APPLICANT-PREPARED
ESSENTIAL FISH HABITAT ASSESSMENT
DON PEDRO PROJECT
FERC NO. 2299

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
HDR Engineering, Inc.

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List of Acronyms

2-D	two-dimensional
7DADM	seven-day average of the daily maximum
ac	acres
ac-ft	acre-foot
ACOE	U.S. Army Corps of Engineers
AFLA	Amendment to the Final License Application
AMF	Adaptive Management Forum
AN	above normal
BDCP	Bay-Delta Conservation Plan
BLM	U.S. Department of the Interior, Bureau of Land Management
BN	below normal
BOD	biological oxygen demand
C	critical
CALFED	CALFED Bay-Delta Program
CCSF	City and County of San Francisco
CDBW	California Division of Boating and Waterways
CDFG	California Department of Fish and Game (as of January 2013, Department of Fish and Wildlife)
CDFW	California Department of Fish and Wildlife
CDPR	California Department of Pesticide Regulation
CDWR	California Department of Water Resources
CFM	constant fractional marking
CFR	Code of Federal Regulations
cfs	cubic feet per second
CSLC	California State Lands Commission
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
CWA	Clean Water Act
D	dry
Delta	Sacramento-San-Joaquin Delta

Districts......................Turlock Irrigation District and Modesto Irrigation District
DO.............................dissolved oxygen
DWSC........................Stockton Deep Water Ship Channel
EFH............................Essential Fish Habitat
EPA............................U.S. Environmental Protection Agency
ESA............................Federal Endangered Species Act
ESRCD.......................East Stanislaus Resource Conservation District
ESU............................Evolutionary Significant Unit
FERC..........................Federal Energy Regulatory Commission
FL...............................full length
FOT............................Friends of the Tuolumne
HGMP........................Hatch Genetic Management Plan
HORB ....Head of Old River Barrier
IFIM...........................instream flow incremental methodology
IG ....Infiltration Gallery
ISR ....Initial Study Report
km ....kilometer
kV...............................kilovolt
LWD ....large woody debris
m ....meter
mm ....millimeter
M&I............................municipal and industrial
mg/L...........................milligram per liter
mgd ....million gallons per day
MID............................Modesto Irrigation District
MVA ....megavolt-ampere
MW ....megawatt
MWh ....megawatt hour
NEPA ....National Environmental Policy Act
NGOs ....Non-Governmental Organizations
NMFS.........................National Marine Fisheries Service
NOAA ....National Oceanic and Atmospheric Administration
NOI ....Notice of Intent

NRCS.........................National Resource Conservation Service
NTU...........................Nephelometric Turbidity Unit
mi..............................miles
mi^2.............................square miles
MW............................megawatt
PAD............................Pre-Application Document
PFMC.........................Pacific Fishery Management Council
PHABSIM..................1-D Physical Habitat Simulation
Project........................Don Pedro Hydroelectric Project
PSP.............................Proposed Study Plan
RM.............................River Mile
RWG..........................resource work group
SD1............................Scoping Document 1
SD2............................Scoping Document 2
SED............................Substitute Environmental Document
SFPUC.......................San Francisco Public Utilities Commission
SJRRP........................San Joaquin River Restoration Program
SPD............................Study Plan Determination
SRP............................Special Run Pools
SWB...........................State Water Resources Control Board
SWP...........................State Water Project
SWRCB......................State Water Resources Control Board
TAC............................Tuolumne River Technical Advisory Committee
TID.............................Turlock Irrigation District
TMDL........................Total Maximum Daily Load
TRC............................Tuolumne River Conservancy
TRT............................Tuolumne River Trust
USBR.........................U.S. Department of the Interior, Bureau of Reclamation
USFWS......................U.S. Department of the Interior, Fish and Wildlife Service
USGS.........................U.S. Department of the Interior, Geological Survey
USR............................Updated Study Report
W................................wet
WQO..........................water quality objective

WSIP..........................Water System Improvement Program

WY.............................water year

YSS............................Yosemite Stanislaus Solutions

PREFACE

On April 28, 2014, the co-licensees of the Don Pedro Hydroelectric Project, Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts), timely filed with the Federal Energy Regulatory Commission (Commission or FERC) the Final License Application (FLA) for the Don Pedro Hydroelectric Project, FERC No. 2299. As noted in the filing and acknowledged by FERC at the time, several studies were ongoing which were likely to inform the development of additional protection, mitigation, and enhancement (PM&E) measures. The Districts have now completed these studies and herein submit this Amendment of Application (Amendment to the Final License Application or AFLA). For ease of review and reference, this AFLA replaces the Districts' April 2014 filing in its entirety.

The Don Pedro Project provides water storage for irrigation and municipal and industrial (M&I) use, flood control, hydroelectric generation, recreation, and natural resource protection (hereinafter, the "Don Pedro Project"). The environmental analysis contained in this AFLA considers all the components, facilities, operations, and maintenance that make up the Don Pedro Project and certain facilities proposed to be included under the new license. The Don Pedro Project is operated to fulfill the following primary purposes and needs: (1) to provide water supply for the Districts for irrigation of over 200,000 acres of Central Valley farmland and M&I use, (2) to provide flood control benefits along the Tuolumne and San Joaquin rivers, and (3) to provide a water banking arrangement for the benefit of the City and County of San Francisco (CCSF) and the 2.6 million people CCSF supplies in the Bay Area. The original license was issued in 1966. In 1995, the Districts entered into an agreement with a number of parties, which resulted in greater flows to the lower Tuolumne River for the protection of aquatic resources.

Hydroelectric generation is a secondary purpose of the Don Pedro Project. Hereinafter, the hydroelectric generation facilities, recreational facilities, and related operations will be referred to as the "Don Pedro Hydroelectric Project," or the "Project". With this AFLA to FERC, the Districts are seeking a new license to continue generating hydroelectric power and implement the Districts' proposed PM&E measures. Based on the information contained in this AFLA, and other sources of information on the record, FERC will consider whether, and under what conditions, to issue a new license for the continued generation of hydropower at the Districts' Don Pedro Project. The Districts are providing a complete description of the facilities and operation of the Don Pedro Project so the effects of the operation and maintenance of the hydroelectric facilities can be distinguished from the effects of the operation and maintenance activities of the overall Don Pedro Project's flood control and water supply/consumptive use purposes.

Being able to differentiate the effects of the hydropower operations from the effects of the flood control and consumptive use purposes and needs of the Don Pedro Project will aid in defining the scope and substance of reasonable PM&E alternatives. As FERC states in Scoping Document 2 in a discussion related to alternative project operation scenarios: "…alternatives that address the consumptive use of water in the Tuolumne River through construction of new structures or methods designed to alter or reduce consumptive use of water are…alternative mitigation strategies that could not replace the Don Pedro *hydroelectric* [emphasis added] project. As such, these recommended alternatives do not satisfy the National Environmental Policy Act (NEPA) purpose and need for the proposed action and are not reasonable alternatives for the NEPA analysis."

1.0 INTRODUCTION

1.1 Essential Fish Habitat Regulatory Framework

During the National Environmental Policy Act (NEPA) scoping conducted by the Federal Energy Regulatory Commission (FERC or Commission) for the relicensing of hydropower generation at the Don Pedro Hydroelectric Project (Project), issues were raised regarding the effects of the Proposed Action on fall-run Chinook salmon (*Oncorhynchus tshawytscha*), a species of anadromous salmonid that is managed in accordance with the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act).

The Magnuson-Stevens Act establishes jurisdiction over marine fisheries within the exclusive economic zone of the United States. These fisheries are managed by Regional Fisheries Management Councils, which are required to develop Fishery Management Plans (FMPs) to administer fisheries management and conservation. Among other things, the FMPs establish Essential Fish Habitat (EFH) to conserve and enhance fish species managed under the FMPs. The Pacific Fisheries Management Council (PFMC) manages all species of Pacific Coast salmon pursuant to the Pacific Coast Salmon FMP (PFMC 2014), which includes Chinook salmon in the State of California. In California, the Pacific Coast Salmon FMP does not distinguish between the EFH of winter, spring, and fall/late fall Chinook salmon run types.

Pursuant to section 305(b)(2) of the Magnuson-Stevens Act, a federal agency (in this case FERC) must consult with the National Marine Fisheries Service (NMFS) regarding any of its actions authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken that may adversely affect a species' EFH. The Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) have drafted this applicant-prepared EFH Assessment to serve as the basis for consultation between FERC and NMFS. The EFH Assessment describes the potential effects of the Proposed Action (see Section 3.1), including the Districts' proposed measures, on fall-run Chinook salmon EFH in the designated EFH Action Area.

1.2 EFH Action Area

According to the PFMC (2014, Appendix A) freshwater EFH for Chinook salmon consists of (1) spawning and incubation, juvenile rearing, juvenile migration corridors, and adult migration corridors and holding habitat. Freshwater EFH depends on floodplain, riparian, hyporheic, and longitudinal connectivity to create suitable conditions. Variables of importance for spawning, rearing, and migration include (1) water quality, (2) water quantity, depth, and velocity, (3) riparian-stream-marine energy exchanges, (4) channel gradient and stability, (5) prey availability, (6) cover and habitat complexity, (7) space, (8) habitat connectivity from headwaters to the ocean; (9) groundwater-stream interactions; and (10) substrate composition.

The U.S. Department of the Interior, Geological Survey's (USGS) 4th field hydrologic units designated as EFH for Chinook salmon in California are shown in Figure 1.2-1. In the Tuolumne River (HU 18040009), EFH extends from La Grange Diversion Dam (RM 52.2) to the confluence with the San Joaquin River. As required by FERC's Scoping Document 2 (SD2; FERC 2011) the Action Area for this EFH Assessment includes all EFH in the Tuolumne River from La Grange

Diversion Dam to the confluence with the San Joaquin River and in the San Joaquin River from RM 84 (i.e., the confluence with the Tuolumne River) downstream through the Sacramento-San Joaquin Delta[1] (Delta) to San Francisco Bay[2].

1.3 Public Review and Consultation during Relicensing

1.3.1 Notice of Intent and Pre-Application Document

Prior to filing the Notice of Intent (NOI) and Pre-Application Document (PAD) in February 2011, the Districts commenced relicensing discussions with a series of meetings with resource agencies and the public. The Districts met with NMFS on August 30, 2010, U.S. Department of the Interior, Fish and Wildlife Service (USFWS) on August 31, 2010, and California Department of Fish and Wildlife (CDFW) on October 19, 2010. In September 2010, the Districts conducted three public information meetings to seek additional sources of existing information, familiarize interested parties with the Don Pedro Project facilities, features, and operations, and review the Districts' relicensing plans and the overall relicensing schedule.

The Districts exercised due diligence in acquiring information to be included in the PAD. The Districts contacted governmental agencies, Indian Tribes, and other parties potentially having relevant information, conducted extensive searches of publicly available databases and their own records, and broadly distributed a request for information designed specifically to identify existing, relevant, and available information related to the Don Pedro Hydroelectric Project and any potential effects on resources within the Project Boundary.

Pursuant to 18 Code of Federal Regulations (CFR) §5.6, the Districts prepared a NOI and PAD and filed the documents with FERC on February 11, 2011. The Districts also distributed the PAD to federal and state resource agencies, Non-Governmental Organizations (NGOs), local governments, Indian Tribes, and other relicensing participants. The PAD included information the Districts had gathered to date as well as 10 proposed study plans, which addressed water quality, terrestrial, wildlife, historic properties, and cultural resources.

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[1] The Delta received its first official boundary in 1959 with the passage of the Delta Protection Act (Section 12220 of the California Water Code), with the southern boundary in the San Joaquin River located at Vernalis (RM 69.3) and the western boundary at the confluence of the Sacramento and San Joaquin Rivers (RM 0) near Chipps Island.

[2] The greater San Francisco Bay estuary extends from the Golden Gate Bridge in San Francisco Bay eastward across salt and brackish water habitats included in San Leandro, Richardson, San Rafael, and San Pablo bays, as well as the Carquinez Strait, Honker, and Suisun bays further to the east near the western edge of the Delta.

