0 (0%)
Dec	All	3,919	3,919	3,919	0 (0%)	0 (0%)

DWR is committed to meeting year-round water temperature targets in the low-flow and high-flow channels of the Feather River for salmonids in the FERC BiOp (NMFS 2016), which would be included under both the FEIS/R PA and Alt 1. Therefore, no temperature-related effects to steelhead in the Feather River are predicted under Alt 1.

3.2.1.3 American River

For this analysis, it is assumed that higher flows are better for habitat conditions for fish. Flows in the American River under Alt 1 would be similar to those under the FEIS/R PA in all months and water years with some exceptions (Table 16). During July of dry and critical water years and August of critical water years, flows would be 11% to 20% lower under Alt 1. During October of critical water years, flows would be 26% higher under Alt 1. The July and August reductions would coincide with steelhead juvenile rearing period, but not spawning, juvenile emigration, or adult immigration. The October flow increase would coincide with the adult migration and juvenile rearing periods, but not spawning or juvenile emigration. Due to the low frequency of these flow changes, they are expected to minimally affect steelhead under Alt 1.

Table 16. Mean Monthly Flows and Absolute (Percent) Differences in Flows between the FEIS/R PA and Alternative 1 and 2 (in cfs) in the American River below Nimbus Dam. Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	9,679	9,679	9,714	0 (0%)	0 (0%)
	AN	7,742	7,747	6,881	4 (0.1%)	4 (0.1%)
	BN	2,121	2,121	2,121	0 (0%)	0 (0%)
	D	1,743	1,755	1,795	12 (0.7%)	12 (0.7%)
	C	1,203	1,216	1,102	13 (1.1%)	105 (8.8%)
Jan	All	5,827	5,832	5,597	5 (0.1%)	23 (0.4%)
	W	10,386	10,386	10,406	0 (0%)	0 (0%)
	AN	7,279	7,279	7,497	0 (0%)	0 (0%)
	BN	3,505	3,505	3,505	0 (0%)	0 (0%)
	D	1,857	1,857	1,878	0 (0%)	0 (0%)
	C	1,163	1,178	1,080	15 (1.3%)	59 (5.1%)
Feb	All	6,176	6,179	6,062	3 (0%)	11 (0.2%)
	W	7,180	7,180	7,181	0 (0%)	0 (0%)
	AN	3,884	3,884	3,917	0 (0%)	0 (0%)
	BN	2,144	2,144	2,144	0 (0%)	0 (0%)
	D	2,277	2,277	2,346	0 (0%)	0 (0%)
	C	1,050	1,050	971	0 (0%)	0 (0%)
Mar	All	4,269	4,269	4,177	0 (0%)	0 (0%)
	W	5,173	5,173	5,173	0 (0%)	0 (0%)
	AN	3,163	3,163	3,163	0 (0%)	0 (0%)
	BN	1,545	1,545	1,545	0 (0%)	0 (0%)
	D	1,623	1,623	1,739	0 (0%)	0 (0%)
	C	934	934	872	0 (0%)	0 (0%)
Apr	All	3,171	3,171	3,113	0 (0%)	0 (0%)
	W	6,954	6,954	6,945	0 (0%)	0 (0%)
	AN	5,358	5,358	5,358	0 (0%)	0 (0%)
	BN	3,544	3,544	3,544	0 (0%)	0 (0%)
	D	1,748	1,748	1,745	0 (0%)	0 (0%)
	C	1,083	1,083	1,000	0 (0%)	0 (0%)
May	All	4,443	4,443	4,323	0 (0%)	0 (0%)
	W	5,298	5,298	5,312	0 (0%)	0 (0%)
	AN	3,136	3,136	3,136	0 (0%)	0 (0%)
	BN	3,212	3,212	3,212	0 (0%)	0 (0%)
	D	2,199	2,197	2,197	-2 (-0.1%)	-2 (-0.1%)
	C	1,035	1,035	958	0 (0%)	0 (0%)
Jun	All	3,440	3,440	3,358	-0.3 (0%)	-0.3 (0%)
	W	4,014	4,014	4,014	0 (0%)	0 (0%)
	AN	3,717	3,717	3,717	0 (0%)	0 (0%)
	BN	3,287	3,287	3,287	0 (0%)	0 (0%)
	D	2,036	1,794	1,794	**-241 (-11.9%)**	**-241 (-11.9%)**
	C	1,529	1,220	1,048	**-309 (-20.2%)**	**-309 (-20.2%)**
Jul	All	3,154	3,060	2,916	-94 (-3%)	-94 (-3%)
	W	2,943	2,943	2,944	0 (0%)	0 (0%)
	AN	2,665	2,665	2,665	0 (0%)	0 (0%)
Aug	BN	1,879	1,879	1,879	0 (0%)	0 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	D	1,525	1,380	1,380	-145 (-9.5%)	-145 (-9.5%)
	C	1,714	1,504	1,217	**-210 (-12.2%)**	**-210 (-12.2%)**
	All	2,367	2,307	2,201	-60 (-2.5%)	-60 (-2.5%)
Sep	W	2,175	2,175	2,178	0 (0%)	0 (0%)
	AN	2,793	2,793	2,793	0 (0%)	0 (0%)
	BN	1,850	1,850	1,850	0 (0%)	0 (0%)
	D	1,383	1,322	1,322	-61 (-4.4%)	-61 (-4.4%)
	C	987	905	789	-83 (-8.4%)	-83 (-8.4%)
	All	1,936	1,912	1,830	-24 (-1.3%)	-24 (-1.3%)
Oct	W	1,623	1,680	1,631	57 (3.5%)	57 (3.5%)
	AN	1,308	1,346	1,173	38 (2.9%)	0 (0%)
	BN	1,518	1,518	1,518	0 (0%)	0 (0%)
	D	1,194	1,194	1,194	0 (0%)	0 (0%)
	C	1,243	1,567	1,288	**324 (26.1%)**	**184 (14.8%)**
	All	1,416	1,505	1,396	90 (6.3%)	57 (4.1%)
Nov	W	4,442	4,493	4,442	51 (1.1%)	51 (1.1%)
	AN	2,075	2,075	1,829	0 (0%)	40 (1.9%)
	BN	3,759	3,759	3,759	0 (0%)	0 (0%)
	D	1,822	1,946	1,837	124 (6.8%)	124 (6.8%)
	C	2,035	2,192	1,869	158 (7.8%)	164 (8.1%)
	All	3,087	3,160	2,951	73 (2.4%)	81 (2.6%)
Dec	W	6,217	6,217	6,251	0 (0%)	0 (0%)
	AN	2,308	2,308	2,011	0 (0%)	0 (0%)
	BN	2,483	2,483	2,483	0 (0%)	0 (0%)
	D	1,855	1,902	1,855	47 (2.5%)	47 (2.5%)
	C	1,536	1,536	1,409	0 (0%)	0 (0%)
	All	3,677	3,686	3,509	9 (0.2%)	9 (0.2%)

Reclamation is committed to meeting the modified flow management standard in the ROC on LTO NMFS BiOp (NMFS 2019:20) in future operations, which would include both the FEIS/R PA and Alt 1. The commitment is to preserve coldwater pool in drier years to improve temperature management. As previously noted, Reclamation has historically backed up and held transfer water over the summer months during critically dry water years to maintain the cold water pool in Shasta and Folsom Reservoirs. Based on modeled flow differences (Table 16) and an assumption that lower flows would increase water temperatures, the only time of year that temperatures under Alt 1 could be higher than the FEIS/R PA is during July and August. However, due to Reclamation's commitments, and the expectation that transfer water would be backed up to maintain cold water pool in Folsom Reservoir during critically dry water years, minimal temperature-related effects to steelhead in the American River are predicted for Alt 1.

3.2.1.4 Merced River

For this analysis, it is assumed that higher flows are better for habitat conditions for steelhead. Little is known about steelhead habitat use in the Merced River. As such, the following periods, based primarily on other rivers, were assumed for presence of each life stage:

- Adult migration – October to April
- Spawning – December to April

- Rearing – Year-round
- Juvenile migration – January through June

Flows at the Merced River mouth under Alt 1 would be similar to those under the FEIS/R PA in all months and water years with some exceptions (Table 17). During July of dry and critical water years and August of critical water years, flows would be 49.5% to 34.7% lower under Alt 1 relative to the FEIS/R PA. During October of above normal years and November of dry years, flows would be 60.8% and 35.7% higher, respectively, under Alt 1. The July and August reductions would coincide with steelhead juvenile rearing period, but not spawning, juvenile emigration, or adult immigration. The October and November flow increase would coincide with the adult migration and juvenile rearing periods, but not spawning or juvenile emigration. Due to the low frequency of these flow changes, they are expected to minimally affect steelhead under Alt 1.

Table 17. Mean Monthly Flows and Absolute (Percent) Differences in Flows between the FEIS/R PA and Alternative 1 and 2 (in cfs) at the Merced River Mouth. Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	2,039	2,077	2,077	37.5 (1.8%)	37.5 (1.8%)
	AN	1,060	1,060	1,060	0 (0%)	0 (0%)
	BN	1,124	1,124	1,124	0 (0%)	0 (0%)
	D	293	293	293	0 (0%)	0 (0%)
	C	142	142	142	0 (0%)	0 (0%)
Jan	All	1,114	1,128	1,128	14.3 (1.3%)	14.3 (1.3%)
	W	2,581	2,581	2,581	0 (0%)	0 (0%)
	AN	1,786	1,701	1,701	-84.8 (-4.8%)	-84.8 (-4.8%)
	BN	1,328	1,328	1,328	0 (0%)	0 (0%)
	D	430	430	430	0 (0%)	0 (0%)
	C	210	210	210	0 (0%)	0 (0%)
Feb	All	1,499	1,484	1,484	-15 (-1%)	-15 (-1%)
	W	2,026	2,026	2,026	0 (0%)	0 (0%)
	AN	764	764	764	0 (0%)	0 (0%)
	BN	782	782	782	0 (0%)	0 (0%)
	D	190	190	190	0 (0%)	0 (0%)
	C	74	74	74	0 (0%)	0 (0%)
Mar	All	1,004	1,004	1,004	0 (0%)	0 (0%)
	W	916	916	916	0 (0%)	0 (0%)
	AN	201	201	201	0 (0%)	0 (0%)
	BN	318	318	318	0 (0%)	0 (0%)
	D	159	159	159	0 (0%)	0 (0%)
	C	145	145	145	0 (0%)	0 (0%)
Apr	All	462	462	462	0 (0%)	0 (0%)
	W	1,382	1,382	1,382	0 (0%)	0 (0%)
	AN	1,141	1,141	1,141	0 (0%)	0 (0%)
	BN	858	858	858	0 (0%)	0 (0%)
	D	158	158	158	0 (0%)	0 (0%)
	C	144	144	144	0 (0%)	0 (0%)
May	All	838	838	838	0 (0%)	0 (0%)
	W	2,046	2,046	2,046	0 (0%)	0 (0%)
	AN	1,612	1,612	1,612	0 (0%)	0 (0%)
Jun	BN	301	301	301	0 (0%)	0 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	D	208	208	208	0 (0%)	0 (0%)
	C	175	175	175	0 (0%)	0 (0%)
	All	1,157	1,157	1,157	0 (0%)	0 (0%)
	W	1,730	1,730	1,730	0 (0%)	0 (0%)
	AN	1,236	1,236	1,236	0 (0%)	0 (0%)
	BN	234	234	234	0 (0%)	0 (0%)
	D	307	155	155	**-151.8 (-49.5%)**	**-151.8 (-49.5%)**
	C	201	131	131	**-69.7 (-34.7%)**	**-69.7 (-34.7%)**
Jul	All	989	948	948	-41.1 (-4.2%)	-41.1 (-4.2%)
	W	1,009	1,009	1,009	0 (0%)	0 (0%)
	AN	833	833	833	0 (0%)	0 (0%)
	BN	557	557	557	0 (0%)	0 (0%)
	D	138	127	127	-10.8 (-7.9%)	-10.8 (-7.9%)
	C	98	98	98	0 (0%)	0 (0%)
Aug	All	610	608	608	-1.9 (-0.3%)	-1.9 (-0.3%)
	W	607	607	607	0 (0%)	0 (0%)
	AN	613	613	613	0 (0%)	0 (0%)
	BN	245	231	231	-14.5 (-5.9%)	-14.5 (-5.9%)
	D	132	132	132	0 (0%)	0 (0%)
	C	102	102	102	0 (0%)	0 (0%)
Sep	All	399	398	398	-0.9 (-0.2%)	-0.9 (-0.2%)
	W	471	471	471	0 (0%)	0 (0%)
	AN	267	430	349	**162.6 (60.8%)**	**81.3 (30.4%)**
	BN	260	260	260	0 (0%)	0 (0%)
	D	406	406	406	0 (0%)	0 (0%)
	C	356	356	356	0 (0%)	0 (0%)
Oct	All	387	416	402	28.7 (7.4%)	14.4 (3.7%)
	W	617	617	617	0 (0%)	0 (0%)
	AN	144	144	228	0 (0%)	**84 (58.4%)**
	BN	380	380	380	0 (0%)	0 (0%)
	D	235	319	319	**84 (35.7%)**	**84 (35.7%)**
	C	156	156	156	0 (0%)	0 (0%)
Nov	All	357	372	387	14.8 (4.1%)	29.7 (8.3%)
	W	1,068	1,068	1,068	0 (0%)	0 (0%)
	AN	188	188	188	0 (0%)	0 (0%)
	BN	566	566	566	0 (0%)	0 (0%)
	D	233	233	233	0 (0%)	0 (0%)
	C	149	149	149	0 (0%)	0 (0%)
Dec	All	546	546	546	0 (0%)	0 (0%)

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the Merced River. Under this assumption, water temperature results would be similar to flow results (Table 17) in that, due to the low frequency of differences between Alt 1 and the FEIS/R PA, effects to steelhead are expected to be minimal.

3.2.1.5 San Joaquin River

For this analysis, it is assumed that higher flows are better for habitat conditions for steelhead. Little is known about steelhead habitat use in the San Joaquin River. As such, the following periods, based primarily on other rivers, were assumed for presence of each life stage:

- Adult migration – October to April
- Spawning – December to April
- Rearing – Year-round
- Juvenile migration – January through June

Flows in the San Joaquin River at Vernalis under Alt 1 would be similar to those under the FEIS/R PA in all months and water years with one exception (Table 18). During July of dry water years, flows would be 11.8% lower under Alt 1 relative to the FEIS/R PA. These reductions would coincide with steelhead juvenile rearing period, but not spawning, juvenile emigration, or adult immigration. However, due to the low frequency of these flow changes, they are expected to minimally affect steelhead under Alt 1.

Table 18. Mean Monthly Flows and Absolute (Percent) Differences in Flows between the FEIS/R PA and Alternative 1 and 2 (in cfs) in the San Joaquin River at Vernalis. Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	11,918	11,956	11,956	37.5 (0.3%)	37.5 (0.3%)
	AN	4,394	4,394	4,394	0 (0%)	0 (0%)
	BN	3,045	3,045	3,045	0 (0%)	0 (0%)
	D	1,963	1,963	1,963	0 (0%)	0 (0%)
	C	1,272	1,272	1,272	0 (0%)	0 (0%)
Jan	All	6,120	6,134	6,134	14.3 (0.2%)	14.3 (0.2%)
	W	13,983	13,983	13,983	0 (0%)	0 (0%)
	AN	8,682	8,597	8,597	-84.8 (-1%)	-84.8 (-1%)
	BN	4,682	4,682	4,682	0 (0%)	0 (0%)
	D	2,178	2,178	2,178	0 (0%)	0 (0%)
	C	1,746	1,746	1,746	0 (0%)	0 (0%)
Feb	All	7,898	7,883	7,883	-15 (-0.2%)	-15 (-0.2%)
	W	14,675	14,675	14,675	0 (0%)	0 (0%)
	AN	8,038	8,038	8,038	0 (0%)	0 (0%)
	BN	5,656	5,656	5,656	0 (0%)	0 (0%)
	D	2,727	2,727	2,727	0 (0%)	0 (0%)
	C	1,364	1,364	1,364	0 (0%)	0 (0%)
Mar	All	8,124	8,124	8,124	0 (0%)	0 (0%)
	W	12,090	12,090	12,090	0 (0%)	0 (0%)
	AN	8,008	8,008	8,008	0 (0%)	0 (0%)
	BN	5,721	5,721	5,721	0 (0%)	0 (0%)
	D	2,962	2,962	2,962	0 (0%)	0 (0%)
	C	1,416	1,416	1,416	0 (0%)	0 (0%)
Apr	All	7,186	7,186	7,186	0 (0%)	0 (0%)
	W	9,615	9,615	9,615	0 (0%)	0 (0%)
	AN	6,603	6,603	6,603	0 (0%)	0 (0%)
	BN	5,032	5,032	5,032	0 (0%)	0 (0%)
	D	2,068	2,068	2,068	0 (0%)	0 (0%)
	C	1,448	1,448	1,448	0 (0%)	0 (0%)
May	All	5,801	5,801	5,801	0 (0%)	0 (0%)
	W	8,734	8,734	8,734	0 (0%)	0 (0%)
Jun	AN	5,433	5,433	5,433	0 (0%)	0 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	BN	1,690	1,690	1,690	0 (0%)	0 (0%)
	D	1,253	1,253	1,253	0 (0%)	0 (0%)
	C	836	836	836	0 (0%)	0 (0%)
	All	4,791	4,791	4,791	0 (0%)	0 (0%)
	W	7,241	7,241	7,241	0 (0%)	0 (0%)
	AN	3,145	3,145	3,145	0 (0%)	0 (0%)
	BN	1,410	1,410	1,410	0 (0%)	0 (0%)
	D	1,283	1,131	1,131	**-151.8 (-11.8%)**	**-151.8 (-11.8%)**
	C	785	715	715	-69.7 (-8.9%)	-69.7 (-8.9%)
Jul	All	3,794	3,753	3,753	-41.1 (-1.1%)	-41.1 (-1.1%)
	W	3,431	3,431	3,431	0 (0%)	0 (0%)
	AN	2,296	2,296	2,296	0 (0%)	0 (0%)
	BN	1,914	1,914	1,914	0 (0%)	0 (0%)
	D	1,291	1,280	1,280	-10.8 (-0.8%)	-10.8 (-0.8%)
	C	831	831	831	0 (0%)	0 (0%)
Aug	All	2,228	2,226	2,226	-1.9 (-0.1%)	-1.9 (-0.1%)
	W	3,600	3,600	3,600	0 (0%)	0 (0%)
	AN	2,555	2,555	2,555	0 (0%)	0 (0%)
	BN	1,893	1,878	1,878	-14.5 (-0.8%)	-14.5 (-0.8%)
	D	1,777	1,777	1,777	0 (0%)	0 (0%)
	C	1,214	1,214	1,214	0 (0%)	0 (0%)
Sep	All	2,502	2,502	2,502	-0.9 (0%)	-0.9 (0%)
	W	3,253	3,253	3,253	0 (0%)	0 (0%)
	AN	1,962	2,125	2,044	162.6 (8.3%)	81.3 (4.1%)
	BN	2,542	2,542	2,542	0 (0%)	0 (0%)
	D	2,848	2,848	2,848	0 (0%)	0 (0%)
	C	2,027	2,027	2,027	0 (0%)	0 (0%)
Oct	All	2,660	2,689	2,674	28.7 (1.1%)	14.4 (0.5%)
	W	4,188	4,188	4,188	0 (0%)	0 (0%)
	AN	1,553	1,553	1,637	0 (0%)	84 (5.4%)
	BN	2,173	2,173	2,173	0 (0%)	0 (0%)
	D	2,234	2,318	2,318	84 (3.8%)	84 (3.8%)
	C	1,668	1,668	1,668	0 (0%)	0 (0%)
Nov	All	2,741	2,756	2,771	14.8 (0.5%)	29.7 (1.1%)
	W	6,685	6,685	6,685	0 (0%)	0 (0%)
	AN	1,535	1,535	1,535	0 (0%)	0 (0%)
	BN	2,245	2,245	2,245	0 (0%)	0 (0%)
	D	1,781	1,781	1,781	0 (0%)	0 (0%)
	C	1,374	1,374	1,374	0 (0%)	0 (0%)
Dec	All	3,556	3,556	3,556	0 (0%)	0 (0%)

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the San Joaquin River. Under this assumption, water temperature results would be similar to flow results (Table 18) in that, due to the low frequency of differences between Alt 1 and the FEIS/R PA, effects to steelhead are expected to be minimal.

3.2.1.6 Delta

Flows in the Sacramento River at Freeport characterize migration flows for Sacramento River basin steelhead in the Delta. Table 19 presents flows at Freeport for each month and water year type.

These results show a decrease in flow under Alt 1 relative to the FEIS/R PA at Freeport during July and August of critical water years and an increase during October of above normal and critical water years. Adult immigration in the Delta likely peaks in August through October based on a similar peak at the Fremont Weir, approximately 35 river miles upstream (Table 1), and observed adult salmon migration speeds in the lower Sacramento River of about 10 to 75 kilometers per day (Martin et al. 2015). Therefore, there would be one month in one water year type in which flows would be lower and one month within two water year types during this peak immigration period in which flows would be higher under Alt 1 relative to the FEIS/R PA. These flow changes would not be large or persistent enough to have biologically meaningful effects on steelhead adult migration.

As shown in Table 1, juvenile migration would generally occur in low numbers during the July-November period when flows changes are greatest at Freeport due to Alt 1, except in July (Table 19). Regardless, the peak of migration occurs between March through June with very few individuals migrating during July. During this period, flows at Freeport under Alt 1 would be nearly identical to those under the FEIS/R PA. Collectively, these results suggest that changes in flow at Freeport would have negligible effects on juvenile migration.

Table 19. Mean Monthly Flows and Absolute (Percent) Differences in Flows between the FEIS/R PA and Alternative 1 and 2 (in cfs) in the Sacramento River at Freeport. Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	49,269	49,269	49,269	0 (0%)	0 (0%)
	AN	49,572	49,645	49,683	72.6 (0.1%)	110.9 (0.2%)
	BN	18,466	18,466	18,466	0 (0%)	0 (0%)
	D	19,057	19,069	19,069	11.8 (0.1%)	11.8 (0.1%)
	C	13,815	13,826	13,905	11.3 (0.1%)	90.3 (0.7%)
Jan	All	34,880	34,897	34,920	17.2 (0%)	40.3 (0.1%)
	W	56,361	56,361	56,361	0 (0%)	0 (0%)
	AN	50,902	50,902	50,902	0 (0%)	0 (0%)
	BN	25,851	25,851	25,851	0 (0%)	0 (0%)
	D	20,411	20,415	20,415	4.5 (0%)	4.5 (0%)
	C	16,615	16,627	16,666	12.5 (0.1%)	50.9 (0.3%)
Feb	All	39,076	39,079	39,087	3.4 (0%)	11.3 (0%)
	W	55,808	55,808	55,808	0 (0%)	0 (0%)
	AN	41,978	41,973	41,973	-4.6 (0%)	-4.6 (0%)
	BN	26,313	26,313	26,313	0 (0%)	0 (0%)
	D	23,938	23,935	23,943	-2.6 (0%)	5.4 (0%)
	C	15,209	15,209	15,209	0 (0%)	0 (0%)
Mar	All	37,650	37,648	37,650	-1.3 (0%)	0.2 (0%)
	W	36,159	36,159	36,159	0 (0%)	0 (0%)
	AN	25,654	25,651	25,651	-2.4 (0%)	-2.4 (0%)
	BN	15,983	15,983	15,983	0 (0%)	0 (0%)
	D	16,128	16,128	16,128	0 (0%)	0 (0%)
	C	11,771	11,771	11,771	0 (0%)	0 (0%)
Apr	All	24,563	24,562	24,562	-0.4 (0%)	-0.4 (0%)
	W	30,334	30,336	30,336	2.5 (0%)	2.5 (0%)
	AN	24,074	24,030	24,030	-43.5 (-0.2%)	-43.5 (-0.2%)
	BN	14,945	14,945	14,945	0 (0%)	0 (0%)
May	D	11,686	11,685	11,685	-1.1 (0%)	-1.1 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	C	8,299	8,300	8,300	0.1 (0%)	0.1 (0%)
	All	20,497	20,490	20,490	-6.9 (0%)	-6.9 (0%)
Jun	W	24,344	24,347	24,347	3.9 (0%)	3.9 (0%)
	AN	16,254	16,247	16,247	-7.4 (0%)	-7.4 (0%)
	BN	15,045	15,045	15,045	0 (0%)	0 (0%)
	D	14,033	14,032	14,032	-1.7 (0%)	-1.7 (0%)
	C	10,589	10,589	10,589	0.1 (0%)	0.1 (0%)
	All	17,718	17,718	17,718	-0.1 (0%)	-0.1 (0%)
Jul	W	20,734	20,705	20,705	-29 (-0.1%)	-29 (-0.1%)
	AN	19,628	19,559	19,559	-69.6 (-0.4%)	-69.6 (-0.4%)
	BN	22,000	22,000	22,000	0 (0%)	0 (0%)
	D	17,892	16,323	16,323	-1569.1 (-8.8%)	-1569.1 (-8.8%)
	C	12,882	10,493	10,493	**-2388.8 (-18.5%)**	**-2388.8 (-18.5%)**
	All	18,495	17,703	17,703	-792.1 (-4.3%)	-792.1 (-4.3%)
Aug	W	16,442	16,413	16,413	-29 (-0.2%)	-29 (-0.2%)
	AN	16,454	16,343	16,343	-111.8 (-0.7%)	-111.8 (-0.7%)
	BN	16,077	16,077	16,077	0 (0%)	0 (0%)
	D	11,596	10,744	10,744	-852 (-7.3%)	-852 (-7.3%)
	C	10,041	9,036	9,036	**-1005.1 (-10%)**	**-1005.1 (-10%)**
	All	14,250	13,862	13,862	-388.1 (-2.7%)	-388.1 (-2.7%)
Sep	W	21,379	21,360	21,360	-18.7 (-0.1%)	-18.7 (-0.1%)
	AN	20,813	20,750	20,750	-63.6 (-0.3%)	-63.6 (-0.3%)
	BN	11,250	11,250	11,250	0 (0%)	0 (0%)
	D	10,034	9,567	9,567	-466.9 (-4.7%)	-466.9 (-4.7%)
	C	8,349	7,707	7,707	-641.9 (-7.7%)	-641.9 (-7.7%)
	All	15,999	15,766	15,766	-232.9 (-1.5%)	-232.9 (-1.5%)
Oct	W	13,211	13,611	13,611	400.2 (3%)	400.2 (3%)
	AN	8,840	10,340	9,521	**1499.6 (17%)**	680.6 (7.7%)
	BN	13,438	14,001	14,001	563.5 (4.2%)	563.5 (4.2%)
	D	10,022	10,958	10,911	936.2 (9.3%)	888.8 (8.9%)
	C	9,104	11,214	10,490	**2110.4 (23.2%)**	**1386.6 (15.2%)**
	All	11,045	12,095	11,793	1050.5 (9.5%)	748.6 (6.8%)
Nov	W	22,719	22,770	22,770	50.9 (0.2%)	50.9 (0.2%)
	AN	11,508	11,645	12,452	136.4 (1.2%)	943.2 (8.2%)
	BN	13,151	13,151	13,151	0 (0%)	0 (0%)
	D	15,157	15,620	15,669	463.2 (3.1%)	512.3 (3.4%)
	C	9,657	10,195	10,817	537.4 (5.6%)	**1159.6 (12%)**
	All	16,154	16,390	16,669	235.9 (1.5%)	515 (3.2%)
Dec	W	39,468	39,474	39,474	6.3 (0%)	6.3 (0%)
	AN	20,864	20,864	20,864	0 (0%)	0 (0%)
	BN	14,862	14,862	14,862	0 (0%)	0 (0%)
	D	16,623	16,669	16,669	46.5 (0.3%)	46.5 (0.3%)
	C	11,851	11,851	11,851	0 (0%)	0 (0%)
	All	25,020	25,031	25,031	10.6 (0%)	10.6 (0%)

South Delta exports can cause entrainment of juvenile steelhead into the facilities. Table 20 presents combined south Delta exports for each month and water year type. These results indicate that export rates under Alt 1 would be lower in July through September of several water year types relative to the FEIS/R PA. Juvenile steelhead are present in very low numbers at salvage facilities and in the Delta during July through November (Table 2). Therefore, assuming entrainment risk is a function of presence in the Delta and export rates, changes in exports during these months would cause a negligible increase in salvage of steelhead juveniles because individuals are present in the Delta such small numbers.

Table 20. Mean Monthly Combined South Delta Exports and Absolute (Percent) Differences between the FEIS/R PA and Alternative 1 and 2 (in cfs). Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	8,080	8,080	8,080	0 (0%)	0 (0%)
	AN	7,227	7,227	7,227	0 (0%)	0 (0%)
	BN	7,464	7,464	7,464	0 (0%)	0 (0%)
	D	6,742	6,742	6,742	0 (0%)	0 (0%)
	C	5,493	5,493	5,493	0 (0%)	0 (0%)
Jan	All	7,124	7,124	7,124	0 (0%)	0 (0%)
	W	10,137	10,137	10,137	0 (0%)	0 (0%)
	AN	8,972	8,969	8,969	-3.9 (0%)	-3.9 (0%)
	BN	7,426	7,426	7,426	0 (0%)	0 (0%)
	D	6,475	6,475	6,475	0 (0%)	0 (0%)
	C	5,877	5,877	5,877	0 (0%)	0 (0%)
Feb	All	8,249	8,248	8,248	-0.7 (0%)	-0.7 (0%)
	W	8,414	8,414	8,414	0 (0%)	0 (0%)
	AN	6,669	6,669	6,669	0 (0%)	0 (0%)
	BN	6,223	6,223	6,223	0 (0%)	0 (0%)
	D	4,860	4,860	4,860	0 (0%)	0 (0%)
	C	4,508	4,508	4,508	0 (0%)	0 (0%)
Mar	All	6,546	6,546	6,546	0 (0%)	0 (0%)
	W	5,765	5,765	5,765	0 (0%)	0 (0%)
	AN	4,044	4,044	4,044	0 (0%)	0 (0%)
	BN	2,735	2,735	2,735	0 (0%)	0 (0%)
	D	2,601	2,601	2,601	0 (0%)	0 (0%)
	C	1,633	1,633	1,633	0 (0%)	0 (0%)
Apr	All	3,874	3,874	3,874	0 (0%)	0 (0%)
	W	6,035	6,035	6,035	0 (0%)	0 (0%)
	AN	5,243	5,243	5,243	0 (0%)	0 (0%)
	BN	4,186	4,186	4,186	0 (0%)	0 (0%)
	D	3,078	3,078	3,078	0 (0%)	0 (0%)
	C	2,175	2,175	2,175	0 (0%)	0 (0%)
May	All	4,470	4,470	4,470	0 (0%)	0 (0%)
	W	7,410	7,410	7,410	0 (0%)	0 (0%)
	AN	6,489	6,489	6,489	0 (0%)	0 (0%)
	BN	4,984	4,984	4,984	0 (0%)	0 (0%)
	D	4,097	4,097	4,097	0 (0%)	0 (0%)
	C	2,566	2,566	2,566	0 (0%)	0 (0%)
Jun	All	5,523	5,523	5,523	0 (0%)	0 (0%)
	W	10,587	10,565	10,565	-22.5 (-0.2%)	-22.5 (-0.2%)
	AN	10,181	10,124	10,124	-57.2 (-0.6%)	-57.2 (-0.6%)
	BN	11,433	11,433	11,433	0 (0%)	0 (0%)
	D	9,068	7,718	7,718	**-1349.5 (-14.9%)**	**-1349.5 (-14.9%)**
	C	4,773	2,799	2,799	**-1973.9 (-41.4%)**	**-1973.9 (-41.4%)**
Jul	All	9,100	8,437	8,437	-663.2 (-7.3%)	-663.2 (-7.3%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	10,051	10,029	10,029	-22.5 (-0.2%)	-22.5 (-0.2%)
	AN	9,715	9,624	9,624	-91 (-0.9%)	-91 (-0.9%)
	BN	11,369	11,369	11,369	0 (0%)	0 (0%)
	D	6,196	5,521	5,521	**-675.7 (-10.9%)**	**-675.7 (-10.9%)**
	C	4,561	3,757	3,757	**-803.2 (-17.6%)**	**-803.2 (-17.6%)**
Aug	All	8,259	7,949	7,949	-309.3 (-3.7%)	-309.3 (-3.7%)
	W	10,567	10,552	10,552	-14.5 (-0.1%)	-14.5 (-0.1%)
	AN	10,343	10,291	10,291	-51.9 (-0.5%)	-51.9 (-0.5%)
	BN	8,830	8,816	8,816	-13.1 (-0.1%)	-13.1 (-0.1%)
	D	7,143	6,746	6,746	-396.8 (-5.6%)	-396.8 (-5.6%)
	C	4,803	4,247	4,247	**-556 (-11.6%)**	**-556 (-11.6%)**
Sep	All	8,634	8,434	8,434	-200 (-2.3%)	-200 (-2.3%)
	W	8,132	8,452	8,452	320.2 (3.9%)	320.2 (3.9%)
	AN	5,009	6,355	5,627	**1346.1 (26.9%)**	**617.6 (12.3%)**
	BN	7,580	8,031	8,031	450.8 (5.9%)	450.8 (5.9%)
	D	6,321	7,070	7,032	**749 (11.8%)**	**711 (11.2%)**
	C	4,957	6,645	6,066	**1688.3 (34.1%)**	**1109.2 (22.4%)**
Oct	All	6,575	7,441	7,187	**866.2 (13.2%)**	611.8 (9.3%)
	W	10,546	10,546	10,546	0 (0%)	0 (0%)
	AN	7,598	7,707	8,429	109.1 (1.4%)	**830.2 (10.9%)**
	BN	10,561	10,561	10,561	0 (0%)	0 (0%)
	D	9,760	10,206	10,245	446.2 (4.6%)	485.4 (5%)
	C	6,367	6,797	7,294	429.9 (6.8%)	**927.6 (14.6%)**
Nov	All	9,028	9,214	9,451	186.5 (2.1%)	423.1 (4.7%)
	W	9,144	9,144	9,144	0 (0%)	0 (0%)
	AN	8,603	8,603	8,603	0 (0%)	0 (0%)
	BN	11,196	11,196	11,196	0 (0%)	0 (0%)
	D	9,105	9,105	9,105	0 (0%)	0 (0%)
	C	6,978	6,978	6,978	0 (0%)	0 (0%)
Dec	All	8,717	8,717	8,717	0 (0%)	0 (0%)

3.2.2 Winter-run Chinook Salmon

3.2.2.1 Sacramento River

Effects to winter-run Chinook salmon as a result of Alt 1 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for winter-run Chinook salmon spawning and egg incubation, rearing, and migration. Therefore, no temperature-related effects from Alt 1 to winter-run Chinook salmon in the Sacramento River are predicted.

As described in Section 3.2.1, *Central Valley Steelhead*, flow differences under Alt 1 relative to the FEIS/R PA in the Sacramento River at Keswick would occur primarily during summer and fall of dry and critical years (Table 11). Flows would decrease in dry and critical water years by up to 14 percent during July and September and increase by up to 27 percent during October.

Flows under Alt 1 could affect winter-run Chinook salmon spawning habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. Results of the analysis predicting how spawning WUA changes under the FEIS/R PA and Alt 1 are presented in Table 21. There would be minimal differences in spawning WUA between FEIS/R PA and Alt 1 during April through June. During July, WUA would be similar between FEIS/R PA and Alt 1 except for an increase in spawning WUA under Alt 1 during July of dry years in Segment 5 (10.7%). These results indicate that there would be minimal effects of Alt 1 on winter-run spawning habitat availability.

Table 21. Spawning WUA Results for Winter-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 1 (Weighted Usable Area Units). Bold indicates >10% difference.

		Segment 6			Segment 5			Segment 4		
Month	WYT	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	W	164,793	164,793	0 (0%)	610,436	610,436	0 (0%)	174,499	174,499	0 (0%)
	AN	201,250	201,250	0 (0%)	699,997	699,997	0 (0%)	176,192	176,192	0 (0%)
	BN	178,843	178,843	0 (0%)	672,174	672,174	0 (0%)	201,506	201,506	0 (0%)
	D	145,768	145,768	0 (0%)	627,878	627,878	0 (0%)	206,282	206,282	0 (0%)
	C	136,607	136,607	0 (0%)	612,323	612,323	0 (0%)	204,789	204,789	0 (0%)
Apr	All	162,893	162,893	0 (0%)	633,339	633,339	0 (0%)	188,231	188,231	0 (0%)
	W	276,000	276,000	0 (0%)	719,782	719,782	0 (0%)	147,440	147,440	0 (0%)
	AN	287,887	287,887	0 (0%)	756,761	756,761	0 (0%)	153,901	153,901	0 (0%)
	BN	265,680	265,496	-184 (0%)	776,185	776,136	-49 (0%)	183,496	183,667	171 (0.1%)
	D	301,565	301,740	175 (0%)	796,610	796,716	106 (0%)	160,373	160,224	-149 (-0.1%)
	C	256,409	256,763	353 (0%)	768,863	769,117	254 (0%)	187,576	187,250	-326 (-0.2%)
May	All	277,969	278,061	93 (0%)	753,288	753,356	68 (0%)	161,247	161,163	-83 (-0.1%)
	W	287,639	287,639	0 (0%)	742,092	742,092	0 (0%)	152,306	152,306	0 (0%)
	AN	303,146	304,024	877 (0.3%)	778,976	779,358	382 (0%)	153,160	151,922	-1238 (-0.8%)
	BN	304,211	304,255	44 (0%)	721,752	722,449	697 (0.1%)	143,822	143,916	94 (0.1%)
	D	295,695	295,344	-351 (0%)	694,670	693,136	-1534 (-0.2%)	146,492	146,436	-56 (0%)
	C	298,710	298,645	-65 (0%)	787,173	784,950	-2223 (-0.3%)	162,749	162,442	-306 (-0.2%)
Jun	All	295,051	295,133	82 (0%)	748,317	747,697	-620 (-0.1%)	153,081	152,796	-286 (-0.2%)
	W	287,108	287,291	183 (0.1%)	642,707	644,513	1806 (0.3%)	134,485	134,711	226 (0.2%)
	AN	279,829	279,829	0 (0%)	606,365	606,365	0 (0%)	131,530	131,530	0 (0%)
	BN	274,283	274,461	178 (0%)	566,083	566,647	565 (0.1%)	128,109	128,211	102 (0.1%)
	D	286,710	296,286	9577 (3%)	617,351	683,127	**65776 (10.7%)**	134,751	142,306	7555 (5.6%)
	C	298,803	301,273	2470 (1%)	711,195	776,587	65392 (9.2%)	149,225	161,694	12469 (8.4%)
Jul	All	287,407	289,686	2279 (0.8%)	641,412	667,207	25794 (4%)	136,670	140,663	3993 (2.9%)

Salmonid redd dewatering can occur when water levels decrease after redd construction, exposing buried and otherwise submerged eggs or alevins to air. In the Sacramento River below Keswick, winter-run Chinook salmon redd dewatering risk under the FEIS/R PA and Alt 1 are expected to be similar during all months of spawning (Table 22). In addition, as described in the 2019 NMFS BiOp

(NMFS 2019), Reclamation attempts to minimize the risk redd dewatering from storage releases and this would continue under both the FEIS/R PA and Alt 1. There is low certainty in these results because the CalSim outputs used to conduct this analysis are at a monthly time step, yet flows can fluctuate and affect redd water levels at a shorter timestep. However, if as expected, this limitation affects the FEIS/R PA and Alt 1 results similarly, the monthly time-step results should provide a relative index of dewatering probability. As a result of these considerations, effects of Alt 1 relative to the FEIS/R PA on winter-run Chinook salmon redd dewatering risk is expected to be less than significant.