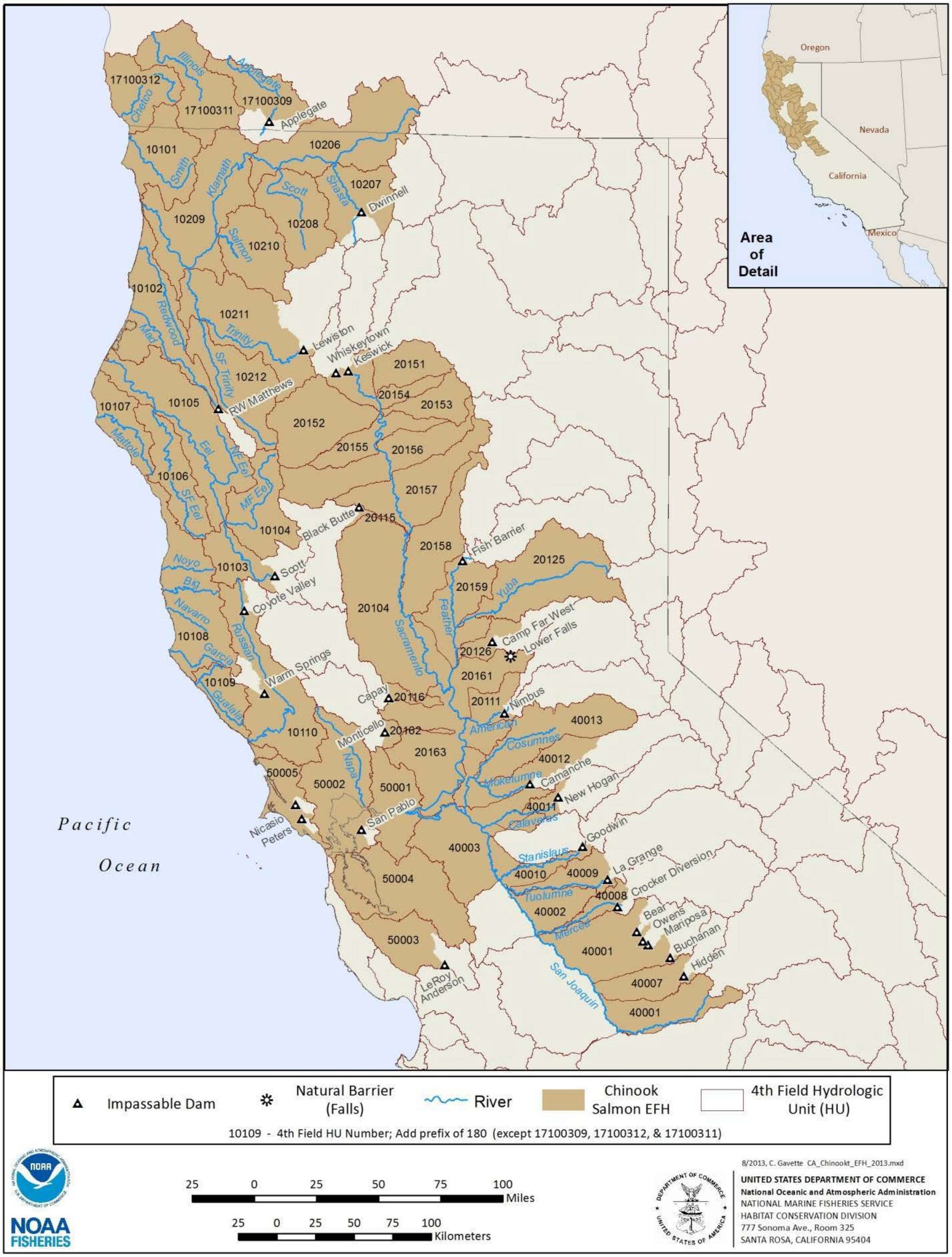

Figure 1.2-1. Chinook salmon EFH in California. EFH designations are based on the USGS 4th field hydrologic units. (Source PFMC 2014, Appendix A to the Pacific Coast Salmon FMP).

1.3.2 Scoping and Study Plan Development

FERC issued a Scoping Document 1 (SD1) and NOI on April 8, 2011, to solicit comments on the scope of environmental studies in the relicensing process, and to encourage participation in the relicensing process. The SD1 was noticed in the Federal Register on April 14, 2011. FERC staff conducted a public site visit of the Don Pedro Project on May 10, 2011, which included an overview of the Don Pedro Project and its operations and a tour of the Don Pedro Reservoir and adjacent recreation facilities and wildlife areas. On May 11, 2011, FERC staff conducted a daytime public scoping meeting in the city of Turlock, California and an evening public scoping meeting in the city of Modesto, California. Attendees included representatives from federal, state and local agencies, elected officials, business leaders, and community members.

After filing the PAD, the Districts held a series of resource work group (RWG) meetings to solicit input on the relicensing study plans. On July 25, 2011, the Districts filed their Proposed Study Plan (PSP) document with FERC. The PSP presented 30 draft study plans that the Districts proposed in response to study requests received from relicensing participants. On that same day, FERC filed its SD2, incorporating relicensing participants' comments received on the SD1, the PAD, and study requests. FERC issued a minor clarification to its SD2 on July 29, 2011.

Between filing the PSP on July 25, 2011 and the October 24, 2011 deadline for filing comments on the PSP, the Districts hosted 13 additional RWG meetings to resolve differences regarding the proposed studies. Through these meetings, all 30 of the Districts' draft study proposals were discussed and two new study plans were formulated. On October 13, 2011, the Districts filed an Updated Study Plan with FERC to provide the most up-to-date version of the PSP. Based on the RWG meetings and comments received on the PSP, the Districts revised many of the original study plans and added five additional studies, bringing the total number of studies to 35. On November 22, 2011, the Districts filed a Revised Study Plan containing the 35 study plans.

On December 22, 2011, FERC issued its Study Plan Determination (SPD) for the Don Pedro Project, approving or approving with modifications 33 studies proposed in the Revised Study Plan, adding one study recommended by the U.S. Department of the Interior, Bureau of Land Management (BLM) (Bald Eagle Study), and recommending that two studies not be undertaken (the Chinook Salmon Fry Movement Study and the Temperature Criteria Study). As required by the SPD, and after further consultation with the resource agencies and other relicensing participants, the Districts filed three revised study plans with more detailed methodologies on February 28, 2012 and one modified study plan on April 6, 2012. FERC approved or approved with modifications these studies on July 25, 2012. In addition, the Districts chose to conduct the Temperature Criteria Study (Farrell et al. 2017).

Following FERC's issuance of the SPD, a total of seven studies (and associated study elements) that were either not adopted in the SPD or were adopted with modifications, formed the basis of Study Dispute proceedings. On April 17, 2012, in response to study disputes, FERC convened a Dispute Resolution Panel technical conference in Sacramento, California. The Panel issued its findings on May 4, 2012. On May 24, 2012, FERC issued its Formal Study Dispute Determination, with additional clarifications related to the Formal Study Dispute Determination issued on August

17, 2012. The Study Dispute Determination resulted in two modifications to the SPD and six clarifications. Studies were implemented consistent with this determination.

In addition to studies required under the relicensing proceedings, the Districts' instream flow incremental methodology (IFIM) study provides information in support of this license application and its associated documents. On July 16, 2009, FERC directed the Districts to develop and implement an IFIM study to determine instream flows necessary to maximize Chinook salmon and *O. mykiss* production and survival in the Tuolumne River. The lower Tuolumne River Instream Flow Studies – Final Study Plan (Stillwater Sciences 2009) was filed on October 14, 2009 and approved by FERC on May 12, 2010.

In order to examine the broad flow ranges identified in FERC's July 2009 Order, the study plan separated the study into two separate investigations: (1) a conventional 1-D Physical Habitat Simulation (PHABSIM) model (Lower Tuolumne Instream Flow Study), which examines in-channel habitat conditions at flows from approximately 100–1,000 cubic feet per second (cfs), and (2) a two-dimensional (2-D) hydraulic model of overbank areas, as well as adjacent in-channel locations, for flows of 1,000–5,000 cfs, developed as part of the Pulse Flow Study. Following approval of the original Study Plan, in its December 22, 2011 SPD, FERC required the scope of the Lower Tuolumne River Instream Flow Study be expanded to include Pacific lamprey (*Entosphenus tridentatus*) and Sacramento splittail (*Pogonichthys macrolepidotus*), if existing habitat suitability criteria (HSC) were available. In its April 8, 2013 comments on the Draft Lower Tuolumne Instream Flow Study Report, the USFWS provided references to existing criteria, developed for the lower Merced River. More recently, FERC's May 21, 2013 Determination on Requests for Study Modifications and New Studies required the scope of the Lower Tuolumne Instream Flow Study be expanded to assess habitat for non-native predatory fish, including smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), and striped bass (*Morone saxatilis*) using existing HSC data, where available. All components of the Lower Tuolumne River Instream Flow Study have now been filed with FERC.

1.3.3 Pre-Filing Consultation Workshop Process

Prior to filing the FLA, the Districts conducted, with FERC concurrence, a series of workshops and meetings associated with the studies listed below to share and discuss relevant data with relicensing participants:

- W&AR-02: Project Operations/Water Balance Model,
- W&AR-03: Reservoir Temperature Model,
- W&AR-05: Salmonid Population Information Integration and Synthesis Study,
- W&AR-06: Chinook Population Model,
- W&AR-10: *O. mykiss* Population Model,
- W&AR-16: Lower Tuolumne River Temperature Model, and
- W&AR-21: Lower Tuolumne River Floodplain Hydraulic Assessment.

The purpose of the workshops was to provide an opportunity for relicensing participants and the Districts to discuss relevant data sources, methods of data use and development, and modeling parameters at specific points in the development of these study plans. The goal of the workshop process was for relicensing participants and the Districts to reach agreement, where possible, after thorough discussion of data and methods. In the December 2011 SPD, FERC directed the Districts to formalize the workshop process. The Districts submitted for review and comment a draft Workshop Consultation Process to relicensing participants in March 2012, and filed the final Workshop Consultation Process with FERC on May 18, 2013.

Throughout 2012, 2013, and 2014, the Districts conducted a total of 18 workshops. In addition, the Districts conducted model training sessions for several of the studies that involved the development of quantitative models. For each workshop, an agenda and materials were provided prior to the meeting date, draft meeting notes were provided for 30-day comment by relicensing participants, and final workshop notes and responses to comments received were filed with FERC to maintain a record of interim study plan decisions. A summary of all consultation documentation related to these Workshops is attached to the Amendment to the Final License Application (AFLA) for the Don Pedro Hydroelectric Project.

1.3.4 Initial and Updated Study Reports

On January 17, 2013, the Districts filed their Initial Study Report (ISR). Included in the ISR was the Districts' NOI to file a DLA rather than a Preliminary Licensing Proposal under the Integrated Licensing Process. The Districts held the ISR meeting on January 30 and 31, 2013, in Modesto, California. On February 8, 2013, the Districts filed an ISR meeting summary.

Following the ISR meeting, relicensing participants filed requests for new studies and study modifications. The Districts responded to these comments on April 9, 2013, and agreed to a new model and three new studies. On May 21, 2013, FERC issued its Determination on Requests for Study Modifications and New Studies. The determination approved five study modifications and five new studies or study elements. The Districts filed an Updated Study Report (USR) for the Don Pedro Project on January 6, 2014, held a USR Meeting on January 16, 2014, and filed a summary of the meeting on January 27, 2014. On March 28, 2014, the Districts filed a response to USR comments received from relicensing participants.

1.3.5 Draft License Application

The DLA was filed on November 26, 2013, which was followed by a 90-day public comment period. Comments on the DLA were received from FERC, American Whitewater, USFWS, Conservation Groups, NMFS, Restore Hetch Hetchy, Tuolumne County Water Agency, Stanislaus National Forest, ARTA, State Water Resources Control Board (SWRCB), BLM, CDFW, and OARS Rafting. The Districts' responses to these comments are provided as Attachment A to Don Pedro Hydroelectric Project AFLA.

1.3.6 Post-Filing Consultation and Alternatives Analysis

Since the filing of the FLA in April 2014, and in accordance with the FERC-approved schedule, the following important studies involving the resources of the lower Tuolumne River were completed. The results of some of these studies, along with some of the aforementioned models and existing studies, were used to assess Project impacts on aquatic resources and conduct the analysis of proposed alternative PM&E measures contained in the BA.

- W&AR-11: Fall-Run Chinook Salmon Otolith Study
- W&AR-12: Addendum to *Oncorhynchus mykiss* Habitat Survey, 2016 large woody debris (LWD) inventory
- W&AR-14: Thermal Performance of Wild Juvenile *Oncorhynchus Mykiss* in the Lower Tuolumne River: A Case for Local Adjustment to High River Temperature
- W&AR-21: Lower Tuolumne River Floodplain Hydraulic Assessment
- Lower Tuolumne River Instream Flow Study Effective Weighted Usable Area Estimate for *O. mykiss*
- Lower Tuolumne River Instream Flow Study Evaluation of Non-Native Predatory Fish
- Development of Tuolumne River Flow and Temperature Without Dams Model

On May 18, 2017, the Districts hosted a Modeling Tools Update Workshop with relicensing participants to provide a status update on several models developed to support the relicensing. The following studies were discussed during the meeting:

- W&AR-02: Project Operations/Water Balance Model,
- W&AR-03: Reservoir Temperature Model,
- W&AR-06: Chinook Population Model,
- W&AR-10: O. mykiss Population Model,
- W&AR-16: Lower Tuolumne River Temperature Model, and
- W&AR-21: Lower Tuolumne River Floodplain Hydraulic Assessment.

2.0 PROJECT DESCRIPTION

The Districts are the co-licensees of the 168-megawatt (MW) Don Pedro Project located at river mile (RM) 54.8 on the Tuolumne River in western Tuolumne County in the Central Valley region of California. The watershed above Don Pedro Dam is approximately 1,533 square miles (mi^2) (U.S. Army Corps of Engineers [ACOE] 1972). The Project is designated by FERC as Project No. 2299. Both TID and MID are local public agencies authorized under the laws of the State of California to provide retail electric service.

2.1 Project Boundary

The current Project Boundary extends from RM 53.2, which is 1 mile below the Don Pedro powerhouse, upstream to RM 80.8 at an elevation corresponding to the 845-foot contour (31 FPC 510 [1964]). The current Project Boundary encompasses approximately 18,370 acres (ac), with 78 percent of the lands owned jointly by the Districts and the remaining 22 percent (approximately 4,000 ac) owned by the United States and administered as a part of the BLM Sierra Resource Management Area.

2.2 Existing Project Facilities

The primary Project facilities include Don Pedro Dam and Reservoir, completed in 1971; a four-unit powerhouse situated at the base of the dam; related facilities including the Project spillway, outlet works, and switchyard; four dikes (Gasburg Creek Dike and Dikes A, B, and C); and three developed recreational facilities (Fleming Meadows, Blue Oaks, and Moccasin Point Recreation Areas). The location of the Project and its primary facilities are shown in Figure 2.2-1.

2.2.1 Don Pedro Dam

Don Pedro Dam is a 1,900-foot-long and 580-foot-high zoned earth and rockfill structure. The crest of the dam is at elevation 855 feet. The dam has a top width of 40 feet and a bottom width of approximately 3,000 feet. The downstream slope is grass-covered and the upstream slope has riprap protection extending to elevation 585 feet. A secured access road runs along the top of the dam for use by the Districts' personnel.

2.2.2 Don Pedro Reservoir

Don Pedro Reservoir extends for approximately 24 miles at the normal maximum water surface elevation of 830 feet and 26 miles at the upstream Project Boundary water elevation of 845 feet. The surface area of the reservoir at the 830-foot elevation is approximately 12,960 ac and the gross storage capacity is 2,030,000 acre-feet (ac-ft). The Don Pedro Reservoir shoreline, including the numerous islands within the lake, is approximately 160 miles long at normal maximum water surface elevation. Under the current license, the minimum operating pool elevation is 600 feet. Water storage below this elevation is approximately 309,000 ac-ft.

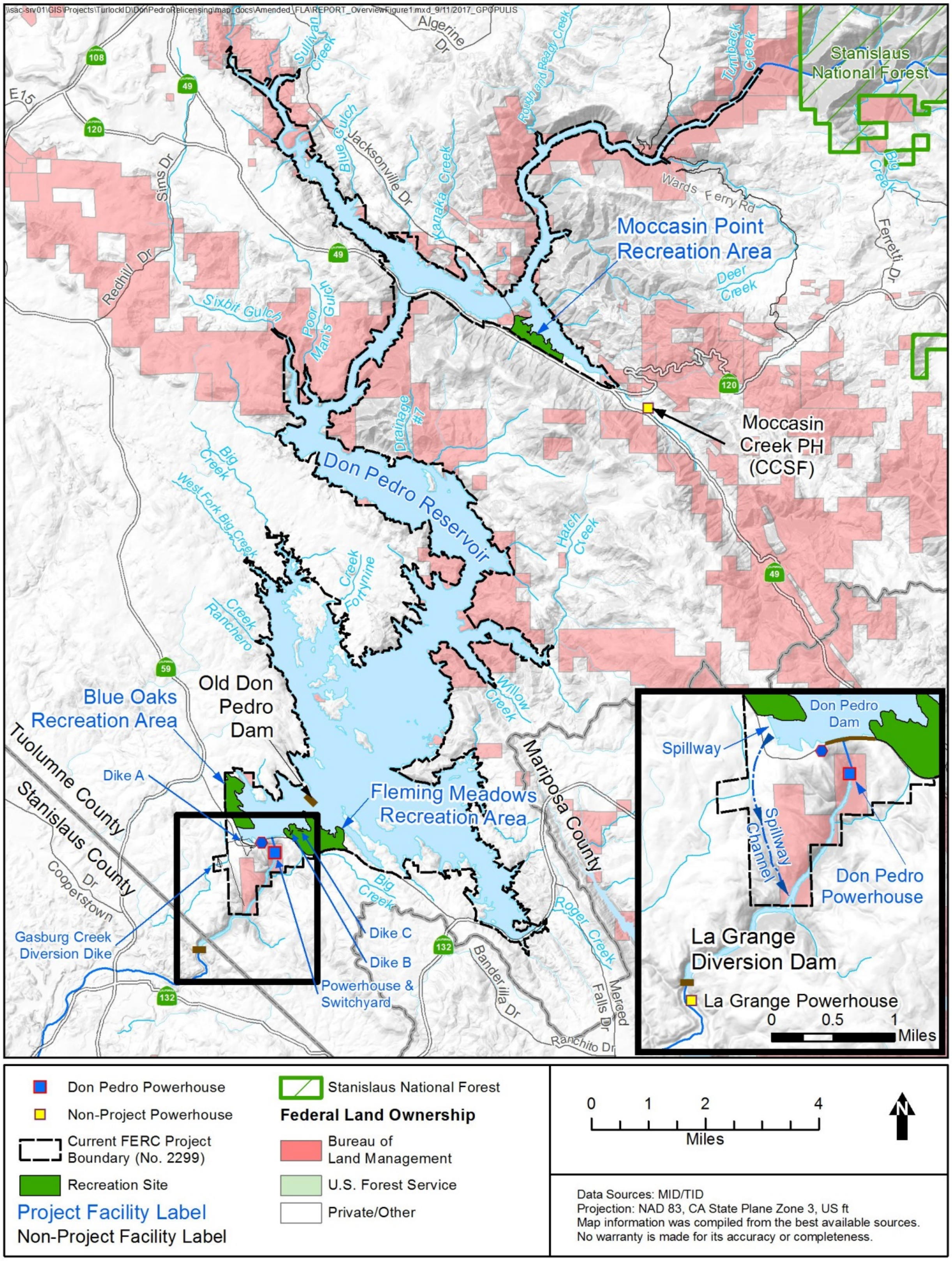

Figure 2.2-1. Don Pedro Project location and facilities.

2.2.3 Don Pedro Spillway

The Don Pedro spillway includes gated and ungated sections, located adjacent to one another in a saddle area west of, and separated from, the main dam. The spillway sections are founded on bedrock. The gated spillway section is 135 feet long, with a permanent crest elevation of 800 feet, and includes three radial gates, each 45 feet wide by 30 feet high. The radial gates are operated by motor-driven steel cables. A travel way is provided over the gated spillway along a top deck at elevation 855 feet. Gate trunnions are located at elevation 810 feet. The ungated spillway is an ogee crest section 995 feet long, with a permanent crest elevation of 830 feet and a top-of-abutment elevation of 855 feet. The total spillway capacity at a reservoir water level of 850 feet is 472,500 cfs. Flow over the ungated ogee crest section of the spillway has occurred only once since Don Pedro Project construction, during the New Year's 1997 flood. Flows over the spillway are released into a normally dry gulch named Twin Gulch, which discharges into the Tuolumne River approximately 1.5 miles downstream of Don Pedro Dam. The substrate in Twin Gulch consists primarily of bedrock and large boulders.

2.2.4 Outlet Works

Low-level outlet works are located at the left (east) abutment of the main dam. The outlet works consist of three service gate housings, each containing a 4-foot-wide by 5-foot-high slide gate. The outlet works are situated in a 3,500-foot-long concrete lined tunnel, a portion of which originally served as the water diversion tunnel during original construction. The original water diversion tunnel had an inlet elevation centerline of 315 feet. At the completion of construction, the original inlet for the diversion tunnel was fitted with a concrete plug and a new 12-foot-diameter inlet was constructed with an inlet invert of 342 feet. The diversion tunnel downstream of the new inlet was fitted with three bonnetted slide gates. The invert of the three slide gates is at approximate elevation 310 feet. The inlet to the outlet works is provided with a maintenance gate, which travels on an inclined gate track. The outlet works tunnel daylights back to the Tuolumne River approximately 400 feet downstream of the powerhouse. The invert of the outlet works at the river discharge is at approximately elevation 300 feet. At a reservoir water surface elevation of 830 feet, the hydraulic capacity of the three gates constituting the outlet works is 7,500 cfs.

2.2.5 Power Intake and Tunnel

Flows are delivered from the reservoir to the powerhouse via a 2,960-foot-long power tunnel located in the left (east) abutment of the main dam. The tunnel transitions from an 18-foot, 6-inch concrete lined section to a 16-foot steel lined section. Emergency closure can be provided by a 21-foot-high by 12-foot-wide fixed-wheel gate operated from a chamber at the top of the gate shaft located at the left dam abutment. Flows from the power tunnel are delivered to the four-unit powerhouse and a hollow jet bypass control valve in the powerhouse. The inlet to the power tunnel is fitted with trash racks and a hydraulically operated bulkhead gate for tunnel dewatering or emergency closure. The power tunnel invert is at elevation 534 feet, 66 feet below the current minimum power pool elevation of 600 feet.

2.2.6 Powerhouse, Turbines, and Generators

Located immediately downstream of the main dam, the reinforced concrete outdoor-type powerhouse contains four turbine generator units and a 72-inch hollow jet valve. The powerhouse is 171 feet long, 110 feet high, and 148 feet wide. It houses four Francis-type turbines directly connected to electrical generators. The current FERC-authorized capacity is 168 megawatts (MW). Combined hydraulic capacity of the four units under the maximum gross operating head of 530 feet is approximately 5,500 cfs. Each of the three original turbines and generators has a rotational speed of 277 revolutions per minute and is rated at 77,700 horsepower and 48 megavolt-amperes (MVA) at 450 feet of net head. Unit 4 was installed in 1989 after FERC approved the Districts' amendment to add the fourth unit in February 1987 (38 FERC 61,097). At maximum head, the powerhouse has an output capability of 203 MW at full gate flow supplied to each of the four units.

There is a 72-inch hollow jet valve located in the east end of the powerhouse with a centerline elevation at discharge of 305 feet. The maximum hydraulic capacity of the hollow jet valve is 3,000 cfs. While turbines 1, 2, and 3 discharge directly to the river channel, Unit 4 discharges to the outlet works tunnel approximately 250 feet upstream of the tunnel outlet. Water to Unit 4 is delivered through a bifurcation from the hollow jet valve piping. With Unit 4 in operation, the hollow jet valve capacity is reduced from 3,000 cfs to 800 cfs.

The powerhouse can be accessed through a secured gate located off the Visitor Center parking area. The road provides access directly onto the top deck of the powerhouse at elevation 340 feet. A 4-foot-high parapet wall surrounds the top deck. A two-hook gantry crane sits atop the deck and provides equipment and materials delivery to the powerhouse and maintenance services. The generator floor in the powerhouse is at elevation 323 feet, and the turbine floor is at elevation 308 feet.

2.2.7 Tailwater

The powerhouse and hollow jet valve discharge directly to the Tuolumne River. Tailwater elevation during turbine operation varies from a low of about 300 feet to a high of about 304 feet under normal operating conditions. The tailwater elevation at the outlet works tunnel is also at approximately 300 feet under low-flow conditions.

2.2.8 Switchyard

The switchyard, located atop the powerhouse at elevation 340 feet, provides power delivery and electrical protection to the TID and MID transmission systems. The switchyard includes isolated phase buses, circuit breakers, and four transformers that raise the 13.8 kilovolt (kV) generator voltage to 69 kV transmission voltage. Transformers 1 through 3 are rated at 55 MVA and Unit 4 at 44 MVA. Although Units 1, 2, and 4 are directly connected to TID's system and Unit 3 to the MID system, the switchyard has been configured to allow interconnection across the systems when needed. This system, when operating in an interconnected fashion, acts as a pathway for electricity flows across the two systems, providing system benefits to both districts. Recognizing this pathway, the Districts on May 4, 2010 filed a request with FERC to amend the Don Pedro license to remove certain transmission lines from their license. FERC granted the amendment on November 11, 2010 (133 FERC ¶62,136).