Table 22. Redd Dewatering Risk Results for Winter-run Chinook Salmon in the Sacramento River below Keswick Dam for the FEIS/R PA and Alt 1 (in Percent of Redds Dewatered).

Month	WYT	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
Apr	W	4.6	4.6	0.0
	AN	0.1	0.0	0.0
	BN	0.0	0.0	0.0
	D	0.0	0.0	0.0
	C	0.1	0.1	0.0
	All	1.8	1.8	0.0
May	W	1.6	1.6	0.0
	AN	1.6	1.5	-0.1
	BN	0.0	0.0	0.0
	D	0.6	0.9	0.3
	C	0.4	0.7	0.3
	All	1.1	1.1	0.1
Jun	W	1.9	1.9	0.0
	AN	3.3	3.3	0.0
	BN	14.1	14.1	0.0
	D	21.9	25.5	3.6
	C	15.8	20.3	4.5
	All	9.3	10.8	1.6
Jul	W	11.9	11.8	-0.1
	AN	18.0	18.0	0.0
	BN	39.2	38.5	-0.6
	D	32.7	28.9	-3.7
	C	25.3	22.4	-2.9
	All	21.0	19.7	-1.3

Flows under Alt 1 could affect winter-run Chinook salmon rearing habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. Results of the analysis predicting how rearing WUA changes under the FEIS/R PA and Alt 1 are presented in Table 23. These results generally show similar rearing WUA amounts under the FEIS/R PA and Alt 1, except for 10.% and -11.8% reductions in Segment 5 during July of dry and critical water years, respectively, under Alt 1. Overall, given the isolated temporal and spatial incidence and generally small magnitude of differences, these differences under Alt 1 are considered less than significant.

Table 23. Juvenile Rearing WUA Results for Winter-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 1 (in Weighted Usable Area Units). Bold indicates >10% difference.

		Segment 6			Segment 5			Segment 4		
Month	WYT	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	W	73,461	73,217	-244 (-0.3%)	631,569	629,755	-1814 (-0.3%)	125,172	125,386	214 (0.2%)
	AN	75,169	75,169	0 (0%)	665,477	665,477	0 (0%)	127,280	127,280	0 (0%)
	BN	80,450	80,426	-23 (0%)	703,623	703,503	-119 (0%)	123,129	122,994	-134 (-0.1%)
	D	79,854	72,783	-7071 (-9%)	664,071	596,664	**-67407 (-10.2%)**	114,283	120,799	6516 (5.7%)
	C	71,956	67,905	-4051 (-6%)	563,561	496,999	**-66562 (-11.8%)**	123,501	129,095	5594 (4.5%)
Jul	All	74,992	72,815	-2177 (-3%)	633,525	607,225	-26300 (-4.2%)	123,158	125,534	2375 (1.9%)
	W	72,005	72,005	0 (0%)	532,363	532,363	0 (0%)	125,787	125,787	0 (0%)
	AN	67,010	67,055	45 (0%)	475,438	473,880	-1558 (-0.3%)	131,653	131,580	-74 (-0.1%)
	BN	70,307	70,321	14 (0%)	477,546	477,047	-499 (-0.1%)	132,079	132,056	-23 (0%)
	D	71,114	74,383	3269 (5%)	469,709	480,769	11060 (2.4%)	133,667	133,065	-603 (-0.5%)
	C	70,625	73,738	3114 (4%)	490,813	493,421	2608 (0.5%)	131,995	131,978	-17 (0%)
Aug	All	70,582	71,809	1227 (2%)	499,482	501,666	2185 (0.4%)	129,861	129,737	-124 (-0.1%)
	W	70,507	70,507	0 (0%)	517,746	517,746	0 (0%)	128,201	128,201	0 (0%)
	AN	75,560	75,658	97 (0.1%)	485,974	485,318	-657 (-0.1%)	132,568	132,722	154 (0.1%)
	BN	82,111	82,545	434 (1%)	537,666	538,036	370 (0.1%)	131,079	131,077	-2 (0%)
	D	90,550	92,118	1568 (2%)	578,118	585,869	7750 (1.3%)	130,727	131,804	1077 (0.8%)
	C	91,828	92,281	453 (0%)	583,364	579,968	-3397 (-0.6%)	132,252	135,629	3377 (2.6%)
Sep	All	80,008	80,420	412 (1%)	537,475	538,049	574 (0.1%)	130,421	131,333	912 (0.7%)
	W	81,234	80,091	-1143 (-1.4%)	507,241	497,652	-9589 (-1.9%)	131,562	131,450	-112 (-0.1%)
	AN	86,262	79,818	-6444 (-7.5%)	549,071	509,287	-39784 (-7.2%)	131,102	132,101	998 (0.8%)
	BN	71,813	70,565	-1248 (-2%)	483,619	486,540	2922 (0.6%)	131,808	130,133	-1674 (-1.3%)
	D	84,527	81,982	-2546 (-3%)	535,410	525,878	-9533 (-1.8%)	131,916	131,971	55 (0%)
	C	86,422	82,525	-3897 (-5%)	551,978	514,052	-37926 (-6.9%)	131,637	131,788	151 (0.1%)
Oct	All	83,216	80,317	-2899 (-3.5%)	527,415	507,409	-20006 (-3.8%)	131,573	131,649	76 (0.1%)

The migration period of adult winter-run Chinook salmon in the Sacramento River is typically November through July (Table 3). During this period, adult attraction flows from Keswick are predicted to be mostly similar between Alt 1 than the FEIS/R PA, except for reduced flows under Alt 1 in critical years during July (Table 11). Due to the limited temporal occurrence and small frequency and magnitude of reduced flows under Alt 1, effects to adult migration are expected to be less than significant.

The primary juvenile winter-run outmigration period in the Sacramento River above Red Bluff is August through December (Table 3). During this period, flows under Alt 1 would be higher during October of above normal, dry, and critical water year types relative to the FEIS/R PA (Table 11). Due to the limited temporal occurrence and small frequency and magnitude of reduced flows under Alt 1, effects to juvenile migration are expected to be less than significant.

3.2.2.2 Delta

Juvenile winter-run Chinook salmon are typically found in the Delta from approximately October through April (Table 4). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 1, except during October of above normal and critical water years in which flows would be 19% and 23% greater under Alt 1, respectively (Table 19). Therefore, minimal effects of Alt 1 are expected during juvenile winter-run Delta migration and residence period.

Adult winter-run Chinook salmon are typically found in the Delta from approximately November through June (Table 4). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 1 (Table 19). Therefore, minimal effects of Alt 1 are expected during adult winter-run Delta migration period.

South Delta export rates during the October through April winter-run juvenile rearing and migration period in the Delta would be mostly similar between the FEIS/R PA and Alt 1, although exports would be higher during October of most water years (Table 20). Overall, due to the isolated incidence of these differences and the small proportion of the overall population in the Delta during October, effects to winter-run would be less than significant.

3.2.3 Spring-run Chinook salmon

3.2.3.1 Sacramento River

Effects to spring-run Chinook salmon as a result of Alt 1 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for spring-run Chinook salmon spawning and egg incubation, rearing, and migration. Therefore, no temperature-related effects from Alt 1 to spring-run Chinook salmon in the Sacramento River are predicted.

As described in Section 3.2.1, *Central Valley Steelhead*, flow differences under Alt 1 relative to the FEIS/R PA in the Sacramento River at Keswick would occur primarily during summer and fall of dry and critical years (Table 11). Flows would decrease in dry and critical water years by up to 14 percent during July and September and increase by up to 27 percent during October.

Flows under Alt 1 could affect spring-run Chinook salmon spawning habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. Results of the analysis predicting how spawning WUA changes under the FEIS/R PA and Alt 1 are presented in Table 24. There would be minimal to minor differences in spawning WUA between FEIS/R PA and Alt 1 during August and September. During October, WUA would be lower in Segment 4 under Alt 1 during above normal and critical water years. However, given the isolated occurrences of this reduction and the trend toward greatly reduced spring-run spawning in the mainstem Sacramento River observed over the last two decades, these effects would be less than significant to the spring-run ESU.

Table 24. Spawning WUA Results for Winter-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 1 (Weighted Usable Area Units). Bold indicates >10% difference.

		Segment 6			Segment 5			Segment 4		
Month	WYT	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	W	239,936	239,936	0 (0%)	320,673	320,673	0 (0%)	123,446	123,446	0 (0%)
	AN	255,747	256,501	754 (0.3%)	369,646	372,397	2751 (0.7%)	135,756	136,169	413 (0.3%)
	BN	268,400	268,631	231 (0%)	405,057	405,829	772 (0.2%)	137,934	138,061	127 (0.1%)
	D	273,156	287,138	13982 (5%)	421,602	462,280	40677 (9.6%)	138,709	142,896	4187 (3%)
	C	289,846	300,389	10543 (4%)	466,885	501,147	34261 (7.3%)	147,772	154,762	6990 (4.7%)
Aug	All	260,539	265,323	4785 (2%)	382,193	396,956	14763 (3.9%)	134,172	136,431	2258 (1.7%)
	W	251,165	251,165	0 (0%)	354,043	354,043	0 (0%)	134,219	134,219	0 (0%)
	AN	292,839	293,235	396 (0%)	479,076	480,394	1317 (0.3%)	151,881	151,895	14 (0%)
	BN	325,503	325,445	-58 (0%)	586,680	586,854	174 (0%)	180,430	180,776	346 (0.2%)
	D	303,905	293,556	-10348 (-3%)	589,394	582,608	-6786 (-1.2%)	221,619	235,546	13927 (6.3%)
	C	296,996	278,671	-18325 (-6%)	583,496	566,829	-16668 (-2.9%)	234,980	251,843	16863 (7.2%)
Sep	All	281,635	276,102	-5533 (-2%)	478,565	474,179	-4386 (-0.9%)	176,222	182,175	5952 (3.4%)
	W	295,357	301,349	5992 (2%)	502,810	502,504	-305 (-0.1%)	163,210	152,618	-10592 (-6.5%)
	AN	300,426	289,996	-10431 (-3.5%)	561,687	507,022	-54666 (-9.7%)	192,112	168,982	**-23130 (-12%)**
	BN	303,616	299,150	-4467 (-1%)	504,867	491,097	-13771 (-2.7%)	150,261	150,110	-151 (-0.1%)
	D	318,621	300,609	-18012 (-6%)	573,138	516,849	-56289 (-9.8%)	171,436	164,134	-7303 (-4.3%)
	C	283,625	300,418	16793 (6%)	535,247	512,237	-23010 (-4.3%)	201,555	160,594	**-40961 (-20.3%)**
Oct	All	298,427	298,894	466 (0%)	532,410	507,166	-25244 (-4.7%)	176,895	159,032	**-17862 (-10.1%)**

Salmonid redd dewatering can occur when water levels decrease after redd construction, exposing buried and otherwise submerged eggs or alevins to air. In the Sacramento River at Clear Creek, spring-run Chinook salmon redd dewatering risk under the FEIS/R PA and Alt 1 is expected to be similar during all months of spawning (Table 25). As described in the 2019 NMFS BiOp (NMFS 2019), Reclamation attempts to minimize the risk redd dewatering from Shasta storage releases and this would continue under both the FEIS/R PA and Alt 1. There is low certainty in these results because the CalSim outputs used to conduct this analysis are at a monthly time step, yet flows can fluctuate and affect redd water levels at a shorter timestep. However, if as expected, this limitation affects the FEIS/R PA and Alt 1 results similarly, the monthly time-step results should provide a relative index of dewatering probability. As a result of these considerations, effects of Alt 1 relative to the FEIS/R PA on spring-run Chinook salmon redd dewatering risk is expected to be less than significant.

Table 25. Redd Dewatering Risk Results for Spring-run Chinook Salmon in the Sacramento River at Clear Creek for the FEIS/R PA and Alt 1 (in Percent of Redds Dewatered).

Month	WYT	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	Wet	16.3	16.3	0.0
	AN	15.3	15.3	0.0
	BN	29.3	25.7	-3.6
	D	24.1	20.2	-3.9
	C	23.2	19.9	-3.3
Aug	All	19.7	18.1	-1.6
	Wet	23.3	23.3	0.0
	AN	14.5	14.5	0.0
	BN	8.9	7.2	-1.7
	D	5.1	3.3	-1.8
	C	3.9	2.1	-1.8
Sep	All	13.7	12.9	-0.8
	Wet	9.5	11.2	1.7
	AN	7.2	15.4	8.1
	BN	25.9	26.9	1.0
	D	15.0	20.4	5.4
	C	8.3	17.3	9.0
Oct	All	10.8	15.7	4.9

Flows under Alt 1 could affect spring-run Chinook salmon rearing habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. In the first several months after emergence from the gravel (typically November through February) when individuals are most vulnerable, there would be negligible changes in rearing WUA (Table 26).

Table 26. Juvenile Rearing WUA Results for Spring-run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 1 (in Weighted Usable Area Units).

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	W	64,005	64,005	0 (0%)	1,077,328	1,077,328	0 (0%)	177,337	177,337	0 (0%)
	AN	62,511	62,511	0 (0%)	1,213,514	1,213,514	0 (0%)	200,377	200,377	0 (0%)
	BN	60,781	60,781	0 (0%)	1,142,629	1,142,629	0 (0%)	189,391	189,391	0 (0%)
	D	61,022	59,730	-1292 (-2%)	980,412	966,101	-14311 (-1.5%)	175,662	173,588	-2074 (-1.2%)
	C	61,684	60,864	-821 (-1%)	1,095,279	1,064,579	-30699 (-2.8%)	193,249	187,255	-5993 (-3.1%)
Nov	All	62,547	62,150	-397 (-1%)	1,091,795	1,082,949	-8846 (-0.8%)	185,092	183,492	-1600 (-0.9%)

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
Dec	W	77,074	77,074	0 (0%)	1,161,824	1,161,824	0 (0%)	166,767	166,767	0 (0%)
	AN	65,025	65,025	0 (0%)	1,277,257	1,277,257	0 (0%)	181,029	181,029	0 (0%)
	BN	68,531	68,531	0 (0%)	1,472,110	1,472,110	0 (0%)	217,118	217,118	0 (0%)
	D	65,854	65,854	0 (0%)	1,363,902	1,363,902	0 (0%)	199,909	199,909	0 (0%)
	C	66,520	66,520	0 (0%)	1,369,784	1,369,784	0 (0%)	209,682	209,682	0 (0%)
	All	70,293	70,293	0 (0%)	1,278,923	1,278,923	0 (0%)	186,930	186,930	0 (0%)
Jan	W	76,240	76,240	0 (0%)	1,096,779	1,096,779	0 (0%)	157,398	157,398	0 (0%)
	AN	70,037	70,037	0 (0%)	1,112,896	1,112,896	0 (0%)	142,229	142,229	0 (0%)
	BN	67,463	67,463	0 (0%)	1,455,076	1,455,076	0 (0%)	195,600	195,600	0 (0%)
	D	70,113	70,113	0 (0%)	1,375,623	1,375,623	0 (0%)	194,932	194,932	0 (0%)
	C	68,912	68,912	0 (0%)	1,369,394	1,369,394	0 (0%)	209,307	209,307	0 (0%)
	All	72,039	72,039	0 (0%)	1,226,034	1,226,034	0 (0%)	174,279	174,279	0 (0%)
Feb	W	74,902	74,902	0 (0%)	1,122,600	1,122,600	0 (0%)	158,767	158,767	0 (0%)
	AN	76,631	76,631	0 (0%)	1,161,305	1,161,305	0 (0%)	155,836	155,836	0 (0%)
	BN	65,307	65,307	0 (0%)	1,342,208	1,342,208	0 (0%)	181,500	181,500	0 (0%)
	D	70,523	70,523	0 (0%)	1,475,446	1,475,446	0 (0%)	192,480	192,480	0 (0%)
	C	68,554	68,554	0 (0%)	1,452,700	1,452,700	0 (0%)	205,243	205,243	0 (0%)
	All	72,563	72,563	0 (0%)	1,272,577	1,272,577	0 (0%)	175,105	175,105	0 (0%)

The primary migration period of adult spring-run Chinook salmon past RBDD is typically March through September (Table 5). Flows under Alt 1 would be mostly similar to the FEIS/R PA during this period, except for July of critical years (14% lower; Table 11). Given these small, isolated differences in flows, Alt 1 would have less than significant effects on adult migration in the Sacramento River.

The primary juvenile spring-run Chinook salmon outmigration period in the upper Sacramento River is November through January (Table 5). This coincides with a period of negligible flow changes in the Sacramento River (Table 11). Therefore, Alt 1 would have negligible effects on juvenile spring-run outmigration in the Sacramento River.

3.2.3.2 Feather River

The large majority of Chinook salmon (fall-run ad spring-run combined) spawning (>95%) and rearing (>99%) occurs in the low flow channel (DWR 2012). Low flow channel flows would not change under Alt 1 compared to the FEIS/R PA. Monthly flows in the low flow channel have been optimized for salmonids. Therefore, minimal effects of Alt 1 to spawning and rearing spring-run Chinook salmon in the low flow channel are expected.

The high flow channel is used primarily as a migration corridor for spring-run juvenile and adults. Adult migration typically occurs from March through June. The majority of juveniles typically emigrate from November through June. Although no relationships between flow and migration are known for spring-run Chinook salmon in the Feather River, it is generally thought that higher flows are better for migration. Predicted flows in the high flow channel are presented in Table 15. Flows in the high flow channel are predicted to be similar between Alt 1 and the FEIS/R PA throughout the juvenile and adult migration periods. These results indicate that both juvenile and adult spring-run Chinook salmon migration in the high flow channel of the Feather River would be minimally impacted by Alt 1.

DWR is committed to meeting year-round water temperature targets in the low-flow and high-flow channels of the Feather River for salmonids in the FERC BiOp (NMFS 2016), which would be included under both the FEIS/R PA and Alt 1. Therefore, no temperature-related effects to spring-run Chinook salmon in the Feather River are predicted under Alt 1.

3.2.3.3 San Joaquin River

For this analysis, it is assumed that higher flows are better for habitat conditions for spring-run Chinook salmon. Although the SJRRP is actively monitoring the experimental spring-run Chinook salmon population in the San Joaquin River, long-term trends in timing of presence of each life stage is limited. The following periods were based on recent SJRRP monitoring reports as cited:

- Adult migration – February to July (Durkacz et al. 2019)
- Adult holding – February to September[3]
- Spawning – September to November (Durkacz et al. 2019)
- Rearing – December to May (Hutcherson et al. No date)
- Juvenile migration – December to May (Hutcherson et al. No date)

Flows in the San Joaquin River at Vernalis under Alt 1 would be similar to those under the FEIS/R PA in all months and water years with one exception (Table 18). During July of dry water years, flows would be 11.8% lower under Alt 1 relative to the FEIS/R PA. This reduction would coincide with spring-run Chinook salmon adult migration and holding, but no other life stages. Due to the low frequency of occurrence, this flow reduction under Alt 1 would cause less than significant effects to spring-run Chinook salmon in the San Joaquin River.

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the San Joaquin River. Under this assumption, water temperature results would be similar to flow results (Table 18) in that, due to the low frequency of differences between Alt 1 and the FEIS/R PA, effects to spring-run Chinook salmon are expected to be minimal.

3.2.3.4 Delta

Juvenile spring-run Chinook salmon are typically found in the Delta from approximately December through May (Table 6). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 1 (Table 19). Therefore, minimal effects of Alt 1 are expected during juvenile spring-run Delta migration and residence period.

Adult spring-run Chinook salmon are typically found in the Delta from approximately January through June (Table 6). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 1 (Table 19). Therefore, minimal effects of Alt 1 are expected during adult spring-run Delta migration period.

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[3] Until fish passage projects in the San Joaquin River are completed, spring-run Chinook salmon adults will not have access to suitable holding and spawning reaches. Individuals are currently trapped and truck-transported from the lower reaches to the spawning reach (Sutphin and Root 2021). As such, no empirical data exist on timing of spring-run holding. Therefore, the holding period used in this analysis consists of the entire adult migration period until spawning commences in September.

South Delta export rates during the December through May winter-run juvenile rearing and migration period in the Delta for would be nearly identical between the FEIS/R PA and Alt 1. Therefore, effects of Alt 1 on spring-run Chinook salmon entrainment risk would be minimal.

3.2.4 Fall-/Late Fall-Run Chinook Salmon

3.2.4.1 Sacramento River

Effects to fall-/late fall-run Chinook salmon as a result of Alt 1 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for fall-/late fall-run Chinook salmon spawning and egg incubation, rearing, and migration. Therefore, no temperature-related effects from Alt 1 to fall-/late fall-run Chinook salmon in the Sacramento River are predicted.

Flows under Alt 1 could affect fall-/late fall-run Chinook salmon spawning habitat availability, measured as WUA, relative to the FEIS/R PA. Results of the analysis predicting how spawning WUA changes under the FEIS/R PA and Alt 1 for fall-run and late fall-run are presented in Table 27 and Table 28, respectively. For fall-run, there would be minimal differences in spawning WUA between FEIS/R PA and Alt 1 in all months except October, in which there would be 12% and 14% reductions in above normal years in Segment 5 and 4, respectively, and a 22% reduction in critical years in Segment 4 (Table 27). Given the isolated occurrence of these reductions under Alt 1, they would be less than significant to fall-run spawning habitat availability. For late fall-run, there would be minimal differences in spawning WUA between FEIS/R PA and Alt 1 during the December through April spawning period (Table 28). Therefore, effects of Alt 1 on late fall-run Chinook salmon spawning habitat availability would be negligible.

Table 27. Spawning WUA Results for Fall-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 1 (Weighted Usable Area Units). Bold indicates >10% difference.

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
Sep	W	251,165	251,165	0 (0%)	354,043	354,043	0 (0%)	134,219	134,219	0 (0%)
	AN	292,839	293,235	396 (0.1%)	479,076	480,394	1317 (0.3%)	151,881	151,895	14 (0%)
	BN	325,503	325,445	-58 (0%)	586,680	586,854	174 (0%)	180,430	180,776	346 (0.2%)
	D	303,905	293,556	-10348 (-3%)	589,394	582,608	-6786 (-1.2%)	221,619	235,546	13927 (6.3%)
	C	296,996	278,671	-18325 (-6%)	583,496	566,829	-16668 (-2.9%)	234,980	251,843	16863 (7.2%)
	All	281,635	276,102	-5533 (-2%)	478,565	474,179	-4386 (-0.9%)	176,222	182,175	5952 (3.4%)
Oct	W	295,357	301,349	5992 (2%)	502,810	502,504	-305 (-0.1%)	163,210	152,618	-10592 (-6.5%)
	AN	300,426	289,996	-10431 (-3%)	561,687	507,022	-54666 (-9.7%)	192,112	168,982	**-23130 (-12%)**
	BN	303,616	299,150	-4467 (-1%)	504,867	491,097	-13771 (-2.7%)	150,261	150,110	-151 (-0.1%)

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	D	318,621	300,609	-18012 (-6%)	573,138	516,849	-56289 (-9.8%)	171,436	164,134	-7303 (-4.3%)
	C	283,625	300,418	16793 (6%)	535,247	512,237	-23010 (-4.3%)	201,555	160,594	**-40961 (-20.3%)**
	All	298,427	298,894	466 (0%)	532,410	507,166	-25244 (-4.7%)	176,895	159,032	**-17862 (-10.1%)**
	W	140,244	140,244	0 (0%)	447,029	447,029	0 (0%)	132,645	132,645	0 (0%)
	AN	203,634	199,719	-3915 (-1.9%)	566,947	570,054	3107 (0.5%)	183,533	179,915	-3618 (-2%)
	BN	184,435	184,435	0 (0%)	583,540	583,540	0 (0%)	174,457	174,457	0 (0%)
	D	115,622	111,487	-4135 (-4%)	429,944	425,231	-4713 (-1.1%)	144,008	143,031	-976 (-0.7%)
	C	169,741	158,780	-10960 (-6%)	549,488	546,468	-3020 (-0.5%)	172,046	164,626	-7420 (-4.3%)
Nov	All	155,758	152,081	-3677 (-2%)	494,300	493,395	-905 (-0.2%)	154,202	151,864	-2338 (-1.5%)

Table 28. Spawning WUA Results for Late Fall-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 1 (Weighted Usable Area Units).

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	W	133,639	133,639	0 (0%)	303,842	303,842	0 (0%)	246,713	246,713	0 (0%)
	AN	203,163	203,163	0 (0%)	480,893	480,893	0 (0%)	377,701	377,701	0 (0%)
	BN	257,563	257,563	0 (0%)	529,101	529,101	0 (0%)	534,401	534,401	0 (0%)
	D	237,246	237,246	0 (0%)	533,951	533,951	0 (0%)	466,359	466,359	0 (0%)
	C	235,227	235,227	0 (0%)	524,282	524,282	0 (0%)	499,899	499,899	0 (0%)
Dec	All	192,396	192,396	0 (0%)	434,329	434,329	0 (0%)	377,639	377,639	0 (0%)
	W	117,046	117,046	0 (0%)	282,700	282,700	0 (0%)	198,337	198,337	0 (0%)
	AN	129,541	129,541	0 (0%)	325,577	325,577	0 (0%)	178,938	178,938	0 (0%)
	BN	253,385	253,385	0 (0%)	533,697	533,697	0 (0%)	480,048	480,048	0 (0%)
	D	241,481	241,481	0 (0%)	494,121	494,121	0 (0%)	455,709	455,709	0 (0%)
	C	240,859	240,859	0 (0%)	514,720	514,720	0 (0%)	490,063	490,063	0 (0%)
Jan	All	174,721	174,721	0 (0%)	390,110	390,110	0 (0%)	316,965	316,965	0 (0%)
	W	123,008	123,008	0 (0%)	290,837	290,837	0 (0%)	192,498	192,498	0 (0%)
	AN	137,573	137,573	0 (0%)	280,587	280,587	0 (0%)	187,321	187,321	0 (0%)
	BN	234,663	234,663	0 (0%)	537,649	537,649	0 (0%)	384,823	384,823	0 (0%)
	D	263,725	263,725	0 (0%)	517,331	517,331	0 (0%)	456,346	456,346	0 (0%)
	C	255,951	255,951	0 (0%)	525,633	525,633	0 (0%)	493,712	493,712	0 (0%)
Feb	All	184,349	184,349	0 (0%)	391,856	391,856	0 (0%)	311,474	311,474	0 (0%)

	W	87,271	87,271	0 (0%)	226,709	226,709	0 (0%)	143,471	143,471	0 (0%)
	AN	144,532	144,572	39 (0%)	411,274	411,484	210 (0.1%)	254,353	254,503	150 (0.1%)
	BN	161,482	161,482	0 (0%)	358,089	358,089	0 (0%)	288,601	288,601	0 (0%)
	D	239,673	239,853	180 (0%)	521,490	521,619	129 (0%)	408,857	409,029	172 (0%)
	C	240,949	240,949	0 (0%)	514,961	514,961	0 (0%)	470,114	470,114	0 (0%)
Mar	All	160,275	160,314	39 (0%)	378,374	378,433	60 (0%)	285,659	285,715	57 (0%)
	W	199,766	199,766	0 (0%)	463,341	463,341	0 (0%)	371,283	371,283	0 (0%)
	AN	223,249	223,249	0 (0%)	505,237	505,237	0 (0%)	390,215	390,215	0 (0%)
	BN	218,928	218,928	0 (0%)	514,622	514,622	0 (0%)	448,969	448,969	0 (0%)
	D	210,500	210,500	0 (0%)	511,650	511,650	0 (0%)	484,119	484,119	0 (0%)
	C	204,037	204,037	0 (0%)	503,701	503,701	0 (0%)	528,673	528,673	0 (0%)
Apr	All	207,811	207,811	0 (0%)	490,586	490,586	0 (0%)	431,510	431,510	0 (0%)

Salmonid redd dewatering can occur when water levels decrease after redd construction, exposing buried and otherwise submerged eggs or alevins to air. In the Sacramento River at Battle Creek, fall-run Chinook salmon redd dewatering risk under the FEIS/R PA and Alt 1 are expected to be similar during the spawning period (Table 29). As described in the 2019 NMFS BiOp (NMFS 2019), Reclamation attempts to minimize the risk redd dewatering from storage releases and this would continue under both the FEIS/R PA and Alt 1. There is low certainty in these results because the CalSim outputs used to conduct this analysis are at a monthly time step, yet flows can fluctuate and affect redd water levels at a shorter timestep. However, if as expected, this limitation affects the FEIS/R PA and Alt 1 results similarly, the monthly time-step results should provide a relative index of dewatering probability. As a result of these considerations, effects of Alt 1 relative to the FEIS/R PA on fall-run Chinook salmon redd dewatering risk is expected to be less than significant. Late fall-run Chinook salmon redd dewatering risk under the FEIS/R PA and Alt 1 are expected to be nearly identical throughout their spawning period (Table 30). Therefore, late fall-run Chinook salmon redd dewatering risk under Alt 1is expected to be less than significant.

Table 29. Redd Dewatering Risk Results for Fall-run Chinook Salmon in the Sacramento River at Battle Creek for the FEIS/R PA and Alt 1 (in Percent of Redds Dewatered). Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	W	13.4	13.4	0.0
	AN	8.5	8.5	0.0
	BN	3.9	3.7	-0.2
	D	0.5	0.1	-0.5
	C	1.0	0.4	-0.6
Sep	All	7.2	7.0	-0.2
	W	3.8	4.6	0.8
	AN	4.7	9.6	4.9
	BN	15.0	16.1	1.1
	D	5.0	8.3	3.4
	C	6.5	10.7	4.2
Oct	All	5.4	8.1	2.7

Month	WYT	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	W	13.2	13.2	0.0
	AN	2.3	2.3	0.0
	BN	8.2	8.2	0.0
	D	25.4	26.1	0.7
	C	13.4	15.1	1.8
Nov	All	13.2	13.7	0.5

Table 30. Redd Dewatering Risk Results for Late Fall-run Chinook Salmon in the Sacramento River below Keswick Dam for the FEIS/R PA and Alt 1 (in Percent of Redds Dewatered).

Month	WYT	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
	W	26.3	26.3	0.0
	AN	8.4	8.4	0.0
	BN	1.1	1.1	0.0
	D	4.3	4.3	0.0
	C	3.3	3.3	0.0
Dec	All	13.0	13.0	0.0
	W	37.2	37.2	0.0
	AN	29.9	29.9	0.0
	BN	0.0	0.0	0.0
	D	5.9	5.9	0.0
	C	2.6	2.6	0.0
Jan	All	21.1	21.1	0.0
	W	40.6	40.6	0.0
	AN	38.6	38.6	0.0
	BN	0.0	0.0	0.0
	D	0.6	0.6	0.0
	C	0.5	0.5	0.0
Feb	All	22.6	22.6	0.0
	W	48.0	48.0	0.0
	AN	15.6	15.6	0.0
	BN	14.0	14.0	0.0
	D	4.4	4.4	0.0
	C	2.9	2.9	0.0
Mar	All	23.3	23.3	0.0
	W	4.9	4.9	0.0
	AN	0.4	0.2	-0.1
	BN	0.0	0.0	0.0
	D	0.0	0.0	0.0
	C	0.4	0.4	0.0
Apr	All	2.0	2.0	0.0

Flows under Alt 1 could affect fall-/late fall-run rearing habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. Results of the analysis predicting how rearing WUA changes under the FEIS/R PA and Alt 1 for fall-run and late fall-run fry are presented in Table 31 and Table 32, respectively. For both races, these results show similar rearing WUA amounts under the FEIS/R PA and Alt 1. Therefore, these differences under Alt 1 are considered less than significant.

Table 31. Juvenile Rearing WUA Results for Fall-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 1 (in Weighted Usable Area Units). Bold indicates >10% difference.

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
Dec	W	77,074	77,074	0 (0%)	1,161,824	1,161,824	0 (0%)	166,767	166,767	0 (0%)
	AN	65,025	65,025	0 (0%)	1,277,257	1,277,257	0 (0%)	181,029	181,029	0 (0%)
	BN	68,531	68,531	0 (0%)	1,472,110	1,472,110	0 (0%)	217,118	217,118	0 (0%)
	D	65,854	65,854	0 (0%)	1,363,902	1,363,902	0 (0%)	199,909	199,909	0 (0%)
	C	66,520	66,520	0 (0%)	1,369,784	1,369,784	0 (0%)	209,682	209,682	0 (0%)
	All	70,293	70,293	0 (0%)	1,278,923	1,278,923	0 (0%)	186,930	186,930	0 (0%)
Jan	W	76,240	76,240	0 (0%)	1,096,779	1,096,779	0 (0%)	157,398	157,398	0 (0%)
	AN	70,037	70,037	0 (0%)	1,112,896	1,112,896	0 (0%)	142,229	142,229	0 (0%)
	BN	67,463	67,463	0 (0%)	1,455,076	1,455,076	0 (0%)	195,600	195,600	0 (0%)
	D	70,113	70,113	0 (0%)	1,375,623	1,375,623	0 (0%)	194,932	194,932	0 (0%)
	C	68,912	68,912	0 (0%)	1,369,394	1,369,394	0 (0%)	209,307	209,307	0 (0%)
	All	72,039	72,039	0 (0%)	1,226,034	1,226,034	0 (0%)	174,279	174,279	0 (0%)
Feb	W	74,902	74,902	0 (0%)	1,122,600	1,122,600	0 (0%)	158,767	158,767	0 (0%)
	AN	76,631	76,631	0 (0%)	1,161,305	1,161,305	0 (0%)	155,836	155,836	0 (0%)
	BN	65,307	65,307	0 (0%)	1,342,208	1,342,208	0 (0%)	181,500	181,500	0 (0%)
	D	70,523	70,523	0 (0%)	1,475,446	1,475,446	0 (0%)	192,480	192,480	0 (0%)
	C	68,554	68,554	0 (0%)	1,452,700	1,452,700	0 (0%)	205,243	205,243	0 (0%)
	All	72,563	72,563	0 (0%)	1,272,577	1,272,577	0 (0%)	175,105	175,105	0 (0%)
Mar	W	74,205	74,205	0 (0%)	1,041,932	1,041,932	0 (0%)	151,210	151,210	0 (0%)
	AN	62,935	62,894	-40 (-0.1%)	1,098,852	1,098,708	-144 (0%)	155,923	156,067	143 (0.1%)
	BN	66,685	66,685	0 (0%)	1,211,510	1,211,510	0 (0%)	174,109	174,109	0 (0%)
	D	67,874	67,858	-16 (0%)	1,357,086	1,358,155	1069 (0.1%)	183,939	183,965	26 (0%)
	C	69,069	69,069	0 (0%)	1,364,327	1,364,327	0 (0%)	196,425	196,425	0 (0%)
	All	69,599	69,589	-10 (0%)	1,183,943	1,184,106	163 (0%)	168,474	168,504	30 (0%)

Table 32. Juvenile Rearing WUA Results for Late Fall-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 1 (in Weighted Usable Area Units). Bold indicates >10% difference.

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA	FEIS/R PA	Alt 1	Alt 1 vs. FEIS/R PA
Mar	W	67,921	67,921	0 (0%)	985,347	985,347	0 (0%)	142,475	142,475	0 (0%)
	AN	60,812	60,753	-58 (-0.1%)	1,063,413	1,063,172	-241 (0%)	135,777	135,884	108 (0.1%)
	BN	60,929	60,929	0 (0%)	1,190,291	1,190,291	0 (0%)	153,975	153,975	0 (0%)
	D	59,966	59,916	-50 (0%)	1,309,887	1,311,098	1211 (0.1%)	165,551	165,579	29 (0%)
	C	62,925	62,925	0 (0%)	1,312,815	1,312,815	0 (0%)	181,151	181,151	0 (0%)
	All	63,823	63,804	-19 (0%)	1,135,871	1,136,042	171 (0%)	154,004	154,028	24 (0%)
Apr	W	106,718	106,718	0 (0%)	1,249,077	1,249,077	0 (0%)	165,445	165,445	0 (0%)

Month	WYT	Segment 6 FEIS/R PA	Segment 6 Alt 1	Segment 6 Alt 1 vs. FEIS/R PA	Segment 5 FEIS/R PA	Segment 5 Alt 1	Segment 5 Alt 1 vs. FEIS/R PA	Segment 4 FEIS/R PA	Segment 4 Alt 1	Segment 4 Alt 1 vs. FEIS/R PA
	AN	102,642	102,642	0 (0%)	1,124,052	1,124,052	0 (0%)	160,300	160,300	0 (0%)
	BN	104,382	104,382	0 (0%)	1,202,911	1,202,911	0 (0%)	176,575	176,575	0 (0%)
	D	116,758	116,758	0 (0%)	1,311,494	1,311,494	0 (0%)	184,544	184,544	0 (0%)
	C	117,447	117,447	0 (0%)	1,351,210	1,351,210	0 (0%)	195,490	195,490	0 (0%)
	All	109,842	109,842	0 (0%)	1,256,340	1,256,340	0 (0%)	174,748	174,748	0 (0%)
May	W	74,376	74,376	0 (0%)	898,646	898,646	0 (0%)	145,739	145,739	0 (0%)
May	AN	72,923	72,923	0 (0%)	857,869	857,869	0 (0%)	147,854	147,854	0 (0%)
May	BN	85,825	85,976	151 (0%)	924,822	925,675	853 (0.1%)	164,262	164,311	49 (0%)
May	D	67,264	67,087	-177 (0%)	793,319	792,785	-533 (-0.1%)	152,134	151,979	-155 (-0.1%)
May	C	90,501	90,132	-369 (0%)	961,163	960,346	-818 (-0.1%)	166,847	166,517	-330 (-0.2%)
May	All	76,858	76,759	-98 (0%)	887,274	887,062	-212 (0%)	152,676	152,584	-92 (-0.1%)
Jun	W	71,471	71,471	0 (0%)	830,849	830,849	0 (0%)	149,290	149,290	0 (0%)
Jun	AN	64,124	63,288	-836 (-1.3%)	808,180	804,164	-4016 (-0.5%)	143,594	143,186	-408 (-0.3%)
Jun	BN	59,796	59,780	-15 (0%)	835,118	834,597	-521 (-0.1%)	134,294	134,359	66 (0%)
Jun	D	70,951	70,986	35 (0%)	860,600	862,143	1543 (0.2%)	136,753	136,751	-2 (0%)
Jun	C	64,895	64,865	-30 (0%)	821,038	821,631	594 (0.1%)	151,723	151,385	-337 (-0.2%)
Jun	All	68,042	67,894	-149 (-0.2%)	830,330	829,985	-345 (0%)	145,691	145,553	-138 (-0.1%)

The migration period of adult fall-run in the Sacramento River is typically June through December. For late-fall-run, the adult migration period is October through April. Sacramento River flows during the fall-run period would be largely similar between the FEIS/R PA and Alt 1, except during July of critical water years (14% reduction) and during October of above normal, dry, and critical water years (22.6%, 15.6%, and 27.2% increases, respectively; Table 11). Due to the limited temporal occurrence and small frequency and magnitude of reduced flows, effects to adult migration are expected to be less than significant.