2.2.9 Gasburg Creek Dike

As noted previously, the spillway discharges into Twin Gulch, a small intermittent drainage which discharges back into the Tuolumne River. To prevent spillway discharges into Twin Gulch from entering the adjacent Gasburg Creek drainage, the Districts constructed the Gasburg Creek Dike. The dike is located in a low saddle that separates the Twin Gulch drainage from the Gasburg Creek drainage, approximately midway down the Twin Gulch waterway. The 75-foot-high dike consists of an earth-and-rock-fill dam with an impervious core. The dike is equipped with a slide-gate-controlled 18-inch-diameter outlet conduit. The crest of the Gasburg Creek Dike is at elevation 725 feet.

2.2.10 Dikes A, B, and C

There are three small rim embankments along the reservoir, i.e., Dikes A, B, and C. These embankments are constructed in low saddles on the reservoir rim, with top elevations of 855 feet. Dike A is located between the main dam and the spillway. Dikes B and C are located east of the main dam.

2.2.11 Station Service

Station service power is provided by primary and secondary station service power transformers. The primary unit is a 69kV/12kV step-down transformer that feeds a 12kV line. The 12kV line feeds three secondary 12kV/480kV step-down transformers. The first two secondary transformers service the spillway motor control centers, and the third services the powerhouse. There is a 45 kVA diesel generator that serves as an emergency backup for station service power. There is also a portable propane power unit that can power the gate hoists for the radial gates in an emergency.

2.2.12 Recreation Facilities

2.2.12.1 Fleming Meadows Recreation Area

Fleming Meadows Recreation Area, the largest of the Project's developed recreation areas, is located just east of the main dam at the southwestern portion of Don Pedro Reservoir referred to as West Bay. The recreation area includes 267 campsites, 90 full-hookup campsites, one boat launch, individual and group picnic areas, concessionaire facilities (one houseboat dock, one full-service marina, camp store, and snack shack), a swimming lagoon and picnic area, and restrooms and showers.

2.2.12.2 Blue Oaks Recreation Area

The Blue Oaks Recreation Area is located west of the main dam in the West Bay area. Amenities at this facility include 34 partial-hookup campsites, 195 tent campsites, one boat launch, and a houseboat repair yard.

2.2.12.3 Moccasin Point Recreation Area

The Moccasin Point Recreation Area is located near the upstream end of the reservoir on the Moccasin Arm of the reservoir. This recreation area includes 18 full-hookup campsites, 96 tent campsites, two picnic areas, one boat launch, and a concessionaire facility and full-service marina.

2.3 Existing Project Operations

2.3.1 Primary Purposes of the Don Pedro Project

The Don Pedro Project is used to satisfy the following primary purposes and needs:

- Provide water storage for irrigation of over 200,000 ac of prime farmland in California's Central Valley. Combined, the Districts supply, on average, approximately 850,000 ac-ft of irrigation water per year to their landowners.
- Provide water storage for municipal and industrial customers. MID provides treated water to the City of Modesto (population: 210,000), and TID and MID jointly provide treated water to the community of La Grange. The Districts provide up to a maximum of 67,500 ac-ft of water per year for municipal and industrial (M&I) use.
- Consistent with agreements between the Districts and the City and County of San Francisco (CCSF), the Don Pedro Project provides a water bank of 570,000 ac-ft of storage when Don Pedro Reservoir is below elevation 801.9 feet, and up to 740,000 ac-ft when Don Pedro Reservoir is at elevation 830 feet. CCSF uses the water bank to help manage the water supply of its Hetch Hetchy water system while meeting the senior water rights of the Districts. CCSF's water bank within Don Pedro Reservoir is a critical component of CCSF's water supply system, which serves 2.6 million Bay Area residents.
- Provide storage for flood management on the Tuolumne and San Joaquin rivers. In cooperation with the ACOE, the Don Pedro Project provides up to 340,000 ac-ft of storage for flood flow management.

These four uses are critical functions of the Don Pedro Project. The water storage capability of the Don Pedro Project substantially improves the reliability of water supply for irrigation of highly productive farmland and for the water needs of over 2.8 million people and numerous commercial, manufacturing, and industrial interests, all of which provide a foundation for the economy of the Central Valley and the San Francisco Bay Area. Other important benefits provided by the Don Pedro Project are protection of aquatic resources, including anadromous and resident fish in the lower Tuolumne River, lake recreation, and renewable hydropower generation.

2.3.2 Overview of Don Pedro Project Operations

The Don Pedro Project operates on an annual cycle consistent with managing and providing a reliable water supply for consumptive use purposes, providing flood flow management, and ensuring delivery of downstream flows to protect aquatic resources. By October 6 of each year, Don Pedro Reservoir must be lowered to at least elevation 801.9 feet to provide the 340,000 ac-ft of flood control storage acquired by the ACOE through its financial contribution to construction of the Don Pedro Project.

Beginning on October 1 of each year, minimum flows provided to the lower Tuolumne River, as measured at the USGS gage at La Grange, are adjusted to meet license requirements to benefit upmigrating adult Chinook salmon. In certain years this includes the provision of a pulse flow, the volume of which varies depending on the water year type.

Pursuant to current FERC license requirements, minimum flows to the lower Tuolumne River are adjusted on October 16, the rate of flow dependent on water year type. These flows are maintained through May 31 of the following year to protect fall-run Chinook salmon egg incubation, fry emergence, fry and juvenile rearing, and smolt outmigration (see Section 2.4.1). A spring pulse flow is provided each year to facilitate fall-run Chinook smolt outmigration, the amount again depending on water year type.

Throughout the winter months, Don Pedro Project operators assess snow conditions in the upper Tuolumne River watershed and, during years with heavy snow accumulation, may reduce reservoir levels to balance forecasted inflows, outflows, and reservoir storage. The goal of operations is to fill the reservoir by early June; however, greater snowpack volumes can extend this filling into early July if needed for maintenance of the aforementioned ACOE flood control space. ACOE flood control guidelines also provide for maintenance of downstream flows in the lower Tuolumne River of less than 9,000 cfs as measured at the USGS gage at Modesto (RM 16), located downstream of Dry Creek almost 40 miles below the Don Pedro Project.

Irrigation deliveries normally begin in early March, but can begin as early as February to provide water for early growing season soil moisture in dry winters. Irrigation deliveries increase considerably by April and normally reach their peak in July and August. Water deliveries from Don Pedro Reservoir for M&I purposes occur year-round. Minimum flows released to the lower Tuolumne River are adjusted again on June 1 and extend through September 30. Irrigation deliveries normally continue through October, but may extend through November depending on moisture conditions.

The current total demand for Tuolumne River water during normal water years is roughly 1.5 million ac-ft, divided among the Districts' needs for irrigation and M&I water (approximately 900,000 ac-ft), CCSF's needs for M&I water (approximately 250,000 ac-ft), and flows to protect anadromous fish in the lower Tuolumne River (approximately 300,000 ac-ft). The storage available in Don Pedro Reservoir provides protection for water dependent uses and natural resources during water shortages in individual and successive dry years, such as those that occurred during the drought periods of 1976–1977, 1987–1992, 2001–2004, and 2012–2015.

Delivery of Don Pedro Project benefits—irrigation water, M&I water, water for the protection of aquatic life, recreation, hydropower generation, and flood protection—requires careful and skillful management of water. The operation of the Don Pedro Project involves the continuous assessment of known and estimated variables, assessment of current and forecasted hydrology, coordination with other water systems, and the balancing of water demands and other Don Pedro Project requirements. The forecasting of future hydrologic conditions, even relatively near-term conditions, involves considerable uncertainty. The timing and degree of droughts and floods remain largely unpredictable.

To manage these highly variable conditions and meet the purposes and needs of the Don Pedro Project, the Districts have adopted a "water first" operations philosophy. Under this approach, the Districts plan and operate the Don Pedro Project to meet the needs for water supply and consumptive use purposes as a first priority, consistent with satisfying all downstream flow requirements for resource protection. Water is released from the Don Pedro Project for three purposes: (1) to meet the irrigation and M&I demands of its customers, (2) to meet the guidelines of the ACOE Flood Control Manual, including pre-releasing flows during wet years in anticipation of high runoff, and (3) to fulfill the FERC license requirements for flows in the lower Tuolumne River as measured at the USGS La Grange gage. Operations for purposes of hydroelectric power generation are secondary to the primary purposes of the Don Pedro Project and therefore do not drive decisions related to overall water management at the Don Pedro Project.

2.4 Existing Environmental Measures

2.4.1 Existing FERC-Mandated Flow Regime for the Lower Tuolumne River

FERC's 1996 order (FERC 1996) amending the Don Pedro Project license required the incorporation of the lower Tuolumne River minimum flow provisions contained in the 1995 settlement agreement between the Districts, CCSF, resource agencies, and environmental groups. The revised minimum instream flows in the lower Tuolumne River vary from 50 to 300 cfs, depending on water year hydrology and time of year. The water year classifications are recalculated each year to maintain approximately the same frequency distribution of water year types. The settlement agreement and license order also specified certain pulse flows for the benefit of upstream migrating adult and downstream migrating juvenile Chinook salmon, the amount of which also varies with water-year type. The downstream flow schedule provided for by the settlement agreement and subsequent FERC Order is shown in Table 2.4.-1.

2.4.2 District-Funded Existing Non-Flow Measures in the Lower Tuolumne River

Conditions in the lower Tuolumne River have been improved by the involvement of the Tuolumne River Technical Advisory Committee (TAC), the role of which was formalized in the Districts' 1995 settlement agreement. Since the early 1990s, the TAC has been engaged in developing, reviewing, and participating in activities to improve and protect the fisheries of the Tuolumne River downstream of La Grange Diversion Dam. In addition to the Districts, the TAC includes members from state and federal resource agencies, CCSF, and NGOs.

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Table 2.4-1. Schedule of flow releases from the Don Pedro Project to the lower Tuolumne River by water year type contained in FERC's 1996 order.

Schedule	Units	# of Days	Critical and Below	Median Critical[1]	Interm. CD	Median Dry	Interm. D-BN	Median Below Normal	Interm. BN-AN[1]	Median Above Normal	Interm. AN-W	Median Wet/Max
Occurrence	%		6.4%	8.0%	6.1%	10.8%	9.1%	10.3%	15.5%	5.1%	15.4%	13.3%
October 1-15	cfs	15	100	100	150	150	180	200	300	300	300	300
	AF		2,975	2,975	4,463	4,463	5,355	5,950	8,926	8,926	8,926	8,926
Attraction Pulse	AF		none	none	None	none	1,676	1,736	5,950	5,950	5,950	5,950
October 16-May 31	cfs	228	150	150	150	150	180	175	300	300	300	300
	AF		67,835	67,835	67,835	67,835	81,402	79,140	135,669	135,669	135,669	135,669
Outmigration Pulse Flow	AF		11,091	20,091	32,619	37,060	35,920	60,027	89,882	89,882	89,882	898
June 1-Sept 30	cfs	122	50	50	50	75	75	75	250	250	250	250
	AF		12,099	12,099	12,099	18,149	18,149	18,149	60,496	60,496	60,496	60,496
Volume (total)	AF	365	94,000	103,000	117,016	127,507	142,502	165,003	300,923	300,923	300,923	300,923

[1] Between a Median Critical Water Year and an Intermediate Below Normal-Above Normal Water Year, the precise volume of flow to be released by the Districts each fish flow year is to be determined using accepted methods of interpolation between index values.

Source: FERC 1996.

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As directed under the 1995 Settlement Agreement, the TAC developed 10 priority habitat restoration projects aimed at improving geomorphic and biological aspects of the lower Tuolumne River corridor (listed below), which have the potential to benefit fall-run Chinook salmon at one or more times during the species' life cycle.