The juvenile fall-run outmigration period in the Sacramento River above Red Bluff is November through May. For late fall-run, this period is April through June. During both of these outmigration periods, Sacramento River flows under Alt 1 would largely similar to those under the FEIS/R PA (Table 11). As a result, effects to juvenile migration are expected to be less than significant.

3.2.4.2 Feather River

The large majority of Chinook salmon (fall-run ad spring-run combined) spawning (>95%) and rearing (>99%) occurs in the low flow channel (DWR 2012). Low flow channel flows would not change under Alt 1 compared to the FEIS/R PA. Monthly flows in the low flow channel have been optimized for salmonids. Therefore, minimal effects of Alt 1 to spawning and rearing fall-run Chinook salmon in the low flow channel are expected.

The high flow channel is used primarily as a migration corridor for fall-run juvenile and adults. Juvenile migration typically occurs from mid-November through June with a peak from January through March. Adult migration typically occurs between September and December. Although no relationships between flow and migration is known for spring-run Chinook salmon in the Feather River, it is generally thought that higher flows are better for migration. Predicted flows in the high flow channel are presented in Table 15. Flows in the high flow channel are predicted to be within 10% between Alt 1 and the FEIS/R PA in most months with one exception. During October of critical years, there would be a 16% increase in flows under Alt 1 relative to the FEIS/R PA, which could be beneficial to adult migration. Given this isolated flow change, these results indicate that both juvenile and adult fall-run Chinook salmon migration in the high flow channel of the Feather River would be minimally impacted by Alt 1.

DWR is committed to meeting year-round water temperature targets in the low-flow and high-flow channels of the Feather River for salmonids in the FERC BiOp (NMFS 2016), which would be included under both the FEIS/R PA and Alt 1. Therefore, no temperature-related effects to fall-run Chinook salmon in the Feather River are predicted under Alt 1.

3.2.4.3 American River

Flows in the American River under Alt 1 would be similar to those under the FEIS/R PA in all months and water years with some exceptions. During July of dry and critical water years and August of critical water years, flows would be 11% to 20% lower under Alt 1. During October of critical water years, flows would be 26% higher under Alt 1 (Table 16). The July and August reductions would not coincide with the presence of any fall-run life stage in the American River. The October flow increase would coincide with the adult migration and spawning periods. Due to the low frequency of these flow changes, they are expected to minimally affect fall-run Chinook salmon under Alt 1.

Reclamation is committed to meeting the modified flow management standard in the ROC on LTO NMFS BiOp (NMFS 2019:20) in future operations, which would include both the FEIS/R PA and Alt 1. The commitment is to preserve coldwater pool in drier years to improve temperature management. Based on modeled flow differences (Table 16) and an assumption that lower flows would increase water temperatures, the only time of year that temperatures under Alt 1 could be higher than the FEIS/R PA is during July and August. Because these flow reductions do not temporally overlap with fall-run Chinook salmon and due to Reclamation's commitments, minimal temperature-related effects to fall-run Chinook salmon in the American River are predicted for Alt 1.

3.2.4.4 Merced River

For this analysis, it is assumed that higher flows are better for habitat conditions for fall-run Chinook salmon. The following periods were assumed for presence of each life stage:

- Adult migration – October to January
- Spawning – October to January
- Rearing – January to June
- Juvenile migration – January through June

Flows at the Merced River mouth under Alt 1 would be similar to those under the FEIS/R PA in all months and water years with some exceptions (Table 17). During July of dry and critical water years and August of critical water years, flows would be 49.5% to 34.7% lower under Alt 1 relative to the FEIS/R PA. During October and November of critical water years, flows would be 60.8% and 35.7% higher under Alt 1. The July and August flow reductions would not coincide with any fall-run Chinook salmon life stage in the Merced River. The October and November flow increase would coincide with the adult migration and spawning periods. Due to the low frequency of these flow changes, they are expected to minimally affect fall-run Chinook salmon under Alt 1.

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the Merced River. Under this assumption, water temperature results would be similar to flow results (Table 17) in that, due to the low frequency of differences between Alt 1 and the FEIS/R PA, effects to fall-run Chinook salmon are expected to be minimal.

3.2.4.5 San Joaquin River

For this analysis, it is assumed that higher flows are better for habitat conditions for fall-run Chinook salmon. The following periods were assumed for presence of each life stage:

- Adult migration – October to January
- Spawning – October to January
- Rearing – January to June
- Juvenile migration – January through June

Flows in the San Joaquin River at Vernalis under Alt 1 would be similar to those under the FEIS/R PA in all months and water years with one exception (Table 18). During July of dry water years, flows would be 11.8% lower under Alt 1 relative to the FEIS/R PA. These reductions would not coincide with any fall-run Chinook salmon life stage in the San Joaquin River. Therefore, there would be negligible effects of Alt 1 on fall-run Chinook salmon in the San Joaquin River.

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the San Joaquin River. Under this assumption, water temperature results would be similar to flow results (Table 18) in that, due to the lack of differences between Alt 1 and the FEIS/R PA during fall-run Chinook salmon presence, effects are expected to be negligible.

3.2.4.6 Delta

Juvenile fall-run Chinook salmon are primarily found in the Delta from approximately December through June (Table 7). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 1, (Table 19). Therefore, minimal effects of Alt 1 are expected during juvenile fall-run Delta migration and residence period.

Juvenile late fall-run Chinook salmon are typically found in the Delta between December and February and between April and June (Table 8). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 1 (Table 19). Therefore, minimal effects of Alt 1 are expected during juvenile late fall-run Delta migration and residence period.

Adult fall-run Chinook salmon are typically found in the Delta from approximately June through November (Table 7). During this period, flows at Freeport would be similar between the FEIS/R PA and Alt 1, except for 18.5% and 10% reductions in July and August, respectively, of critical years and 17% and 23.2% increases in October of above normal and critical water years, respectively (Table 19). Due to the isolated occurrences of reduced flows during the adult migration period through the Delta, the effects of Alt 1 are expected to be less than significant.

Adult late fall-run Chinook salmon are typically found in the Delta from approximately October through May (Table 8). During this period, flows at Freeport would be mostly similar between the FEIS/R PA and Alt 1, except for 17% and 23.2% increases in October in above normal and critical water years, which would likely be beneficial for migration cues (Table 19). Therefore, minimal effects of Alt 1 are expected during adult winter-run Delta migration period.

South Delta export rates during the June through November fall-run juvenile rearing and migration period in the Delta for would be mostly similar between the FEIS/R PA and Alt 1, although exports would be lower during dry and critical water years during July and August and in critical years during September, and higher during October of above normal, dry, and critical water years (Table 20). Overall, due to the isolated incidence of higher exports and the incidence of reduced exports, effects to fall-run would be less than significant.

South Delta export rates during the October through May late fall-run juvenile rearing and migration period in the Delta for would be mostly similar between the FEIS/R PA and Alt 1, although exports would be higher during October of above normal, dry, and critical water years (Table 20). Overall, due to the isolated incidence of these differences, effects to fall-run would be less than significant.

3.2.5 Green Sturgeon

3.2.5.1 Sacramento River

Effects to green sturgeon as a result of Alt 1 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for green sturgeon spawning and egg incubation, rearing, and migration. Therefore, no temperature-related effects from Alt 1 to green sturgeon in the Sacramento River are predicted.

The effects of flow on green sturgeon spawning in the Sacramento River were recently studied by Wyman et al. (2018). They determined that spawning WUA for the green sturgeon was roughly uniform from about 7,500 cfs, the lowest flow level included in the study, to about 12,360 cfs. From 12,360 cfs to the highest flow included in the study, about 23,500 cfs, the WUA fell sharply. For purposes of this effects analysis, Sacramento River flows that exceed 12,360 cfs or fall below 7,500 cfs within the green sturgeon spawning reach and during the spawning period are considered to adversely affect green sturgeon spawning habitat.

The frequency of occurrence outside this 7,500 to 12,360 cfs range was calculated by month and water years type during the March through July green sturgeon spawning period. Results indicate that the occurrence of flows outside the flow range would be predominantly similar between the FEIS/R PA and Alt 1, except in July of dry and critical years, during which there would be 3 years and 1 year fewer with flows outside of the optimal range under Alt 1 (Table 33). These results indicate that the effect of Alt 1 on green sturgeon spawning habitat availability would be less than significant.

Table 33. Occurrence (as # of years from the CalSim II Record) of Flows in the Sacramento River at Battle Creek Outside the 7,500 to 12,360 cfs Optimal Range for Green Sturgeon Spawning Habitat Availability)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Total years	Alt 1 vs FEIS/R PA	At 2 vs FEIS/R PA
	W	12	12	12	13	0	0
	AN	4	4	4	6	0	0
	BN	2	2	2	2	0	0
	D	4	4	4	6	0	0
	C	6	6	6	7	0	0
Mar	All	28	28	28	34	0	0
	W	10	10	10	13	0	0
	AN	3	3	3	6	0	0
	BN	1	1	1	2	0	0
	D	6	6	6	6	0	0
	C	7	7	7	7	0	0
Apr	All	27	27	27	34	0	0
	W	7	7	7	13	0	0
	AN	2	2	2	6	0	0
	BN	0	0	0	2	0	0
	D	0	0	0	6	0	0
	C	4	4	4	7	0	0
May	All	13	13	13	34	0	0
	W	2	2	2	13	0	0
	AN	0	0	0	6	0	0
	BN	0	0	0	2	0	0
	D	4	4	4	6	0	0
	C	1	1	1	7	0	0
June	All	7	7	7	34	0	0
	W	7	7	7	13	0	0
	AN	4	4	4	6	0	0
	BN	2	2	2	2	0	0
	D	6	3	3	6	-3	-3
	C	2	1	1	7	-1	-1
July	All	21	17	17	34	-4	-4

Green sturgeon larvae and juveniles likely occur in the Sacramento River between April through September and May through December, respectively. The effects of flow on green sturgeon larvae and juveniles are poorly understood. There appears to be a positive relationship between annual outflow and abundance in rotary screw traps at RBDD of green sturgeon larvae and juveniles (Heublein et al. 2017). Increased flows may transport larvae to areas with greater food availability, disperse them over a wider area, and/or enhance nutrient availability to the Sacramento River and Delta/Estuary food web, any of which could result in increased abundance of larvae and juveniles. For the purposes of evaluating potential effects of Alt 1 on green sturgeon larvae and juveniles, flow rates were evaluated in the Sacramento River at Wilkins Slough during April through December for the FEIS/R PA and Alt 1(Table 34). These results indicate that flows under Alt 1 would generally be similar to the FEIS/R PA during April through June and November through December and wetter water year types during July through September, lower in drier water year types during July through September, and higher in most water year types during October. Overall, due to the limited incidence of flow reductions during their period of presence, the effect of Alt 1 on green sturgeon larvae and juveniles is considered less than significant. There is low certainty in this conclusion due to a general lack of understanding of how flow may affect green sturgeon larvae and juveniles.

Table 34. Absolute (Percent) Modeled Flow Differences between the FEIS/R PA and Alternative 1 and 2 (in cfs), Sacramento River at Wilkins Slough. Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	18,798	18,798	18,798	0 (0%)	0 (0%)
	AN	20,437	20,437	20,437	0 (0%)	0 (0%)
	BN	9,597	9,597	9,597	0 (0%)	0 (0%)
	D	11,128	11,128	11,128	0 (0%)	0 (0%)
	C	8,762	8,762	8,762	0 (0%)	0 (0%)
Jan	All	15,126	15,126	15,126	0 (0%)	0 (0%)
	W	19,386	19,386	19,386	0 (0%)	0 (0%)
	AN	19,833	19,833	19,833	0 (0%)	0 (0%)
	BN	13,317	13,317	13,317	0 (0%)	0 (0%)
	D	10,176	10,176	10,176	0 (0%)	0 (0%)
	C	8,597	8,597	8,597	0 (0%)	0 (0%)
Feb	All	15,261	15,261	15,261	0 (0%)	0 (0%)
	W	19,769	19,769	19,769	0 (0%)	0 (0%)
	AN	18,844	18,835	18,835	-8.8 (0%)	-8.8 (0%)
	BN	15,063	15,063	15,063	0 (0%)	0 (0%)
	D	14,046	14,040	14,040	-5.3 (0%)	-5.3 (0%)
	C	9,660	9,660	9,660	0 (0%)	0 (0%)
Mar	All	16,237	16,235	16,235	-2.5 (0%)	-2.5 (0%)
	W	12,855	12,855	12,855	0 (0%)	0 (0%)
	AN	12,745	12,745	12,745	0 (0%)	0 (0%)
	BN	8,162	8,162	8,162	0 (0%)	0 (0%)
	D	7,444	7,444	7,444	0 (0%)	0 (0%)
	C	5,794	5,794	5,794	0 (0%)	0 (0%)
Apr	All	10,151	10,151	10,151	0 (0%)	0 (0%)
	W	9,673	9,676	9,676	2.5 (0%)	2.5 (0%)
	AN	9,361	9,320	9,320	-41.1 (-0.4%)	-41.1 (-0.4%)
	BN	4,767	4,767	4,767	0 (0%)	0 (0%)
	D	4,866	4,865	4,865	-1.1 (0%)	-1.1 (0%)
	C	4,301	4,301	4,301	0.1 (0%)	0.1 (0%)
May	All	7,375	7,369	7,369	-6.5 (-0.1%)	-6.5 (-0.1%)
	W	7,351	7,354	7,354	3.9 (0.1%)	3.9 (0.1%)
	AN	6,478	6,478	6,478	0 (0%)	0 (0%)
	BN	5,918	5,918	5,918	0 (0%)	0 (0%)
	D	5,660	5,660	5,660	0 (0%)	0 (0%)
	C	4,998	4,998	4,998	0.1 (0%)	0.1 (0%)
Jun	All	6,330	6,331	6,331	1.5 (0%)	1.5 (0%)
	W	7,766	7,739	7,739	-27.2 (-0.3%)	-27.2 (-0.3%)
	AN	7,330	7,265	7,265	-65.7 (-0.9%)	-65.7 (-0.9%)
	BN	8,136	8,136	8,136	0 (0%)	0 (0%)
	D	7,749	6,594	6,594	**-1154.6 (-14.9%)**	**-1154.6 (-14.9%)**
	C	6,873	5,188	5,188	**-1685.4 (-24.5%)**	**-1685.4 (-24.5%)**
Jul	All	7,524	6,951	6,951	-572.7 (-7.6%)	-572.7 (-7.6%)
	W	6,252	6,256	6,256	4.1 (0.1%)	4.1 (0.1%)
Aug	AN	5,629	5,521	5,521	-107.9 (-1.9%)	-107.9 (-1.9%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	BN	5,123	5,123	5,123	0 (0%)	0 (0%)
	D	5,242	4,582	4,582	**-659.3 (-12.6%)**	**-659.3 (-12.6%)**
	C	5,431	4,771	4,771	**-659.6 (-12.1%)**	**-659.6 (-12.1%)**
	All	5,728	5,459	5,459	-269.6 (-4.7%)	-269.6 (-4.7%)
	W	10,452	10,454	10,454	2.6 (0%)	2.6 (0%)
	AN	8,183	8,122	8,122	-61.1 (-0.7%)	-61.1 (-0.7%)
	BN	5,815	5,815	5,815	0 (0%)	0 (0%)
	D	5,151	4,787	4,787	-364.5 (-7.1%)	-364.5 (-7.1%)
	C	4,733	4,254	4,254	**-478.9 (-10.1%)**	**-478.9 (-10.1%)**
Sep	All	7,666	7,493	7,493	-172.7 (-2.3%)	-172.7 (-2.3%)
	W	7,715	8,010	8,010	294.9 (3.8%)	294.9 (3.8%)
	AN	5,757	7,015	6,437	**1257.8 (21.8%)**	**680.6 (11.8%)**
	BN	7,451	7,654	7,654	203 (2.7%)	203 (2.7%)
	D	5,981	6,917	6,870	**936.2 (15.7%)**	**888.8 (14.9%)**
	C	6,042	7,554	7,211	**1512 (25%)**	**1169 (19.3%)**
Oct	All	6,704	7,527	7,346	**823.2 (12.3%)**	642.3 (9.6%)
	W	10,802	10,802	10,802	0 (0%)	0 (0%)
	AN	6,769	6,866	7,462	96.8 (1.4%)	**693.3 (10.2%)**
	BN	5,823	5,823	5,823	0 (0%)	0 (0%)
	D	9,861	9,990	10,039	128.3 (1.3%)	177.3 (1.8%)
	C	5,876	6,161	6,515	284.4 (4.8%)	**638.8 (10.9%)**
Nov	All	8,617	8,716	8,903	98.3 (1.1%)	285.2 (3.3%)
	W	16,630	16,630	16,630	0 (0%)	0 (0%)
	AN	12,382	12,382	12,382	0 (0%)	0 (0%)
	BN	6,035	6,035	6,035	0 (0%)	0 (0%)
	D	9,243	9,243	9,243	0 (0%)	0 (0%)
	C	6,801	6,801	6,801	0 (0%)	0 (0%)
Dec	All	11,930	11,930	11,930	0 (0%)	0 (0%)

Green sturgeon adults enter the Sacramento River from the Delta as early as February and ultimately make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence (Heublein et al. 2017). Very low flows (<3,250 cfs) potentially create difficult upstream passage conditions (NMFS 2018b). However, modeled flows at Wilkins Slough during the February through June migration period are always >3,250 cfs (Table 35). These results indicate that there would be no risk of additional passage limitations under Alt 1 and, therefore, negligible flow-related effects of Alt 1 on green sturgeon upstream passage.

Table 35. Number of Years in which Mean Monthly Flows would be below the 3,250 cfs Passage Minimum for Green Sturgeon, Sacramento River at Wilkins Slough.

Month	WYT	FEIS/R PA	Alt 1	Alt 2
	W	0	0	0
	AN	0	0	0
	BN	0	0	0
	D	0	0	0
	C	0	0	0
Feb	All	0	0	0
Mar	W	0	0	0

Month	WYT	FEIS/R PA	Alt 1	Alt 2
	AN	0	0	0
	BN	0	0	0
	D	0	0	0
	C	0	0	0
	All	0	0	0
Apr	W	0	0	0
	AN	0	0	0
	BN	0	0	0
	D	0	0	0
	C	0	0	0
	All	0	0	0
May	W	0	0	0
	AN	0	0	0
	BN	0	0	0
	D	0	0	0
	C	0	0	0
	All	0	0	0
Jun	W	0	0	0
	AN	0	0	0
	BN	0	0	0
	D	0	0	0
	C	0	0	0
	All	0	0	0

3.2.5.2 Feather River

Green sturgeon irregularly spawn in the Feather River, likely only during wet, high-flow years (Seesholtz et al. 2015, Heublein et al. 2017). Spawning was documented in 2011 at the Thermalito Afterbay outlet and in 2017 below the Fish Barrier Dam (NMFS 2018, Seesholtz et al. 2015). In both 2011 and 2017, water temperature was substantially cooler than average, likely due to the above average flow that occurred in the spring (Heublein et al. 2017). In most years, water temperatures downstream of the Thermalito Afterbay outlet are too warm for normal egg incubation by late May (Heublein et al. 2017). As in the Sacramento River, spawning likely occurs between about March and July in the Feather River. During this period, flows in the low flow channel would be identical between the FEIS/R PA and Alt 1. Flows in the high flow channel below Thermalito Afterbay under Alt 1 would be predominantly similar to those under the FEIS/R PA (Table 15).

The extent to which larval and juvenile green sturgeon reside in the Feather River is poorly understood. If individuals rear in the Feather River for the same April through December period as in the Sacramento River, flows during this period in the high flow channel below Thermalito would be largely similar between the FEIS/R PA and Alt 1, except during October of critical water years (16% increase; Table 15). For reasons discussed above, it is unlikely that green sturgeon would spawn in the Feather River during a critical water year, and this has never been observed. Therefore, flow-related effects of Alt 1 to green sturgeon larvae and juveniles would be less than significant.

Because flows in the low-flow and high-flow channel would be similar between the FEIS/R PA and Alt 1 in all months of wetter water years when sturgeon would migrate and spawn in the Feather River (Table 15), any effects of Alt 1 to juvenile and adult migration would be minimal.

DWR is committed to meeting year-round water temperature targets in the low-flow and high-flow channels of the Feather River for salmonids in the FERC BiOp (NMFS 2016), which would be included under both the FEIS/R PA and Alt 1. These temperature targets are generally protective of green sturgeon and, therefore, no temperature-related effects to green sturgeon in the Feather River are predicted under Alt 1.

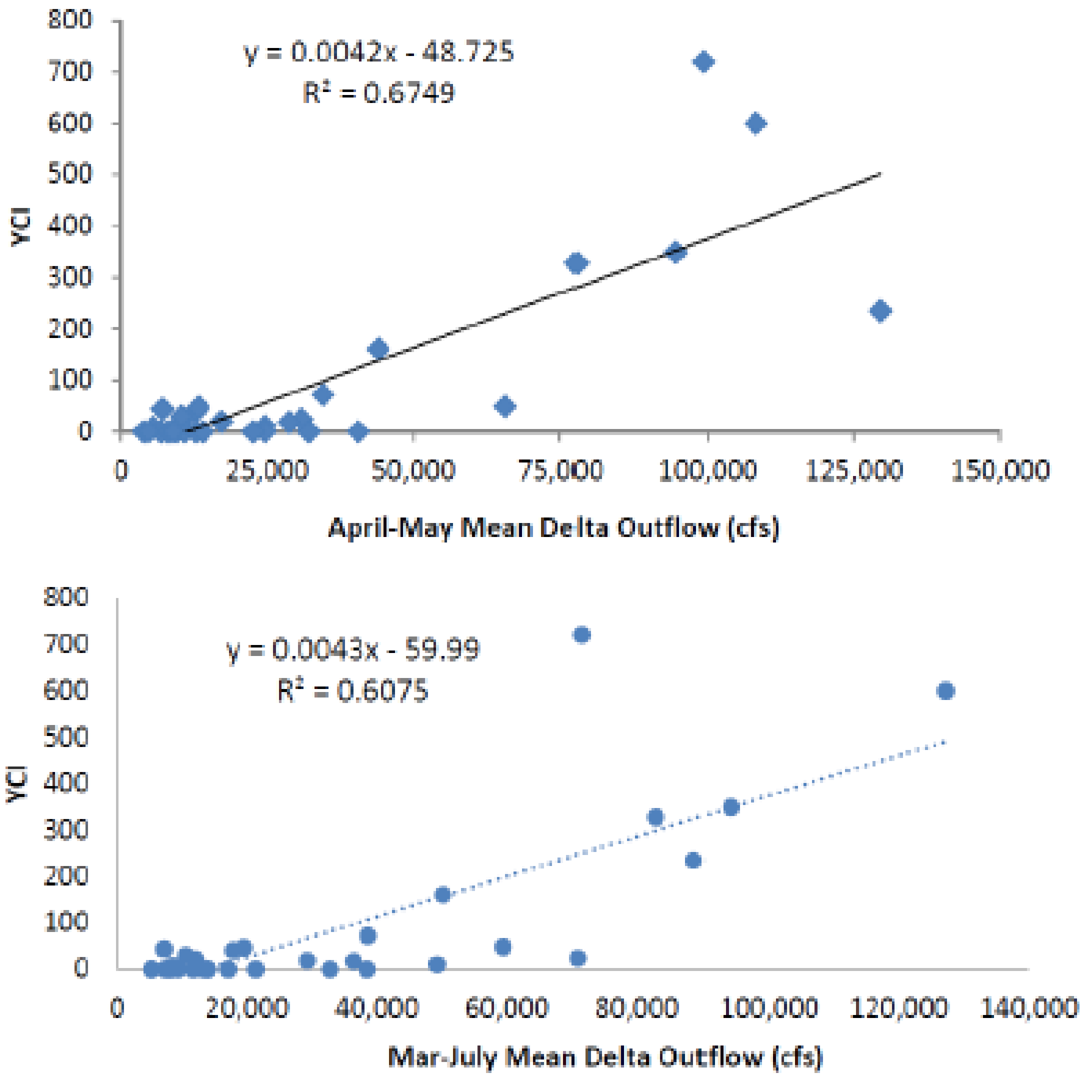
3.2.5.3 San Joaquin River

Because very little information regarding green sturgeon presence in the San Joaquin River exists, this analysis evaluates potential effects by comparing flows at Vernalis between FEIS/R PA and Alt 1 for all months. Flows at Vernalis under Alt 1 would be similar to those under the FEIS/R PA in all months and water years with one exception (Table 18). During July of dry water years, flows would be 11.8% lower under Alt 1 relative to the FEIS/R PA. Due to the low frequency of occurrence, this flow reduction under Alt 1 would cause less than significant effects. Similarly, assuming flow and water temperature are inversely related, the low frequency in flow differences between Alt 1 and the FEIS/R PA indicates that water temperature-related effects to green sturgeon in the San Joaquin River would be negligible.

3.2.5.4 Delta

Due to the year-round presence of juveniles in the Delta, green sturgeon entrainment can occur in most months of the year. However, salvage of green sturgeon has been very low since 2009. A total of 22 individuals have been salvaged at both CVP and SWP facilities between 2009 and 2018 (CDFW unpubl. data). Entrainment is regarded as a threat of low importance to the population in the NMFS green sturgeon recovery plan (NMFS 2018). Given the minor changes in total exports under Alt 1 relative to the FEIS/R PA (Table 20) and the very low total salvage numbers, Alt 1 would have a less than significant effect to green sturgeon entrainment.

The NMFS green sturgeon recovery plan suggested that larval abundance and distribution may be influenced by spring and summer outflow and recruitment may be highest in wet years, making water flow an important habitat parameter (NMFS 2018). As noted by NMFS (2018), there are statistically significant correlations between white sturgeon year class strength and Delta outflow during April through May and March through July, which have previously been used to infer potential effects on green sturgeon (Figure 9; ICF International 2016). Year-class strength in this case is an index of year class abundance based on age-0 and age-1 white sturgeon abundance indices from otter trawling by the San Francisco Bay Study. The mechanisms for these correlations are uncertain and could reflect upstream or in-Delta impacts. Appreciable amounts of variation are left unexplained by the relationships (i.e., r^2 of ~70%). Additional uncertainty comes from applying white sturgeon relationships to green sturgeon. However, because there are many similarities in the ecology of these two species, it was deemed legitimate to apply the relationship to analyzing effects on green sturgeon while acknowledging that the validity of the results is uncertain (Heublein et al. 2017). Here, we applied CalSim outputs from the FEIS/R PA, Alt 1, and Alt 2 to these relationships to determine the potential effects of Alt 1 and 2 to green sturgeon year class strength.



Source: ICF International (2016).

Figure 9. White Sturgeon Year-Class Index (YCI) for 1980–2011 as function of Mean April–May Delta Outflow (Upper Panel) and Mean March–July Delta Outflow (Lower Panel) in Cubic Feet Per Second (cfs).

Results are presented in Table 36 and Table 37. These results indicate that there would be negligible differences between the FEIS/R PA and Alt 1 in year-class strength. There is low certainty in this conclusion for reasons discussed above.

Table 36. Year-Class Strength of White Sturgeon Based on April–May Regression with Delta Outflow.

WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA[1]	Alt 2 vs. FEIS/R PA[1]
W	129.2	129.2	129.2	0 (0%)	0 (0%)
AN	66.2	66.1	66.1	-0.1 (-0.1%)	-0.1 (-0.1%)

BN	17.7	17.7	17.7	0 (0%)	0 (0%)
D	0	0	0	0 (0%)	0 (0%)
C	0	0	0	0 (0%)	0 (0%)

[1] Absolute Difference (Percent Difference)

Table 37. Year-Class Strength of White Sturgeon Based on March-July Regression with Delta Outflow.

WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA[1]	Alt 2 vs. FEIS/R PA[1]
W	129.3	129.3	129.3	0 (0%)	0 (0%)
AN	50.7	50.7	50.9	0 (0%)	0.1 (0.3%)
BN	4.9	4.9	4.9	0 (0%)	0 (0%)
D	0	0	0	0 (0%)	0 (0%)
C	0	0	0	0 (0%)	0 (0%)

[1] Absolute Difference (Percent Difference)

3.2.6 Delta Smelt

Adult delta smelt can be entrained into the south Delta export facilities during dispersal prior to spawning, with this dispersal typically occurring during December–March in response to increases in precipitation, flow, and turbidity (Grimaldo et al. 2009; Sommer et al. 2011). Alt 1 would not include any changes to the criteria such as Old and Middle River flows from the USFWS (2019) ROC on LTO BiOp and CDFW (2020) SWP ITP, which limit export pumping to minimize the risk of adult delta smelt south Delta entrainment. Modeled flows in the Sacramento River at Freeport (Table 19), Delta exports (Table 20), and Delta outflow (Table 38) generally would be very similar under the FEIS/R PA and Alt 1 which, combined with the same real-time criteria to minimize risk as currently implemented (USFWS 2019, CDFW 2020), suggests there would be little difference in entrainment risk for adult delta smelt between the FEIS/R PA and Alt 1.

Table 38. Mean Monthly Delta Outflow and Absolute (Percent) Differences in Delta Outflow between the FEIS/R PA and Alternative 1 and 2 (in cfs). Bold indicates >10% difference.

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	94,295	94,332	94,332	37.5 (0%)	37.5 (0%)
	AN	66,065	66,138	66,176	72.6 (0.1%)	110.9 (0.2%)
	BN	16,613	16,613	16,613	0 (0%)	0 (0%)
	D	16,876	16,888	16,888	11.8 (0.1%)	11.8 (0.1%)
	C	10,620	10,631	10,710	11.3 (0.1%)	90.3 (0.9%)
Jan	All	53,854	53,886	53,909	31.6 (0.1%)	54.6 (0.1%)
	W	103,027	103,027	103,027	0 (0%)	0 (0%)
	AN	77,417	77,336	77,336	-81 (-0.1%)	-81 (-0.1%)
	BN	27,853	27,853	27,853	0 (0%)	0 (0%)
	D	17,639	17,644	17,644	4.5 (0%)	4.5 (0%)
	C	13,979	13,991	14,029	12.5 (0.1%)	50.9 (0.4%)
Feb	All	60,684	60,673	60,681	-10.9 (0%)	-3 (0%)
	W	97,340	97,340	97,340	0 (0%)	0 (0%)
Mar	AN	53,313	53,309	53,309	-4.6 (0%)	-4.6 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	BN	28,272	28,272	28,272	0 (0%)	0 (0%)
	D	24,048	24,045	24,053	-2.6 (0%)	5.4 (0%)
	C	12,296	12,296	12,296	0 (0%)	0 (0%)
	All	55,065	55,063	55,065	-1.3 (0%)	0.2 (0%)
	W	49,681	49,681	49,681	0 (0%)	0 (0%)
	AN	30,191	30,189	30,189	-2.4 (0%)	-2.4 (0%)
	BN	17,607	17,607	17,607	0 (0%)	0 (0%)
	D	14,754	14,754	14,754	0 (0%)	0 (0%)
	C	9,970	9,970	9,970	0 (0%)	0 (0%)
Apr	All	30,016	30,015	30,015	-0.4 (0%)	-0.4 (0%)
	W	35,057	35,060	35,060	3.1 (0%)	3.1 (0%)
	AN	24,515	24,470	24,470	-44.7 (-0.2%)	-44.7 (-0.2%)
	BN	14,037	14,037	14,037	0 (0%)	0 (0%)
	D	8,464	8,464	8,464	0 (0%)	0 (0%)
	C	5,489	5,489	5,489	0 (0%)	0 (0%)
May	All	21,180	21,173	21,173	-6.7 (0%)	-6.7 (0%)
	W	23,903	23,908	23,908	4.7 (0%)	4.7 (0%)
	AN	12,168	12,159	12,159	-9.3 (-0.1%)	-9.3 (-0.1%)
	BN	7,886	7,886	7,886	0 (0%)	0 (0%)
	D	7,050	7,050	7,050	0 (0%)	0 (0%)
	C	4,905	4,905	4,905	0 (0%)	0 (0%)
Jun	All	14,004	14,005	14,005	0.2 (0%)	0.2 (0%)
	W	14,065	14,060	14,060	-5.6 (0%)	-5.6 (0%)
	AN	8,632	8,617	8,617	-14.3 (-0.2%)	-14.3 (-0.2%)
	BN	7,610	7,610	7,610	0 (0%)	0 (0%)
	D	5,698	5,328	5,328	-369.6 (-6.5%)	-369.6 (-6.5%)
	C	4,522	4,038	4,038	**-484.8 (-10.7%)**	**-484.8 (-10.7%)**
Jul	All	9,285	9,116	9,116	-169.7 (-1.8%)	-169.7 (-1.8%)
	W	7,366	7,360	7,360	-5.6 (-0.1%)	-5.6 (-0.1%)
	AN	6,327	6,304	6,304	-22.8 (-0.4%)	-22.8 (-0.4%)
	BN	4,002	4,002	4,002	0 (0%)	0 (0%)
	D	3,798	3,612	3,612	-185.4 (-4.9%)	-185.4 (-4.9%)
	C	3,624	3,422	3,422	-201.9 (-5.6%)	-201.9 (-5.6%)
Aug	All	5,585	5,504	5,504	-80.5 (-1.4%)	-80.5 (-1.4%)
	W	13,043	13,040	13,040	-3.6 (0%)	-3.6 (0%)
	AN	11,497	11,484	11,484	-13 (-0.1%)	-13 (-0.1%)
	BN	3,001	3,000	3,000	-1.5 (0%)	-1.5 (0%)
	D	3,130	3,061	3,061	-68.9 (-2.2%)	-68.9 (-2.2%)
	C	3,200	3,092	3,092	-107.3 (-3.4%)	-107.3 (-3.4%)
Sep	All	8,404	8,366	8,366	-38 (-0.5%)	-38 (-0.5%)
	W	7,838	7,918	7,918	80 (1%)	80 (1%)
	AN	5,083	5,399	5,227	316.2 (6.2%)	144.2 (2.8%)
	BN	7,500	7,613	7,613	112.7 (1.5%)	112.7 (1.5%)
	D	6,040	6,228	6,218	187.2 (3.1%)	177.8 (2.9%)
	C	5,353	5,775	5,631	422.1 (7.9%)	277.3 (5.2%)
Oct	All	6,503	6,716	6,654	213 (3.3%)	151.2 (2.3%)
	W	19,884	19,935	19,935	50.9 (0.3%)	50.9 (0.3%)
	AN	5,644	5,671	5,841	27.3 (0.5%)	197 (3.5%)
Nov	BN	4,733	4,733	4,733	0 (0%)	0 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	D	8,033	8,134	8,144	101.1 (1.3%)	110.9 (1.4%)
	C	4,470	4,578	4,702	107.5 (2.4%)	231.9 (5.2%)
	All	11,215	11,279	11,337	64.2 (0.6%)	121.5 (1.1%)
	W	50,339	50,345	50,345	6.3 (0%)	6.3 (0%)
	AN	16,003	16,003	16,003	0 (0%)	0 (0%)
	BN	6,003	6,003	6,003	0 (0%)	0 (0%)
	D	10,034	10,081	10,081	46.5 (0.5%)	46.5 (0.5%)
	C	5,721	5,721	5,721	0 (0%)	0 (0%)
Dec	All	25,373	25,384	25,384	10.6 (0%)	10.6 (0%)

South Delta entrainment of larval/early juvenile delta smelt generally occurs in March–June, with the risk of entrainment limited through criteria related to factors such as Old and Middle River flows (UUSFWS 2019, DFW 2020). Alt 1 does not include any changes to these criteria. As described in the Interagency Ecological Program Management, Analysis, and Synthesis Team (IEP MAST 2015: 88) conceptual model, larval/early juvenile entrainment risk is a function of exports and spring hydrology. Entrainment risk increases as Old and Middle River flows decrease and become more negative (reflecting an increasing hydrodynamic influence of the south Delta export facilities) and X2 increases (reflecting less Delta outflow and a greater portion of delta smelt occurring farther upstream in the Delta) (USFWS 2008:220). CalSim model output indicates that there would be negligible differences in X2 position between the FEIS/R PA and Alt 1 throughout the March-June period (Table 39). Old and Middle River (OMR) flows are a function of San Joaquin River flows and exports. Because neither variable changes during the March through June period, OMR flows will not change. As a result, effects of Alt 1 to larval/early juvenile delta smelt entrainment would be less than significant.

Table 39. Mean Monthly X2 Position and Absolute (Percent) Differences in X2 Position between the FEIS/R PA and Alternative 1 and 2 (in cfs).

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	W	59.2	59.2	59.2	0 (0%)	0 (0%)
	AN	63.2	63.2	63.2	0 (0%)	-0.1 (-0.1%)
	BN	75.3	75.3	75.3	0 (0%)	0 (0%)
	D	75.8	75.7	75.7	0 (-0.1%)	0 (-0.1%)
	C	79.9	79.9	79.9	0 (-0.1%)	-0.1 (-0.1%)
Jan	All	68.1	68.0	68.0	0 (0%)	0 (-0.1%)
	W	54.8	54.8	54.8	0 (0%)	0 (0%)
	AN	57.7	57.7	57.7	0 (0%)	0 (0%)
	BN	68.9	68.9	68.9	0 (0%)	0 (0%)
	D	72.6	72.5	72.5	0 (0%)	0 (0%)
	C	76.4	76.4	76.4	0 (0%)	0 (-0.1%)
Feb	All	63.7	63.7	63.7	0 (0%)	0 (0%)
	W	53.8	53.8	53.8	0 (0%)	0 (0%)
	AN	58.2	58.2	58.2	0 (0%)	0 (0%)
	BN	66.2	66.2	66.2	0 (0%)	0 (0%)
	D	69.3	69.3	69.3	0 (0%)	0 (0%)
	C	76.1	76.1	76.1	0 (0%)	0 (0%)
Mar	All	62.7	62.6	62.6	0 (0%)	0 (0%)
	W	58.8	58.8	58.8	0 (0%)	0 (0%)
Apr	AN	62.6	62.6	62.6	0 (0%)	0 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	BN	69.1	69.1	69.1	0 (0%)	0 (0%)
	D	71.6	71.6	71.6	0 (0%)	0 (0%)
	C	76.7	76.7	76.7	0 (0%)	0 (0%)
	All	66.0	66.0	66.0	0 (0%)	0 (0%)
	W	63.1	63.1	63.1	0 (0%)	0 (0%)
	AN	65.8	65.8	65.8	0 (0%)	0 (0%)
	BN	72.1	72.1	72.1	0 (0%)	0 (0%)
	D	76.6	76.6	76.6	0 (0%)	0 (0%)
	C	81.5	81.5	81.5	0 (0%)	0 (0%)
May	All	70.3	70.3	70.3	0 (0%)	0 (0%)
	W	68.0	68.0	68.0	0 (0%)	0 (0%)
	AN	72.3	72.4	72.4	0 (0%)	0 (0%)
	BN	77.1	77.1	77.1	0 (0%)	0 (0%)
	D	79.5	79.5	79.5	0 (0%)	0 (0%)
	C	84.1	84.1	84.1	0 (0%)	0 (0%)
Jun	All	74.6	74.6	74.6	0 (0%)	0 (0%)
	W	72.6	72.6	72.6	0 (0%)	0 (0%)
	AN	76.5	76.5	76.5	0 (0%)	0 (0%)
	BN	79.0	79.0	79.0	0 (0%)	0 (0%)
	D	82.0	82.5	82.5	0.5 (0.6%)	0.5 (0.6%)
	C	85.2	86.1	86.1	0.9 (1%)	0.9 (1%)
Jul	All	77.9	78.2	78.2	0.3 (0.4%)	0.3 (0.4%)
	W	78.1	78.1	78.1	0 (0%)	0 (0%)
	AN	80.2	80.2	80.2	0 (0%)	0 (0%)
	BN	84.5	84.5	84.5	0 (0%)	0 (0%)
	D	85.9	86.4	86.4	0.5 (0.6%)	0.5 (0.6%)
	C	87.3	88.1	88.1	0.7 (0.8%)	0.7 (0.8%)
Aug	All	82.1	82.4	82.4	0.3 (0.3%)	0.3 (0.3%)
	W	75.3	75.3	75.3	0 (0%)	0 (0%)
	AN	76.8	76.8	76.8	0 (0%)	0 (0%)
	BN	88.5	88.5	88.5	0 (0%)	0 (0%)
	D	88.7	89.0	89.0	0.4 (0.4%)	0.4 (0.4%)
	C	89.0	89.5	89.5	0.5 (0.6%)	0.5 (0.6%)
Sep	All	81.5	81.7	81.7	0.2 (0.2%)	0.2 (0.2%)
	W	79.6	79.5	79.5	-0.1 (-0.1%)	-0.1 (-0.1%)
	AN	85.4	84.9	85.2	-0.4 (-0.5%)	-0.2 (-0.2%)
	BN	79.0	78.9	78.9	-0.1 (-0.1%)	-0.1 (-0.1%)
	D	82.4	82.1	82.1	-0.3 (-0.4%)	-0.3 (-0.3%)
	C	84.7	84.1	84.4	-0.6 (-0.7%)	-0.4 (-0.4%)
Oct	All	82.1	81.8	81.9	-0.3 (-0.4%)	-0.2 (-0.2%)
	W	76.5	76.4	76.4	0 (-0.1%)	0 (-0.1%)
	AN	84.7	84.5	84.3	-0.2 (-0.2%)	-0.4 (-0.5%)
	BN	83.3	83.2	83.2	0 (0%)	0 (0%)
	D	82.0	81.7	81.7	-0.2 (-0.3%)	-0.3 (-0.3%)
	C	85.6	85.3	85.1	-0.4 (-0.5%)	-0.6 (-0.6%)
Nov	All	81.2	81.0	80.9	-0.2 (-0.2%)	-0.3 (-0.3%)
	W	67.9	67.9	67.9	0 (0%)	0 (0%)
	AN	78.0	77.9	77.8	-0.1 (-0.1%)	-0.1 (-0.2%)
Dec	BN	83.1	83.0	83.0	0 (0%)	0 (0%)

Month	WYT	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
	D	80.5	80.4	80.4	-0.1 (-0.1%)	-0.1 (-0.1%)
	C	84.6	84.5	84.4	-0.1 (-0.1%)	-0.2 (-0.2%)
	All	76.2	76.2	76.1	-0.1 (-0.1%)	-0.1 (-0.1%)

Spring (March–May) X2 is positively correlated with the density of the delta smelt zooplankton prey *Eurytemora affinis* (Kimmerer 2002a; Greenwood 2018), suggesting a potential positive effect of Delta outflow on this prey species, and thereby affecting individual delta smelt growth and survival per the IEP MAST (2015:88) conceptual model. X2 position during March through May would be nearly identical between the FEIS/R PA and Alt 1 (Table 39). Therefore, there would be negligible effects of Alt 1 on delta smelt prey availability.

The IEP MAST conceptual model (2015) suggests that the probability of egg/larval Delta Smelt surviving to the juvenile life stage is influenced by predation risk, which may involve different factors such as turbidity, water temperature, and predators (Mississippi silversides). Operations have limited potential to affect water temperature in the Delta (Wagner et al. 2011), and turbidity during spring would be expected to be similar under the FEIS/R PA and Alt 1. The main potential factor being influenced by Alt 1 would be predators (silversides), for which Mahardja et al. (2017) showed that summer (June–September) Delta inflow and spring (March–May) South Delta exports had the strongest correlations with silverside cohort strength (both relationships were negative). Mahardja et al. (2016) cautioned that the relationships are not meant to imply causality, given that the mechanisms could not be identified, and that further investigation is merited. Nonetheless, should the relationships be found to be causative, examination of CALSIM-modeled inflow and south Delta exports for the FEIS/R PA and Alt 1 would allow inference of potential effects on delta smelt predation. Delta inflow is calculated as the sum of Sacramento River at Freeport, Yolo Bypass flows, Mokelumne River, and San Joaquin River at Vernalis. Mean June-September Delta inflow under Alt 1 would generally be similar to those under the FEIS/R PA (Table 40). Mean March-May combined South Delta exports would be identical between the FEIS/R PA and Alt 1(Table 41). These results indicate that delta smelt silverside abundance would remain similar under the FEIS/R PA and Alt 1.

Table 40. Mean June–September Delta Inflow (cfs) and Differences (Absolute [Percent]) by Water Year Type.

Water Year Type	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
Wet	42095	42088	42088	-7 (0%)	-7 (0%)
Above Normal	31904	31868	31875	-36 (-0.1%)	-28 (-0.1%)
Below Normal	19159	19156	19156	-3 (0%)	-3 (0%)
Dry	16593	15985	15985	-608 (-3.7%)	-608 (-3.7%)
Critically Dry	12392	11574	11589	-819 (-6.6%)	-803 (-6.5%)

Table 41. Mean March–May Combined South Delta Exports (cfs) by Alternative and Differences (Absolute [Percent]) by Water Year Type.

Water Year Type	FEIS/R PA	Alt 1	Alt 2	Alt 1 vs. FEIS/R PA	Alt 2 vs. FEIS/R PA
Wet	6738	6738	6738	0 (0%)	0 (0%)
Above Normal	5319	5319	5319	0 (0%)	0 (0%)
Below Normal	4381	4381	4381	0 (0%)	0 (0%)
Dry	3513	3513	3513	0 (0%)	0 (0%)
Critically Dry	2772	2772	2772	0 (0%)	0 (0%)

The IEP MAST (2015) delta smelt conceptual model posits that size and location of the low salinity zone is a habitat attribute that could affect subadult delta smelt survival. Note that there is debate regarding the importance of low salinity zone habitat to delta smelt (e.g., Manly et al. 2015; Feyrer et al. 2015; Murphy and Weiland 2019). Regardless, X2 position, a measure of the low salinity zone, under the FEIS/R PA and Alt 1 would be nearly identical in all months (Table 39). Therefore, effects of Alt 1 on the low salinity zone size and position would be less than significant.

3.2.7 Longfin Smelt

Key hydrodynamic variables influencing longfin smelt entrainment risk at the south Delta export facilities include OMR flow (Grimaldo et al. 2009) and flow in the lower San Joaquin River near Jersey Point (QWEST) (CDFG 2009). During the main winter-spring months of potential adult, larval, and juvenile longfin smelt entrainment risk (i.e., December through May), CalSim modeling indicates little difference in combined South Delta exports between the FEIS/R PA and Alt 1 (Table 20). Because neither San Joaquin River flows nor Southern Delta exports would change during this period, Old and Middle River flows would not change. CDFG (2009) showed that longfin smelt salvage divided by prior fall midwater trawl index is positively correlated with higher mean December–March X2. CalSim modeling indicates that there would be negligible differences in mean December–March X2 between the FEIS/R PA and Alt 1 (Table 39). Combined, these results indicate that the effect of Alt 1 on longfin smelt entrainment risk at the South Delta export facilities would be less than significant.

Two approaches to evaluate flow-based effects to longfin smelt abundance were considered. In both cases, the full analysis was not needed due to negligible differences between the FEIS/R PA and Alt 1 in the CalSim modeled outputs that would be used as inputs to the analyses. Both approaches indicate that the effect of Alt 1 would be less than significant.

First, Nobriga and Rosenfield (2016) examined various formulations of a Ricker (1954) stock-recruitment model to simulate fall midwater trawl longfin smelt indices through time. They found that December–May Delta outflow had a positive association with recruits per spawner and that juvenile recruitment from age 0 to age 2 was density dependent (lower survival with greater numbers of juveniles) but cautioned that the density dependence in the model may be too strong. Delta outflow under Alt 1 would be nearly identical to that under the FEIS/R PA (Table 38). Because Delta outflow is the only model parameter that would be affected by Alt 1, these results indicate that there would be minimal effects of Alt 1 on longfin smelt abundance if calculated using the Nobriga and Rosenfield (2016) approach.

A second approach to evaluate potential flow-based effects of Alt 1 on longfin smelt abundance is based on Kimmerer et al. (2009) and Mount et al. (2013) and updated in DWR (2020). The analysis uses a regression that estimates longfin smelt fall midwater trawl index as a function of mean January through June X2 position and accounts for step changes in 1987/1988 due to *Potamocorbula* and 2002/2003 due to the Pelagic Organism Decline. January through June X2 under Alt 1 would be nearly identical to that under the FEIS/R PA (Table 39). Because X2 position is the only model parameter that would be affected by Alt 1, these results indicate that there would be minimal effects of Alt 1 on longfin smelt abundance if calculated using this regression approach.

3.3 Impacts from Alternative 2: Maximum November

3.3.1 Central Valley Steelhead

3.3.1.1 Sacramento River

As with Alt 1, effects to steelhead as a result of Alt 2 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for steelhead spawning, rearing, and migration. Additionally, Reclamation has previously backed up and held transfer water over the summer months during critically dry water years—such as 2014, 2015, and 2021—to maintain the cold water pool in Shasta and Folsom Reservoirs. Under such conditions, Alt 2 would help maintain the cold water pool and would be beneficial to all special-status species evaluated in this Addendum. Therefore, no temperature-related effects from Alt 2 to steelhead in the Sacramento River are predicted.

Flow changes under Alt 2 relative to the FEIS/R PA in the Sacramento River at Keswick would occur primarily during summer and fall of dry and critical years (Table 11). Flows would decrease in critical water years by 14% during July and increase by up to 21% during October and November. Compared to Alt 1, Alt 2 flows below Keswick during October would not increase as much relative to the FEIS/R PA but would increase in November compared to the FEIS/R PA. Flow decreases during July under Alt 2 compared to the FEIS/R PA would be similar to those under Alt 1.

Changes in flows under Alt 2 relative to the FEIS/R PA during fall months could affect the availability of suitable spawning habitat for steelhead in the Sacramento River mainstem channel, measured as weighted usable area (WUA). Results of the analysis predicting how spawning WUA changes under the FEIS/R PA and Alt 2 are presented in Table 42. As with Alt 1, these results indicate that there would be minimal effects of Alt 2 on steelhead spawning habitat availability.

Table 42. Spawning WUA Results for Steelhead in the Sacramento River for the FEIS/R PA and Alt 2 (in Weighted Usable Area Units).

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Nov	W	53,052	53,052	0 (0%)	149,892	149,892	0 (0%)	56,164	56,164	0 (0%)
	AN	44,324	44,324	0 (0%)	120,662	120,662	0 (0%)	45,056	45,056	0 (0%)
	BN	59,132	59,132	0 (0%)	162,562	162,562	0 (0%)	61,495	61,495	0 (0%)
	D	54,074	52,832	-1242 (-2%)	153,307	150,031	-3275 (-2.1%)	58,657	54,415	-4243 (-7.2%)
	C	62,961	60,059	-2902 (-5%)	159,915	161,370	1455 (0.9%)	62,544	64,767	2224 (3.6%)
	All	54,346	53,530	-817 (-2%)	149,005	148,727	-279 (-0.2%)	56,597	56,306	-291 (-0.5%)
Dec	W	44,925	44,925	0 (0%)	117,612	117,612	0 (0%)	46,566	46,566	0 (0%)
	AN	52,243	52,243	0 (0%)	133,411	133,411	0 (0%)	53,121	53,121	0 (0%)
	BN	60,573	60,573	0 (0%)	160,934	160,934	0 (0%)	56,518	56,518	0 (0%)
	D	49,569	49,569	0 (0%)	124,314	124,314	0 (0%)	47,275	47,275	0 (0%)
	C	64,710	64,710	0 (0%)	156,512	156,512	0 (0%)	62,377	62,377	0 (0%)
	All	51,815	51,815	0 (0%)	131,675	131,675	0 (0%)	51,496	51,496	0 (0%)
Jan	W	34,405	34,405	0 (0%)	85,882	85,882	0 (0%)	31,423	31,423	0 (0%)
	AN	35,875	35,875	0 (0%)	104,596	104,596	0 (0%)	32,712	32,712	0 (0%)
	BN	64,528	64,528	0 (0%)	157,864	157,864	0 (0%)	65,907	65,907	0 (0%)
	D	64,760	64,760	0 (0%)	154,759	154,759	0 (0%)	61,535	61,535	0 (0%)
	C	64,708	64,708	0 (0%)	157,336	157,336	0 (0%)	62,153	62,153	0 (0%)
	All	48,032	48,032	0 (0%)	120,284	120,284	0 (0%)	45,319	45,319	0 (0%)
Feb	W	35,556	35,556	0 (0%)	86,614	86,614	0 (0%)	33,207	33,207	0 (0%)
	AN	37,011	37,011	0 (0%)	86,491	86,491	0 (0%)	32,285	32,285	0 (0%)
	BN	63,224	63,224	0 (0%)	159,343	159,343	0 (0%)	58,449	58,449	0 (0%)
	D	66,280	66,280	0 (0%)	156,849	156,849	0 (0%)	64,950	64,950	0 (0%)
	C	65,115	65,115	0 (0%)	157,423	157,423	0 (0%)	63,664	63,664	0 (0%)
	All	48,948	48,948	0 (0%)	117,843	117,843	0 (0%)	46,402	46,402	0 (0%)

Salmonid redd dewatering can occur when water levels decrease after redd construction, exposing buried and otherwise submerged eggs or alevins to air. In the Sacramento River at Clear Creek, steelhead redd dewatering risk under the FEIS/R PA and Alt 2 are expected to be similar during all months of spawning (Table 43). In addition, as described in the 2019 NMFS BiOp (NMFS 2019), Reclamation attempts to minimize the risk redd dewatering from storage releases and this would continue under both the FEIS/R PA and Alt 2. There is low certainty in these results because the CalSim outputs used to conduct this analysis are at a monthly time step, yet flows can fluctuate and affect redd water levels at a shorter timestep. However, if as expected, this limitation affects the FEIS/R PA and Alt 2 results similarly, the monthly time-step results should provide a relative index of dewatering probability. As a result of these considerations, effects of Alt 2 relative to the FEIS/R PA on steelhead redd dewatering risk is expected to be less than significant., although slightly higher than Alt 1.

Table 43. Redd Dewatering Risk Results for Steelhead in the Sacramento River at Clear Creek for the FEIS/R PA and Alt 2 (in Percent of Redds Dewatered).

Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
	W	18.2	18.2	0.0
	AN	6.2	10.4	4.3
	BN	14.6	14.6	0.0
	D	29.5	30.4	0.9
	C	15.6	19.2	3.6
Nov	All	17.3	19.0	1.6
	W	33.7	33.7	0.0
	AN	10.3	10.3	0.0
	BN	1.5	1.5	0.0
	D	5.1	5.1	0.0
	C	3.9	3.9	0.0
Dec	All	16.5	16.5	0.0
	W	45.1	45.1	0.0
	AN	41.6	41.6	0.0
	BN	0.7	0.7	0.0
	D	6.4	6.4	0.0
	C	4.2	4.2	0.0
Jan	All	26.6	26.6	0.0
	W	47.0	47.0	0.0
	AN	45.8	45.8	0.0
	BN	1.1	1.1	0.0
	D	1.8	1.8	0.0
	C	1.7	1.7	0.0
Feb	All	26.8	26.8	0.0

Differences in flows under Alt 2 relative to the FEIS/R PA could affect the availability of juvenile steelhead rearing habitat, measured as weighted usable area (WUA). In the first several months after emergence from the gravel (typically January through May) when individuals are most vulnerable, there would be negligible changes in rearing WUA except during February of below normal water years in Segment 4 of the river (Table 44). For the small number of juveniles that remain in the river past May, rearing WUA would increase under Alt 2 relative to the FEIS/R PA in some segments and water years during July and August and would decrease in some segments and water years during October. Overall, similar to Alt 1, given the isolated temporal and spatial incidence, and generally low magnitude of change, and small number of individuals these changes would affect, these differences under Alt 2 are considered less than significant.

Table 44. Juvenile Rearing WUA Results for Steelhead in the Sacramento River for the FEIS/R PA and Alt 2 (in Weighted Usable Area Units). Bold indicates >10% difference.

		Segment 6			Segment 5			Segment 4		
Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	NAA	Alt 2	Alt 2 vs. FEIS/R PA
	W	29,013	29,013	0 (0%)	349,507	349,507	0 (0%)	58,233	58,233	0 (0%)
	AN	25,460	25,460	0 (0%)	347,480	347,480	0 (0%)	44,267	44,267	0 (0%)
Jan	BN	31,234	31,234	0 (0%)	459,473	459,473	0 (0%)	127,854	127,854	0 (0%)

Month	WYT	Segment 6 FEIS/R PA	Segment 6 Alt 2	Segment 6 Alt 2 vs. FEIS/R PA	Segment 5 FEIS/R PA	Segment 5 Alt 2	Segment 5 Alt 2 vs. FEIS/R PA	Segment 4 NAA	Segment 4 Alt 2	Segment 4 Alt 2 vs. FEIS/R PA
	D	31,626	31,626	0 (0%)	447,530	447,530	0 (0%)	116,507	116,507	0 (0%)
	C	31,557	31,557	0 (0%)	448,832	448,832	0 (0%)	124,247	124,247	0 (0%)
	All	29,501	29,501	0 (0%)	393,365	393,365	0 (0%)	83,739	83,739	0 (0%)
Feb	W	29,197	29,197	0 (0%)	355,392	355,392	0 (0%)	59,081	59,081	0 (0%)
Feb	AN	29,746	29,746	0 (0%)	362,813	362,813	0 (0%)	57,252	57,252	0 (0%)
Feb	BN	30,747	30,747	0 (0%)	441,079	441,079	0 (0%)	85,367	85,367	0 (0%)
Feb	D	32,041	32,041	0 (0%)	465,019	465,019	0 (0%)	118,232	118,232	0 (0%)
Feb	C	31,505	31,505	0 (0%)	460,271	460,271	0 (0%)	128,537	128,537	0 (0%)
Feb	All	30,362	30,362	0 (0%)	402,681	402,681	0 (0%)	85,043	85,043	0 (0%)
Mar	W	26,710	26,710	0 (0%)	319,342	319,342	0 (0%)	50,848	50,848	0 (0%)
Mar	AN	25,939	25,943	4 (0%)	366,931	366,977	46 (0%)	60,057	60,101	44 (0.1%)
Mar	BN	25,565	25,565	0 (0%)	371,035	371,035	0 (0%)	80,154	80,154	0 (0%)
Mar	D	31,618	31,620	2 (0%)	447,156	447,317	161 (0%)	95,935	95,954	18 (0%)
Mar	C	31,543	31,543	0 (0%)	449,724	449,724	0 (0%)	122,217	122,217	0 (0%)
Mar	All	28,368	28,369	1 (0%)	380,180	380,216	37 (0%)	76,847	76,858	11 (0%)
Apr	W	39,400	39,400	0 (0%)	421,025	421,025	0 (0%)	95,731	95,731	0 (0%)
Apr	AN	42,301	42,301	0 (0%)	411,906	411,906	0 (0%)	85,670	85,670	0 (0%)
Apr	BN	42,483	42,483	0 (0%)	432,702	432,702	0 (0%)	111,173	111,173	0 (0%)
Apr	D	41,951	41,951	0 (0%)	448,848	448,848	0 (0%)	125,087	125,087	0 (0%)
Apr	C	41,582	41,582	0 (0%)	455,752	455,752	0 (0%)	135,223	135,223	0 (0%)
Apr	All	40,993	40,993	0 (0%)	432,162	432,162	0 (0%)	108,175	108,175	0 (0%)
May	W	37,421	37,421	0 (0%)	337,197	337,197	0 (0%)	63,422	63,422	0 (0%)
May	AN	39,073	39,073	0 (0%)	341,494	341,494	0 (0%)	62,042	62,042	0 (0%)
May	BN	42,739	42,715	-24 (0%)	382,456	382,630	174 (0%)	80,577	80,699	123 (0.2%)
May	D	40,602	40,579	-22 (0%)	337,698	337,430	-269 (0%)	62,842	62,710	-132 (-0.2%)
May	C	42,162	42,098	-64 (0%)	380,168	379,511	-657 (0%)	91,554	91,270	-284 (-0.3%)
May	All	39,563	39,544	-19 (0%)	349,553	349,381	-172 (0%)	69,877	69,803	-74 (-0.1%)
Jun	W	39,489	39,489	0 (0%)	336,909	336,909	0 (0%)	62,547	62,547	0 (0%)
Jun	AN	37,880	37,833	-47 (-0.1%)	322,580	321,198	-1381 (-0.4%)	57,732	56,833	-899 (-1.6%)
Jun	BN	32,429	32,469	40 (0%)	291,040	291,223	183 (0%)	51,159	51,201	42 (0.1%)
Jun	D	33,415	33,395	-20 (0%)	300,912	300,851	-61 (0%)	54,350	54,347	-4 (0%)
Jun	C	38,649	38,502	-147 (0%)	329,619	328,886	-732 (0%)	65,936	65,721	-215 (-0.3%)
Jun	All	37,545	37,505	-40 (0%)	323,829	323,434	-395 (0%)	60,279	60,078	-201 (-0.3%)
Jul	W	32,127	32,206	79 (0.2%)	287,853	288,234	381 (0.1%)	49,305	49,414	108 (0.2%)

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	NAA	Alt 2	Alt 2 vs. FEIS/R PA
	AN	31,913	31,913	0 (0%)	284,345	284,345	0 (0%)	47,880	47,880	0 (0%)
	BN	30,403	30,415	13 (0%)	278,461	278,384	-77 (0%)	45,947	45,925	-22 (0%)
	D	30,312	31,910	1598 (5%)	279,572	288,736	9164 (3%)	46,804	50,679	3875 (8.3%)
	C	33,387	37,261	**3874 (12%)**	299,429	322,103	22674 (8%)	55,325	64,861	**9536 (17.2%)**
	All	31,927	33,038	1111 (3%)	287,603	294,030	6427 (2%)	49,654	52,341	2687 (5.4%)
	W	35,360	35,360	0 (0%)	309,896	309,896	0 (0%)	58,212	58,212	0 (0%)
	AN	37,855	37,979	124 (0%)	321,524	322,284	760 (0%)	62,208	62,432	224 (0.4%)
	BN	39,316	39,354	38 (0%)	332,862	333,060	198 (0%)	69,752	69,821	69 (0.1%)
	D	40,022	40,685	663 (2%)	337,633	351,389	13756 (4%)	71,813	81,240	**9428 (13.1%)**
	C	40,725	41,689	964 (2%)	354,024	366,269	12245 (3%)	84,362	92,598	8236 (9.8%)
Aug	All	37,961	38,300	340 (1%)	327,279	332,373	5094 (2%)	67,380	70,783	3403 (5.1%)
	W	36,569	36,569	0 (0%)	322,670	322,670	0 (0%)	64,463	64,463	0 (0%)
	AN	41,250	41,306	56 (0.1%)	359,227	359,613	386 (0.1%)	84,722	84,888	167 (0.2%)
	BN	42,960	42,919	-41 (0%)	401,585	401,808	223 (0%)	121,167	121,297	131 (0.1%)
	D	41,161	40,703	-458 (-1%)	434,771	445,291	10519 (2%)	136,325	139,869	3544 (2.6%)
	C	40,872	40,709	-163 (0%)	441,432	450,750	9318 (2%)	139,165	143,009	3844 (2.8%)
Sep	All	39,467	39,360	-107 (0%)	377,997	381,853	3856 (1%)	99,435	100,889	1454 (1.5%)
	W	41,252	41,511	259 (0.6%)	377,233	369,250	-7983 (-2.1%)	92,531	88,112	-4419 (-4.8%)
	AN	41,551	41,692	141 (0.3%)	412,671	397,680	-14990 (-3.6%)	119,281	105,893	**-13388 (-11.2%)**
	BN	42,457	41,924	-533 (-1%)	366,718	362,513	-4204 (-1%)	86,972	85,156	-1816 (-2.1%)
	D	41,956	40,764	-1193 (-3%)	400,778	382,724	-18054 (-5%)	111,304	99,195	**-12109 (-10.9%)**
	C	40,676	40,769	93 (0%)	415,769	387,848	-27921 (-7%)	117,814	100,850	**-16964 (-14.4%)**
Oct	All	41,381	41,282	-99 (0%)	394,957	380,078	-14880 (-4%)	105,443	95,654	-9789 (-9.3%)
	W	28,061	28,061	0 (0%)	370,766	370,766	0 (0%)	83,393	83,393	0 (0%)
	AN	30,142	28,914	-1229 (-4%)	419,263	401,794	-17469 (-4%)	109,963	100,583	-9380 (-8.5%)
Nov	BN	29,607	29,607	0 (0%)	407,884	407,884	0 (0%)	112,207	112,207	0 (0%)

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	NAA	Alt 2	Alt 2 vs. FEIS/R PA
	D	27,659	27,137	-522 (-2%)	356,462	352,179	-4284 (-1%)	73,285	71,078	-2207 (-3%)
	C	29,623	29,042	-581 (-2%)	396,174	382,241	-13933 (-4%)	105,517	95,174	-10343 (-9.8%)
	All	28,770	28,341	-429 (-1%)	384,215	377,507	-6707 (-2%)	92,548	88,374	-4174 (-4.5%)
Dec	W	28,078	28,078	0 (0%)	356,472	356,472	0 (0%)	76,123	76,123	0 (0%)
	AN	29,226	29,226	0 (0%)	415,988	415,988	0 (0%)	96,136	96,136	0 (0%)
	BN	31,525	31,525	0 (0%)	460,928	460,928	0 (0%)	140,332	140,332	0 (0%)
	D	30,922	30,922	0 (0%)	446,876	446,876	0 (0%)	115,309	115,309	0 (0%)
	C	30,803	30,803	0 (0%)	445,706	445,706	0 (0%)	128,293	128,293	0 (0%)
	All	29,546	29,546	0 (0%)	407,445	407,445	0 (0%)	101,088	101,088	0 (0%)

The primary migration period of adult steelhead past RBDD is typically September and October (Table 1). During September, adult attraction flows from Keswick are predicted to be somewhat lower under Alt 2 than the FEIS/R PA, although <10%, or within model noise (Table 11). During October, flows are expected to be higher under Alt 2. Due to the limited temporal occurrence and small frequency and magnitude of reduced flows under Alt 2, effects to juvenile migration are expected to be less than significant. This result is similar to Alt 1.

The primary juvenile outmigration period in the Sacramento River is February through May (Table 1). This coincides with a period of no flow changes in the Sacramento River (Table 11). Therefore, similar to Alt 1, Alt 2 would have negligible effects on juvenile outmigration in the Sacramento River.

3.3.1.2 Feather River

As with Alt 1, flows in the low flow channel, where the large majority of steelhead spawning and rearing occurs, would not change under Alt 2 compared to the FEIS/R PA. Therefore, minimal effects of Alt 2 to spawning and rearing steelhead in the low flow channel are expected.

The high flow channel is used primarily as a migration corridor for juvenile and adults. Adult migration typically occurs from July through March. The majority of juveniles typically emigrate from February through September, with a peak during March and April. Although no relationship between flow and migration is known for steelhead in the Feather River, it is generally thought that higher flows are better for migration. Predicted flows in the Feather River high flow channel are presented in Table 15. Flows in the high flow channel are predicted to be within 10% between Alt 2 and the FEIS/R PA in most months with one exception. During November of critical years, there would be a 22% increase in flows under Alt 2 relative to the FEIS/R PA, which could be beneficial to adult migration. Given this isolated flow change, and similar to Alt 1, these results indicate that both juvenile and adult migration in the high flow channel of the Feather River would be minimally impacted by Alt 2.

DWR is committed to meeting year-round water temperature targets in the low-flow and high-flow channels of the Feather River for salmonids in the FERC BiOp (NMFS 2016), which would be included under both the FEIS/R PA and Alt 2. Therefore, similar to Alt 1, no temperature-related effects to steelhead in the Feather River are predicted for Alt 2 relative to the FEIS/R PA.

3.3.1.3 American River

Flows in the American River under Alt 2 would be similar to those under the FEIS/R PA in all months and water years with some exceptions (Table 16). During July of dry and critical water years and August of critical water years, flows would be 11% to 20% lower under Alt 2. During October of critical water years, flows would be 14.8% higher under Alt 2. The July and August reductions would coincide with steelhead juvenile rearing period, but not spawning, juvenile emigration, or adult immigration. The October flow increase would coincide with the adult migration and juvenile rearing periods, but not spawning or juvenile emigration. Due to the low frequency of these flow changes, they are expected to minimally affect steelhead under Alt 2.

Reclamation is committed to meeting the modified flow management standard in the ROC on LTO NMFS BiOp (NMFS 2019:20) in future operations, which would include both the FEIS/R PA and Alt 2. The commitment is to preserve coldwater pool in drier years to improve temperature management. As previously noted, Reclamation has historically backed up and held transfer water over the summer months during critically dry water years to maintain the cold water pool in Shasta and Folsom Reservoirs. Based on modeled flow differences (Table 16) and an assumption that lower flows would increase water temperatures, the only time of year that temperatures under Alt 2 could be higher than the FEIS/R PA is during July and August. Due to Reclamation's commitments, and the expectation that transfer water would be backed up to maintain cold water pool in Folsom Reservoir during critically dry water years, minimal temperature-related effects to steelhead in the American River are predicted for Alt 2.

3.3.1.4 Merced River

Flows at the Merced River mouth under Alt 2 would be similar to those under the FEIS/R PA in all months and water years with some exceptions (Table 17). During July of dry and critical water years and August of critical water years, flows would be 49.5% to 34.7% lower under Alt 2 relative to the FEIS/R PA. During October of above normal water years and November of above normal and dry years, flows would be 30.4%, 58.5%, and 35.7% higher, respectively, under Alt 2. The July and August reductions would coincide with steelhead juvenile rearing period, but not spawning, juvenile emigration, or adult immigration. The October and November flow increases would coincide with the adult migration and juvenile rearing periods, but not spawning or juvenile emigration. Due to the low frequency of these flow changes, they are expected to minimally affect steelhead under Alt 2, similar to Alt 1.

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the Merced River. Under this assumption, water temperature results would be similar to flow results (Table 17) in that, due to the low frequency of differences between Alt 2 and the FEIS/R PA, effects to steelhead are expected to be minimal.

3.3.1.5 San Joaquin River

Flows in the San Joaquin River at Vernalis under Alt 2 would be similar to those under the FEIS/R PA in all months and water years with one exception (Table 18). During July of dry water years, flows would be 11.8% lower under Alt 2 relative to the FEIS/R PA. These reductions would coincide with steelhead juvenile rearing period, but not spawning, juvenile emigration, or adult immigration. However, due to the low frequency of these flow changes, they are expected to minimally affect steelhead under Alt 2, similar to Alt 1.

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the San Joaquin River. Under this assumption, water temperature results would be similar to flow results (Table 18) in that, due to the low frequency of differences between Alt 2 and the FEIS/R PA, effects to steelhead are expected to be minimal.

3.3.1.6 Delta

Flows in the Sacramento River at Freeport characterize migration flows for Sacramento River basin steelhead in the Delta. Table 19 presents flows at Freeport for each month and water year type. These results show a decrease in flow under Alt 2 relative to the FEIS/R PA at Freeport during July and August of critical water years and an increase during October and November of critical water years. Adult immigration in the Delta likely peaks in August through October based on a similar peak at the Fremont Weir, approximately 35 river miles upstream (Table 1). Therefore, there would be one month in one water year type in which flows would be lower and one month within two water year types during this peak immigration period in which flows would be higher under Alt 2 relative to the FEIS/R PA. Similar to Alt 1, these flow differences between Alt 2 and the FEIS/R PA would not be large or persistent enough to have biologically meaningful effects on steelhead adult migration.

As shown in Table 1, juvenile migration would generally occur in low numbers during the July-November period when flows changes are greatest at Freeport due to Alt 2, except in July (Table 19). Regardless, the peak of migration occurs between March through June with very few individuals migrating during July. During this period, flows at Freeport under Alt 2 would be nearly identical to those under the FEIS/R PA. Collectively, similar to Alt 1, these results suggest that changes in flow at Freeport would not affect juvenile migration in a biologically meaningful way.

South Delta exports can cause entrainment of juvenile steelhead into the facilities. Table 20 presents combined south Delta exports for each month and water year type. These results indicate that export rates under Alt 2 would be lower in July through September of dry and critical years and would be higher in October and November of above normal and critical years and November of dry years relative to the FEIS/R PA. Juvenile steelhead are present in very low numbers at salvage facilities and in the Delta during July through November (Table 2). Therefore, assuming entrainment risk is a function of presence in the Delta and export rates, changes in exports during these months would cause a negligible increase in salvage of steelhead juveniles because individuals are present in the Delta such small numbers.

3.3.2 Winter-run Chinook Salmon

3.3.2.1 Sacramento River

As with Alt 1, effects to winter-run Chinook salmon as a result of Alt 2 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for winter-run Chinook salmon spawning and egg incubation, rearing, and migration. Therefore, no temperature-related effects from Alt 2 to winter-run Chinook salmon in the Sacramento River are predicted.

Flows under Alt 2 could affect winter-run Chinook salmon spawning habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. Results of the analysis predicting how spawning WUA changes under the FEIS/R PA and Alt 2 are presented in Table 45. There would be minimal differences in spawning WUA between FEIS/R PA and Alt 2 during April through June. During July, WUA would be similar between FEIS/R PA and Alt 2 except for an increase in spawning WUA under Alt 2 during July of dry years in Segment 5 (10.8%). These results indicate that, similar to Alt 1, there would be minimal effects of Alt 2 on winter-run spawning habitat availability.

Table 45. Spawning WUA Results for Winter-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 2 (Weighted Usable Area Units). Bold indicates >10% difference.

		Segment 6			Segment 5			Segment 4		
Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Apr	W	164,793	164,793	0 (0%)	610,436	610,436	0 (0%)	174,499	174,499	0 (0%)
	AN	201,250	201,250	0 (0%)	699,997	699,997	0 (0%)	176,192	176,192	0 (0%)
	BN	178,843	178,843	0 (0%)	672,174	672,174	0 (0%)	201,506	201,506	0 (0%)
	D	145,768	145,768	0 (0%)	627,878	627,878	0 (0%)	206,282	206,282	0 (0%)
	C	136,607	136,607	0 (0%)	612,323	612,323	0 (0%)	204,789	204,789	0 (0%)
	All	162,893	162,893	0 (0%)	633,339	633,339	0 (0%)	188,231	188,231	0 (0%)
May	W	276,000	276,000	0 (0%)	719,782	719,782	0 (0%)	147,440	147,440	0 (0%)
	AN	287,887	287,887	0 (0%)	756,761	756,761	0 (0%)	153,901	153,901	0 (0%)
	BN	265,680	265,496	-184 (0%)	776,185	776,136	-49 (0%)	183,496	183,667	171 (0.1%)
	D	301,565	301,740	175 (0%)	796,480	796,716	235 (0%)	160,373	160,224	-149 (-0.1%)
	C	256,409	256,763	353 (0%)	767,858	769,117	1259 (0.2%)	187,576	187,250	-326 (-0.2%)
	All	277,969	278,061	93 (0%)	753,058	753,356	298 (0%)	161,247	161,163	-83 (-0.1%)
Jun	W	287,639	287,639	0 (0%)	742,092	742,092	0 (0%)	152,306	152,306	0 (0%)
	AN	303,146	304,024	877 (0.3%)	778,976	779,358	382 (0%)	153,160	151,922	-1238 (-0.8%)
	BN	304,211	304,255	44 (0%)	721,752	722,449	697 (0.1%)	143,822	143,916	94 (0.1%)
	D	295,695	295,344	-351 (0%)	695,968	693,136	-2832 (-0.4%)	146,492	146,436	-56 (0%)
	C	298,710	298,645	-65 (0%)	787,971	784,950	-3021 (-0.4%)	162,749	162,442	-306 (-0.2%)
	All	295,051	295,133	82 (0%)	748,711	747,697	-1013 (-0.1%)	153,081	152,796	-286 (-0.2%)
Jul	W	287,108	287,291	183 (0.1%)	642,707	644,513	1806 (0.3%)	134,485	134,711	226 (0.2%)
	AN	279,829	279,829	0 (0%)	606,365	606,365	0 (0%)	131,530	131,530	0 (0%)
	BN	274,283	274,461	178 (0%)	566,083	566,647	565 (0.1%)	128,109	128,211	102 (0.1%)
	D	286,710	296,286	9577 (3%)	616,676	683,127	**66,451 (10.8%)**	134,751	142,306	7555 (5.6%)
	C	298,803	301,273	2470 (1%)	707,399	776,587	69188 (9.8%)	149,225	161,694	12469 (8.4%)

	All	287,407	289,686	2279 (0.8%)	640,512	667,207	26695 (4.2%)	136,670	140,663	3993 (2.9%)

In the Sacramento River below Keswick, winter-run Chinook salmon redd dewatering risk under the FEIS/R PA and Alt 2 are expected to be similar during all months of spawning (Table 46). In addition, as described in the 2019 NMFS BiOp (NMFS 2019), Reclamation attempts to minimize the risk redd dewatering from storage releases and this would continue under both the FEIS/R PA and Alt 2. There is low certainty in these results because the CalSim outputs used to conduct this analysis are at a monthly time step, yet flows can fluctuate and affect redd water levels at a shorter timestep. However, if as expected, this limitation affects the FEIS/R PA and Alt 2 results similarly, the monthly time-step results should provide a relative index of dewatering probability. As a result of these considerations, similar to Alt 1, effects of Alt 2 relative to the FEIS/R PA on winter-run Chinook salmon redd dewatering risk is expected to be less than significant.