- Channel and Riparian Restoration Projects (RM 34.3-RM 40.3)
  - Gravel Mining Reach Phase I - 7/11 Gravel Mining Reach Restoration (restored channel and floodplain along 1.5 river miles) (RM 38-39.5) (completed in 2003)
  - Gravel Mining Reach Phase II (not completed)[1]
  - Gravel Mining Reach Phase III (not completed)
  - Gravel Mining Reach Phase IV (not completed)
- Predator Isolation Projects
  - Special Run Pool (SRP) 9 Channel and Floodplain Restoration (restored channel and floodplain along 0.2 river miles) (RM 25.7-25.9) (completed in 2001)
  - SRP 10 (RM 25.5) (not completed)
  - Sediment Management Projects (RM 43.0-RM 51.8)
  - River Mile 43 Channel Restoration (restored channel and floodplain along 0.5 river miles) (completed in 2005)
  - Gasburg Creek Fine Sediment Retention Project (RM 50) (completed in 2008)
  - Gravel Augmentation (coarse sediment) (not completed)
  - Riffle Cleaning (fine sediment) (not completed)

[1] By the terms of the 1995 Settlement Agreement, the Districts and CCSF pledged $500,000 and an additional $500,000 in matching funds for Tuolumne River restoration projects. Also by the terms of the agreement, CDFW and USFWS were responsible for actively pursuing state and federal funding. After securing funding and constructing the initial four priority projects identified by the TAC, CDFW, while supporting additional restoration projects at the TAC, actively opposed using CALFED funding for additional projects. Consequently, approved CALFED funding of over $14.75 million for three additional TAC projects, designed to benefit fall-run Chinook and *O. mykiss*, was never able to be used and the projects were never implemented due to factors outside the control of the Districts.

3.0 PROPOSED ACTION AND MEASURES

3.1 Proposed Action

FERC is the federal agency authorized to issue licenses for the construction, operation, and maintenance of the nation's non-federal hydroelectric facilities. In accordance with the Federal Power Act, FERC is able to issue such licenses for a period not less than 30 years, but no more than 50 years. Upon expiration of an existing license, FERC must decide whether, and under what terms, to issue a new license. Under the Federal Power Act, FERC issues licenses that are best adapted to a comprehensive plan for improving or developing a waterway, and in so doing, must consider a suite of beneficial public uses including, among others, water supply, flood control, *irrigation, and fish and wildlife. As the federal "action agency," FERC must also comply with the requirements of NEPA, under which FERC must clearly define the specific proposed action it is considering and define the purpose and need for the proposed action.

In the case of the Don Pedro Project, the Proposed Action under review by FERC is the issuance of a new license to the Districts to authorize the continued generation of hydroelectric power at Don Pedro Dam, and the Districts' proposed resource enhancement measures (see Section 3.1.1). As generally described in FERC's SD2 issued on July 25, 2011, any alternatives to mitigate the Project's effects must be reasonably related to the purpose and need for the Proposed Action, which in this case is whether, and under what terms, to authorize continued hydroelectric power generation at the Project.

As noted in the previous section, flow releases through the powerhouse from Don Pedro Reservoir are scheduled based on requirements for (1) flood flow management, including pre-releases in advance of anticipated high flows during wet years, (2) the Districts' irrigation and M&I demands, including flows to maintain water storage in Turlock Lake and Modesto Reservoir, and (3) protection of aquatic resources in the lower Tuolumne River in accordance with the terms of the existing FERC license. Once the weekly and daily flow schedules are established based on these demands, outflows from the Don Pedro powerhouse are scheduled to deliver these flows. During periods of greater electrical demand, outflows may be shaped to generate more electricity during on-peak periods and less during off-peak periods, subject to meeting the requirements of the pre-established flow schedule. In accordance with the Districts' "water-first" policy, flow releases are scheduled around the three primary Project requirements listed above, then delivered via the generation units up to their capacity and availability. Hydropower generation at the Don Pedro Project is a secondary consideration with respect to flow scheduling.

Issuing a new license will allow the Districts to continue generating electricity at the Project for the term of the new license, producing low-cost electric power from a non-polluting, renewable resource. Clean, renewable hydroelectric power generation is a valuable benefit of the Project. The average annual generation from the Project from 1997 to 2012 was 535,000 megawatt hours (MWh) of electricity. The current maximum hydraulic capacity of the four turbines is 5,500 cfs, and the current FERC-authorized capacity is 168 MW.

The electricity generated at the Project is important to the State of California and will be increasingly important as the demand for electric power grows in the future. In January 2016, the

California Energy Commission issued the California Energy Demand 2016–2026, Revised Electricity Forecast. The updated forecast presents low, mid, and high forecasts for the state: average annual growth rates for electricity consumption for 2014–2026 are 0.54 percent, 0.97 percent, and 1.27 percent, respectively (Kavalec et al. 2016).

3.1.1 Proposed Aquatic Resource Measures

This EFH Assessment includes analysis of the effects on fall-run Chinook salmon that would result from the Districts' proposed resource measures for the lower Tuolumne River, many of which are designed to benefit fall-run Chinook salmon EFH. The following list provides brief descriptions of the measures proposed for the Lower Tuolumne River. The proposed details and benefits of these enhancements are discussed in relevant subsections under Direct and Indirect Effects of the Proposed Action (Section 5.2 of this EFH Assessment).

A substantial body of detailed physical and biological data is available to evaluate aquatic resources in the lower Tuolumne River. The Districts relied on this site-specific, empirical data to develop the measures presented below. Using these empirical data and the computer models developed based on these data, the Districts identified measures that would benefit fall-run Chinook EFH while protecting the Districts' water supply, especially during drought years.

- **Improve Spawning Gravel Quantity and Quality**
  - Gravel augmentation from RM 52 to RM 39 over a 10-year period to enhance the quality and quantity of fall-run Chinook spawning habitat.
  - Gravel mobilization flows of 6,000-7,000 cfs for gravel mobilization and movement of fines to enhance the quality of fall-run Chinook spawning habitat, and perhaps rearing habitat depending on the extent of fines displacement.
  - Conduct a five-year program of experimental gravel cleaning coinciding with May pulse flows (see below) to aid smolt outmigration by increasing turbidity to reduce predator sight-feeding effectiveness and improve gravel quality for Chinook egg incubation.
- **Instream Habitat Improvement**
  - Placement of boulders between RM 50 and RM 42 to provide salmonid microhabitat and promote localized scour of fines to benefit salmonid spawning.
- **Contribute to CDBW's Efforts to Remove Water Hyacinth**
  - The Districts would contribute $50,000 per year to the California Division of Boating and Waterways (CDBW) for the removal of water hyacinth in the lower Tuolumne River.
- **Fall-Run Chinook Spawning Improvement Superimposition Reduction Program**
  - To reduce superimposition of fall-run Chinook redds, a temporary barrier would be installed below the new La Grange Bridge (RM 49.9) after November 15 once passage at the proposed RM 25.5 fish counting weir (see next measure, below) exceeds 4,000 total spawners. The barrier would encourage salmonid spawning on less frequently used, but still suitable, riffles downstream of the barrier.

- **Predator Control and Suppression Plan**
  - Implement a predator control and suppression plan, which would involve the following components:
    - Construction and operation of a barrier weir (less than 5 feet of head at normal flows) at approximately RM 25.5. The weir would provide (1) a permanent upstream counting station for anadromous salmonids, (2) a barrier to the upstream movement of striped bass and a means of removing or isolating striped bass during smolt outmigration, and (3) a barrier to the upstream movement of black bass.
    - Specific incentives and measures to target an annual reduction in the population of black bass and striped bass by approximately 20 percent above the proposed barrier weir (at RM 25.5) and 10 percent below the barrier weir.
    - The Districts' advocacy for changes to current fishing regulations for the lower Tuolumne River to reduce black and striped bass abundance.
- **Fall-Run Chinook Salmon Restoration Hatchery Program**
  - Temporary fall-run Chinook salmon restoration hatchery program to protect, improve, and conserve the Tuolumne River fall-run Chinook population. The facility would be designed and constructed in cooperation with CDFW and operated by CDFW.
- **Flow-Related Measures for Fish and Aquatic Resources**
  - Flow Release Summary: The Districts proposed flow releases for the lower Tuolumne River are summarized in Table 3.1-1 and briefly described below.
  - Infiltration Galleries 1 and 2: The Districts are proposing to complete construction of TID's IG1 (RM 25.9) and construct a second infiltration gallery (IG2) at the same general location. IG1 has a design capacity of approximately 100 cfs, and IG2 would have a capacity of 100–125 cfs. The IGs would be used to allow for greater water releases to the reach between RM 52 and RM 25.8, which could then be recaptured at the IGs to provide for consumptive uses.
  - *O. mykiss* Fry Rearing: To enhance habitat for *O. mykiss* fry rearing, a flow of 200 cfs would be provided at the La Grange gauge (USGS 11289650) from June 1–June 30 of all water year types. At RM 25.5 (i.e., downstream of the infiltration galleries), instream flows during this period would be between 75 cfs and 100 cfs, depending on water-year type.
  - *O. mykiss* Juvenile Rearing: To enhance habitat for *O. mykiss* juvenile rearing, flows of 300–350 cfs would be provided, depending on water-year type, at the La Grange gauge from July 1–October 15. At RM 25.5, flows of 75–150 cfs would be provided during this period, depending on water-year type. Also during this period, the Districts would provide a flushing flow during Wet, Above Normal, and Below Normal water years to clean gravels of accumulated algae and fines prior to the onset of substantial spawning. The flushing flow of 1,000 cfs (not to exceed 5,950 ac-ft) would be provided on October 5, 6, and 7, with appropriate up- and down-ramps and IGs shut off.

Table 3.1-1. Proposed lower Tuolumne River flows to benefit aquatic resources and accommodate recreational boating.

Water Year/Time Period	Flow (cfs)	
	La Grange Gage (No. 11289650)	RM 25.5
Wet, Above Normal, Below Normal		
June 1 – June 30	200	100[1]
July 1 – October 15[3]	350	150[2]
October 15 – December 31	275	275
January 1 – February 28/29	225	225
March 1 – April 15	250	250
April 16 – May 15[4]	275	275
May 16 – May 31[4]	300	300
Dry		
June 1 – June 30	200	75
July 1 – October 15	300	75[2]
October 15 – December 31	225	225
January 1 – February 28/29	200	200
March 1 – April 15	225	225
April 16 – May 15[4]	250	250
May 16 – May 31[4]	275	275
Critical		
June 1 – June 30	200	75
July 1 – October 15	300	75
October 15 – December 31	200	200
January 1 – February 28/29	175	175
March 1 – April 15	200	200
April 16 – May 15[4]	200	200
May 16 – May 31[4]	225	225

1 Cease IG withdrawal for one pre-scheduled weekend.
2 200 cfs for three-day July 4 holiday, for three-day Labor Day holiday, and for two pre-scheduled additional weekends in either June, July, or August.
3 1,000 cfs flushing flow (not to exceed 5,950 ac-ft) on October 5, 6 and 7, with appropriate up and down ramps and IGs shut off.
4 Fall-run Chinook outmigration pulse flows: 150,000 ac-ft (Wet, Above Normal), 100,000 ac-ft (Below Normal), 75,000 ac-ft (Dry), 35,000 ac-ft (first Critical), and 11,000 ac-ft (sequential Critical[s]).

- Fall-run Chinook spawning (October 15 – December 31): Minimum instream flows of 275 cfs (W, AN, BN water years), 225 cfs (D water years), and 200 cfs (C water years).
- Fall-run Chinook fry-rearing (January 1 – February 28/29): Minimum instream flows of 225 cfs (W, AN, BN water years), 200 cfs (D water years), and 175 cfs (C water years).
- Fall-run Chinook juvenile rearing (March 1 – April 15): 250 cfs (W, AN, BN water years), 225 cfs (D water years), and 200 cfs (C water years).
- Fall-run Chinook outmigration base flows (April 16 – May 15): 275 cfs (W, AN, BN water years), 250 cfs (D water years), and 200 cfs (C water years).
- Fall-run Chinook outmigration base flows (May 16 – May 31): 300 cfs (W, AN, BN water years), 275 cfs (D water years), and 225 cfs (C water years).
- Fall-run Chinook outmigration pulse flows (April 16 – May 31): 150,000 ac-ft (W, AN water years), 100,000 ac-ft (BN water years), 75,000 ac-ft (initial D water years), 45,000

ac-ft (sequential D water years), 35,000 ac-ft (initial C water years), and 11,000 ac-ft (sequential C water years).[4]

- During spill years, a reasonable effort would be made to shape the descending limb of the snowmelt runoff hydrograph to mimic natural conditions to benefit riparian native vegetation (e.g., cottonwoods) that depends on seed deposition during these periods.