Table 46. Redd Dewatering Risk Results for Steelhead in the Sacramento River below Keswick Dam for the FEIS/R PA and Alt 2 (in Percent of Redds Dewatered).

Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Apr	W	4.6	4.5	-0.1
	AN	0.1	0.0	0.0
	BN	0.0	0.0	0.0
	D	0.0	0.0	0.0
	C	0.2	0.1	0.0
	All	1.8	1.8	-0.1
May	W	1.6	1.7	0.2
	AN	1.6	1.6	0.0
	BN	0.0	0.0	0.0
	D	0.6	0.9	0.4
	C	0.3	0.7	0.3
	All	1.0	1.3	0.2
Jun	W	1.9	1.9	0.0
	AN	3.3	3.1	-0.2
	BN	14.1	14.0	-0.1
	D	21.5	25.5	3.9
	C	15.4	20.4	5.0
	All	9.1	10.8	1.7
Jul	W	11.9	11.9	0.0
	AN	18.0	18.3	0.4
	BN	39.2	35.6	-3.6
	D	32.7	30.2	-2.5
	C	25.9	24.0	-1.8
	All	21.1	20.2	-1.0
Aug	W	11.0	11.6	0.6
	AN	8.5	8.9	0.4
	BN	20.2	16.6	-3.7
	D	16.4	13.9	-2.5
	C	17.1	14.6	-2.6
	All	13.3	12.4	-0.9

Flows under Alt 2 could affect winter-run Chinook salmon rearing habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. Results of the analysis predicting how rearing WUA changes under the FEIS/R PA and Alt 2 are presented in Table 47. These results generally show similar rearing WUA amounts under the FEIS/R PA and Alt 2 except for 10.2% and 11.8% reductions in Segment 5 during July of dry and critical water years, respectively, under Alt 2. Overall, given the isolated temporal and spatial incidence and generally small magnitude of differences, these differences under Alt 2 are considered less than significant.

Table 47. Juvenile Rearing WUA Results for Winter-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 2 (in Weighted Usable Area Units). Bold indicates >10% difference.

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
	W	73,461	73,217	-244 (-0.3%)	631,569	629,755	-1814 (-0.3%)	125,172	125,386	214 (0.2%)
	AN	75,169	75,169	0 (0%)	665,477	665,477	0 (0%)	127,280	127,280	0 (0%)
	BN	80,450	80,426	-23 (0%)	703,623	703,503	-119 (0%)	123,129	122,994	-134 (-0.1%)
	D	79,854	72,783	-7071 (-9%)	664,071	596,664	**-67407 (-10.2%)**	114,283	120,799	6516 (5.7%)
	C	71,956	67,905	-4051 (-6%)	563,561	496,999	**-66562 (-11.8%)**	123,501	129,095	5594 (4.5%)
Jul	All	74,992	72,815	-2177 (-3%)	633,525	607,225	-26300 (-4.2%)	123,158	125,534	2375 (1.9%)
	W	72,005	72,005	0 (0%)	532,363	532,363	0 (0%)	125,787	125,787	0 (0%)
	AN	67,010	67,055	45 (0%)	475,438	473,880	-1558 (-0.3%)	131,653	131,580	-74 (-0.1%)
	BN	70,307	70,321	14 (0%)	477,546	477,047	-499 (-0.1%)	132,079	132,056	-23 (0%)
	D	71,114	74,383	3269 (5%)	469,709	480,769	11060 (2.4%)	133,667	133,065	-603 (-0.5%)
	C	70,625	73,738	3114 (4%)	490,813	493,421	2608 (0.5%)	131,995	131,978	-17 (0%)
Aug	All	70,582	71,809	1227 (2%)	499,482	501,666	2185 (0.4%)	129,861	129,737	-124 (-0.1%)
	W	70,507	70,507	0 (0%)	517,746	517,746	0 (0%)	128,201	128,201	0 (0%)
	AN	75,560	75,658	97 (0.1%)	485,974	485,318	-657 (-0.1%)	132,568	132,722	154 (0.1%)
	BN	82,111	82,545	434 (1%)	537,666	538,036	370 (0.1%)	131,079	131,077	-2 (0%)
	D	90,550	92,118	1568 (2%)	578,118	585,869	7750 (1.3%)	130,727	131,804	1077 (0.8%)
	C	91,828	92,281	453 (0%)	583,364	579,968	-3397 (-0.6%)	132,252	135,629	3377 (2.6%)
Sep	All	80,008	80,420	412 (1%)	537,475	538,049	574 (0.1%)	130,421	131,333	912 (0.7%)
	W	81,234	80,091	-1143 (-1.4%)	507,241	497,652	-9589 (-1.9%)	131,562	131,450	-112 (-0.1%)
	AN	86,262	79,513	-6749 (-7.8%)	549,071	524,570	-24502 (-4.5%)	131,102	131,864	762 (0.6%)
Oct	BN	71,813	70,565	-1248 (-2%)	483,619	486,540	2922 (0.6%)	131,808	130,133	-1674 (-1.3%)

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
	D	84,527	82,341	-2186 (-3%)	535,410	526,921	-8489 (-1.6%)	131,916	132,204	288 (0.2%)
	C	86,422	79,906	-6516 (-8%)	551,978	527,717	-24260 (-4.4%)	131,637	130,826	-811 (-0.6%)
	All	83,216	79,788	-3429 (-4.1%)	527,415	513,104	-14311 (-2.7%)	131,573	131,450	-123 (-0.1%)

The migration period of adult winter-run in the Sacramento River is typically November through July (Table 3). During this period, adult attraction flows from Keswick are predicted to be mostly similar between Alt 2 than the FEIS/R PA, except for increased flows under Alt 2 during November of above normal and critical water years and reduced flows under Alt 2 in critical years during July (Table 1). Similar to Alt 1, due to the limited temporal occurrence and small frequency and magnitude of reduced flows, effects of Alt 2 on adult migration are expected to be less than significant.

The primary juvenile winter-run outmigration period in the Sacramento River above Red Bluff is August through December (Table 3). During this period , flows under Alt 2 would be higher during October and November during in multiple water year types relative to the FEIS/R PA (Table 1). Due to very limited reduced flows under Alt 2, effects to juvenile migration are expected to be less than significant

3.3.2.2 Delta

Juvenile winter-run Chinook salmon are typically found in the Delta from approximately October through April (Table 4). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 2, except during October and November of critical water years in which flows would be 15.2% and 12% greater under Alt 2, respectively (Table 19). Therefore, minimal effects of Alt 2 are expected during juvenile winter-run Delta migration and residence period.

Adult winter-run Chinook salmon are typically found in the Delta from approximately November through June (Table 4). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 2, except in November of critical water years, in which there would be a 12% increase under Alt 2 (Table 19). Therefore, minimal effects of Alt 2 are expected during adult winter-run Delta migration period.

South Delta export rates during the October through April winter-run juvenile rearing and migration period in the Delta for would be mostly similar between the FEIS/R PA and Alt 2, although exports would be higher during October and November of above normal and critical water years and November of dry years (Table 20). Overall, due to the isolated incidence of these differences and the small proportion of the overall population in the Delta during periods of higher export rates, effects to winter-run would be less than significant.

3.3.3 Spring-run Chinook salmon

3.3.3.1 Sacramento River

As with Alt 1, effects to spring-run Chinook salmon as a result of Alt 2 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for spring-run Chinook salmon spawning and egg incubation, rearing, and migration. Therefore, no temperature-related effects from Alt 2 to spring-run Chinook salmon in the Sacramento River are predicted.

Flows under Alt 2 could affect spring-run Chinook salmon spawning habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. Results of the analysis predicting how spawning WUA changes under the FEIS/R PA and Alt 2 are presented in Table 48. There would be minimal differences in spawning WUA between FEIS/R PA and Alt 2, except in August of dry years (10% increase in Segment 5) and October of critical years (15.9% reduction in Segment 4). Given the isolated occurrence of these two differences and the trend toward reduced spring-run spawning in the mainstem Sacramento River observed over the last two decades, these effects would be less than significant to the spring-run ESU.

Table 48. Spawning WUA Results for Winter-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 2 (Weighted Usable Area Units). Bold indicates >10% difference.

		Segment 6			Segment 5			Segment 4		
Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Aug	W	239,936	239,936	0 (0%)	320,673	320,673	0 (0%)	123,446	123,446	0 (0%)
	AN	255,747	256,501	754 (0.3%)	369,646	372,397	2751 (0.7%)	135,756	136,169	413 (0.3%)
	BN	268,400	268,631	231 (0%)	405,057	405,829	772 (0.2%)	137,934	138,061	127 (0.1%)
	D	273,156	287,138	13,982 (5%)	420,349	462,280	**41,930 (10%)**	138,709	142,896	4187 (3%)
	C	289,846	300,389	10,543 (4%)	466,885	501,147	34,261 (7.3%)	147,772	154,762	6990 (4.7%)
	All	260,539	265,323	4785 (2%)	381,972	396,956	14,984 (3.9%)	134,172	136,431	2258 (1.7%)
Sep	W	251,165	251,165	0 (0%)	354,043	354,043	0 (0%)	134,219	134,219	0 (0%)
	AN	292,839	293,235	396 (0%)	479,076	480,394	1317 (0.3%)	151,881	151,895	14 (0%)
	BN	325,503	325,445	-58 (0%)	586,680	586,854	174 (0%)	180,430	180,776	346 (0.2%)
	D	303,905	293,556	-10,348 (-3%)	589,397	582,608	-6789 (-1.2%)	221,619	235,546	13,927 (6.3%)
	C	296,996	278,671	-18,325 (-6%)	583,496	566,829	-16,668 (-2.9%)	234,980	251,843	16,863 (7.2%)
	All	281,635	276,102	-5533 (-2%)	478,566	474,179	-4387 (-0.9%)	176,222	182,175	5952 (3.4%)
Oct	W	295,357	301,349	5992 (2%)	502,810	502,504	-305 (-0.1%)	163,210	152,618	-10,592 (-6.5%)
	AN	300,426	299,908	-518 (-0.2%)	561,687	539,413	-22,275 (-4%)	192,112	174,918	-17,194 (-8.9%)

	BN	303,616	299,150	-4467 (-1%)	504,867	491,097	-13,771 (-2.7%)	150,261	150,110	-151 (-0.1%)
	D	318,621	301,708	-16,913 (-5%)	573,138	519,827	-53,311 (-9.3%)	171,436	164,201	-7236 (-4.2%)
	C	283,625	298,098	14,473 (5%)	535,247	520,408	-14,839 (-2.8%)	201,555	169,445	**-32,109 (-15.9%)**
	All	298,427	300,359	1932 (1%)	532,410	515,090	-17,320 (-3.3%)	176,895	161,914	-14,981 (-8.5%)

Salmonid redd dewatering can occur when water levels decrease after redd construction, exposing buried and otherwise submerged eggs or alevins to air. In the Sacramento River at Clear Creek, spring-run Chinook salmon redd dewatering risk under Alt 2 is expected to be slightly lower in August and September and slightly higher in October relative to the FEIS/R PA (Table 49). As described in the 2019 NMFS BiOp (NMFS 2019), Reclamation attempts to minimize the risk redd dewatering from Shasta storage releases and this would continue under both the FEIS/R PA and Alt 2. There is low certainty in these results because the CalSim outputs used to conduct this analysis are at a monthly time step, yet flows can fluctuate and affect redd water levels at a shorter timestep. However, if as expected, this limitation affects the FEIS/R PA and Alt 2 results similarly, the monthly time-step results should provide a relative index of dewatering probability. As a result of these considerations, effects of Alt 2 relative to the FEIS/R PA on spring-run Chinook salmon redd dewatering risk is expected to be less than significant.

Table 49. Redd Dewatering Risk Results for Spring-run Chinook Salmon in the Sacramento River at Clear Creek for the FEIS/R PA and Alt 2 (in Percent of Redds Dewatered).

Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Aug	W	16.3	16.3	0.0
	AN	15.3	15.3	0.0
	BN	29.3	25.7	-3.6
	D	24.1	20.2	-3.9
	C	23.2	19.9	-3.3
	All	19.7	18.1	-1.6
Sep	W	23.3	23.3	0.0
	AN	14.5	14.5	0.0
	BN	8.9	7.2	-1.7
	D	5.1	3.3	-1.8
	C	3.9	2.1	-1.8
	All	13.7	12.9	-0.8
Oct	W	9.5	11.2	1.7
	AN	7.2	15.4	8.1
	BN	25.9	26.9	1.0
	D	15.0	20.4	5.4
	C	8.3	17.3	9.0
	All	10.8	15.7	4.9

Flows under Alt 2 could affect spring-run Chinook salmon rearing habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. In the first several months after emergence from the gravel (typically November through February) when individuals are most vulnerable, there would be negligible changes in rearing WUA (Table 50).

Table 50. Juvenile Rearing WUA Results for Spring-run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 2 (in Weighted Usable Area Units).

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
	W	64,005	64,200	195 (0.3%)	1,077,328	1,088,933	11606 (1.1%)	177,337	178,581	1243 (0.7%)
	AN	62,511	60,080	-2430 (-3.9%)	1,213,514	1,099,354	-114160 (-9.4%)	200,377	185,465	-14912 (-7.4%)
	BN	60,781	60,282	-498 (-1%)	1,142,629	1,171,608	28979 (2.5%)	189,391	190,901	1509 (0.8%)
	D	61,022	59,638	-1384 (-2%)	980,412	961,792	-18620 (-1.9%)	175,662	173,572	-2089 (-1.2%)
	C	61,684	60,465	-1219 (-2%)	1,095,279	1,016,883	-78396 (-7.2%)	193,249	184,581	-8668 (-4.5%)
Nov	All	62,547	61,669	-879 (-1%)	1,091,795	1,058,365	-33430 (-3.1%)	185,092	180,872	-4221 (-2.3%)
	W	77,074	77,074	0 (0%)	1,161,824	1,161,824	0 (0%)	166,767	166,767	0 (0%)
	AN	65,025	65,025	0 (0%)	1,277,257	1,277,257	0 (0%)	181,029	181,029	0 (0%)
	BN	68,531	68,531	0 (0%)	1,472,110	1,472,110	0 (0%)	217,118	217,118	0 (0%)
	D	65,854	65,854	0 (0%)	1,363,902	1,363,902	0 (0%)	199,909	199,909	0 (0%)
	C	66,520	66,520	0 (0%)	1,369,784	1,369,784	0 (0%)	209,682	209,682	0 (0%)
Dec	All	70,293	70,293	0 (0%)	1,278,923	1,278,923	0 (0%)	186,930	186,930	0 (0%)
	W	76,240	76,240	0 (0%)	1,096,779	1,096,779	0 (0%)	157,398	157,398	0 (0%)
	AN	70,037	70,037	0 (0%)	1,112,896	1,112,896	0 (0%)	142,229	142,229	0 (0%)
	BN	67,463	67,463	0 (0%)	1,455,076	1,455,076	0 (0%)	195,600	195,600	0 (0%)
	D	70,113	70,113	0 (0%)	1,375,623	1,375,623	0 (0%)	194,932	194,932	0 (0%)
	C	68,912	68,912	0 (0%)	1,369,394	1,369,394	0 (0%)	209,307	209,307	0 (0%)
Jan	All	72,039	72,039	0 (0%)	1,226,034	1,226,034	0 (0%)	174,279	174,279	0 (0%)
	W	74,902	73,731	-1172 (-1.6%)	1,122,600	1,145,430	22830 (2%)	158,767	159,074	308 (0.2%)
	AN	76,631	73,677	-2954 (-3.9%)	1,161,305	1,142,686	-18619 (-1.6%)	155,836	156,632	796 (0.5%)
	BN	65,307	62,268	-3039 (-5%)	1,342,208	1,341,681	-527 (0%)	181,500	183,511	2011 (1.1%)
	D	70,523	66,270	-4253 (-6%)	1,475,446	1,428,814	-46632 (-3.2%)	192,480	201,579	9098 (4.7%)
	C	68,554	66,397	-2157 (-3%)	1,452,700	1,436,322	-16378 (-1.1%)	205,243	216,802	11559 (5.6%)
Feb	All	72,563	70,220	-2343 (-3.2%)	1,272,577	1,266,388	-6189 (-0.5%)	175,105	179,467	4362 (2.5%)

The primary migration period of adult spring-run Chinook salmon past RBDD is typically March through September (Table 5). Flows under Alt 2 would be mostly similar to the FEIS/R PA during this period, except for July of critical years (14% lower; Table 11). Given these small, isolated differences in flows, Alt 2 would have less than significant effects on adult migration in the Sacramento River.

The primary juvenile spring-run Chinook salmon outmigration period in the upper Sacramento River is November through January (Table 5). This coincides with a period of negligible flow changes in the Sacramento River, except for November in which there would be 13.3% and 10.4% flow increases under Alt 2 in above normal and critical water years, respectively (Table 11). Overall, given these isolated flow differences, Alt 2 would have less than significant effects on juvenile spring-run outmigration in the Sacramento River.

3.3.3.2 Feather River

The large majority of Chinook salmon (fall-run ad spring-run combined) spawning (>95%) and rearing (>99%) occurs in the low flow channel (DWR 2012). Low flow channel flows would not change under Alt 2 compared to the FEIS/R PA. Monthly flows in the low flow channel have been optimized for salmonids. Therefore, minimal effects of Alt 2 to spawning and rearing spring-run Chinook salmon in the low flow channel are expected.

The high flow channel is used primarily as a migration corridor for spring-run juvenile and adults. Adult migration typically occurs from March through June. The majority of juveniles typically emigrate from November through June. Although no relationships between flow and migration is known for spring-run Chinook salmon in the Feather River, it is generally thought that higher flows are better for migration. Predicted flows in the high flow channel are presented in Table 15. Flows in the high flow channel are predicted to be similar between Alt 2 and the FEIS/R PA throughout the juvenile and adult migration periods, except for a 22% flow increase in November of critical water years under Alt 2 relative to the FEIS/R PA, which could benefit adult migration. Given this isolated flow change, and similar to Alt 1, these results indicate that both juvenile and adult spring-run Chinook salmon migration in the high flow channel of the Feather River would be minimally impacted by Alt 2.

DWR is committed to meeting year-round water temperature targets in the low-flow and high-flow channels of the Feather River for salmonids in the FERC BiOp (NMFS 2016), which would be included under both the FEIS/R PA and Alt 2. Therefore, no temperature-related effects to spring-run Chinook salmon in the Feather River are predicted under Alt 2.

3.3.3.3 San Joaquin River

For this analysis, it is assumed that higher flows are better for habitat conditions for spring-run Chinook salmon. Flows in the San Joaquin River at Vernalis under Alt 2 would be similar to those under the FEIS/R PA in all months and water years with one exception (Table 18). During July of dry water years, flows would be 11.8% lower under Alt 2 relative to the FEIS/R PA. This reduction would coincide with spring-run Chinook salmon adult migration and holding, but no other life stages. Due to the low frequency of occurrence, this flow reduction under Alt 2 would cause less than significant effects to spring-run Chinook salmon in the San Joaquin River, similar to Alt 1.

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the San Joaquin River. Under this assumption, water temperature results would be similar to flow results (Table 18) in that, due to the low frequency of differences between Alt 2 and the FEIS/R PA, effects to spring-run Chinook salmon are expected to be minimal.

3.3.3.4 Delta

Juvenile spring-run Chinook salmon are typically found in the Delta from approximately December through May (Table 6). During this period, flows at Freeport would be nearly identical between the

FEIS/R PA and Alt 2 (Table 16). Therefore, minimal effects of Alt 2 are expected during juvenile spring-run Delta migration and residence period.

Adult spring-run Chinook salmon are typically found in the Delta from approximately January through June (Table 6). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 2 (Table 16). Therefore, minimal effects of Alt 2 are expected during adult spring-run Delta migration period.

South Delta export rates during the December through May winter-run juvenile rearing and migration period in the Delta for would be nearly identical between the FEIS/R PA and Alt 2. Therefore, effects of Alt 2 on spring-run Chinook salmon entrainment risk would be minimal.

3.3.4 Fall-/Late Fall-Run Chinook Salmon

3.3.4.1 Sacramento River

Effects to fall-/late fall-run Chinook salmon as a result of Alt 2 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for fall-/late fall-run Chinook salmon spawning and egg incubation, rearing, and migration. Therefore, no temperature-related effects from Alt 2 to fall-/late fall-run Chinook salmon in the Sacramento River are predicted.

Flows under Alt 2 could affect fall-/late fall-run Chinook salmon spawning habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. Results of the analysis predicting how spawning WUA changes under the FEIS/R PA and Alt 2 for fall-run and late fall-run are presented in Table 51 and Table 52, respectively. For fall-run, there would be minimal differences in spawning WUA between FEIS/R PA and Alt 2 except October of critical years in Segment 4 and November of above normal and critical water years in Segment 6 and above normal water years in Segment 4 (Table 51). Given the isolated occurrence of these reductions under Alt 2, they would be less than significant to fall-run spawning habitat availability. For late fall-run, there would be minimal differences in spawning WUA between FEIS/R PA and Alt 2 during the December through April spawning period (Table 52). Therefore, effects of Alt 2 on late fall-run Chinook salmon spawning habitat availability would be less than significant.

Table 51. Spawning WUA Results for Fall-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 2 (Weighted Usable Area Units). Bold indicates >10% difference.

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
	W	251,165	251,165	0 (0%)	354,043	354,043	0 (0%)	134,219	134,219	0 (0%)
	AN	292,839	293,235	396 (0.1%)	479,076	480,394	1317 (0.3%)	151,881	151,895	14 (0%)
	BN	325,503	325,445	-58 (0%)	586,680	586,854	174 (0%)	180,430	180,776	346 (0.2%)
	D	303,905	293,556	-10348 (-3%)	589,397	582,608	-6789 (-1.2%)	221,619	235,546	13927 (6.3%)
Sep	C	296,996	278,671	-18325 (-6%)	583,496	566,829	-16668 (-2.9%)	234,980	251,843	16863 (7.2%)

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
	All	281,635	276,102	-5533 (-2%)	478,566	474,179	-4387 (-0.9%)	176,222	182,175	5952 (3.4%)
	W	295,357	301,349	5992 (2%)	502,810	502,504	-305 (-0.1%)	163,210	152,618	-10592 (-6.5%)
	AN	300,426	299,908	-518 (0%)	561,687	539,413	-22275 (-4%)	192,112	174,918	-17194 (-8.9%)
	BN	303,616	299,150	-4467 (-1%)	504,867	491,097	-13771 (-2.7%)	150,261	150,110	-151 (-0.1%)
	D	318,621	301,708	-16913 (-5%)	573,138	519,827	-53311 (-9.3%)	171,436	164,201	-7236 (-4.2%)
	C	283,625	298,098	14473 (5%)	535,247	520,408	-14839 (-2.8%)	201,555	169,445	**-32109 (-15.9%)**
Oct	All	298,427	300,359	1932 (1%)	532,410	515,090	-17320 (-3.3%)	176,895	161,914	-14981 (-8.5%)
	W	140,244	140,244	0 (0%)	447,029	447,029	0 (0%)	132,645	132,645	0 (0%)
	AN	203,634	176,067	**-27567 (-13.5%)**	566,947	571,855	4909 (0.9%)	183,533	161,503	**-22030 (-12%)**
	BN	184,435	184,435	0 (0%)	583,540	583,540	0 (0%)	174,457	174,457	0 (0%)
	D	115,622	109,845	-5777 (-5%)	429,944	428,469	-1475 (-0.3%)	144,008	141,161	-2847 (-2%)
	C	169,741	145,591	**-24150 (-14%)**	549,488	536,263	-13225 (-2.4%)	172,046	157,648	-14398 (-8.4%)
Nov	All	155,758	144,901	-10856 (-7%)	494,300	492,184	-2117 (-0.4%)	154,202	146,848	-7354 (-4.8%)

Table 52. Spawning WUA Results for Late Fall-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 2 (Weighted Usable Area Units). Bold indicates >10% difference.

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
	W	133,639	133,639	0 (0%)	303,842	303,842	0 (0%)	246,713	246,713	0 (0%)
	AN	203,163	203,163	0 (0%)	480,893	480,893	0 (0%)	377,701	377,701	0 (0%)
	BN	257,563	257,563	0 (0%)	529,101	529,101	0 (0%)	534,401	534,401	0 (0%)
	D	237,246	237,246	0 (0%)	533,951	533,951	0 (0%)	466,359	466,359	0 (0%)
	C	235,227	235,227	0 (0%)	524,282	524,282	0 (0%)	499,899	499,899	0 (0%)
Dec	All	192,396	192,396	0 (0%)	434,329	434,329	0 (0%)	377,639	377,639	0 (0%)
	W	117,046	117,046	0 (0%)	282,700	282,700	0 (0%)	198,337	198,337	0 (0%)
	AN	129,541	129,541	0 (0%)	325,577	325,577	0 (0%)	178,938	178,938	0 (0%)
	BN	253,385	253,385	0 (0%)	533,697	533,697	0 (0%)	480,048	480,048	0 (0%)
	D	241,481	241,481	0 (0%)	494,121	494,121	0 (0%)	455,709	455,709	0 (0%)
	C	240,859	240,859	0 (0%)	514,720	514,720	0 (0%)	490,063	490,063	0 (0%)
Jan	All	174,721	174,721	0 (0%)	390,110	390,110	0 (0%)	316,965	316,965	0 (0%)

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Feb	W	123,008	123,008	0 (0%)	290,837	290,837	0 (0%)	192,498	192,498	0 (0%)
	AN	137,573	137,573	0 (0%)	280,587	280,587	0 (0%)	187,321	187,321	0 (0%)
	BN	234,663	234,663	0 (0%)	537,649	537,649	0 (0%)	384,823	384,823	0 (0%)
	D	263,725	263,725	0 (0%)	517,331	517,331	0 (0%)	456,346	456,346	0 (0%)
	C	255,951	255,951	0 (0%)	525,633	525,633	0 (0%)	493,712	493,712	0 (0%)
	All	184,349	184,349	0 (0%)	391,856	391,856	0 (0%)	311,474	311,474	0 (0%)
Mar	W	87,271	87,271	0 (0%)	226,709	226,709	0 (0%)	143,471	143,471	0 (0%)
	AN	144,532	144,572	39 (0%)	411,274	411,484	210 (0.1%)	254,353	254,503	150 (0.1%)
	BN	161,482	161,482	0 (0%)	358,089	358,089	0 (0%)	288,601	288,601	0 (0%)
	D	239,673	239,853	180 (0%)	521,490	521,619	129 (0%)	408,857	409,029	172 (0%)
	C	240,949	240,949	0 (0%)	514,961	514,961	0 (0%)	470,114	470,114	0 (0%)
	All	160,275	160,314	39 (0%)	378,374	378,433	60 (0%)	285,659	285,715	57 (0%)
Apr	W	199,766	199,766	0 (0%)	463,341	463,341	0 (0%)	371,283	371,283	0 (0%)
	AN	223,249	223,249	0 (0%)	505,237	505,237	0 (0%)	390,215	390,215	0 (0%)
	BN	218,928	218,928	0 (0%)	514,622	514,622	0 (0%)	448,969	448,969	0 (0%)
	D	210,500	210,500	0 (0%)	511,650	511,650	0 (0%)	484,119	484,119	0 (0%)
	C	204,037	204,037	0 (0%)	503,701	503,701	0 (0%)	528,673	528,673	0 (0%)
	All	207,811	207,811	0 (0%)	490,586	490,586	0 (0%)	431,510	431,510	0 (0%)

Redd dewatering risk results for fall-run and late fall-run Chinook salmon are presented in Table 53 and Table 54, respectively. For both fall-run and late fall-run, differences in redd dewatering risk between the FEIS/R PA and Alt 2 would be minimal during the spawning period. As described in the 2019 NMFS BiOp (NMFS 2019), Reclamation attempts to minimize the risk redd dewatering from storage releases and this would continue under both the FEIS/R PA and Alt 2. There is low certainty in these results because the CalSim outputs used to conduct this analysis are at a monthly time step, yet flows can fluctuate and affect redd water levels at a shorter timestep. However, if as expected, this limitation affects the FEIS/R PA and Alt 2 results similarly, the monthly time-step results should provide a relative index of dewatering probability. As a result of these considerations, effects of Alt 2 relative to the FEIS/R PA on fall-/late fall-run Chinook salmon redd dewatering risk are expected to be less than significant.

Table 53. Redd Dewatering Risk Results for Fall-run Chinook Salmon in the Sacramento River at Battle Creek for the FEIS/R PA and Alt 2 (in Percent of Redds Dewatered).

Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Sep	W	13.4	13.4	0.0
	AN	8.5	8.5	0.0
	BN	3.9	3.7	-0.2
	D	0.5	0.1	-0.5
	C	1.0	0.4	-0.6
	All	7.2	7.0	-0.2

Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Oct	W	3.8	4.6	0.8
	AN	4.7	4.1	-0.7
	BN	15.0	16.1	1.1
	D	5.0	8.1	3.1
	C	6.5	9.2	2.7
	All	5.4	6.8	1.3
Nov	W	13.2	13.2	0.0
	AN	2.3	3.0	0.7
	BN	8.2	8.2	0.0
	D	25.4	26.3	0.9
	C	13.4	17.6	4.3
	All	13.2	14.3	1.2
	All	13.4	13.4	0.0

Table 54. Redd Dewatering Risk Results for Late Fall-run Chinook Salmon in the Sacramento River below Keswick Dam for the FEIS/R PA and Alt 2 (in Percent of Redds Dewatered).

Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Dec	W	26.3	26.3	0.0
	AN	8.4	8.4	0.0
	BN	1.1	1.1	0.0
	D	4.3	4.3	0.0
	C	3.3	3.3	0.0
	All	13.0	13.0	0.0
Jan	W	37.2	37.2	0.0
	AN	29.9	29.9	0.0
	BN	0.0	0.0	0.0
	D	5.9	5.9	0.0
	C	2.6	2.6	0.0
	All	21.1	21.1	0.0
Feb	W	40.6	40.6	0.0
	AN	38.6	38.6	0.0
	BN	0.0	0.0	0.0
	D	0.6	0.6	0.0
	C	0.5	0.5	0.0
	All	22.6	22.6	0.0
Mar	W	48.0	48.0	0.0
	AN	15.6	15.6	0.0
	BN	14.0	14.0	0.0
	D	4.4	4.4	0.0
	C	2.9	2.9	0.0

Month	WYT	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
	All	23.3	23.3	0.0
Apr	W	4.9	4.9	0.0
	AN	0.4	0.2	-0.1
	BN	0.0	0.0	0.0
	D	0.0	0.0	0.0
	C	0.4	0.4	0.0
	All	2.0	2.0	0.0

Flows under Alt 2 could affect fall-/late fall-run Chinook salmon rearing habitat availability, measured as weighted usable area (WUA), relative to the FEIS/R PA. Results of the analysis predicting how rearing WUA changes under the FEIS/R PA and Alt 2 for fall-run and late fall-run fry are presented in Table 55 and Table 56, respectively. For both races, these results show similar rearing WUA amounts under the FEIS/R PA and Alt 2. Therefore, these differences under Alt 2 are considered less than significant.

Table 55. Juvenile Rearing WUA Results for Fall-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 2 (in Weighted Usable Area Units). Bold indicates >10% difference.

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Dec	W	77,074	77,074	0 (0%)	1,161,824	1,161,824	0 (0%)	166,767	166,767	0 (0%)
	AN	65,025	65,025	0 (0%)	1,277,257	1,277,257	0 (0%)	181,029	181,029	0 (0%)
	BN	68,531	68,531	0 (0%)	1,472,110	1,472,110	0 (0%)	217,118	217,118	0 (0%)
	D	65,854	65,854	0 (0%)	1,363,902	1,363,902	0 (0%)	199,909	199,909	0 (0%)
	C	66,520	66,520	0 (0%)	1,369,784	1,369,784	0 (0%)	209,682	209,682	0 (0%)
	All	70,293	70,293	0 (0%)	1,278,923	1,278,923	0 (0%)	186,930	186,930	0 (0%)
Jan	W	76,240	76,240	0 (0%)	1,096,779	1,096,779	0 (0%)	157,398	157,398	0 (0%)
	AN	70,037	70,037	0 (0%)	1,112,896	1,112,896	0 (0%)	142,229	142,229	0 (0%)
	BN	67,463	67,463	0 (0%)	1,455,076	1,455,076	0 (0%)	195,600	195,600	0 (0%)
	D	70,113	70,113	0 (0%)	1,375,623	1,375,623	0 (0%)	194,932	194,932	0 (0%)
	C	68,912	68,912	0 (0%)	1,369,394	1,369,394	0 (0%)	209,307	209,307	0 (0%)
	All	72,039	72,039	0 (0%)	1,226,034	1,226,034	0 (0%)	174,279	174,279	0 (0%)
Feb	W	74,902	74,902	0 (0%)	1,122,600	1,122,600	0 (0%)	158,767	158,767	0 (0%)
	AN	76,631	76,631	0 (0%)	1,161,305	1,161,305	0 (0%)	155,836	155,836	0 (0%)
	BN	65,307	65,307	0 (0%)	1,342,208	1,342,208	0 (0%)	181,500	181,500	0 (0%)
	D	70,523	70,523	0 (0%)	1,475,446	1,475,446	0 (0%)	192,480	192,480	0 (0%)
	C	68,554	68,554	0 (0%)	1,452,700	1,452,700	0 (0%)	205,243	205,243	0 (0%)
	All	72,563	72,563	0 (0%)	1,272,577	1,272,577	0 (0%)	175,105	175,105	0 (0%)
Mar	W	74,205	74,205	0 (0%)	1,041,932	1,041,932	0 (0%)	151,210	151,210	0 (0%)
	AN	62,935	62,894	-40 (-0.1%)	1,098,852	1,098,708	-144 (0%)	155,923	156,067	143 (0.1%)
	BN	66,685	66,685	0 (0%)	1,211,510	1,211,510	0 (0%)	174,109	174,109	0 (0%)
	D	67,874	67,858	-16 (0%)	1,357,086	1,358,155	1069 (0.1%)	183,939	183,965	26 (0%)
	C	69,069	69,069	0 (0%)	1,364,327	1,364,327	0 (0%)	196,425	196,425	0 (0%)
	All	69,599	69,589	-10 (0%)	1,183,943	1,184,106	163 (0%)	168,474	168,504	30 (0%)

Table 56. Juvenile Rearing WUA Results for Late Fall-Run Chinook Salmon in the Sacramento River for the FEIS/R PA and Alt 2 (in Weighted Usable Area Units). Bold indicates >10% difference.

Month	WYT	Segment 6			Segment 5			Segment 4		
		FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA	FEIS/R PA	Alt 2	Alt 2 vs. FEIS/R PA
Mar	W	67,921	67,921	0 (0%)	985,347	985,347	0 (0%)	142,475	142,475	0 (0%)
	AN	60,812	60,753	-58 (-0.1%)	1,063,413	1,063,172	-241 (0%)	135,777	135,884	108 (0.1%)
	BN	60,929	60,929	0 (0%)	1,190,291	1,190,291	0 (0%)	153,975	153,975	0 (0%)
	D	59,966	59,916	-50 (0%)	1,309,887	1,311,098	1211 (0.1%)	165,551	165,579	29 (0%)
	C	62,925	62,925	0 (0%)	1,312,815	1,312,815	0 (0%)	181,151	181,151	0 (0%)
	All	63,823	63,804	-19 (0%)	1,135,871	1,136,042	171 (0%)	154,004	154,028	24 (0%)
Apr	W	106,718	106,718	0 (0%)	1,249,077	1,249,077	0 (0%)	165,445	165,445	0 (0%)
	AN	102,642	102,642	0 (0%)	1,124,052	1,124,052	0 (0%)	160,300	160,300	0 (0%)
	BN	104,382	104,382	0 (0%)	1,202,911	1,202,911	0 (0%)	176,575	176,575	0 (0%)
	D	116,758	116,758	0 (0%)	1,311,494	1,311,494	0 (0%)	184,544	184,544	0 (0%)
	C	117,447	117,447	0 (0%)	1,351,210	1,351,210	0 (0%)	195,490	195,490	0 (0%)
	All	109,842	109,842	0 (0%)	1,256,340	1,256,340	0 (0%)	174,748	174,748	0 (0%)
May	W	74,376	74,376	0 (0%)	898,646	898,646	0 (0%)	145,739	145,739	0 (0%)
	AN	72,923	72,923	0 (0%)	857,869	857,869	0 (0%)	147,854	147,854	0 (0%)
	BN	85,825	85,976	151 (0%)	924,822	925,675	853 (0.1%)	164,262	164,311	49 (0%)
	D	67,264	67,087	-177 (0%)	793,319	792,785	-533 (-0.1%)	152,134	151,979	-155 (-0.1%)
	C	90,501	90,132	-369 (0%)	961,163	960,346	-818 (-0.1%)	166,847	166,517	-330 (-0.2%)
	All	76,858	76,759	-98 (0%)	887,274	887,062	-212 (0%)	152,676	152,584	-92 (-0.1%)
Jun	W	71,471	71,471	0 (0%)	830,849	830,849	0 (0%)	149,290	149,290	0 (0%)
	AN	64,124	63,288	-836 (-1.3%)	808,180	804,164	-4016 (-0.5%)	143,594	143,186	-408 (-0.3%)
	BN	59,796	59,780	-15 (0%)	835,118	834,597	-521 (-0.1%)	134,294	134,359	66 (0%)
	D	70,951	70,986	35 (0%)	860,600	862,143	1543 (0.2%)	136,753	136,751	-2 (0%)
	C	64,895	64,865	-30 (0%)	821,038	821,631	594 (0.1%)	151,723	151,385	-337 (-0.2%)
	All	68,042	67,894	-149 (-0.2%)	830,330	829,985	-345 (0%)	145,691	145,553	-138 (-0.1%)

The migration period of adult fall-run in the Sacramento River is typically June through December. For late-fall-run, the adult migration period is October through April. Sacramento River flows during the fall-run period would be largely similar between the FEIS/R PA and Alt 2, except for a 14% reduction during July of critical water years and up to 21% increases during October and November (Table 11). Due to the limited temporal occurrence and small frequency and magnitude of reduced flows, effects of Alt 2 to fall-/late fall-run adult migration are expected to be less than significant.

The juvenile fall-run outmigration period in the Sacramento River above Red Bluff is November through May. For late fall-run, this period is April through June. During both of these outmigration periods, Sacramento River flows under Alt 2 would largely be similar to those under the FEIS/R PA, although flows would be 13.3% and 10.4% higher under Alt 2 in November, the beginning of the fall-run outmigration period, in above normal and critical years, respectively, (Table 11). Overall, effects of Alt 2 to juvenile fall-/late fall-run migration are expected to be less than significant.

3.3.4.2 Feather River

The large majority of spawning (>95%) and rearing (>99%) by Chinook salmon (fall-run and spring-run combined) occurs in the low flow channel (DWR 2012). Low flow channel flows would not change under Alt 2 compared to the FEIS/R PA. Monthly flows in the low flow channel have been optimized for salmonids. Therefore, minimal effects of Alt 2 to spawning and rearing fall-run Chinook salmon in the low flow channel are expected.

The high flow channel is used primarily as a migration corridor for fall-run juvenile and adults. Juvenile migration typically occurs from mid-November through June with a peak from January through March. Adult migration typically occurs between September and December. Although no relationships between flow and migration is known for fall-run Chinook salmon in the Feather River, it is generally thought that higher flows are better for migration. Predicted flows in the high flow channel are presented in Table 15. Flows in the high flow channel are predicted to be within 10% between Alt 2 and the FEIS/R PA in most months with one exception. During November of critical years, there would be a 2% increase in flows under Alt 2 relative to the FEIS/R PA, which could be beneficial to adult migration. Given this isolated flow change, these results indicate that both juvenile and adult fall- run Chinook salmon migration in the high flow channel of the Feather River would be minimally impacted by Alt 2.

DWR is committed to meeting year-round water temperature targets in the low-flow and high-flow channels of the Feather River for salmonids in the FERC BiOp (NMFS 2016), which would be included under both the FEIS/R PA and Alt 2. Therefore, no temperature-related effects to fall-run Chinook salmon in the Feather River are predicted under Alt 2.

3.3.4.3 American River

Flows in the American River under Alt 2 would be similar to those under the FEIS/R PA in all months and water years some exceptions (Table 16). During July of dry and critical water years and August of critical water years, flows would be 11% to 20% lower under Alt 2. During October of critical water years, flows would be 14.8% higher under Alt 2. The July and August reductions would not coincide with the presence of any fall-run life stage in the American River. The October flow increase would coincide with the adult migration and spawning periods. Due to the low frequency of these flow changes, they are expected to minimally affect fall-run Chinook salmon under Alt 2.

Reclamation is committed to meeting the modified flow management standard in the ROC on LTO NMFS BiOp (NMFS 2019:20) in future operations, which would include both the FEIS/R PA and Alt 2. The commitment is to preserve coldwater pool in drier years to improve temperature management. Based on modeled flow differences (Table 16) and an assumption that lower flows would increase water temperatures, the only time of year that temperatures under Alt 2 could be higher than the FEIS/R PA is during July and August. Because these flow reductions do not temporally overlap with fall-run Chinook salmon and due to Reclamation's commitments, minimal temperature-related effects to fall-run Chinook salmon in the American River are predicted for Alt 2.

3.3.4.4 Merced River

For this analysis, it is assumed that higher flows are better for habitat conditions for fall-run Chinook salmon. Flows at the Merced River mouth under Alt 2 would be similar to those under the FEIS/R PA in all months and water years with some exceptions (Table 17). During July of dry and critical water years and August of critical water years, flows would be 49.5% to 34.7% lower under Alt 2 relative to the FEIS/R PA. During October of above normal water years and November of above normal and dry years, flows would be 30.4%, 58.5%, and 35.7% higher, respectively, under Alt 2. The July and August flow reductions would not coincide with any fall-run Chinook salmon life stage in the Merced River. The October and November flow increases would coincide with the adult migration and spawning periods. Due to the low frequency of these flow changes, they are expected to minimally affect fall-run Chinook salmon under Alt 2, similar to Alt 1.

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the Merced River. Under this assumption, water temperature results would be similar to flow results (Table 17) in that, due to the low frequency of differences between Alt 2 and the FEIS/R PA, effects to fall-run Chinook salmon are expected to be minimal.

3.3.4.5 San Joaquin River

For this analysis, it is assumed that higher flows are better for habitat conditions for fall-run Chinook salmon. Flows in the San Joaquin River at Vernalis under Alt 2 would be similar to those under the FEIS/R PA in all months and water years with one exception (Table 18). During July of dry water years, flows would be 11.8% lower under Alt 2 relative to the FEIS/R PA. These reductions would not coincide with any fall-run Chinook salmon life stage in the San Joaquin River. Therefore, there would be negligible effects of Alt 2 on fall-run Chinook salmon in the San Joaquin River, similar to Alt 1.

For this analysis, it is assumed that there is an inverse relationship between flow and water temperature in the San Joaquin River. Under this assumption, water temperature results would be similar to flow results (Table 18) in that, due to the lack of differences between Alt 2 and the FEIS/R PA during fall-run Chinook salmon presence, effects are expected to be negligible.

3.3.4.6 Delta

Juvenile fall-run Chinook salmon are primarily found in the Delta from approximately December through June (Table 7). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 2 (Table 19). Therefore, minimal effects of Alt 2 are expected during juvenile fall-run Delta migration and residence period.

Juvenile late fall-run Chinook salmon are typically found in the Delta between December and February and between April and June (Table 8). During this period, flows at Freeport would be nearly identical between the FEIS/R PA and Alt 2 (Table 19). Therefore, minimal effects of Alt 2 are expected during juvenile late fall-run Delta migration and residence period.

Adult fall-run Chinook salmon are typically found in the Delta from approximately June through November (Table 7). During this period, flows at Freeport would be similar between the FEIS/R PA and Alt 2, except for 18.5% and 10% reductions in July and August, respectively, of critical years and 15.2% and 12% increases in October and November of critical water years, respectively (Table 19). Due to the isolated occurrences of reduced flows during the adult migration period through the Delta, the effects of Alt 2 are expected to be less than significant.

Adult late fall-run Chinook salmon are typically found in the Delta from approximately October through May (Table 8). During this period, flows at Freeport would be mostly similar between the FEIS/R PA and Alt 2, except for 15.2% and 12% increases in October and November of critical water years, which would likely be beneficial for migration cues (Table 19). Therefore, minimal effects of Alt 2 are expected during adult winter-run Delta migration period.

South Delta export rates during the June through November fall-run juvenile rearing and migration period in the Delta for would be mostly similar between the FEIS/R PA and Alt 2, although exports would be lower during dry and critical water years during July and August and in critical years during September, and higher during October and November of above normal and critical water years (Table 20). Overall, due to the isolated incidence of higher exports and the incidence of reduced exports, effects to fall-run would be less than significant.

South Delta export rates during the October through May late fall-run juvenile rearing and migration period in the Delta for would be mostly similar between the FEIS/R PA and Alt 2, although exports would be higher during October and November of above normal and critical water years (Table 20). Overall, due to the isolated incidence of these differences, effects to fall-run would be less than significant.

3.3.5 Green Sturgeon

3.3.5.1 Sacramento River

Effects to green sturgeon as a result of Alt 2 could be temperature-based or flow-based. Water temperature management for Chinook salmon in the 2019 NMFS BiOp (NMFS 2019) should provide adequate temperatures for green sturgeon spawning and egg incubation, rearing, and migration. Therefore, no temperature-related effects from Alt 2 to green sturgeon in the Sacramento River are predicted.

To assess the potential effect of Alt 2 on green sturgeon spawning habitat availability, the frequency of occurrence outside the 7,500 to 12,360 cfs optimal range (Wyman et al. 2018) was calculated by month and water years type during the March through July spawning period. Results indicate that the occurrence of flows outside the period would be predominantly similar between the FEIS/R PA and Alt 2, except in July of dry and critical years, during which there would be 3 years and 1 year fewer with flows outside of the optimal range under Alt 2 (Table 33). These results indicate that the effect of Alt 2 on green sturgeon spawning habitat availability would be less than significant.

To assess the potential effect of Alt 2 on green sturgeon larvae and juveniles, flow rates were evaluated in the Sacramento River at Wilkins Slough during April through December for the FEIS/R PA and Alt 2. These results indicate that flows under Alt 2 would generally be similar to the FEIS/R PA during April through June and December and wetter water year types during July through September, lower in drier water year types during July through September, and higher in multiple water year types during October and November (Table 34). Overall, due to the limited incidence of flow reductions, the effect of Alt 2 is considered less than significant. There is low certainty in this conclusion due to a general lack of understanding of how flow may affect green sturgeon larvae and juveniles.

To assess the potential effect of Alt 2 on green sturgeon adult migration, the frequency of flows <3,250 cfs in the Sacramento River at Wilkins Slough during the February through June migration period were evaluated for the FEIS/R PA and Alt 2. Flows under FEIS/R PA and Alt 2 are always >3,250 cfs (Table 3). These results indicate that there would be no risk of additional passage limitations under Alt 2 and, therefore, negligible flow-related effects of Alt 2 on green sturgeon upstream passage.

3.3.5.2 Feather River

During the March through July spawning period in the Feather River, flows in the low flow channel would be identical between the FEIS/R PA and Alt 2. Flows in the high flow channel below Thermalito Afterbay under Alt 2 would be predominantly similar to those under the FEIS/R PA (Table 15). The similarity in flows during this period suggests that the project would not cause flow-related effects to green sturgeon spawning in the Feather River.

During the April through December likely larval and juvenile rearing period, flows in the high flow channel below Thermalito under the FEIS/R PA and Alt 2 would be largely similar, except during November of critical water years (22.1% increase; Table 15). For reasons discussed above, it is unlikely that green sturgeon would spawn in the Feather River during a critical water year, and this has never been observed. Therefore, flow-related effects of Alt 2 to green sturgeon larvae and juveniles would be less than significant.

Because flows in the low flow and high flow channel would be similar between the FEIS/R PA and Alt 2 in all months of wetter water years when sturgeon would migrate and spawn in the Feather River (Table 15), any effects of Alt 2 to juvenile and adult migration would be minimal.

DWR is committed to meeting year-round water temperature targets in the low-flow and high-flow channels of the Feather River for salmonids in the FERC BiOp (NMFS 2016), which would be included under both the FEIS/R PA and Alt 2. These temperature targets are generally protective of green sturgeon and, therefore, no temperature-related effects to green sturgeon in the Feather River are predicted under Alt 2.

3.3.5.3 San Joaquin River

Because very little information regarding green sturgeon presence in the San Joaquin River exists, this analysis evaluates potential effects by comparing flows at Vernalis between FEIS/R PA and Alt 2 for all months. Flows at Vernalis under Alt 2 would be similar to those under the FEIS/R PA in all months and water years with one exception (Table 18). During July of dry water years, flows would be 11.8% lower under Alt 2 relative to the FEIS/R PA. Due to the low frequency of occurrence, this flow reduction under Alt 2 would cause less than significant effects. Similarly, assuming flow and water temperature are inversely related, the low frequency in flow differences between Alt 2 and the FEIS/R PA indicates that water temperature-related effects to green sturgeon in the San Joaquin River would be negligible.

3.3.5.4 Delta

Given the minor changes in total exports under Alt 2 relative to the FEIS/R PA (Table 20) and the recent very low total salvage numbers (22 individuals between 2009 and 2018; CDFW unpubl. data), Alt 2 would have a less than significant effect to green sturgeon entrainment.

Results of the green sturgeon year class strength regressions analysis indicate that there would be negligible differences between the FEIS/R PA and Alt 2 in year-class strength (Table 36 and Table 37).

3.3.6 Delta Smelt

To evaluate potential effects of Alt 2 on adult delta smelt entrainment in the South Delta export facilities, flows in the Sacramento River at Freeport (Table 19), South Delta exports (Table 20), and Delta outflow (Table 38) during December-March were compared between the FEIS/R PA and Alt 2. Model results for all three parameters generally would be very similar under the FEIS/R PA and Alt 2 which, combined with the same real-time criteria to minimize risk as currently implemented (USFWS 2019, CCDFW 2020), suggests there would be little difference in entrainment risk for adult delta smelt between the FEIS/R PA and Alt 2.

To evaluate potential effects of Alt 2 on larval/early juvenile delta smelt in the South Delta export facilities, March–June Old and Middle River flows and X2 position were compared between the FEIS/R PA and Alt 2. Old and Middle River flows are a function of San Joaquin River flows and exports. Because neither variable changes during the March through June period, OMR flows will not change. In addition, there would be negligible differences in X2 position between the FEIS/R PA and Alt 2 throughout the March-June period (Table 39). As a result, effects of Alt 2 to larval/early juvenile delta smelt entrainment would be less than significant.

Spring (March–May) X2 is positively correlated with the density of the delta smelt zooplankton prey *Eurytemora affinis* (Kimmerer 2002a; Greenwood 2018), suggesting a potential positive effect of Delta outflow on this prey species, and thereby affecting individual delta smelt growth and survival per the IEP MAST conceptual model (IEP MAST 2015:88). X2 position during March through May would be nearly identical between the FEIS/R PA and Alt 2 (Table 39). Therefore, there would be negligible effects of Alt 2 on delta smelt prey availability.

To assess abundance of a delta smelt predator under Alt 2, Mississippi silverside, June-September Delta inflow and March-May South Delta exports were compared for the FEIS/R PA and Alt 2. Delta inflow is calculated as the sum of Sacramento River at Freeport, Yolo Bypass flows, Mokelumne River, and San Joaquin River at Vernalis. Mean June-September Delta inflow under Alt 2 would generally be similar to those under the FEIS/R PA (Table 40). Mean March-May combined South Delta exports would be identical (Table 41). These results indicate that delta smelt silverside abundance would remain similar under the FEIS/R PA and Alt 2.

The IEP MAST (2015: 89) delta smelt conceptual model posits that size and location of the low salinity zone is a habitat attribute that could affect subadult delta smelt survival. Note that there is debate regarding the importance of low salinity zone habitat to delta smelt (e.g., Manly et al. 2015; Feyrer et al. 2015; Murphy and Weiland 2019). Regardless, X2 position, a measure of the low salinity zone, under the FEIS/R PA and Alt 2 would be nearly identical in all months (Table 39). Therefore, effects of Alt 2 on the low salinity zone size and position would be less than significant.

3.3.7 Longfin Smelt

Potential effects of Alt 2 to entrainment risk of adult, larval, and juvenile longfin smelt was evaluated by comparing December through May South Delta exports and December through March X2, as described for Alt 1 in Section 3.2.7, *Longfin Smelt*. Because there would be negligible differences in both parameters during the specified months (Table 20, Table 39), it is concluded that the effect of Alt 2 on longfin smelt entrainment risk at the South Delta export facilities would be less than significant.

Flow-based effects of Alt 2 were evaluated using the Nobriga and Rosenfield (2016) and X2-longfin smelt abundance methods based on DWR (2020) as described in Section 3.2.7, *Longfin Smelt*. Due to negligible differences between the FEIS/R PA and Alt 2 CalSim-modeled December-May Delta outflow (Table 38) and January-June X2 position (Table 39), it is concluded that the effect of Alt 2 on longfin smelt abundance would be less than significant.

Chapter 4
Conclusions

4.1 Alternative 1 CEQA Determination

4.1.1 Central Valley Steelhead

Cumulatively, effects of Alt 1 on Central Valley steelhead would be less than significant. Differences in modeled flows associated with Alt 1 would cause small or negligible effects to spawning, rearing and migration conditions for steelhead in the Sacramento, Feather, American, Merced, and San Joaquin Rivers. There would be minimal temperature-related effects in the Sacramento, Feather, and American Rivers because existing temperature management would be protective of steelhead. There would be minimal temperature-related effects in the Merced and San Joaquin Rivers because differences in flow would be minimal. In the Delta, differences in modeled flows and South Delta export rates under Alt 1 would cause small or negligible effects to Delta rearing, migration, and entrainment risk.

4.1.2 Winter-Run Chinook Salmon

Cumulatively, effects of Alt 1 on winter-run Chinook salmon would be less than significant. Differences in modeled flows associated with Alt 1 would cause small or negligible effects to spawning, rearing and migration conditions for winter-run Chinook salmon in the Sacramento River. There would be minimal temperature-related effects in the Sacramento River because existing temperature management would be protective of winter-run. In the Delta, differences in modeled flows and South Delta export rates under Alt 1 would cause small or negligible effects to Delta rearing, migration, and entrainment risk.

4.1.3 Spring-Run Chinook Salmon

Cumulatively, effects of Alt 1 on spring-run Chinook salmon would be less than significant. Differences in modeled flows associated with Alt 1 would cause small or negligible effects to spawning, rearing and migration conditions for spring-run Chinook salmon in the Sacramento, Feather and San Joaquin Rivers. There would be minimal temperature-related effects in the Sacramento and Feather Rivers because existing temperature management would be protective of spring-run Chinook salmon. There would be minimal temperature-related effects in the San Joaquin River because differences in flow would be minimal. In the Delta, differences in modeled flows and South Delta export rates under Alt 1 would cause small or negligible effects to Delta rearing, migration, and entrainment risk.

4.1.4 Fall-/Late Fall-Run Chinook Salmon

Cumulatively, effects of Alt 1 on fall-/late fall-run Chinook salmon would be less than significant. Differences in modeled flows associated with Alt 1 would cause small or negligible effects to spawning, rearing and migration conditions for fall-/late fall-run -run Chinook salmon in the

Sacramento, Feather, American, Merced, and San Joaquin Rivers. There would be minimal temperature-related effects in the Sacramento, Feather, and American Rivers because existing temperature management would be protective of fall-/late fall-run Chinook salmon. There would be minimal temperature-related effects in the Merced and San Joaquin Rivers because differences in flow would be minimal. In the Delta, differences in modeled flows and South Delta export rates under Alt 1 would cause small or negligible effects to Delta rearing, migration, and entrainment risk.

4.1.5 Green Sturgeon

Cumulatively, effects of Alt 1 on southern DPS green sturgeon would be less than significant. Differences in modeled flows associated with Alt 1 would cause small or negligible effects to spawning, rearing and migration conditions for southern DPS green sturgeon in the Sacramento, Feather, and San Joaquin Rivers. There would be minimal temperature-related effects in the Sacramento and Feather Rivers because existing temperature management would be protective of southern DPS green sturgeon. There would be minimal temperature-related effects in the San Joaquin River because differences in flow would be minimal. In the Delta, differences in modeled flows and South Delta export rates under Alt 1 would cause small or negligible effects to Delta rearing, migration, and entrainment risk and to southern DPS green sturgeon year-class strength.

4.1.6 Delta Smelt

Cumulatively, effects of Alt 1 on delta smelt would be less than significant. Differences in modeled Delta flows, X2 position, and South Delta export rates under Alt 1 would cause negligible effects to delta smelt entrainment risk, prey availability, predator abundance, and habitat location and size.

4.1.7 Longfin Smelt

Cumulatively, effects of Alt 1 on longfin smelt would be less than significant. Differences in modeled Delta flows and X2 position under Alt 1 would cause negligible effects to entrainment risk and longfin smelt abundance.

4.2 Alternative 2 CEQA Determination

4.2.1 Central Valley Steelhead

Cumulatively, effects of Alt 2 on Central Valley steelhead would be less than significant. Differences in modeled flows associated with Alt 2 would cause small or negligible effects to spawning, rearing and migration conditions for steelhead in the Sacramento, Feather, American, Merced, and San Joaquin Rivers. There would be minimal temperature-related effects in the Sacramento, Feather, and American Rivers because existing temperature management would be protective of steelhead. There would be minimal temperature-related effects in the Merced and San Joaquin Rivers because differences in flow would be minimal. In the Delta, differences in modeled flows and South Delta export rates under Alt 2 would cause small or negligible effects to Delta rearing, migration, and entrainment risk.

4.2.2 Winter-Run Chinook Salmon

Cumulatively, effects of Alt 2 on winter-run Chinook salmon would be less than significant. Differences in modeled flows associated with Alt 2 would cause small or negligible effects to spawning, rearing and migration conditions for winter-run Chinook salmon in the Sacramento River. There would be minimal temperature-related effects in the Sacramento River because existing temperature management would be protective of winter-run. In the Delta, differences in modeled flows and South Delta export rates under Alt 2 would cause small or negligible effects to Delta rearing, migration, and entrainment risk.

4.2.3 Spring-Run Chinook Salmon

Cumulatively, effects of Alt 2 on spring-run Chinook salmon would be less than significant. Differences in modeled flows associated with Alt 2 would cause small or negligible effects to spawning, rearing and migration conditions for spring-run Chinook salmon in the Sacramento, Feather and San Joaquin Rivers. There would be minimal temperature-related effects in the Sacramento and Feather Rivers because existing temperature management would be protective of spring-run Chinook salmon. There would be minimal temperature-related effects in the San Joaquin River because differences in flow would be minimal. In the Delta, differences in modeled flows and South Delta export rates under Alt 2 would cause small or negligible effects to Delta rearing, migration, and entrainment risk.

4.2.4 Fall-/Late Fall-Run Chinook Salmon

Cumulatively, effects of Alt 2 on fall-/late fall-run Chinook salmon would be less than significant. Differences in modeled flows associated with Alt 2 would cause small or negligible effects to spawning, rearing and migration conditions for fall-/late fall-run -run Chinook salmon in the Sacramento, Feather, American, Merced, and San Joaquin Rivers. There would be minimal temperature-related effects in the Sacramento, Feather, and American Rivers because existing temperature management would be protective of fall-/late fall-run Chinook salmon. There would be minimal temperature-related effects in the Merced and San Joaquin Rivers because differences in flow would be minimal. In the Delta, differences in modeled flows and South Delta export rates under Alt 2 would cause small or negligible effects to Delta rearing, migration, and entrainment risk.

4.2.5 Green Sturgeon

Cumulatively, effects of Alt 2 on southern DPS green sturgeon would be less than significant. Differences in modeled flows associated with Alt 2 would cause small or negligible effects to spawning, rearing and migration conditions for southern DPS green sturgeon in the Sacramento, Feather, and San Joaquin Rivers. There would be minimal temperature-related effects in the Sacramento and Feather Rivers because existing temperature management would be protective of southern DPS green sturgeon. There would be minimal temperature-related effects in the San Joaquin River because differences in flow would be minimal. In the Delta, differences in modeled flows and South Delta export rates under Alt 2 would cause small or negligible effects to Delta rearing, migration, and entrainment risk and to southern DPS green sturgeon year-class strength.

4.2.6 Delta Smelt

Cumulatively, effects of Alt 2 on delta smelt would be less than significant. Differences in modeled Delta flows, X2 position, and South Delta export rates under Alt 2 would cause negligible effects to delta smelt entrainment risk, prey availability, predator abundance, and habitat location and size.

4.2.7 Longfin Smelt

Cumulatively, effects of Alt 2 on longfin smelt would be less than significant. Differences in modeled Delta flows and X2 position under Alt 2 would cause negligible effects to entrainment risk and longfin smelt abundance.

Chapter 5
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Attachment 1
Additional Methods Description

This attachment provides details on three analytical tools that were too complex to include with the text of Chapter 3, *Impact Analysis*. The three analytical tools are: salmonid spawning weighted usable area (WUA), salmonid redd dewatering, and juvenile salmonid rearing (WUA).

1.1 Salmonid Spawning Weighted Usable Area (WUA)

The WUA curves used for Chinook salmon and steelhead spawning habitat in the Sacramento River were obtained from two U.S. Fish and Wildlife Service (USFWS) reports (USFWS 2003a, 2006). Modeling assumptions used to derive spawning WUA curves include that the suitability of physical habitat for salmon and steelhead spawning is largely a function of substrate particle size, water depth, and flow velocity. The race- or species-specific suitability of the habitat with respect to these variables is determined by cataloguing conditions at active redds and is used to develop habitat suitability criteria (HSC) for each race or species of fish. Hydraulic modeling is then used to estimate the amount of habitat available for different HSC levels at different river flows, and the results are used to develop spawning habitat WUA curves (Bovee et al. 1998). The WUA curves and tables are used to look up the amount of spawning WUA available at different flows during the spawning periods of the race or species.

USFWS (2003a) provides WUA curves and tables for spawning winter-run, fall-run, and late fall–run Chinook salmon and steelhead for three segments of the Sacramento River encompassing the reach from Keswick Dam to Battle Creek (Figure A-1). The WUA tables were updated in 2006 (U.S. Fish and Wildlife Service 2006). No WUA curves were developed for spring-run Chinook salmon, but as discussed later, the fall-run curves were used to quantify spring-run spawning habitat. Also as further discussed below, the HSC used to develop the steelhead WUA curve for Sacramento River spawning were obtained from investigations of steelhead redds in the American River (U.S. Fish and Wildlife Service 2003b) because few steelhead redds were observed in the Sacramento River. Figure A-2 through Figure A-5 show the flow versus spawning WUA results for winter-run, fall-run, late fall–run and steelhead in the three river segments (Segment 6 = Keswick to Anderson-Cottonwood Irrigation District [ACID] Dam, Segment 5 = ACID Dam to Cow Creek, and Segment 4 = Cow Creek to Battle Creek) as provided by USFWS (2006). Figure A-6 shows spawning WUA results for fall-run in an additional downstream segment (Segment 3 = Battle Creek to Red Bluff Diversion Dam) because spawning for fall run occurs further downstream than it does for the other salmon runs. Note that for Segment 6, separate WUA curves were developed for periods when the ACID Dam boards were installed (April through October) and for when the boards were out because installation of the boards affects water depths and velocities for some of the sampling transects used to develop the curves.

Because several tributaries enter the Sacramento River between Keswick Dam and Battle Creek, flows generally differ among the segments. For the USFWS studies, Sacramento River flows were measured directly at the sampling transects and were estimated as the sum of Keswick Dam flow releases and tributary gauge readings upstream of the transects. To estimate WUA for the effects analysis, the segment flows were estimated using Sacramento River CALSIM II flows at Keswick Dam, the Clear Creek confluence, and Battle Creek. Keswick Dam flows were used for Segment 5 upstream of the Clear Creek confluence. For Segment 6, the WUA curves for the months when the ACID Dam boards are installed (April through October) were used with the Keswick Dam flows for those months and the WUA curves for the months when the ACID Dam boards are out were used with the flows for the rest of the year. To evaluate the relative importance of results from the three segments for each race or species in the effects analysis, the typical spawning distributions of the salmon with respect to the segments (Table A-1) was estimated from aerial redd surveys conducted by California Department of Fish and Wildlife (ICF 2016). All races other than fall-run primarily spawn upstream of the Battle Creek confluence, and most fall-run spawning occurs upstream of the RBDD. 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 RBDD, where nearly all Chinook salmon spawn (Table A-1).

Table A-1. Distributions of Spawning Redds among WUA River Segments as Percent of Total in the Sacramento River for Chinook Salmon Runs.

Segment	Description	River Miles	Winter-run	Spring-run	Fall-run	Late fall–run
6	Keswick to ACID[a]	302-298.5	45.0%	12.4%	16.3%	67.6%
5	ACID to Cow Creek	298.5-280	54.6%	66.0%	25.9%	12.7%
4	Cow Creek to Battle Creek	280-271	0.4%	12.8%	18.4%	9.2%
3	Battle Creek to RBDD	271-243	0.0%	4.9%	22.8%	4.3%
—	Downstream of RBDD	—	0.0%	4.0%	16.6%	6.2%

[a] ACID = Anderson-Cottonwood Irrigation District

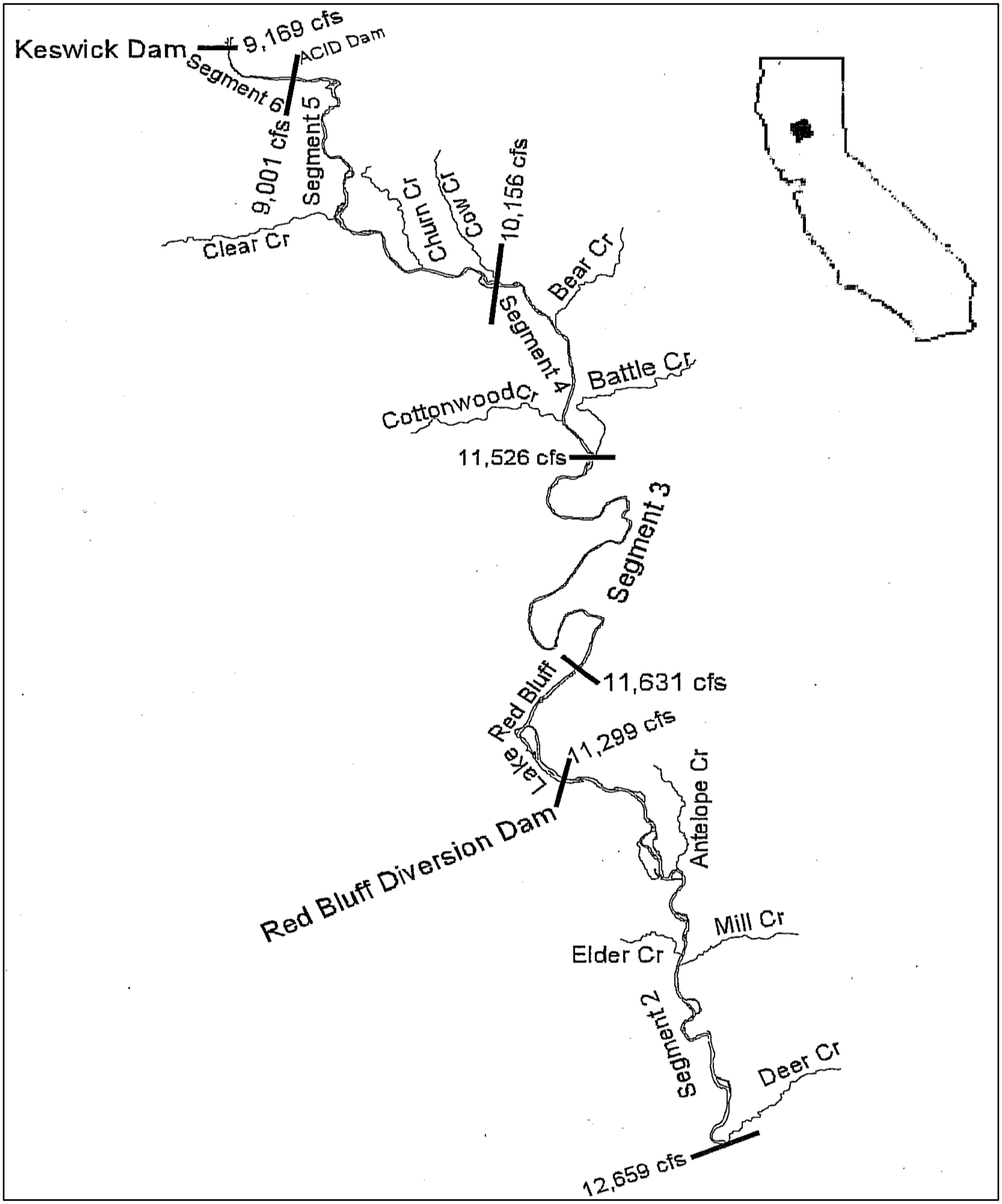

Figure A-1. Segments 2–6 of the Sacramento River Used in U.S. Fish and Wildlife Service Studies to Determine Spawning and Rearing Weighted Usable Area (WUA) (flows in the figure are the average flows at the upstream boundary of each segment for October 1974 to September 1993). Source: U.S. Fish and Wildlife Service 2003a.

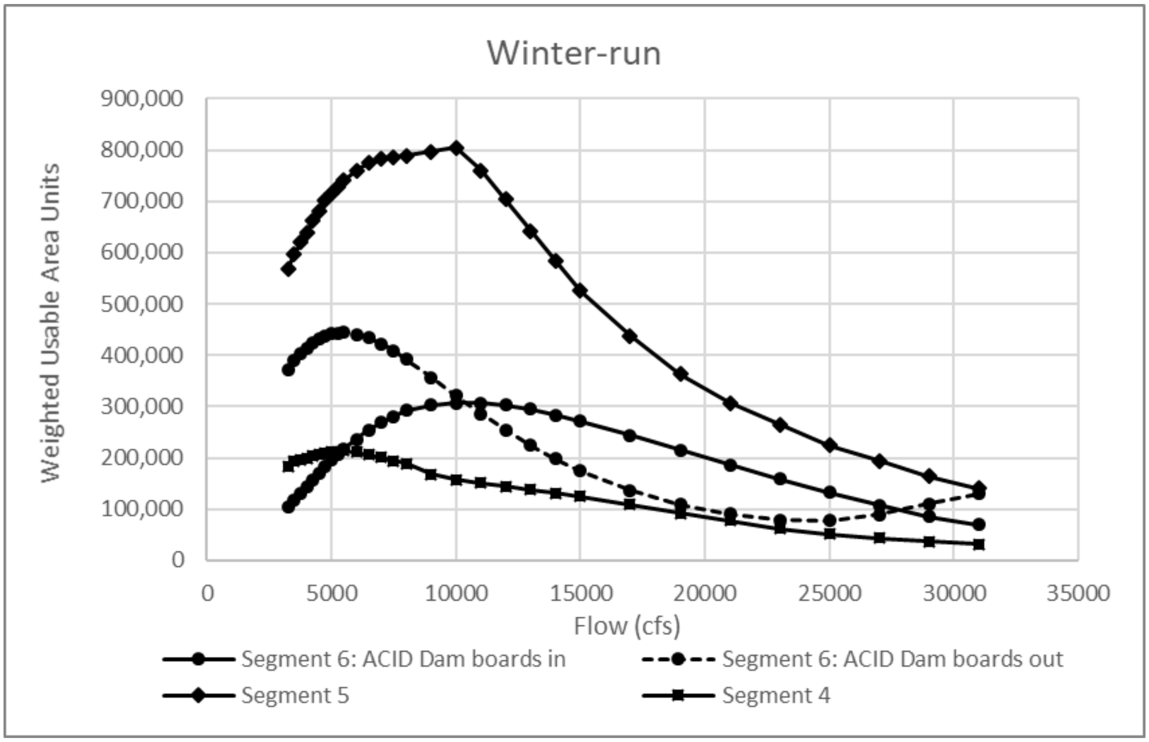

Figure A-2. Spawning WUA curves for Winter-Run Chinook Salmon in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

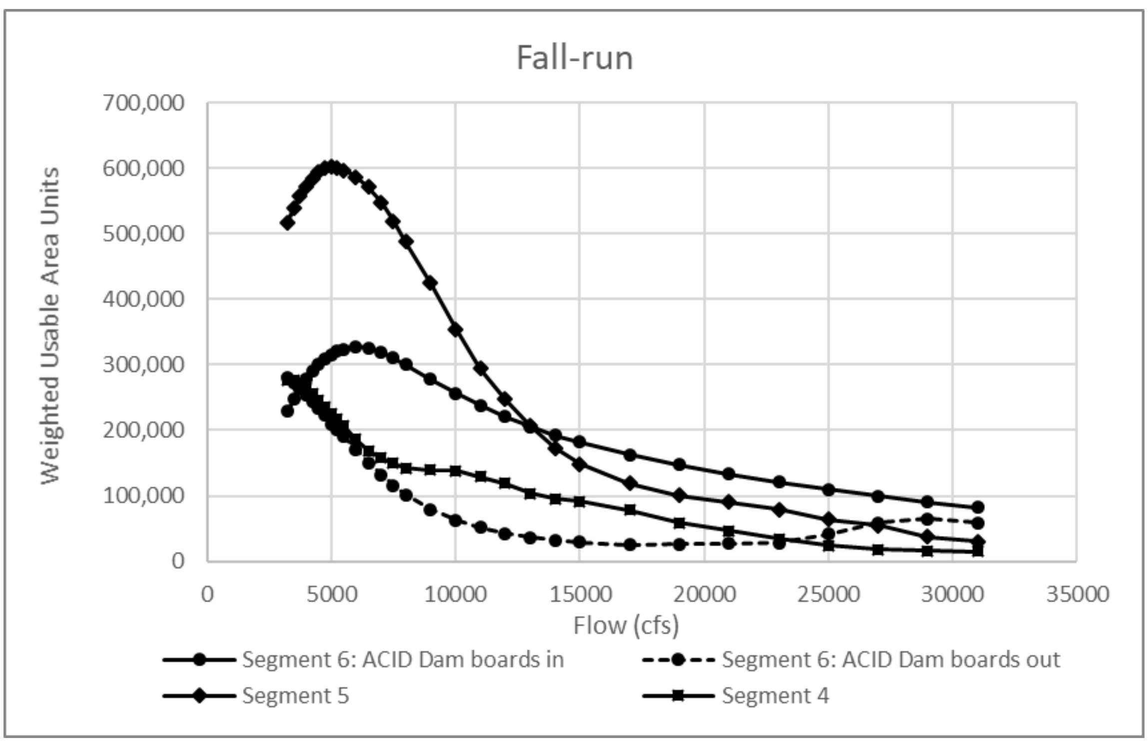

Figure A-3. Spawning WUA Curves for Fall-Run Chinook Salmon in the Sacramento River, Segments 4 to 6. The fall-run curves were also used to quantify spring-run Chinook salmon WUA, as discussed in the text. ACID = Anderson-Cottonwood Irrigation District.