▪ **Flows to Enhance Recreational Boating**

- A flow of 200 cfs or greater would be provided at the La Grange gage from April 1–May 31 in all water years.
- A flow of 200 cfs would be provided at the La Grange gage from June 1–June 30 in all water years. In Wet, Above Normal, and Below Normal water years, withdrawal of water at the infiltration galleries would cease for one pre-scheduled weekend in June to provide an additional 100 cfs (for a total of 200 cfs) at RM 25.5.
- A flow of 350 cfs would be provided at the La Grange gage from July 1–October 15 in Wet, Above Normal, and Below Normal water years, and 300 cfs would be provided in Dry and Critical water years. In all but Critical water years, a flow of 200 cfs would be provided at RM 25.8 for the three-day July 4 holiday, the three-day Labor Day holiday, and for two pre-scheduled additional weekends in either July or August.

3.2 Interrelated and Interdependent Actions

Interrelated actions are actions that are part of a larger action and depend on the larger action for their justification (50 CFR § 402.02), whereas interdependent actions are actions with no independent utility apart from a proposed action (50 CFR § 402.02). If a private activity would not occur were it not for the occurrence of the proposed action, the effects of that private activity are interdependent and interrelated to the proposed action, and the effects of the private activity are considered attributable to the proposed federal action for consultation purposes.

In contrast, actions that would occur without the occurrence of the proposed action are not interdependent or interrelated to the proposed action. The USFWS and NMFS (1998) state that if a project would exist independent of a proposed action, it cannot be considered “interrelated” or “interdependent” and included in the effects of the proposed action.

As noted above, the Proposed Action being assessed in the Districts’ AFLA is the issuance of a FERC license for the continuation of the hydroelectric power generation at the Project, along with the Districts’ suite of measures proposed for the enhancement of aquatic resources. Water storage and releases for the Project’s primary purposes, i.e., irrigation, M&I uses, CCSF’s water bank, and flood control in cooperation with the ACOE, are not dependent on the issuance of a FERC license for the Project, and will occur with or without the licensing of the Proposed Action. As such, these primary purposes are *not* interrelated or interdependent with the issuance of a FERC license for hydroelectric power generation. Because the Districts are consulting with NMFS on the Proposed Action, and power would be generated as it has been historically (i.e., the effects of hydroelectric

[4] This reduced pulse flow, while still greater than or equal to Base Case pulse flows, would also occur in a sequence of “D” and “C” years. For example, in a sequence of the years C, D, C, D, C, D, the second and third “critical” years and the second and third “dry” years would each have pulse flows of 11 TAF and 45 TAF, respectively.

power generation would be equivalent to those occurring under baseline conditions as defined by FERC, resulting in no effects on lower river resources), the aforementioned non-hydropower water uses are not interrelated or interdependent actions, and as a result, their potential effects on EFH, although assessed in the cumulative effects section of this EFH Assessment, are not considered part of the Proposed Action.

4.0 EXISTING CONDITIONS IN THE ACTION AREA

4.1 Delineation of EFH Action Area

As described in Section 1.2, the EFH Action Area for fall-run Chinook salmon addressed in this EFH Assessment includes the Tuolumne River from La Grange Diversion Dam (RM 52.2) to the confluence with the San Joaquin River and the San Joaquin River from RM 84 (i.e., the confluence with the Tuolumne River) downstream through the Delta.

4.2 Overview of the EFH Action Area

4.2.1 Lower Tuolumne River

The 150-mile-long Tuolumne River originates at an elevation just above 8,600 feet in the high alpine Tuolumne Meadows located in Yosemite National Park. From Tuolumne Meadows, the Tuolumne River flows generally westward through a number of waterfalls, including Tuolumne, California, Le Conte, and Waterwheel falls (DeLorme 2003), before entering the steep-sided and rocky Grand Canyon of the Tuolumne. Downstream of Don Pedro Reservoir, the rolling hills of the eastern Central Valley gradually flatten to become a terraced floodplain. From here, the river flows to its confluence with the San Joaquin River, at RM 84 of the San Joaquin River.

Lands along the Tuolumne River downstream of La Grange Diversion Dam (i.e., the "lower" Tuolumne River) are primarily privately owned and used for agriculture, grazing, rural residential purposes, and denser residential purposes, such as the communities of Waterford and Modesto (Stanislaus County 2006). A small portion of land downstream of the Project is under state ownership, i.e., Turlock Lake State Recreation Area, which is a small state park that extends from the southern bank of the Tuolumne River to the north shore of Turlock Lake.

The lower Tuolumne River consists of two broad geomorphic zones defined by channel slope and bed material. The upper zone (RM 24–52.1) is gravel-bedded with moderate slope (0.10–0.15 percent), whereas the lower zone (RM 0–24) is sand-bedded with a slope generally less than 0.03 percent (McBain and Trush 2000). The gravel-bedded and sand-bedded geomorphic zones have been subdivided into seven reaches based on present and historical land uses, valley confinement, channel substrate and slope, and salmonid use:

- Reach 1 (RM 0–10.5): Lower sand-bedded reach,
- Reach 2 (RM 10.5–19.3): Urban sand-bedded reach,
- Reach 3 (RM 19.3–24.0): Upper sand-bedded reach,
- Reach 4 (RM 24.0–34.2): In-channel gravel mining reach,
- Reach 5 (RM 34.2–40.3): Gravel mining reach,
- Reach 6 (RM 40.3–45.5): Dredger tailings reach, and
- Reach 7 (RM 45.5–52.1): Dominant salmon spawning reach.

Historically, the native fish community of the lower Tuolumne River included species from the deep-bodied fish assemblage, such as Sacramento perch (*Archoplites interruptus*), tule perch (*Hysterocarpus traskii*), hitch (*Lavinia exilcauda*), Sacramento blackfish (*Orthodon microlepidotus*), and Sacramento splittail (*Pogonichthys macrolepidotus*) (Moyle 2002). Sacramento pikeminnow (*Ptychocheilus grandis)* and Sacramento sucker (*Catostomus occidentalis*) were also abundant, migrating upstream from the San Joaquin River to spawn in the Tuolumne River. Currently, in addition to the native species identified above, an array of introduced species, many of them piscivorous, also occupy the river.

Central Valley fall-run Chinook salmon escapement to the Tuolumne River consists to a large degree of hatchery-origin fish (TID/MID 2013; W&AR-05). Although precise estimates of the proportion of hatchery- and naturally-produced salmon cannot readily be estimated based on the historical record because hatchery-origin fish have not been consistently marked, straying of hatchery-origin fish has been documented in the Tuolumne River and has likely affected the numbers and genetic characteristics of Chinook salmon in annual spawning runs (TID/MID 2012; TID/MID 2013f).

Dams and water diversions; instream and floodplain mining; water quality degradation; hatchery programs; state and federal Delta water exports; development in and adjacent to the lower San Joaquin River, the Delta, and San Francisco Bay; commercial and recreational harvest; and poaching have all affected historical patterns of anadromous salmonid abundance in the Tuolumne River (TID/MID 2005).

Dams and water diversions had affected fish migration in the Tuolumne River as early as 1852 (Snyder 1993 unpublished memorandum, as cited in Yoshiyama et al.1996). Access to historical spawning and rearing habitat was significantly restricted beginning in the 1870s, when a number of dams and irrigation diversion projects were constructed by parties unaffiliated with and pre-dating the Districts. Wheaton Dam, built in 1871 near the site of the current-day La Grange Diversion Dam, was a barrier to upstream fish migration.

Extensive instream and floodplain mining for aggregate and gold had adversely affected salmon runs in the Tuolumne River prior to dam construction (TID/MID 2005). These activities left large pits in the river and floodplain that altered the river's morphology and flow patterns and harbored predators, such as largemouth and smallmouth bass (both species were introduced by CDFW in the late 1800s and early 1900s for recreational fisheries). Introduced predators were and continue to be most abundant in the slow-water areas prevalent in the middle section of the lower Tuolumne River, downstream of the major fall-run Chinook spawning areas (Orr 1997). Because much of the habitat that supports introduced piscivores was created by instream sand and gravel mining, the present pattern and degree of predation mortality on Chinook smolts in the Tuolumne River is to a large extent the result of past mining coupled with the introduction of non-native fish species (Orr 1997).

4.2.2 Lower San Joaquin River

The San Joaquin River originates in the high Sierra Nevada range, flows west and then northward for approximately 330 miles, and enters the legally-defined Delta near the USGS Vernalis gaging station (RM 73). The drainage area of the San Joaquin River above the Vernalis gage is 13,539 mi^2. The average annual flow at Vernalis was 3.26 million ac-ft from WY 1924 through WY 2012 (3.19 million ac-ft for WY 1971–WY 2012).

The San Joaquin River below an elevation of about 80 feet is typically characterized by warm sluggish channels, swamps, and sloughs (Moyle 2002). The fish assemblage of the lower San Joaquin River is similar to that described in the previous section for the lower Tuolumne River. Anadromous fish pass through the lower San Joaquin River on their way upstream to spawn in tributaries.

Under present conditions, flows in the lower San Joaquin River consist largely of tributary inflows from the Stanislaus (drainage area 1,075 mi^2), Tuolumne (drainage area 1,960 mi^2), and Merced (drainage area 1,037 mi^2) rivers (SWRCB 2010). Much of the flow from the San Joaquin River is diverted before reaching the Delta, due largely to the operation of the State Water Project (SWP) and federal Central Valley Project (CVP). Water is also diverted from the San Joaquin River between the mouth of the Tuolumne River and Vernalis. Many of these are small, private irrigation diversions, which are often unscreened.

4.2.3 Sacramento-San Joaquin Delta

The Sacramento and San Joaquin rivers meet at the western boundary of the Sacramento-San Joaquin Delta. Freshwater from the rivers mingles with saltwater from the Pacific Ocean, creating the West Coast's largest estuary. Under historical conditions, the south Delta and lower San Joaquin River were composed of tidal wetlands merging southward into floodplain wetlands interspersed with complex side-channel habitats, lakes, and ponds, with seasonal wetlands bordering upland habitats (Whipple et al. 2012; Fox et al. 2015).

As summarized by Lund et al. (2007), the present day Delta encompasses about 60,000 acres of open water (exclusive of Suisun Bay), 520,000 acres of agricultural lands, 64,000 acres of towns and cities, and 75,000 acres of undeveloped areas. As noted above, much of the San Joaquin River's flow is diverted before reaching the Delta, due largely to the operation of the SWP and CVP. Much of the rich Delta farmland has lost soil from oxidation, compaction, and wind erosion, resulting in lowered elevations of some islands up to 25 feet below sea level (California Department of Water Resources [CDWR] 2009). The Delta is interlaced with hundreds of miles of waterways, and relies on more than 1,000 miles (1,600 km) of levees for flood protection (Moore and Shlemon 2008). These levees have eliminated numerous wetlands and the majority of tidal exchange with marsh habitats in the Delta (Whipple et al. 2012), areas historically used for fish rearing (Kimmerer et al. 2008).

4.3 Central Valley Fall-Run Chinook Salmon

Spawning populations of Chinook salmon are distributed across the northern temperate latitudes of the Pacific Ocean from Asia, Alaska, Washington, Oregon, to as far south as the San Joaquin River in California's Central Valley (Healey 1991). Chinook salmon exhibit variable life-history patterns depending on environmental conditions across the species' range (Healey 1991; Quinn 2005). Most Chinook salmon return from the ocean to spawn in freshwater streams when they are between two and five years old. Homing fidelity of Chinook salmon to their natal streams is related to the sequence of olfactory cues imprinted during juvenile rearing and outmigration.

There are four distinct Chinook salmon runs in the Sacramento and San Joaquin River basins. Individuals belonging to the fall run migrate upstream as adults typically from July through December and spawn from early October through the end of December. Run timing varies among stream systems. In the Tuolumne River, fall-run/late fall-run Chinook migrate upstream from late August through December, with peak migration in November, and spawn primarily in November and December. Fall-run Chinook, which are currently the most abundant of the Central Valley races, contribute significantly to large commercial and recreational fisheries. Because of concerns over population size and hatchery influence, the Central Valley fall/late fall-run Chinook salmon Evolutionary Significant Unit (ESU) is considered a Species of Concern under the federal Endangered Species Act (ESA).

4.3.1 Fall-Run Chinook Studies in the Lower Tuolumne River

The Don Pedro Project and its potential environmental effects have undergone continuous study and evaluation since the early 1970s. The Districts, in cooperation with state and federal resource agencies and environmental groups, have conducted over 200 individual resource investigations since the Don Pedro Project began commercial operation in 1971. The first 20 years of study led in 1995 to the development of a FERC-mediated settlement agreement with resource agencies and NGOs, whereby the Districts agreed to modify their operations to increase the flows released to the lower Tuolumne River for the benefit of salmonids.

On an annual basis, the Districts file with FERC, and share with the TAC, results of ongoing monitoring downstream of the Project Boundary. The up-to-date record created by the continuous process of environmental investigation and resource monitoring has produced detailed baseline information. Pre-relicensing studies pertaining directly or indirectly to fall-run Chinook are listed in Table 4.3-1. Studies fall into the following general categories: (1) salmon population models, (2) salmon spawning surveys, (3) seine, snorkel, and fyke net reports and various juvenile salmon studies, (4) screw trap monitoring, (5) flow fluctuation assessments, (6) smolt monitoring and survival evaluations, (7) fish community assessments (8) invertebrate reports, (9) Delta salmon salvage reports, (10) gravel, incubation, and redd distribution studies, (11) water temperature and water quality assessments, (12) IFIM assessments, (13) flow and Delta water export reports, (14) restoration, monitoring, and mapping, and (15) general monitoring.

Table 4.3-1. Article 39 and 58 monitoring reports and other fish studies conducted in the lower Tuolumne River prior to and independent of the current relicensing.

Study No.	Study Name
Salmon Population Models	
1992 Appendix 1	Population Model Documentation
1992 Appendix 26	Export Mortality Fraction Submodel
1992 Appendix 2	Stock Recruitment Analysis of the Population Dynamics of San Joaquin River System Chinook salmon
Report 1996-5	Stock-Recruitment Analysis Report
Salmon Spawning Surveys	
1992 Appendix 3	Tuolumne River Salmon Spawning Surveys 1971-88
Report 1996-1	Spawning Survey Summary Report
Report 1996-1.1	1986 Spawning Survey Report
Report 1996-1.2	1987 Spawning Survey Report
Report 1996-1.3	1988 Spawning Survey Report
Report 1996-1.4	1989 Spawning Survey Report
Report 1996-1.5	1990 Spawning Survey Report
Report 1996-1.6	1991 Spawning Survey Report
Report 1996-1.7	1992 Spawning Survey Report
Report 1996-1.8	1993 Spawning Survey Report
Report 1996-1.9	1994 Spawning Survey Report
Report 1996-1.10	1995 Spawning Survey Report
Report 1996-1.11	1996 Spawning Survey Report
Report 1996-1.12	Population Estimation Methods
Report 1997-1	1997 Spawning Survey Report and Summary Update
Report 1998-1	Spawning Survey Summary Update
Report 1999-1	1998 Spawning Survey Report
Report 2000-1	1999 and 2000 Spawning Survey Reports
Report 2000-2	Spawning Survey Summary Update
Report 2001-1	2001 Spawning Survey Report
Report 2001-2	Spawning Survey Summary Update
Report 2002-1	2002 Spawning Survey Report
Report 2002-2	Spawning Survey Summary Update
Report 2003-1	Spawning Survey Summary Update
Report 2004-1	2003 and 2004 Spawning Survey Reports
Report 2004-2	Spawning Survey Summary Update
Report 2006-1	2005 and 2006 Spawning Survey Reports
Report 2006-2	Spawning Survey Summary Update
Report 2007-1	2007 Spawning Survey Report
Report 2007-2	Spawning Survey Summary Update
Report 2008-2	Spawning Survey Summary Update
Report 2009-1	2008 and 2009 Spawning Survey Reports
Report 2009-2	Spawning Survey Summary Update
Report 2009-8	2009 Counting Weir Report
Report 2010-1	2010 Spawning Survey Reports
Report 2010-2	Spawning Survey Summary Update
Report 2010-8	2010 Counting Weir Report
Report 2011-2	Spawning Survey Summary Update
Report 2011-8	2011 Tuolumne River Weir Report
Report 2012-2	Spawning Survey Summary Update
Report 2012-6	2012 Tuolumne River Weir Report
Report 2013-1	2013 Spawning Survey Reports
Report 2013-2	Spawning Survey Summary Update

Study No.	Study Name
Report 2013-6	2013 Tuolumne River Weir Report
Report 2014-1	2014 Spawning Survey Reports
Report 2014-2	Spawning Survey Summary Update
Report 2014-6	2014 Tuolumne River Weir Report
Report 2015-1	2015 Spawning Survey Reports
Report 2015-2	Spawning Survey Summary Update
Report 2015-6	2015 Tuolumne River Weir Report
Report 2016-1	2016 Spawning Survey Reports
Report 2016-2	Spawning Survey Summary Update
Report 2016-6	2016 Tuolumne River Weir Report
Seine, Snorkel, Fyke Reports and Various Juvenile Salmon Studies	
1992 Appendix 10	1987 Juvenile Chinook salmon Mark-Recapture Study
1992 Appendix 12	Data Reports: Seining of Juvenile Chinook Salmon in the Tuolumne, San Joaquin, and Stanislaus Rivers, 1986-89
1992 Appendix 13	Report on Sampling of Chinook Salmon Fry and Smolts by Fyke Net and Seine in the Lower Tuolumne River, 1973-86
1992 Appendix 20	Juvenile Salmon Pilot Temperature Observation Experiments
Report 1996-2	Juvenile Salmon Summary Report
Report 1996-2.1	1986 Snorkel Survey Report
Report 1996-2.2	1988-89 Pulse Flow Reports
Report 1996-2.3	1990 Juvenile Salmon Report
Report 1996-2.4	1991 Juvenile Salmon Report
Report 1996-2.5	1992 Juvenile Salmon Report
Report 1996-2.6	1993 Juvenile Salmon Report
Report 1996-2.7	1994 Juvenile Salmon Report
Report 1996-2.8	1995 Juvenile Salmon Report
Report 1996-2.9	1996 Juvenile Salmon Report
Report 1996-9	Aquatic Invertebrate Report
Report 1997-2	1997 Juvenile Salmon Report and Summary Update
Report 1998-2	1998 Juvenile Salmon Report and Summary Update
Report 1999-4	1999 Juvenile Salmon Report and Summary Update
Report 2000-3	2000 Seine/Snorkel Report and Summary Update
Report 2001-3	2001 Seine/Snorkel Report and Summary Update
Report 2002-3	2002 Seine/Snorkel Report and Summary Update
Report 2003-2	2003 Seine/Snorkel Report and Summary Update
Report 2004-3	2004 Seine/Snorkel Report and Summary Update
Report 2005-3	2005 Seine/Snorkel Report and Summary Update
Report 2006-3	2006 Seine/Snorkel Report and Summary Update
Report 2007-3	2007 Seine/Snorkel Report and Summary Update
Report 2008-3	2008 Seine Report and Summary Update
Report2008-5	2008 Snorkel Report and Summary Update
Report 2009-3	2009 Seine Report and Summary Update
Report 2009-5	2009 Snorkel Report and Summary Update
Report 2010-3	2010 Seine Report and Summary Update
Report 2010-5	2010 Snorkel Report and Summary Update
Report 2011-3	2011 Seine Report and Summary Update
Report 2011-5	2011 Snorkel Report and Summary Update
Report 2012-3	2012 Seine Report and Summary Update
Report 2012-5	2012 Snorkel Report and Summary Update
Report 2013-3	2013 Seine Report and Summary Update
Report 2013-5	2013 Snorkel Report and Summary Update
Report 2014-3	2014 Seine Report and Summary Update

Study No.	Study Name
Report 2014-5	2014 Snorkel Report and Summary Update
Report 2015-3	2015 Seine Report and Summary Update
Report 2015-5	2015 Snorkel Report and Summary Update
Report 2016-3	2016 Seine Report and Summary Update
Report 2016-5	2016 Snorkel Report and Summary Update
Screw Trap Monitoring	
Report 1996-12	Screw Trap Monitoring Report: 1995-96
Report 1997-3	1997 Screw Trap and Smolt Monitoring Report
Report 1998-3	1998 Tuolumne River Outmigrant Trapping Report
Report 1999-5	1999 Tuolumne River Upper Rotary Screw Trap Report
Report 2000-4	2000 Tuolumne River Smolt Survival and Upper Screw Traps Report
Report 2000-5	1999-2000 Grayson Screw Trap Report
Report 2001-4	2001 Grayson Screw Trap Report
Report 2004-4	1998, 2002, and 2003 Grayson Screw Trap Reports
Report 2004-5	2004 Grayson Screw Trap Report
Report 2005-4	2005 Grayson Screw Trap Report
Report 2005-5	Rotary Screw Trap Summary Update
Report 2006-4	2006 Rotary Screw Trap Report
Report 2006-5	Rotary Screw Trap Summary Update
Report 2007-4	2007 Rotary Screw Trap Report
Report 2008-4	2008 Rotary Screw Trap Report
Report 2009-4	2009 Rotary Screw Trap Report
Report 2010-4	2010 Rotary Screw Trap Report
Report 2011-4	2011 Rotary Screw Trap Report
Report 2012-4	2012 Rotary Screw Trap Report
Report 2013-4	2013 Rotary Screw Trap Report
Report 2014-4	2014 Rotary Screw Trap Report
Report 2015-4	2015 Rotary Screw Trap Report
Report 2016-4	2016 Rotary Screw Trap Report
Flow Fluctuation Assessments	
1992 Appendix 14	Fluctuation Flow Study Report
1992 Appendix 15	Fluctuation Flow Study Plan: Draft
Report 2000-6	Tuolumne River Chinook Salmon Fry and Juvenile Stranding Report
2005 Ten-Year Summary Report Appendix E	Stranding Survey Data (1996-2002)
Predation Evaluations	
1992 Appendix 22	Lower Tuolumne River Predation Study Report
1992 Appendix 23	Effects of Turbidity on Bass Predation Efficiency
Report 2006-9	Lower Tuolumne River Predation Assessment Final Report
Smolt Monitoring and Survival Evaluations	
1992 Appendix 21	Possible Effects of High Water Temperature on Migrating Salmon Smolts in the San Joaquin River
Report 1996-13	Coded-wire Tag Summary Report
Report 1998-4	1998 Smolt Survival Peer Review Report
Report 1998-5	CWT Summary Update
Report 1999-7	Coded-wire Tag Summary Update
Report 2000-4	2000 Tuolumne River Smolt Survival and Upper Screw Traps Report
Report 2000-8	Coded-wire Tag Summary Update
Report 2001-5	Large CWT Smolt Survival Analysis
Report 2001-6	Coded-wire Tag Summary Update
Report 2002-4	Large CWT Smolt Survival Analysis
Report 2002-5	Coded-wire Tag Summary Update

Study No.	Study Name
Report 2003-3	Coded-wire Tag Summary Update
Report 2004-7	Large CWT Smolt Survival Analysis Update
Report 2004-8	Coded-wire Tag Summary Update
Report 2005-6	Coded-wire Tag Summary Update
Report 2006-6	Coded-wire Tag Summary Update
Report 2007-5	Coded-wire Tag Summary Update
Fish Community Assessments	
1992 Appendix 24	Effects of Introduced Species of Fish in the San Joaquin River System
1992 Appendix 27	Summer Flow Study Report 1988-90
Report 1996-3	Summer Flow Fish Study Annual Reports: 1991-94
Report 1996-3.1	1991 Report
Report 1996-3.2	1992 Report
Report 1996-3.3	1993 Report
Report 1996-3.4	1994 Report
Report 2001-8	Distribution and Abundance of Fishes Publication
Report 2002-9	Publication on the Effects of Flow on Fish Communities
Invertebrate Reports	
1992 Appendix 16	Aquatic Invertebrate Studies Report
1992 Appendix 28	Summer Flow Invertebrate Study
Report 1996-4	Summer Flow Aquatic Invertebrate Annual Reports: 1989-93
Report 1996-4.1	1989 Report
Report 1996-4.2	1990 Report
Report 1996-4.3	1991 Report
Report 1996-4.4	1992 Report
Report 1996-4.5	1993 Report
Report 1996-9	Aquatic Invertebrate Report
Report 2002-8	Aquatic Invertebrate Report
Report 2004-9	Aquatic Invertebrate Monitoring Report (2003-2004)
Report 2008-7	Aquatic Invertebrate Monitoring (2005, 2007, 2008) and Summary Update
Report 2009-7	2009 Aquatic Invertebrate Monitoring and Summary Update
Delta Salmon Salvage	
Report 1999-6	1993-99 Delta Salmon Salvage Report
Gravel, Incubation, and Redd Studies	
1992 Appendix 6	Spawning Gravel Availability and Superimposition Report (incl. map)
1992 Appendix 7	Salmon Redd Excavation Report
1992 Appendix 8	Spawning Gravel Studies Report
1992 Appendix 9	Spawning Gravel Cleaning Methodologies
1992 Appendix 11	An Evaluation of the Effect of Gravel Ripping on Redd Distribution
Report 1996-6	Redd Superimposition Report
Report 1996-7	Redd Excavation Report
Report 1996-8	Gravel Studies Report: 1987-89
Report 1996-10	Gravel Cleaning Report: 1991-93
Report 2000-7	Tuolumne River Substrate Permeability Assessment and Monitoring Program Report
Report 2006-7	Survival to Emergence Study Report
Report 2008-9	Monitoring of Winter 2008 Runoff Impacts from Peaslee Creek
Water Temperature and Water Quality	
1992 Appendix 17	Preliminary Tuolumne River Water Temperature Report
1992 Appendix 18	Instream Temperature Model Documentation: Description and Calibration
1992 Appendix 19	Modeled Effects of La Grange Releases on Instream Temperatures in the Lower Tuolumne River
Report 1996-11	Intragravel Temperature Report: 1991