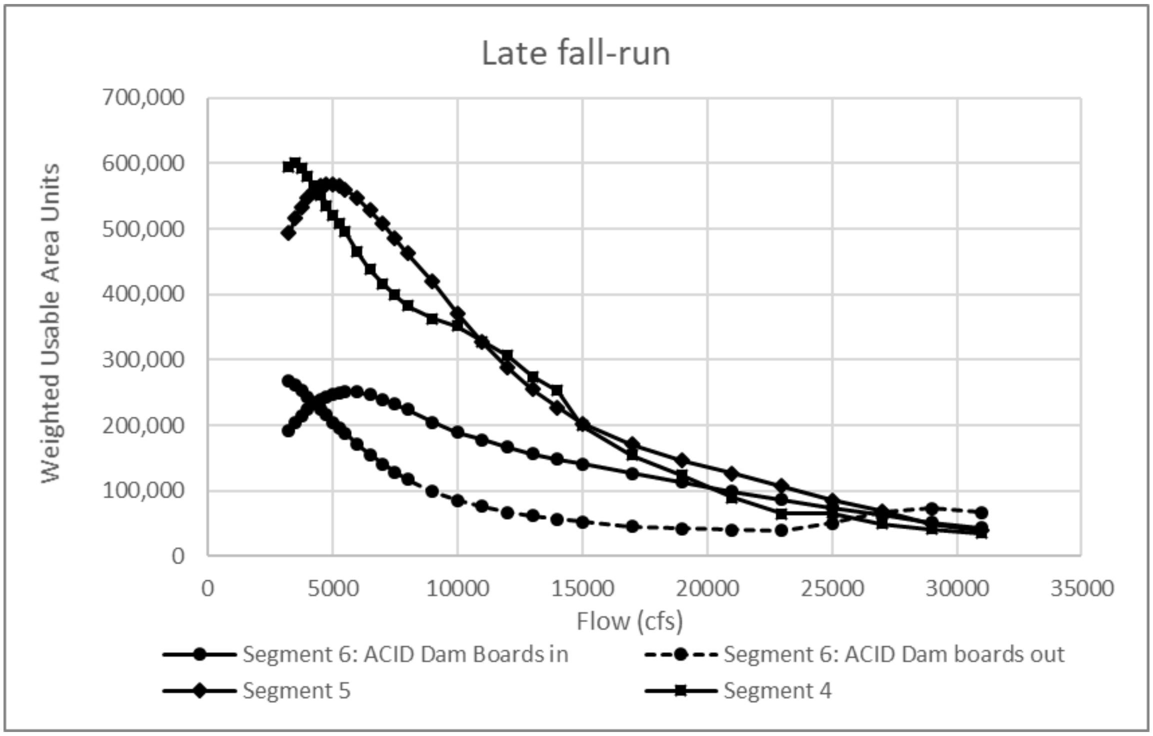

Figure A-4. Spawning WUA Curves for Late Fall–Run Chinook Salmon in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

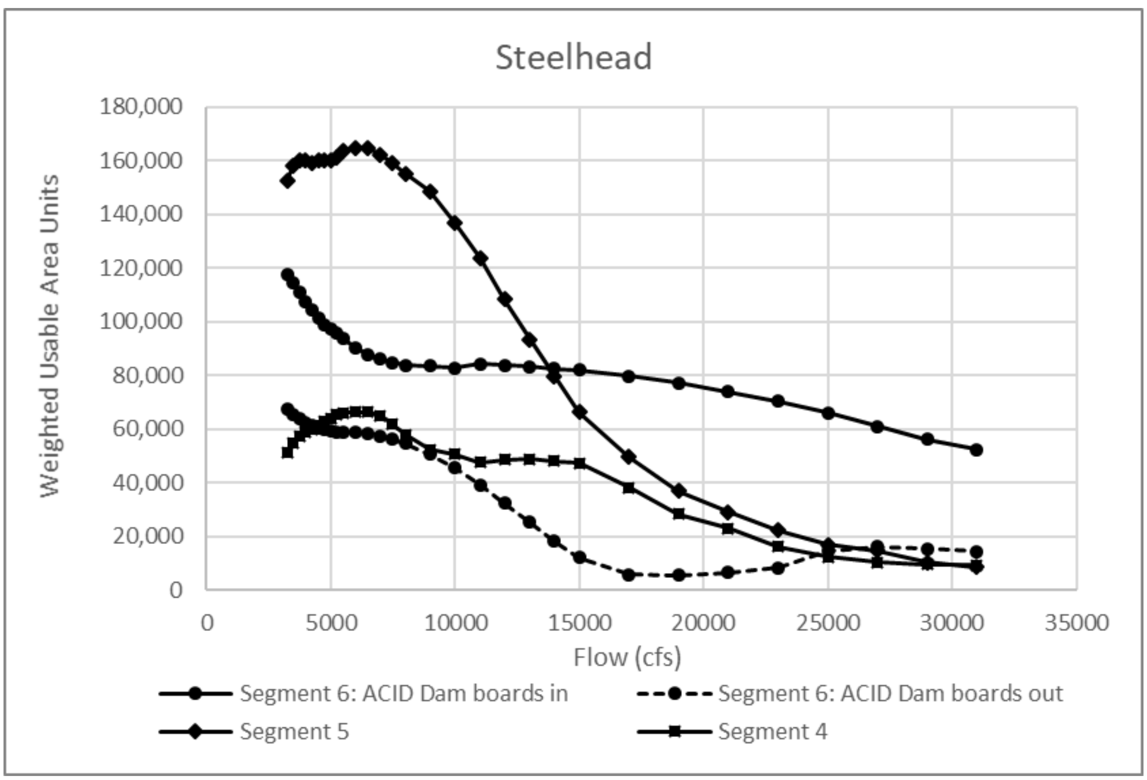

Figure A-5. Spawning WUA curves for Steelhead in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

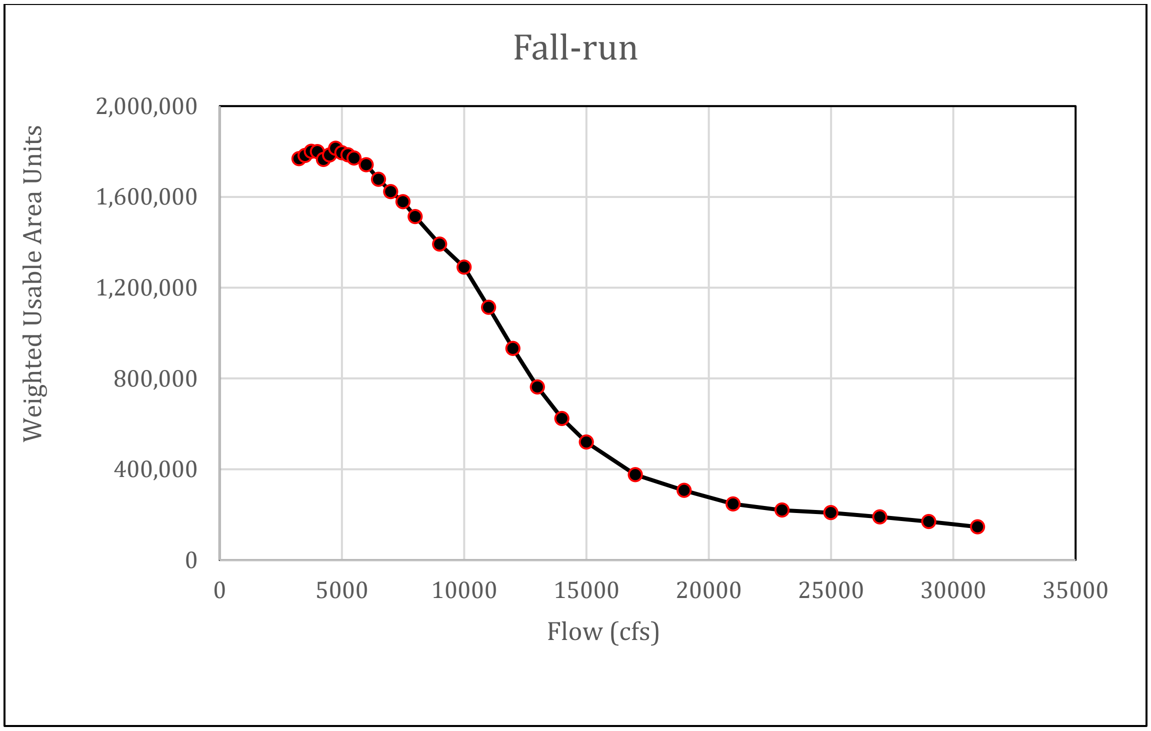

Figure A-6. Spawning WUA Curve for Fall–Run Chinook Salmon in the Sacramento River, Segment 3.

Because there are no spring-run Chinook salmon WUA curves in the USFWS documentation, the previous practice (described below) has been to use fall-run Chinook salmon WUA curves to model spring-run habitat. Two models that currently produce spawning WUA outputs for spring-run Chinook salmon, SALMOD and SacEFT (Sacramento River Ecological Flows Tool), derive the spring-run WUA results using the fall-run Chinook salmon spawning WUA curves as surrogates (Bartholow 2004; ESSA Technologies 2011). Mark Gard, who led the USFWS studies that produced the Sacramento River WUA curves, has endorsed this practice (Gard pers. comm.). However, this practice introduces uncertainty to the spring-run Chinook salmon results. Although fall-run spawning WUA curves were used as surrogates for spring-run spawning, CALSIM II flows for the months of spring-run spawning, not those of fall-run spawning, were used to compute the spring-run WUA results.

A potential limitation of the Sacramento River spawning WUA curves for steelhead is the use of previously obtained American River steelhead HSC used in developing the curves (U.S. Fish and Wildlife Service 2003b). 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).

A further limitation of the WUA curves presented above, as of all such habitat-based studies, is that they assume the channel characteristics of the river during the time of field data collection by USFWS (1995–1999), such as proportions of mesohabitat types, have remained in dynamic equilibrium to the present time and would continue to do so through the life of the Project. If the channel characteristics substantially change, the shape of the curve may no longer be applicable.

1.2 Salmonid Redd Dewatering

The redd dewatering analysis for the Sacramento River is based on the maximum reduction in flow from the initial flow, or spawning flow, that occurs over the duration of an egg cohort. The duration of a cohort in a redd includes egg incubation and alevin development to emergence from the gravel. Based on technical assistance from the National Marine Fisheries Service (NMFS), cohort duration was estimated as 3 months for the four Chinook salmon races (fall-run, spring-run, winter-run, and late fall–run) and steelhead. The minimum flow of the egg cohort period is referred to herein as the dewatering flow. If flows during the 3 months subsequent to spawning are all greater than the spawning flow, no dewatering is assumed to occur. The analysis assumes that in Sacramento River, a new egg cohort begins each month of the spawning period. The spawning period is assumed to end 3 months prior to the end of the full spawning and incubation period. The use of monthly time-step flow estimates likely underestimates redd dewatering rates, but this potential bias is expected to affect all alternative scenarios equally.

Table A-2 presents the spring-run spawning period and spawning distribution of Chinook salmon in the Sacramento River. The percentage of redds in the Sacramento River lost to dewatering was estimated using U.S. Fish and Wildlife (USFWS) (2006) tables that relate spawning and dewatering flows to percent reductions in species-specific spawning habitat weighted usable area (WUA) (see Section 1.1, *Salmonid Spawning Weighted Usable Area [WUA]*). These tables are reproduced in Table A-3 through Table A-10. USFWS (2006) developed the dewatering tables for winter-run, fall-run, and late fall–run Chinook salmon and steelhead but not for spring-run Chinook salmon. Therefore, as was done for the WUA curves, the fall-run salmon tables (Table A-5 and Table A-6) were used to estimate spring-run redd dewatering, but flows from the spring-run spawning period and spawning distribution (Table A-2) were used to look up the percent of spring-run redds dewatered. The validity of substituting the fall-run tables for spring-run is discussed above in Section 1.1, *Salmonid Spawning Weighted Usable Area (WUA)*. Separate tables were developed for periods when the Anderson-Cottonwood Irrigation District (ACID) Dam boards are installed (April through October) and for when the boards are out because installation of the boards affects water levels for some of the sampling transects used to produce the tables.

The field studies used for USFWS (2006) were conducted in the Sacramento River between Keswick Dam and Battle Creek at the same locations as the spawning WUA studies discussed in Attachment 1. USRDOM flow data are available for three locations in the Keswick Dam to Battle Creek river section: Keswick Dam (River Mile [RM] 302), the Sacramento River at Clear Creek (RM 289), and the Sacramento River at Battle Creek (RM 271). In contrast to the WUA studies, a single relationship for flows was developed for the entire river section, but the flows used to estimate redd dewatering in the current analysis were those that best matched the longitudinal distribution of the redds of the different salmon runs in the river as estimated from aerial redd surveys conducted by California Department of Fish and Wildlife from 2003 through 2019 (Table A-2). The redd distributions of steelhead in the Sacramento River are poorly known but are expected to be similar to that of spring-run (USFWS 2003a). Therefore, Keswick Dam flows were used for winter-run and late fall–run, Sacramento River at Clear Creek flows were used for spring-run and steelhead, and Sacramento River at Battle Creek flows were used for fall-run. Redd dewatering was computed for these flows under Alternatives 1 and 2 and the FEIS/R PA.

Table A-2. Average 2003–2019 Distributions of Spawning Redds of Chinook Salmon runs in the Sacramento River as Percent of Total, from Aerial Redd Surveys by California Department of Fish and Wildlife

Description	River Miles	Winter-run	Spring-run	Fall-run	Late fall–run
Keswick to ACID[a]	302–298	44.6%	12.8%	19.5%	71.3%
ACID to Highway 44	298–296	38.8%	33.9%	6.6%	5.2%
Highway 44 to Airport Rd.	296–284	15.7%	29.7%	14.7%	3.9%
Airport Rd. to Balls Ferry Br.	284–275	0.6%	11.1%	19.4%	8.9%
Balls Ferry Br. To Battle Creek	275–271	0.2%	7.4%	12.5%	5.9%
Battle Creek to Jellys Ferry Br.	271–266	0.1%	1.5%	15.2%	3.1%
Jellys Ferry Br. to Bend Bridge	266–257	0.1%	2.6%	8.0%	1.2%
Bend Bridge to RBDD[b]	257–242	0.0%	0.8%	4.2%	0.6%

[a] ACID = Anderson-Cottonwood Irrigation District

[b] RBDD = Red Bluff Diversion Dam

Table A-3. Percent Redd Dewatered Look-up Table for Winter-Run Chinook Salmon with ACID Dam Boards Out (the percent of redds dewatered are looked up at the intersection of the "Spawning Flow" columns and "Dewatering Flow" rows)

	Spawning Flow																
Dewatering Flow	3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
3,250	0.8	1.5	2.2	3	3.9	4.9	5.8	7	8.2	11	13.8	16.7	19.7	22.6	28.8	34.8	39.4
3,500	-	0.6	1	1.4	2	2.7	3.4	4.2	5.1	7.2	9.5	12.1	14.7	17.4	23.4	29.5	34.3
3,750	-	-	0.2	0.5	0.8	1.2	1.6	2.1	2.8	4.3	6.1	8.3	10.6	13.1	18.9	25.1	30
4,000	-	-	-	0.2	0.4	0.7	1	1.4	2	3.2	4.7	7.6	8.9	11.3	16.9	23.1	27.9
4,250	-	-	-	-	0.1	0.3	0.5	0.8	1.2	2.2	3.4	5.9	7	9.1	14.3	20.3	25
4,500	-	-	-	-	-	0.2	0.3	0.6	0.8	1.7	2.6	3.9	5.5	7.6	12.2	17.8	22.3
4,750	-	-	-	-	-	-	0.1	0.3	0.5	1.2	1.9	2.9	4.3	5.8	10.2	15.5	19.8
5,000	-	-	-	-	-	-	-	0.2	0.4	0.9	1.5	2.4	3.5	4.8	8.7	13.8	17.9
5,250	-	-	-	-	-	-	-	-	0.2	0.6	1.1	1.8	2.7	3.8	7	11.8	15.7
5,500	-	-	-	-	-	-	-	-	-	0.3	0.8	1.4	2.1	3	5.8	10.3	14.1
6,000	-	-	-	-	-	-	-	-	-	-	0.2	0.6	1.1	1.7	3.7	7.7	10.9
6,500	-	-	-	-	-	-	-	-	-	-	-	0.1	0.4	0.8	2.2	5.5	8.4
7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.4	1.2	3.5	5.6
7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.7	2.6	4.3
8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	1.9	3.2
9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	1.8
10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4
11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-3 (cont.)

		Spawning Flow											
Dewatering Flow		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
	3,250	43.2	46.2	49.1	51.4	55	57.6	59.9	62.6	64.7	68.9	73.3	77.3
	3,500	38.3	41.5	44.6	47.1	51	53.6	56.1	58.8	61.1	65.4	70.2	74.5
	3,750	34.1	37.5	40.6	43.2	47.2	50	52.5	55.4	57.7	62.3	67.4	72
	4,000	32.1	35.5	38.6	41.2	45.4	48.2	50.7	53.6	56.1	60.8	66.1	70.8
	4,250	29.1	32.5	35.5	38.2	42.4	45.3	47.8	50.8	53.4	58.3	63.8	68.8
	4,500	26.3	29.6	32.6	35.3	39.6	42.5	45.1	48.2	51	56	61.7	66.9
	4,750	23.7	26.9	29.9	32.7	37	40	42.7	45.9	48.8	54	59.9	65.4
	5,000	21.6	24.7	27.7	30.4	34.8	37.9	40.6	43.8	44.1	52.3	58.4	64.1
	5,250	19.4	22.4	25.4	28.2	32.7	35.8	38.6	41.9	45.2	50.7	57	62.8
	5,500	17.6	20.6	23.5	26.2	30.7	33.9	36.8	40.1	43.5	49	55.5	61.5
	6,000	14	16.7	19.4	22	26.4	29.6	32.6	35.9	39.6	45.4	52.2	58.5
	6,500	11.2	13.6	16.2	18.8	23.1	26.2	29.3	32.7	36.5	42.6	49.7	56.4
	7,000	7.9	10.1	12.4	14.8	19	22.3	25.6	29.2	33.3	39.7	47.2	54.1
	7,500	6.3	8.1	10.2	12.4	16.3	19.7	23	26.7	31	37.6	45.3	52.5
	8,000	4.9	6.6	8.6	10.5	14.3	17.7	21.1	25	29.3	36.1	44.1	51.4
	9,000	3	4.4	6	7.8	11.4	14.7	18.3	22.1	26.6	33.6	41.9	49.5
	10,000	1.3	2.3	3.7	5.3	8.6	11.8	15.4	19.3	23.8	30.6	39.7	47.5
	11,000	0.6	1.2	2.2	3.5	6.4	9.5	13.2	17.1	21.7	28.5	37.6	45.6
	12,000	-	0.2	0.9	1.8	4.1	7	10.5	14.7	19.3	26.3	35.7	43.8
	13,000	-	-	0.4	1	2.8	5.3	8.7	13	17.5	24.5	34	42.3
	14,000	-	-	-	0.4	1.6	4.2	7.5	11.8	16.2	23	32.6	41
	15,000	-	-	-	-	0.9	2.8	5.9	10.6	14.9	21.8	31.5	40.1
	17,000	-	-	-	-	-	1.3	3.9	7.8	11.8	18.3	28.1	36.9
	19,000	-	-	-	-	-	-	1.4	4	7.1	13	22.5	31.7
	21,000	-	-	-	-	-	-	-	1.3	3.6	9.2	18.7	28
	23,000	-	-	-	-	-	-	-	-	1.4	6.2	15.4	24.6
	25,000	-	-	-	-	-	-	-	-	-	0	8.3	15.2
	27,000	-	-	-	-	-	-	-	-	-	-	1.6	3.6
	29,000	-	-	-	-	-	-	-	-	-	-	-	0.6

Table A-4. Percent Redd Dewatered Look-up Table for Winter-Run Chinook Salmon with ACID Dam Boards In (the percent of redds dewatered are looked up at the intersection of the "Spawning Flow" columns and "Dewatering Flow" rows)

	Spawning Flow																
Dewatering Flow	3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
3,250	1.2	2.2	3.1	4.1	5.2	6.4	7.5	8.8	10.2	13	16	18.9	21.9	24.7	30.5	35.9	40.1
3,500	-	0.9	1.4	2	2.7	3.6	4.4	5.3	6.3	8.5	11	13.6	16.2	18.9	24.7	30.4	34.8
3,750	-	-	0.4	0.8	0.2	1.7	2.2	2.8	3.5	5.1	7	9.3	11.7	14.2	19.9	25.9	30.5
4,000	-	-	-	0.4	0.7	1.1	1.4	1.9	2.5	3.8	5.4	7.5	9.8	12.2	17.7	23.7	28.3
4,250	-	-	-	-	0.3	0.5	0.8	1.1	1.5	2.6	3.9	5.6	7.6	9.7	15	20.7	25.2
4,500	-	-	-	-	-	0.3	0.5	0.8	1.1	1.9	2.9	4.3	5.9	7.9	12.6	18.1	22.4
4,750	-	-	-	-	-	-	0.2	0.4	0.7	1.3	2.1	3.1	4.5	6.1	10.5	15.7	20
5,000	-	-	-	-	-	-	-	0.3	0.5	1	1.6	2.5	3.7	5	9	14	18.1
5,250	-	-	-	-	-	-	-	-	0.3	0.7	1.2	1.9	2.9	3.9	7.3	11.9	15.9
5,500	-	-	-	-	-	-	-	-	-	0.4	0.9	1.5	2.3	3.2	6.1	10.5	14.3
6,000	-	-	-	-	-	-	-	-	-	-	0.3	0.7	1.3	1.9	4	8	11.3
6,500	-	-	-	-	-	-	-	-	-	-	-	0.2	0.5	1	2.4	5.8	8.8
7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.5	1.4	3.8	6.1
7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.9	2.9	4.8
8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	2.1	3.7
9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.3	2.4
10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9
11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-4 (cont.)

		Spawning Flow											
		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
Dewatering Flow	3,250	43.4	46	48.4	50.3	53.5	56	58.9	62.4	65.4	69.5	73.7	77.2
	3,500	38.5	41.1	43.9	46.1	49.6	52.3	55.3	58.8	61.9	65.9	69.9	73.5
	3,750	34.4	37.3	40	42.4	46.1	49	52.1	55.7	58.8	62.8	66.7	70.2
	4,000	32.2	35.3	38	40.4	44.2	47.2	50.3	53.9	57	61.1	65	68.5
	4,250	29.2	32.2	34.9	37.4	41.4	44.4	47.5	51.2	54.4	58.5	62.3	65.7
	4,500	26.3	29.3	32	34.6	38.6	41.7	45	48.7	52	56	59.8	63.2
	4,750	23.7	26.7	29.5	32.1	36.3	39.5	42.8	46.6	49.9	53.9	57.6	61.1
	5,000	21.7	24.6	27.4	29.9	34.2	37.4	40.8	44.6	48	51.9	55.7	59.1
	5,250	19.5	22.5	25.2	27.9	32.2	35.6	39	42.8	46.4	50.3	54.1	57.5
	5,500	17.9	20.7	23.5	26.1	30.5	33.9	37.4	41.2	44.8	48.7	52.4	55.8
	6,000	14.5	17.1	19.8	22.3	26.8	30.2	33.7	37.5	41.3	45.1	48.8	52.2
	6,500	11.8	14.3	16.8	19.3	23.7	27.2	30.7	34.7	38.4	42.3	45.9	49.3
	7,000	8.7	10.9	13.3	15.7	20.1	23.7	27.5	31.5	35.4	39.4	42.9	46.2
	7,500	7	9	11.2	13.5	17.7	21.4	25.2	29.3	33.2	37.2	40.7	44
	8,000	5.7	7.6	9.7	11.8	15.9	19.6	23.5	27.7	31.6	35.7	39.1	42.4
	9,000	4	5.6	7.4	9.4	13.3	16.9	20.8	24.9	28.7	32.8	36.3	39.6
	10,000	2.2	3.6	5.2	7	10.5	14	17.7	18.6	25.4	28.9	32.6	35.8
	11,000	1.1	2	3.1	4.6	7.6	10.5	13.8	17.4	20.6	23.5	26.7	29.4
	12,000	-	0.5	1.2	2.2	4.2	6.4	9.1	12.1	14.6	16.8	19.1	21.1
	13,000	-	-	0.5	1.1	2.6	4.4	6.7	9.2	11.7	13.5	15.3	17
	14,000	-	-	-	0.5	1.7	3.5	5.5	8.2	10.1	11.7	13.4	14.9
	15,000	-	-	-	-	0.7	2.1	3.9	6.8	8.6	10.1	11.6	13
	17,000	-	-	-	-	-	0.9	2.5	4.9	6.5	7.7	9.1	10.4
	19,000	-	-	-	-	-	-	1	2.5	3.6	4.4	5.5	6.6
	21,000	-	-	-	-	-	-	-	0.9	1.6	2.1	3	4
	23,000	-	-	-	-	-	-	-	-	0.4	0.6	1.1	1.9
	25,000	-	-	-	-	-	-	-	-	-	0.3	0.9	1.6
	27,000	-	-	-	-	-	-	-	-	-	-	0.3	0.7
	29,000	-	-	-	-	-	-	-	-	-	-	-	0.3

Table A-5. Percent Redd Dewatered Look-up Table for Fall-Run Chinook Salmon (Also Used for the Spring-Run Chinook Salmon Analysis) with ACID Dam Boards Out (the percent of redds dewatered are looked up at the intersection of the "Spawning Flow" columns and "Dewatering Flow" rows)

	Spawning Flow																
Dewatering Flow	3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
3,250	1	2	3.4	4.8	6.6	8.4	10.6	12.9	15.3	20.6	26.2	31.7	37	41.5	50.2	56.3	60.4
3,500	-	1	2.1	3.2	4.6	6.2	8.1	10.1	12.2	17	22.2	27.4	29.2	37	45.9	52.8	57.3
3,750	-	-	0.9	1.6	2.6	3.9	5.5	7.3	9.2	13.6	18.4	23.1	28	32.4	41.5	48.7	53.6
4,000	-	-	-	0.9	1.7	2.8	4.1	5.7	7.3	11.4	15.8	20.3	24.8	29	38	45.7	50.7
4,250	-	-	-	-	0.8	1.6	2.7	4	5.4	8.9	13	17.2	21.6	25.8	34.9	42.8	48
4,500	-	-	-	-	-	0.8	1.7	2.8	4	6.9	10.4	14.2	18.2	22.1	30.9	38.8	44.2
4,750	-	-	-	-	-	-	0.8	1.6	2.5	4.8	7.6	10.8	14.2	17.6	25.8	33.2	38.8
5,000	-	-	-	-	-	-	-	0.7	1.3	3.2	5.6	8.6	11.6	14.7	22.6	30.2	36
5,250	-	-	-	-	-	-	-	-	0.7	2.1	4.2	6.8	9.4	12.3	19.8	27.2	33.1
5,500	-	-	-	-	-	-	-	-	-	1.4	3.2	5.4	7.7	10.3	17.6	24.9	31
6,000	-	-	-	-	-	-	-	-	-	-	1.2	2.8	4.6	6.4	12.9	19.7	25.8
6,500	-	-	-	-	-	-	-	-	-	-	-	1.3	2.6	4.2	9.8	15.6	21.1
7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.9	2	6.6	11.8	17.3
7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	4.4	9.1	14.1
8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.6	6.6	11.5
9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	5.5
10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9
11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-5 (cont.)

	Spawning Flow											
Dewatering Flow	12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
3,250	62.9	63.7	65.3	66.4	66.8	65.7	67.8	71.3	74.5	80.4	87.3	92
3,500	60.1	61.1	63	64.2	64.9	63.8	66	69.5	73	79.1	86.2	91
3,750	56.9	58.3	60.3	61.8	62.7	61.7	64	67.7	71.4	77.7	84.9	89.6
4,000	54.3	55.9	58.2	59.9	61.2	60.2	62.7	66.5	70.4	77.1	84.1	88.8
4,250	51.8	53.6	56	58.1	59.6	58.8	61.3	65	68.5	75.7	83.1	87.8
4,500	48.3	50.2	52.8	55.1	57.1	56.4	59	62.7	66.2	73.3	81.8	86.5
4,750	43.3	45.6	48.6	51.4	54	53.7	56.6	60.4	64.5	71.7	80.3	85
5,000	40.6	43	46.1	49.1	52.2	52.2	55.2	59.1	63.3	70.6	79.4	84.1
5,250	37.7	40.2	43.5	46.5	50	50.2	53.5	57.4	60.7	68	78.2	83
5,500	35.8	38.4	41.7	44.8	48.3	48.8	52.3	56.1	60.1	67.5	77.3	82
6,000	30.9	33.8	37.3	40.6	45	45.8	49.5	53.2	57.2	65	75.4	80
6,500	26.5	29.2	32.7	36.1	41	42.4	46.5	50.4	54.8	63	73.3	77.7
7,000	22.8	25.8	29.3	32.9	38.3	40	44.4	48.3	52.9	61.3	71.8	76.1
7,500	20	23.2	26.9	30.7	36.4	38.2	42.8	46.8	51.9	60.5	70.9	75.3
8,000	17.2	20.9	24.9	28.9	34.9	36.6	41.3	45.4	50.5	59.3	70.2	74.7
9,000	10.6	14.4	18.4	22.5	29.2	31.9	37.4	41.8	47.7	57	68.2	72.6
10,000	4.5	7.7	12	16.4	23.5	26.9	33	38.5	44.5	54.1	65.9	70.5
11,000	2.7	5.3	9	13.6	21.4	24.8	30.2	35.3	41.8	51.6	63.7	68.4
12,000	-	1.6	4.7	9	16.8	20.6	27	32.9	39.8	50	62.3	67.2
13,000	-	-	1.6	4.8	12.2	16.9	24.4	31.3	38.1	48.4	60.8	65.9
14,000	-	-	-	2.6	9.5	14.8	22.1	28.9	36.2	46.8	59.5	64.7
15,000	-	-	-	-	5.3	11.1	18.5	26.2	33.5	44.6	57.6	63.1
17,000	-	-	-	-	-	4.1	11.3	18.5	26.1	37.8	51.5	57.9
19,000	-	-	-	-	-	-	4.6	10.8	18.8	30.4	44.2	51.1
21,000	-	-	-	-	-	-	-	4.2	11.7	23.9	38.4	46.3
23,000	-	-	-	-	-	-	-	-	6.7	17.8	31.2	38.9
25,000	-	-	-	-	-	-	-	-	-	2.3	6.4	10.7
27,000	-	-	-	-	-	-	-	-	-	-	1.8	5.3
29,000	-	-	-	-	-	-	-	-	-	-	-	2.2

Table A-6. Percent Redd Dewatered Look-up Table for Fall-Run Chinook Salmon (Also Used for the Spring-Run Chinook Salmon Analysis) with ACID Dam Boards In (the percent of redds dewatered are looked up at the intersection of the "Spawning Flow" columns and "Dewatering Flow" rows)

Dewatering Flow	Spawning Flow																
	3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
3,250	1.0	2.0	3.3	4.7	6.2	7.8	9.7	11.7	13.6	17.8	22.2	26.3	30.2	33.4	39.5	43.5	46.0
3,500	-	1.0	2.0	3.1	4.4	5.7	7.4	9.2	10.9	14.8	18.8	22.8	23.9	29.8	36.2	40.8	43.6
3,750	-	-	0.9	1.6	2.5	3.6	5.1	6.7	8.3	11.9	15.6	19.3	23.0	26.2	32.8	37.7	40.9
4,000	-	-	-	0.9	1.7	2.6	3.8	5.3	6.6	10.0	13.5	16.9	20.4	23.5	30.1	35.4	38.7
4,250	-	-	-	-	0.8	1.5	2.5	3.7	5.0	7.8	11.1	14.4	17.8	20.9	27.5	33.1	36.6
4,500	-	-	-	-	-	0.8	1.6	2.6	3.7	6.0	8.9	11.9	15.0	17.8	24.4	29.9	33.6
4,750	-	-	-	-	-	-	0.8	1.6	2.4	4.3	6.6	9.1	11.8	14.3	20.3	25.7	29.5
5,000	-	-	-	-	-	-	-	0.7	1.3	2.9	4.9	7.2	9.6	11.9	17.7	23.1	26.9
5,250	-	-	-	-	-	-	-	-	0.6	1.9	3.5	5.6	7.7	9.7	15.3	20.4	24.1
5,500	-	-	-	-	-	-	-	-	-	1.2	2.7	4.4	6.2	8.1	13.5	18.5	22.3
6,000	-	-	-	-	-	-	-	-	-		1.0	2.3	3.7	5.1	9.8	14.5	18.3
6,500	-	-	-	-	-	-	-	-	-	-	-	1.1	2.1	3.3	7.4	11.5	15.0
7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.7	1.6	5.0	8.6	12.1
7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	3.4	6.7	9.9
8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	4.9	8.1
9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	3.8
10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2
11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-6 (cont.)

	Spawning Flow											
Dewatering Flow	12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
3,250	47.6	48.0	49.3	50.5	52.0	52.5	55.1	57.6	57.4	59.0	61.1	63.3
3,500	45.5	46.0	47.4	48.8	50.4	50.8	53.4	55.9	55.7	57.2	59.3	61.6
3,750	43.1	43.9	45.5	47.0	48.7	49.1	51.8	54.3	54.1	55.6	57.6	59.8
4,000	41.2	42.2	43.8	45.5	47.5	47.9	50.5	53.1	52.9	54.5	56.3	58.5
4,250	39.2	4.0	42.1	43.9	46.0	46.4	49.0	51.3	50.8	52.5	54.4	56.5
4,500	36.4	37.6	39.4	41.4	43.6	43.9	46.4	48.7	47.8	49.1	51.6	53.7
4,750	32.6	34.0	36.1	38.3	40.8	41.1	43.6	45.7	44.9	46.0	48.3	50.3
5,000	30.0	31.2	33.2	35.3	37.6	37.6	39.8	41.7	40.5	41.3	43.2	45.1
5,250	27.1	28.2	29.9	31.8	33.9	33.5	35.4	36.8	34.6	35.0	37.4	39.0
5,500	25.3	26.4	28.0	29.7	31.5	31.0	32.7	33.8	31.7	31.9	33.6	35.1
6,000	21.5	22.7	24.4	26.2	28.2	27.5	29.0	29.8	27.1	27.1	28.7	29.8
6,500	18.3	19.5	21.1	23.0	25.2	24.7	26.4	27.1	24.4	24.2	25.3	26.3
7,000	15.6	17.0	18.7	20.7	23.2	22.8	24.5	25.1	22.4	22.1	23.2	24.0
7,500	13.7	15.3	17.1	19.3	21.9	21.5	23.3	23.9	21.3	21.0	21.9	22.7
8,000	11.8	13.7	15.7	17.9	20.7	20.2	21.9	22.4	19.8	19.4	20.5	21.4
9,000	7.2	9.2	11.3	13.6	16.8	16.8	18.9	19.6	17.2	16.8	17.9	18.5
10,000	3.0	4.9	7.2	9.8	13.3	13.8	16.2	17.4	14.9	14.5	15.9	16.7
11,000	1.9	3.4	5.4	8.2	12.1	12.2	14.5	15.6	13.3	12.8	14.1	15.0
12,000	-	1.0	2.8	5.4	9.4	10.0	12.5	14.0	11.9	11.5	12.9	13.9
13,000	-	-	1.0	3.0	6.9	8.1	11.1	13.1	11.0	10.7	12.1	13.1
14,000	-	-	-	1.8	5.4	7.0	9.8	11.8	10.0	9.9	11.4	12.4
15,000	-	-	-	-	2.8	4.8	7.7	10.2	8.6	8.7	10.4	11.5
17,000	-	-	-	-	-	1.8	5.0	7.5	6.5	6.8	8.5	10.0
19,000	-	-	-	-	-	-	2.3	4.8	4.6	5.0	6.9	8.4
21,000	-	-	-	-	-	-	-	1.9	2.0	2.6	4.7	6.6
23,000	-	-	-	-	-	-	-	-	0.7	1.6	3.6	5.7
25,000	-	-	-	-	-	-	-	-	-	1.2	3.0	5.0
27,000	-	-	-	-	-	-	-	-	-	-	1.2	3.3
29,000	-	-	-	-	-	-	-	-	-	-	-	1.5

Table A-7. Percent Redd Dewatered Look-up Table for Late Fall–Run Chinook Salmon with ACID Dam Boards Out (the percent of redds dewatered are looked up at the intersection of the "Spawning Flow" columns and "Dewatering Flow" rows)

	Spawning Flow															
Dewatering Flow	3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000
3,250	0.9	1.5	2.6	3.6	4.9	6.3	8	9.8	11.7	15.9	20.1	24.1	28	31.5	37.8	42.7
3,500	-	0.9	1.6	2.4	3.4	4.5	6	7.6	9.3	13.1	17.1	21	24.9	28.2	35	40.2
3,750	-	-	0.8	1.1	2	2.9	4.1	5.5	7	10.5	14.2	17.8	21.6	25	32	37.5
4,000	-	-	-	0.7	1.2	2	3	4.2	5.5	8.8	12.1	15.6	19.2	22.5	29.5	35.3
4,250	-	-	-	-	0.6	1.1	1.9	3	4.1	6.9	10	13.4	16.9	20.1	27.3	33.3
4,500	-	-	-	-	-	0.6	1.2	2.1	3.1	5.5	8.3	11.3	14.6	17.7	24.8	30.8
4,750	-	-	-	-	-	-	0.6	1.3	2	4	6.3	9	11.8	14.7	21.5	27.6
5,000	-	-	-	-	-	-	-	0.5	1	2.6	4.6	7	9.6	12.2	18.9	25.2
5,250	-	-	-	-	-	-	-	-	0.5	1.8	3.5	5.6	7.9	10.4	16.9	23.1
5,500	-	-	-	-	-	-	-	-	-	1.3	2.7	4.6	6.7	8.9	15.3	21.5
6,000	-	-	-	-	-	-	-	-	-	-	0.9	2.3	3.8	5.5	11.2	17.1
6,500	-	-	-	-	-	-	-	-	-	-	-	1	2.1	3.5	8.3	13.4
7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.8	1.8	5.9	10.4
7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	3.9	7.9
8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	5.5
9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7
10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-7 (cont.)

		Spawning Flow												
		11,000	12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
Dewatering Flow	3,250	45.6	47.8	48.9	50.6	52.6	55.5	57.5	61.6	67.3	73.5	79.8	86.6	91.1
	3,500	43.3	45.6	46.8	48.6	50.7	53.6	55.5	59.6	65.4	71.5	78.3	85.4	90.1
	3,750	40.7	43.3	44.6	46.5	48.6	51.5	53.3	57.4	63.3	69.6	76.6	83.9	88.5
	4,000	38.7	41.5	42.8	44.8	46.9	49.9	51.8	55.9	61.8	68.3	75.6	82.9	87.6
	4,250	36.8	39.7	41.1	43.1	45.3	48.4	50.2	54.3	60.2	66.6	74.2	81.7	86.5
	4,500	34.5	37.5	38.9	41	43.3	46.5	48.3	52.4	58.1	64.5	72.2	80.2	85
	4,750	31.5	34.6	36.6	38.5	40.9	44.2	46	50.1	55.3	62.4	70.2	78.4	83.3
	5,000	29.3	32.6	34.3	36.7	39.1	42.6	44.5	48.6	54.2	60.8	68.9	77.3	82.3
	5,250	27.4	30.8	32.5	34.9	37.5	41.1	42.9	47	52.6	58.9	67	76	81.1
	5,500	25.8	29.4	31.2	33.2	36.1	39.7	41.6	45.7	51.2	57.7	65.9	74.9	80
	6,000	21.7	25.5	27.5	29.9	32.6	36.4	38.3	42.3	47.7	54.1	62.7	72.1	77.3
	6,500	17.6	21.7	23.8	26.4	29.1	33.1	35.1	39.2	44.5	50.9	59.7	69.1	74
	7,000	14.4	18.6	20.7	23.2	26.1	30.3	32.4	36.4	41.6	48	57	66.6	71.6
	7,500	11.5	16	18.4	21.1	24	28.3	30.4	34.5	39.6	46.3	55.4	65.2	70.3
	8,000	8.9	13.3	16	18.9	21.9	26.3	28.3	32.5	37.6	44.3	53.7	63.7	69
	9,000	3.9	7.8	10.5	13.6	16.7	21.5	23.7	28.1	33.2	40.2	50	60.5	65.9
	10,000	1.2	3.1	5.6	8.8	12.1	17	19.6	24	29.8	36.7	46.7	57.4	62.9
	11,000	-	2.3	4.1	6.7	10	15.2	17.4	21.8	26.9	34	44.2	55.1	60.7
	12,000	-	-	1.2	3.4	6.5	11.7	14.2	18.7	24.5	31.8	42.2	53.3	58.9
	13,000	-	-	-	1.1	3.4	8.3	11.3	16.2	22.7	29.9	40.3	51.5	57.2
	14,000	-	-	-	-	1.9	6.4	9.8	14.6	21.1	28.3	38.8	50.1	55.9
	15,000	-	-	-	-	-	3.3	6.7	11.7	18.8	26	36.7	48.2	54.1
	17,000	-	-	-	-	-	-	3.5	7	13.1	20.3	31.1	42.9	49.1
	19,000	-	-	-	-	-	-	-	2.5	7.1	14.4	25.2	36.9	43.2
	21,000	-	-	-	-	-	-	-	-	3.1	9.3	20	32.1	39.1
	23,000	-	-	-	-	-	-	-	-	-	5.1	14.5	25.7	32.6
	25,000	-	-	-	-	-	-	-	-	-	-	1.8	5.2	9.4
	27,000	-	-	-	-	-	-	-	-	-	-	-	1.4	4.4
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	1.6

Table A-8. Percent Redd Dewatered Look-up Table for Late Fall–Run Chinook Salmon with ACID Dam Boards In (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)

	Spawning Flow																
Dewatering Flow	3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
3,250	0.9	1.7	2.6	3.7	4.9	6.2	7.8	9.5	11.3	15.1	18.9	22.5	26	29.1	34.9	39.4	42.3
3,500	-	0.9	1.6	2.4	3.4	4.5	5.9	7.4	9	12.5	16.1	19.6	23.1	26.1	32.3	37.1	40.1
3,750	-	-	0.8	1.1	2	2.9	4.1	5.5	6.9	10.1	13.4	16.7	20.1	23.1	29.5	34.6	37.8
4,000	-	-	-	0.7	1.3	2	3	4.2	5.4	8.4	11.5	14.7	17.9	20.9	27.3	32.7	36
4,250	-	-	-	-	0.7	1.2	2	3	4.1	6.7	9.6	12.6	15.8	18.7	25.2	30.8	34.2
4,500	-	-	-	-	-	0.6	1.3	2.1	3.1	5.3	7.9	10.7	13.6	16.4	22.9	28.4	32
4,750	-	-	-	-	-	-	0.6	1.3	2.1	3.9	6	8.5	11.1	13.7	19.9	25.4	29.1
5,000	-	-	-	-	-	-	-	0.6	1.1	2.6	4.4	6.6	8.9	11.3	17.4	22.9	26.7
5,250	-	-	-	-	-	-	-	-	0.5	1.7	3.3	5.2	7.3	9.5	15.3	20.7	24.4
5,500	-	-	-	-	-	-	-	-	-	1.2	2.5	4.3	6.1	8.1	13.7	19.1	22.8
6,000	-	-	-	-	-	-	-	-	-	-	0.9	2.1	3.4	5	10	15.1	19
6,500	-	-	-	-	-	-	-	-	-	-	-	0.9	1.9	3.1	7.4	11.8	15.4
7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.8	1.6	5.2	9.1	12.5
7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	3.5	6.9	9.9
8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4.9	7.7
9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	3.3
10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1
11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-8 (cont.)

		Spawning Flow											
Dewatering Flow		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
	3,250	44.6	46	47.9	50.1	53.4	55.4	59.2	63.7	66.8	69.7	74.4	79.1
	3,500	42.6	44	46	48.2	51.5	53.5	57.2	61.8	64.6	67.8	72.6	77.3
	3,750	40.5	42	44	46.3	49.6	51.5	55.1	59.7	62.6	65.6	70.4	75.1
	4,000	38.8	40.4	42.4	44.8	48.1	50	53.6	58.3	61.1	64.3	68.9	73.5
	4,250	37.1	38.7	40.8	43.2	46.5	48.3	51.9	56.4	59	62.2	66.9	71.5
	4,500	34.9	36.5	38.6	41.1	44.4	46.1	49.6	53.9	56.3	59.2	64.1	68.7
	4,750	32.2	33.8	36	38.5	41.9	43.5	46.8	50.6	53.2	55.9	60.6	65.1
	5,000	29.8	31.4	33.5	35.9	39.1	40.5	43.6	47.5	49.3	51.9	56.3	60.6
	5,250	27.5	28.9	30.9	33.2	36.3	37.3	40.2	43.6	44.8	46.9	51.4	55.5
	5,500	25.9	27.3	28.9	31.4	34.2	35.1	37.8	41	42.1	43.9	48	51.9
	6,000	22.2	23.7	25.6	27.7	30.6	31.3	33.7	36.4	37	38.6	42.4	45.9
	6,500	18.8	20.3	22.3	24.5	27.4	28.1	30.5	33	33.3	34.5	37.8	40.8
	7,000	16	17.6	19.6	21.8	24.9	25.5	27.8	30.2	30.2	31.1	34.3	37.1
	7,500	13.7	15.5	17.6	20	23.1	23.8	26	28.3	28.4	29.2	32.2	35.2
	8,000	11.4	13.5	15.7	18.1	21.3	21.8	24.1	26.3	26.2	27	30.1	33.1
	9,000	6.6	8.7	11.1	13.6	17	17.7	20.1	22.2	22.1	22.8	25.8	28.7
	10,000	2.7	4.6	7	9.8	13.3	14.3	16.7	19.3	19	19.4	22.3	25.1
	11,000	2	3.4	5.4	8.1	12	12.6	16.6	17	16.7	17	19.9	22.6
	12,000	-	0.9	2.7	5.3	9.1	10	12.3	15	14.7	14.9	17.7	20.5
	13,000	-	-	0.9	2.8	6.5	7.8	10.4	13.7	13.3	13.6	16.3	19
	14,000	-	-	-	1.7	5.1	6.7	9.2	12.4	12.1	12.4	15	17.7
	15,000	-	-	-	-	2.5	4.2	6.9	10.6	10.3	10.8	13.3	16
	17,000	-	-	-	-	-	2.4	4.3	7.5	7.7	8.2	10.6	13.2
	19,000	-	-	-	-	-	-	1.7	4.2	5.1	5.8	8.1	10.5
	21,000	-	-	-	-	-	-	-	2	2.7	3.5	5.8	8.4
	23,000	-	-	-	-	-	-	-	-	1.1	2.1	4.3	7.4
	25,000	-	-	-	-	-	-	-	-	-	1.3	3.4	6.4
	27,000	-	-	-	-	-	-	-	-	-	-	1.3	4
	29,000	-	-	-	-	-	-	-	-	-	-	-	1.5

Table A-9. Percent Redd Dewatered Look-up Table for CCV Steelhead with ACID Dam Boards Out (the percent of redds dewatered are looked up at the intersection of the "Spawning Flow" columns and "Dewatering Flow" rows)

	Spawning Flow																
Dewatering Flow	3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
3,250	1.2	2.6	3.7	4.9	6.8	8.9	10.9	13.3	15.7	19.9	23.4	26.2	28.5	31.1	37.2	43.5	49.8
3,500	-	1.6	2.4	3.2	4.7	6.4	8	10.2	12.4	16.5	19.9	22.8	25.1	27.7	33.8	40.1	46.2
3,750	-	-	0.5	1.2	2.5	3.8	5.3	7.3	9.1	12.7	15.9	18.9	21.1	23.9	30.3	36.5	42.4
4,000	-	-	-	0.8	1.9	2.9	4	5.7	7.3	10.5	13.4	16	18.2	20.8	27.1	33.5	39.5
4,250	-	-	-	-	1.1	2.2	3.2	4.8	6.2	9.3	12	14.6	16.7	19.1	25.3	31.5	37.3
4,500	-	-	-	-	-	1.1	1.9	3.3	4.5	7.1	9.6	12	14	16.3	22.4	28.5	34.2
4,750	-	-	-	-	-	-	0.8	2	2.8	5.1	7.4	9.7	11.6	13.8	19.8	25.8	31.4
5,000	-	-	-	-	-	-	-	1.1	1.8	3.7	5.8	8	9.7	11.8	17.7	23.8	26.6
5,250	-	-	-	-	-	-	-	-	0.8	2.4	4.2	6.2	7.7	9.4	14.9	21.1	26.8
5,500	-	-	-	-	-	-	-	-	-	1.5	3.2	5	6.1	7.8	13	19.1	24.6
6,000	-	-	-	-	-	-	-	-	-	-	1.3	2.7	3.8	5.3	10.2	15.9	21.2
6,500	-	-	-	-	-	-	-	-	-	-	-	2.8	1.3	2.6	6.9	12.1	17.2
7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.5	1.3	4.8	9.4	14.3
7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	3.8	8.1	12.7
8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.8	6.7	10.9
9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.6	5.3
10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9
11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-9 (cont.)

	Spawning Flow												
Dewatering Flow		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
	3,250	56.6	63.7	70.7	76.8	84.2	86.5	88.5	89.1	91	91.3	93.1	94.7
	3,500	52.9	60	67.1	73.6	81.4	84	86.4	87.4	89.9	90.5	92.3	94
	3,750	49	55.9	63	69.7	77.8	80.9	84.3	85.9	88.9	89.7	91.7	93.8
	4,000	46	52.9	60	66.8	74.9	78.2	82.1	84.1	88.1	89.4	91.6	93.7
	4,250	43.6	50.3	57.3	64.1	72.3	75.6	79.8	82	86.8	88.3	91	93.3
	4,500	40.3	46.9	53.7	60.5	69.4	73.1	77.4	79.4	84.3	86.3	89.7	92.2
	4,750	37.3	43.7	50.2	57	66.1	70.1	74.6	77	83.1	85.5	89.2	91.9
	5,000	35.4	41.7	48.2	55	64.1	68.2	72.8	75.2	82.1	85	88.8	91.6
	5,250	32.6	38.7	45.2	51.9	61.3	66.1	70.8	73.2	79.3	82.9	88.1	90.8
	5,500	30.1	36	42.2	48.8	58.2	63.6	69.2	71.9	78.2	82.1	87.2	89.9
	6,000	26.6	32.3	38.4	44.7	53.8	58.8	64.6	67.7	74.9	79.2	84.3	86.8
	6,500	22.9	28.7	34.5	40.4	48.6	52.6	58.2	61	69.2	74	79.2	81.4
	7,000	19.9	25.7	31.6	37.5	46.2	50.2	56	59.1	67.5	72.2	77.3	79.4
	7,500	18.2	24.1	30	35.8	44.4	48.2	54.1	57.3	66.2	71.1	76	78.2
	8,000	16.3	22	27.7	33.4	42.1	46.4	52.7	55.9	64.6	69.5	75	77.2
	9,000	9.6	14.5	19.7	25.7	35.2	40.4	47.2	50.7	60.2	65.3	71.1	73.5
	10,000	4.6	8.9	13.4	18.9	27.7	33.7	41.4	45.6	55.7	61.7	68.3	70.8
	11,000	2.8	6.8	10.9	15.7	24.3	29.5	37.4	42	52.8	58.7	65.1	67.7
	12,000	-	3.1	6.3	10.4	18.9	25.1	33.9	38.9	50.3	56.5	63	65.7
	13,000	-	-	5.4	5.4	12.7	19.7	29.1	36.4	48	54.6	61.2	64.1
	14,000	-	-	-	3	9.5	15.6	25.1	32.3	44.5	51.7	58.3	61.5
	15,000	-	-	-	-	5	10.9	20.7	29.5	42.1	49.3	55.8	58.8
	17,000	-	-	-	-	-	4.8	13.4	20.8	34.1	42.5	49.7	53
	19,000	-	-	-	-	-	-	7.3	13.3	26.4	35.7	43.1	46.6
	21,000	-	-	-	-	-	-	-	6.8	20	29.2	36.3	39.9
	23,000	-	-	-	-	-	-	-	-	13.5	20.5	26.9	31.2
	25,000	-	-	-	-	-	-	-	-	-	4	9.3	14.6
	27,000	-	-	-	-	-	-	-	-	-	-	3.9	9.2
	29,000	-	-	-	-	-	-	-	-	-	-	-	5.1

Table A-10. Percent Redd Dewatered Look-up Table for CCV Steelhead with ACID Dam Boards In (the percent of redds dewatered are looked up at the intersection of the "Spawning Flow" columns and "Dewatering Flow" rows)

		Spawning Flow																
Dewatering Flow		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
	3,250	1.1	2.3	3.3	4.7	6.5	8.7	11	13.6	16	20.3	23.9	26.9	29.3	31.8	37.6	42.3	46.7
	3,500	-	1.4	2.2	3.2	4.6	6.4	8.4	10.8	13	17.1	20.6	23.7	26.1	28.6	34.5	39.2	43.5
	3,750	-	-	0.6	1.3	2.6	4.1	5.9	8.1	10	13.6	17	20	22.5	25.1	31.2	35.9	40.3
	4,000	-	-	-	0.9	2.1	3.3	4.7	6.7	8.3	11.6	14.6	17.4	19.7	22.2	28.3	33.3	37.8
	4,250	-	-	-	-	1.3	2.6	4	5.8	7.2	10.3	13.2	15.9	18.1	20.5	26.5	31.3	35.7
	4,500	-	-	-	-	-	1.4	2.7	4.2	5.5	8.2	10.8	13.3	15.4	17.6	23.6	28.4	32.7
	4,750	-	-	-	-	-	-	1.5	2.9	3.8	6.2	8.5	11	12.9	15.1	20.9	25.7	30
	5,000	-	-	-	-	-	-	-	1.7	2.4	4.4	6.5	8.8	10.6	12.6	18.3	23.1	27.5
	5,250	-	-	-	-	-	-	-	-	1.1	2.6	4.6	6.5	8	9.6	15	19.7	24
	5,500	-	-	-	-	-	-	-	-		1.5	3.2	4.8	6.2	7.7	12.8	17.5	21.6
	6,000	-	-	-	-	-	-	-	-	-	-	1.3	2.7	3.8	5.1	9.9	14.3	18.3
	6,500	-	-	-	-	-	-	-	-	-	-	-	2.7	1.4	2.5	6.9	10.8	14.8
	7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.5	1.3	4.9	8.4	12.2
	7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	4	7.3	10.8
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5.9	9.2
	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	4.4
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6
	11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A-10 (cont.)

	Spawning Flow											
Dewatering Flow	12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
3,250	50.5	53.5	55.6	56.3	54.1	49.5	46.8	42.3	39.1	38.3	37.7	39.2
3,500	47.4	50.6	52.9	54.1	52.3	48.1	45.6	41.3	38.2	37.6	37	38.5
3,750	44.2	47.4	49.9	51.4	50.6	46.3	44.4	40.4	37.6	37	36.5	38.1
4,000	41.7	45.1	47.7	49.4	48.3	44.8	43.2	39.4	37	36.5	36.2	37.8
4,250	36.5	42.8	45.5	47.3	46.6	43.2	41.7	38.2	36	35.6	35.4	37.1
4,500	36.6	39.8	42.6	44.6	44.5	41.5	40.1	36.5	34.2	34	34	35.8
4,750	33.7	37	39.7	41.8	42.1	39.4	38.2	34.8	32.9	32.8	33	34.8
5,000	31.2	34.4	37.2	39.4	39.8	37.2	36.2	32.8	31.1	31.1	31.1	32.8
5,250	27.9	31.1	33.8	36.2	36.9	34.8	33.8	30.3	28.2	28.4	28.9	30.4
5,500	25.3	28.4	31.1	33.5	34.5	32.8	32.3	28.9	26.8	27	27.3	28.8
6,000	21.9	25.1	27.8	30.2	31.3	29.7	29.4	26.3	24.3	24.5	24.8	26
6,500	18.7	22.1	27.8	27.1	28.1	26.2	25.9	22.9	21.2	21.5	21.7	22.8
7,000	16.2	19.6	22.5	24.9	26.4	24.7	24.5	21.7	19.9	20.2	20.4	21.4
7,500	14.8	18.3	21.2	23.7	25.2	23.5	23.5	20.7	19.1	19.3	19.4	20.4
8,000	13.1	16.6	19.5	21.9	23.7	22.2	22.5	19.7	18	18.1	18.5	19.5
9,000	7.6	10.8	13.6	16.6	19.4	18.7	19.3	16.8	15.2	15.4	15.9	17
10,000	3.6	6.6	9.2	12.1	15.1	15.3	16.4	14.5	12.9	13.4	14.3	15.5
11,000	2.3	5	7.5	10.1	13.1	13.1	14.5	12.8	11.5	11.9	12.8	14.1
12,000	-	2.2	4.3	6.7	10.1	10.9	12.9	11.4	10.4	10.9	11.9	13.2
13,000	-	-	3.7	3.6	6.8	8.3	10.7	10.5	9.6	10.3	11.3	12.7
14,000	-	-	-	2.1	5.1	6.6	9.1	9	8.3	9.2	10.3	11.9
15,000	-	-	-	-	2.6	4.2	7.2	7.9	7.4	8.3	9.4	10.9
17,000	-	-	-	-	-	1.9	5.1	5.8	5.6	6.8	8.3	10
19,000	-	-	-	-	-	-	3	3.7	3.8	5.1	6.7	8.4
21,000	-	-	-	-	-	-	-	1.4	1.8	2.9	4.4	6.3
23,000	-	-	-	-	-	-	-	-	0.9	2.2	3.8	5.7
25,000	-	-	-	-	-	-	-	-	-	1.7	3.4	5.4
27,000	-	-	-	-	-	-	-	-	-	-	1.8	3.8
29,000	-	-	-	-	-	-	-	-	-	-	-	2.2

1.3 Juvenile Salmonid Rearing (WUA)

The availability of rearing habitat was estimated using WUA curves obtained from the literature (U.S. Fish and Wildlife Service 2005). WUA is an index of the surface area of physical habitat available, weighted by the suitability of that habitat. WUA curves are normally developed as part of instream flow incremental methodology studies. Modeling assumptions used to derive rearing WUA curves include that the suitability of physical habitat for salmon and steelhead rearing is largely a function of water depth, flow velocity, and the availability and type of cover. The race- or species-specific suitability of the habitat with respect to these variables is determined by observing the fish and is used to develop HSC for each race or species. Hydraulic modeling is then used to estimate the amount of rearing habitat available for different HSC levels at different river flows, and the results are used to develop rearing habitat WUA curves and tables (Bovee et al. 1998). These curves and tables are used to look up the amount of rearing WUA available at different flows.

USFWS (2005) provides WUA curves and tables for rearing winter-run, fall-run, and late fall–run Chinook salmon for three segments of the Sacramento River encompassing the reach from Keswick Dam to Battle Creek (Figure A-1). Separate curves were developed for fry and juveniles, with fry defined as fish less than 60 millimeters and juveniles defined as greater than 60 millimeters. No WUA curves were developed for spring-run Chinook salmon or steelhead, but as discussed later, the fall-run curves were used to quantify spring-run rearing habitat and the late fall–run curves were used for steelhead. Figure A-7 through Figure A-12 show the flow versus rearing WUA results for fry and juvenile winter-run, fall-run, and late fall–run Chinook salmon in the three river segments (Segment 6 = Keswick to ACID Dam, Segment 5 = ACID Dam to Cow Creek, and Segment 4 = Cow Creek to Battle Creek) as provided in USFWS (2006). Note that for Segment 6, separate WUA curves were developed for periods when the ACID Dam boards are installed (April through October) and for when the boards are out because installation of the boards affects water depths and velocities for some of the sampling transects used to develop the curves. All rearing WUA analyses were limited to juveniles less than a year old.

Because tributaries enter the Sacramento River between Keswick Dam and Battle Creek, flows are generally different among the three segments. For the USFWS studies, flows were measured directly at the sampling transects and were estimated as the sum of Keswick flow releases and tributary gage readings upstream of the transects. To estimate WUA for the effects analysis, the segment flows were estimated using Sacramento River CALSIM II flows at Keswick Dam, the Clear Creek confluence, and Battle Creek for Segments 6, 5, and 4, respectively. Keswick Dam flows were used for Segment 5 upstream of the Clear Creek confluence. For Segment 6, the WUA curves for the months when the ACID Dam boards are installed (April through October) were used with the flows for those months and the WUA curves for the months when the ACID Dam boards are out were used with the flows for the rest of the year.

Although fall-run rearing WUA curves were used as surrogates for spring-run rearing, CALSIM II flows for the months of spring-run rearing, not those of fall-run rearing, were used to compute the spring-run WUA results. This caveat applies as well to the use of the late fall–run rearing WUA curves to compute steelhead WUA results.

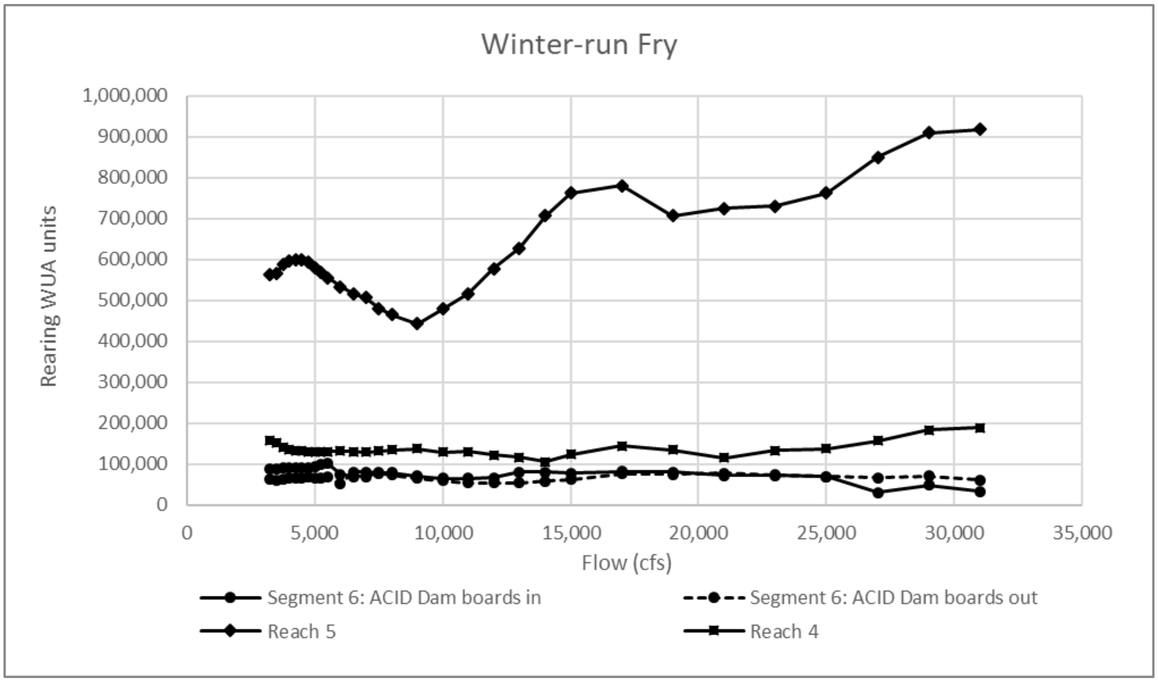

Figure A-7. Rearing WUA curves for Winter-Run Chinook Salmon Fry in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

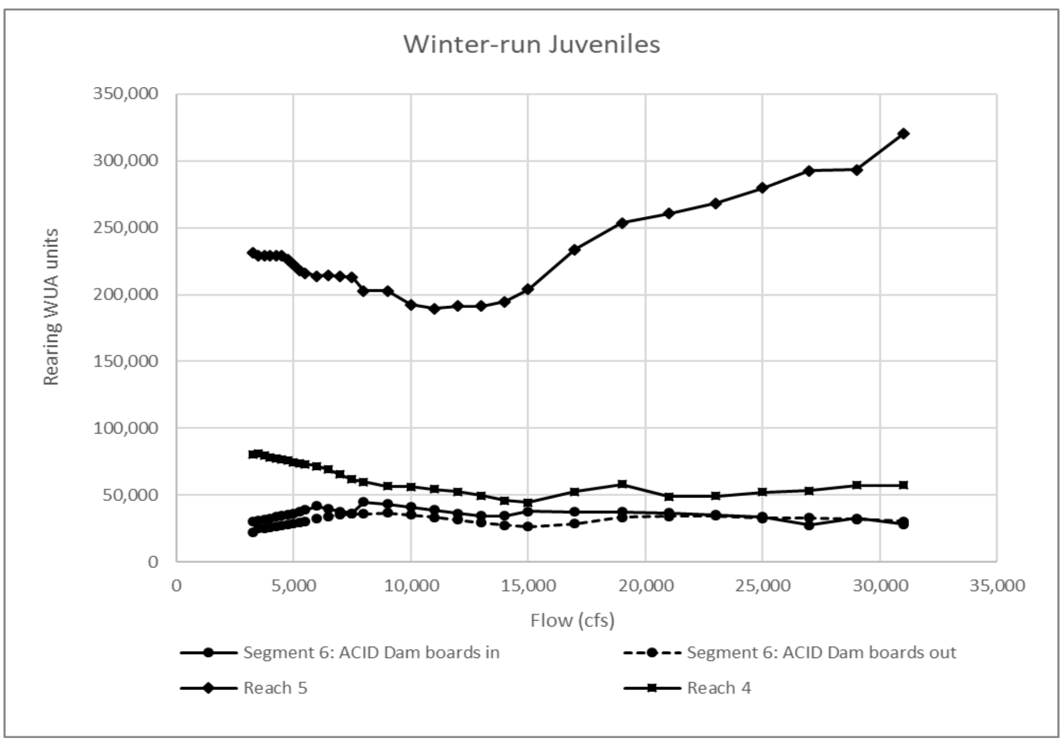

Figure A-8. Rearing WUA curves for Winter-Run Chinook Salmon Juveniles in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

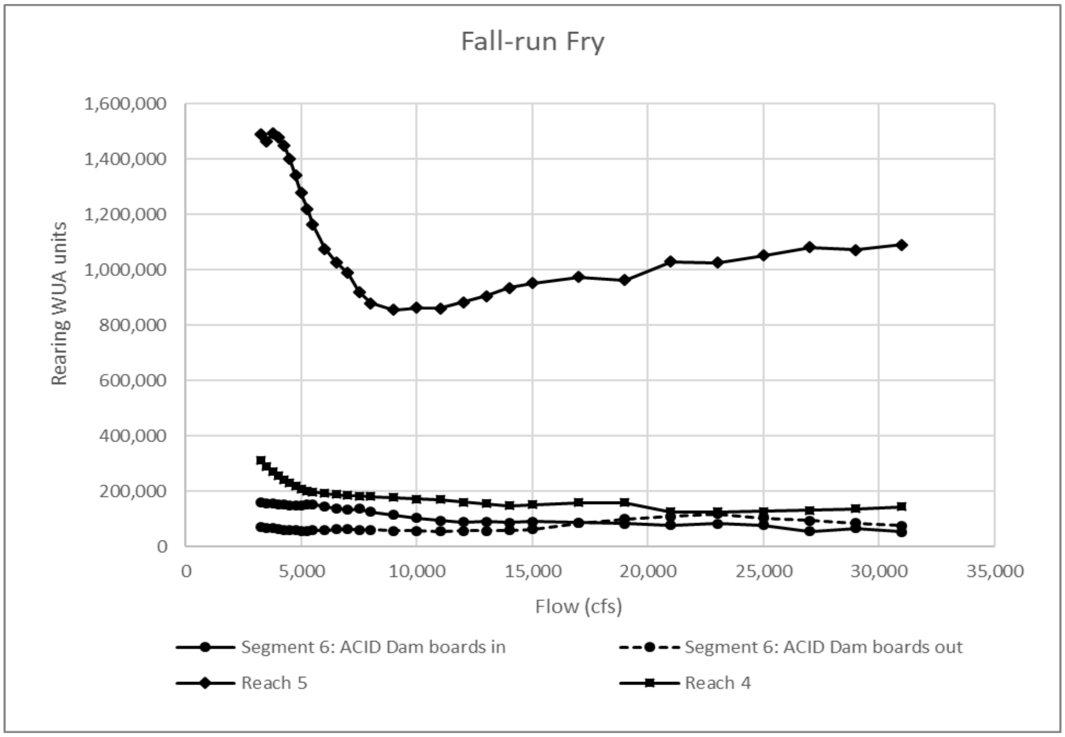

Figure A-9. Rearing WUA Curves for Fall-Run Chinook Salmon Fry in the Sacramento River, Segments 4 to 6. (The fall-run curves were used to quantify spring-run Chinook salmon WUA, as discussed in the text.) ACID = Anderson-Cottonwood Irrigation District.

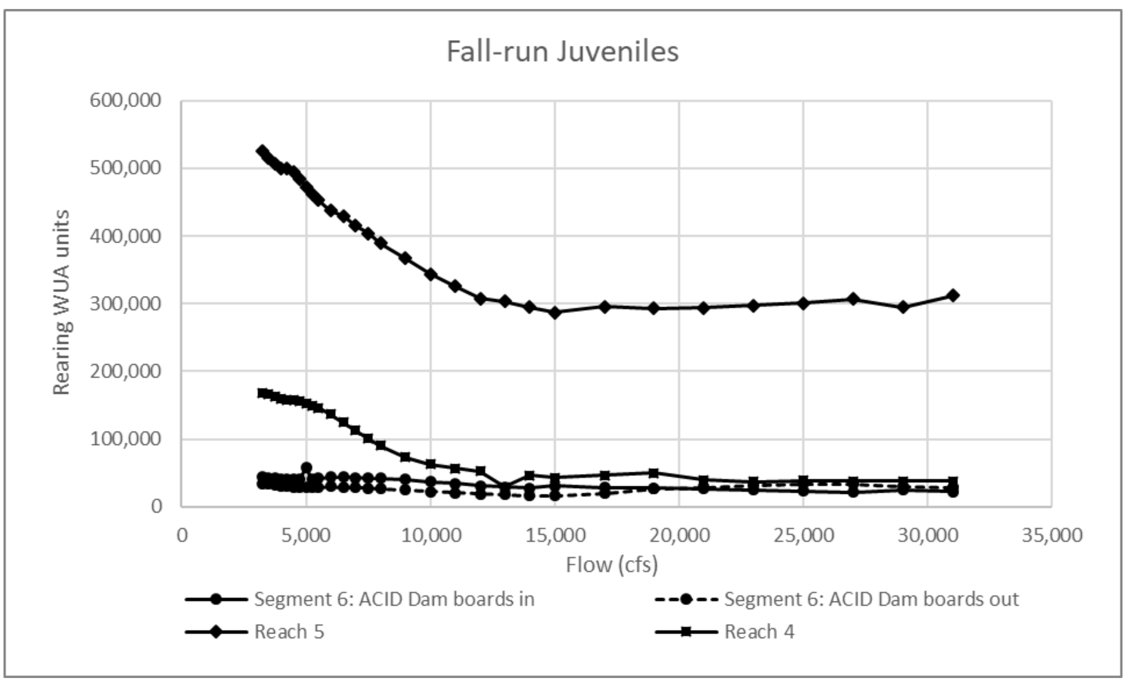

Figure A-10. Rearing WUA Curves for Fall-Run Chinook Salmon Juveniles in the Sacramento River, Segments 4 to 6. (The fall-run curves were used to quantify spring-run Chinook salmon WUA, as discussed in the text.) ACID = Anderson-Cottonwood Irrigation District.

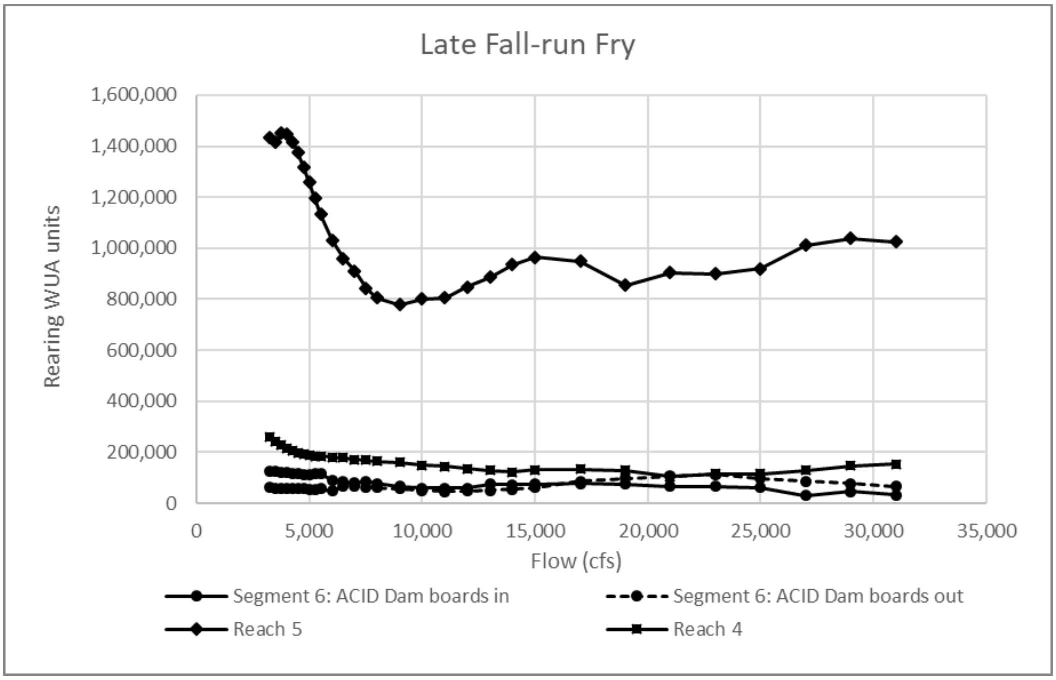

Figure A-11. Rearing WUA Curves for Late Fall–Run Chinook Salmon Fry in the Sacramento River, Segments 4 to 6. (The late fall–run rearing curves were used to quantify steelhead rearing WUA, as discussed in the text.) ACID = Anderson-Cottonwood Irrigation District.

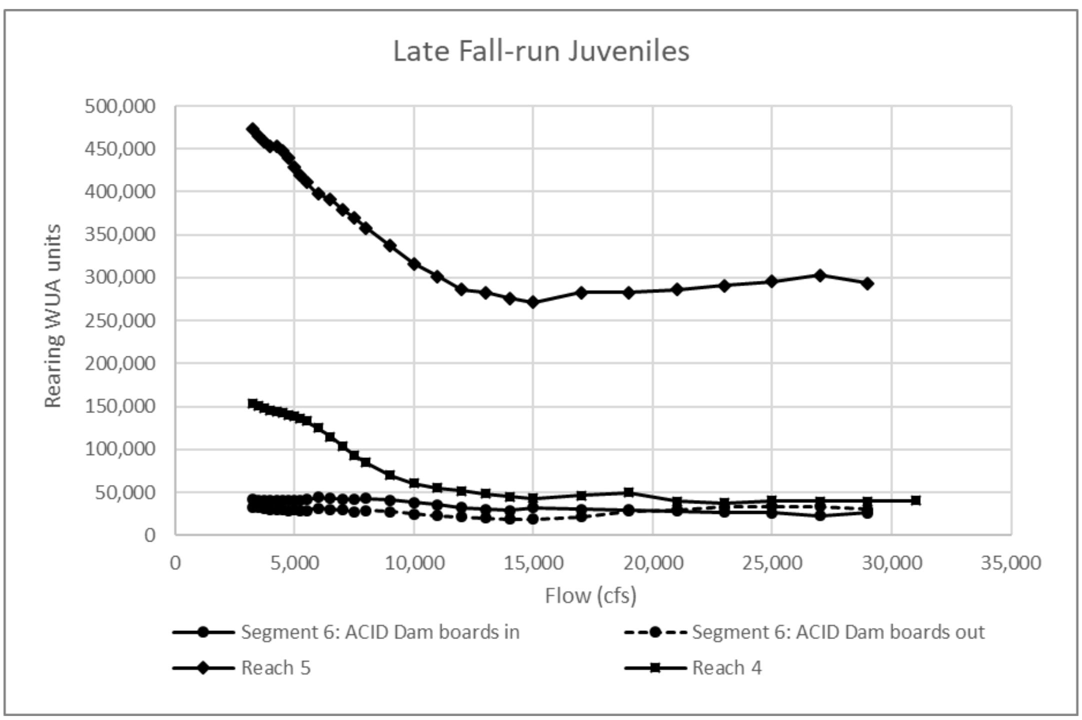

Figure A-12. Rearing WUA Curves for Late Fall–Run Chinook Salmon Juveniles in the Sacramento River, Segments 4 to 6. (The late fall–run rearing curves were used to quantify steelhead rearing WUA, as discussed in the text.) ACID = Anderson-Cottonwood Irrigation District.

As noted above, there are no spring-run or steelhead rearing WUA curves in the USFWS documentation, so the fall-run and late fall–run Chinook salmon rearing WUA curves were used as surrogates to model rearing habitat for spring-run and steelhead, respectively. Mark Gard, who led the USFWS studies that produced the Sacramento River WUA curves, has endorsed this practice for both spring-run Chinook salmon and steelhead (Gard pers. comm.). The use of these substitutions has been adopted in subsequent studies. For instance, the SacEFT model, which produces spawning and rearing WUA outputs for CV spring-run Chinook salmon and steelhead, derives the spring-run spawning and rearing WUA results using the fall-run WUA curves as surrogates and the steelhead rearing WUA results using the late fall–run WUA curves as surrogates (ESSA Technologies 2011; Robinson pers. comm.). It should be noted that this practice introduces additional uncertainty to the spring-run and steelhead results.

A potential limitation of the WUA curves presented above, as of all such habitat-based studies, is that they assume the channel characteristics of the river during the time of field data collection by USFWS (1995–1999), such as proportions of mesohabitat types, have remained in dynamic equilibrium to the present time and would continue to do so through the life of the Project. If the channel characteristics substantially change, the shape of the curves may no longer be applicable. A further limitation is that the curves were developed for the Sacramento River upstream of Battle Creek, but all races of Chinook salmon and steelhead spend time rearing downstream of this part of the river.

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Gard, Mark. Fish and Wildlife Biologist. U.S. Fish and Wildlife Service. July 5, 2015—Email to Sophie Unger, Senior Fish Biologist, ICF, Sacramento, CA.

Robinson, Donald. Senior Systems Ecologist. ESSA Technologies, Vancouver, BC. June 16, 2015—Email to Clint Alexander, President, ESSA Technologies, Vancouver, BC.