Study No.	Study Name
Report 1997-5	1987-97 Water Temperature Monitoring Data Report
Report 2002-7	1998-2002 Temperature and Conductivity Data Report
Report 2004-10	2004 Water Quality Report
Report 2007-6	Flow, Delta Export, Weather, and Water Quality Data Report: 2003-2007
IFIM Assessment	
1992Appendix 4	Instream Flow Data Processing, Tuolumne River
1992 Appendix 5	Analysis of 1981 Lower Tuolumne River IFIM Data
	1995 USFWS Report on the Relationship between Instream Flow and Physical Habitat Availability (submitted by Districts to FERC in May 2004)
Flow and Delta Exports	
Report 1997-4	Streamflow and Delta Water Export Data Report
Report 2002-6	1998-2002 Streamflow and Delta Water Export Data Report
Report 2003-4	Review of 2003 Summer Flow Operation
Report 2007-6	Flow, Delta Export, Weather, and Water Quality Data Report: 2003-2007
Report 2008-8	Review of 2008 Summer Flow Operation
Report 2009-6	Review of 2009 Summer Flow Operation
Restoration, Project Monitoring, and Mapping	
Report 1996-14	Tuolumne River GIS Database Report and Map
Report 1999-8	A Summary of the Habitat Restoration Plan for the Lower Tuolumne River Corridor
Report 1999-9	Habitat Restoration Plan for the Lower Tuolumne River Corridor
Report 1999-10	1998 Restoration Project Monitoring Report
Report 1999-11	1999 Restoration Project Monitoring Report
Report 2001-7	Adaptive Management Forum Report
Report 2004-12	Coarse Sediment Management Plan
Report 2004-13	Tuolumne River Floodway Restoration (Design Manual)
2005 Ten-Year Summary Report Appendix D	Salmonid Habitat Maps
2005 Ten-Year Summary Report Appendix F	GIS Mapping Products
Report 2005-7	Bobcat Flat/River Mile 43: Phase 1 Project Completion Report
Report 2006-8	Special Run Pool 9 and 7/11 Reach: Post-Project Monitoring Synthesis Report
Report 2006-10	Tuolumne River La Grange Gravel Addition, Phase II Annual Report
Report 2006-11	Tuolumne River La Grange Gravel Addition, Phase II Geomorphic Monitoring Report
General Monitoring Information	
Report	1992 Fisheries Studies Report
Report 2002-10	2001-2002 Annual CDFW Sportfish Restoration Report
Report	2005 Ten-Year Summary Report

As part of FERC relicensing of the Don Pedro Project, the Districts conducted the following studies that pertain directly or indirectly to lower Tuolumne River fall-run Chinook salmon.

4.3.1.1 Spawning Gravel in the Lower Tuolumne River (W&AR-04)

In 2012, the Districts conducted a spawning gravel survey (TID/MID 2013h) on the lower Tuolumne River. The reach surveyed extended from just downstream of La Grange Diversion Dam at RM 52.1 to RM 23, which accounts for the extent of riffle habitats documented in historical surveys (TID/MID 1992). The spawning gravel survey involved the application of a variety of analyses and modeling to: (1) estimate average annual sediment yield to Don Pedro Reservoir, (2) estimate changes in the volume of coarse bed material in the lower Tuolumne River channel from

2005 to 2012, (3) map fine bed material in the lower Tuolumne River and compare the results with previous surveys, (4) develop a reach-specific coarse sediment budget to evaluate the Project's contribution to cumulative effects on river sediment in the lower Tuolumne River, and (5) map current riffle, spawning gravel, and suitable spawning habitat areas in the lower Tuolumne River and compare the results with previous surveys.

4.3.1.2 Salmonid Population Information Integration and Synthesis (W&AR-05)

The Districts conducted a Salmonid Population Information Integration and Synthesis Study in 2012 (TID/MID 2013f) to collect and summarize existing information to characterize fall-run Chinook salmon and resident and anadromous *O. mykiss* populations in the Tuolumne River and develop hypotheses related to factors potentially affecting those populations. The study area included the lower Tuolumne River from La Grange Diversion Dam (RM 52.2) downstream to the confluence with the San Joaquin River (RM 0), the lower San Joaquin River from the Tuolumne River confluence (RM 84) to Vernalis (RM 69.3), the Delta, San Francisco Bay Estuary, and the Pacific Ocean. Local and regional information, as well as broader scientific literature sources, were reviewed to examine issues affecting habitat use and life history progression of Tuolumne River fall-run Chinook salmon.

4.3.1.3 Chinook Salmon Population Model Study (W&AR-06)

The Districts have developed the Tuolumne River Chinook Salmon Population Model (TID/MID 2017a) to investigate the relative influences of various factors on the life-stage-specific production of Chinook salmon in the Tuolumne River, identify critical life-stage-specific limitations that may represent population "bottlenecks," and compare relative changes in population size between potential alternative management scenarios. Drawing on information developed through interrelated studies, linked sub-models were developed using functional relationships of habitat use, growth, movement, and predation to predict changes in fry, juvenile, and smolt productivity metrics in response to changes in flow and habitat availability in particular locations along the lower Tuolumne River corridor. This model was developed with substantial involvement of interested agencies and NGOs in accordance with a workshop consultation process used to obtain critical input at key stages of model development.

4.3.1.4 Predation (W&AR-07)

In 2012, the Districts conducted a study to understand the effects of predation on rearing and outmigrating juvenile Chinook salmon in the lower river (TID/MID 2013e). The study, which built upon previously conducted evaluations (TID/MID 1992), involved estimating the relative abundance of native and non-native piscivores, updating estimates of predation rates, and evaluating habitat use by juvenile Chinook salmon and predator species at typical flows encountered during the juvenile outmigration period. The study area included the Tuolumne River from La Grange Diversion Dam (RM 52.2) to the confluence with the San Joaquin River (RM 0). Because sampling restrictions contained in the Section 10 permit issued by NMFS for the protection of Central Valley Steelhead limited the use of electrofishing to locations downstream of RM 31.5, predation study sites were generally concentrated between RM 3.7 and RM 41.3.

On May 21, 2013, FERC issued its Determination on Requests for Study Modifications and New Studies, which included a recommendation that the Districts conduct another year of predation studies in 2014. Following consultation with relicensing participants, and review and revision of the study plan based on agency comments, the 2014 final study plan was approved by FERC on October 18, 2013. However, as noted in the Districts' June 28, 2016 letter to the Commission, CDFW refused to issue an amended scientific collector permit to allow the Districts to conduct electrofishing of non-native predators in the lower Tuolumne River, and CDFW formally denied the Districts' request for hatchery smolts needed to perform the study.

4.3.1.5 Salmonid Redd Mapping (W&AR-08)

The purpose of the Salmonid Redd Mapping study was to document the spatial distribution of fall-run Chinook redds to assist with quantifying the current spawning capacity and redd/recruit relationships of the lower Tuolumne River (TID/MID 2013g; FISHBIO 2017). The study area, which extended from La Grange Diversion Dam (RM 52) to Santa Fe Bridge (RM 22), was divided into four reaches, which correspond to reach designations used by CDFW. Bi-weekly redd mapping surveys were conducted to evaluate redd characteristics, redd status, redd superimposition, and fish presence on or near redds.

4.3.1.6 Chinook Salmon Otolith Study (W&AR-11)

The objective of the Chinook Salmon Otolith Study (TID/MID 2016) was to use otolith microstructural growth patterns and/or microchemistry to (1) evaluate whether adult Chinook salmon returning to the Tuolumne River originated from hatcheries or riverine environments other than the Tuolumne River and (2) estimate growth rates and sizes of 'wild' fish when they exited the Tuolumne River and when they made the transition from freshwater to the Delta.

4.3.1.7 Lower Tuolumne River Floodplain Hydraulic Assessment (W&AR-21)

The July 16, 2009 FERC Order (128 FERC 61,035) required the Districts to conduct a 2-D pulse flow study. The purpose of the 2-D Pulse Flow Study (Stillwater Sciences 2012) was to assess habitat suitability for lower Tuolumne River fish species, including Chinook salmon, at conditions above bankfull discharge, and gather empirical data on the relationship between water temperature and flow during pulse flow events (i.e., >1,200 cfs). The study included the development of a 2-D hydraulic model at three study sites to assess the habitat suitability of overbank inundation areas during flows up to 5,000 cfs.

The Lower Tuolumne River Floodplain Hydraulic Assessment (TID/MID 2017d) was undertaken by the Districts to supplement the 2-D modeling described above and to update the GIS-based relationships used in the USFWS (2008) assessment of floodplain inundation (i.e., Flow-Overbank Inundation Relationship for Potential Fall-Run Chinook Salmon and Steelhead/Rainbow Trout Juvenile Outmigration Habitat in the Tuolumne River, USFWS 2008).
The goal of the floodplain hydraulic assessment (TID/MID 2017d) was to develop a hydraulic model to simulate the interaction between flow in the main channel and the floodplain from La Grange Diversion Dam (RM 52.2) to the confluence with the San Joaquin River to address the following objectives: (1) determine floodplain inundation extents for flows between 1,000 and

3,000 cfs at 250 cfs intervals and between 3,000 cfs and 9,000 cfs at 500 cfs intervals, (2) estimate the area, frequency, and duration of inundation over a range of flows for Base Case (WY 1971–2012) hydrology, and (3) apply modeled water depths and velocities to quantify the amount of suitable rearing habitat area for juvenile Chinook salmon and *O. mykiss* at the designated flow increments.

4.3.1.8 One-Dimensional (1-D) PHABSIM model (Stillwater Sciences 2013)

A number of instream flow studies have been conducted on the lower Tuolumne River. The most recent study was filed with FERC in April 2013 (Stillwater Sciences 2013). The purpose of this latest PHABSIM model, conducted per a July 16, 2009 FERC Order (128 FERC 61,035), was "to determine instream flows necessary to maximize fall-run Chinook salmon and *O. mykiss* production and survival throughout their various life stages." The instream flow assessment methodology (Bovee 1982) applied a mesohabitat and transect-based approach (i.e., 1-D model) for implementing the PHABSIM component of the USFWS Instream Flow Incremental Methodology (IFIM) to address flow-habitat relationships in the lower Tuolumne River from RM 51.7 to 29.0.

4.3.1.9 Development of Tuolumne River Flow and Temperature Without Dams Model (Jayasundara et al. 2017)

The purpose of the Development of Tuolumne River Flow and Temperature Without Dams Model (Jayasundara et al. 2017) was to develop a flow and water temperature model to simulate water temperatures in the Tuolumne River without the existing Hetch Hetchy (including Cherry and Eleanor reservoirs), Don Pedro, and La Grange projects in place. The model was developed to complement detailed models developed for Don Pedro Reservoir and the La Grange headpond (TID/MID 2013f) and the lower Tuolumne River (TID/MID 2013h). Supporting data included the characterization of long-term flow and meteorological conditions to assess flow and water temperatures over a multi-decade period, i.e., 1970-2012. In its December 2011 Study Plan Determination, FERC indicated that Environmental Protection Agency (EPA) (2003) temperature guidelines would apply to the lower Tuolumne River, unless other empirical information could be developed specific to the Tuolumne River to inform potential alternative water temperature considerations. The "without dams" model developed by this study is one such study.

4.3.2 Tuolumne River Fall-Run Chinook Salmon

4.3.2.1 Adult Immigration

Adult fall-run Chinook salmon return to the Tuolumne River from September through December, with peak activity occurring in October and November (TID/MID 2013f). From 1971 to 2009 the date of the peak weekly live spawner count ranged from October 31 (1996) to November 27 (1972), with a median date of November 12 (TID/MID 2010). During upstream migration, Tuolumne River flows, flows of other San Joaquin River tributaries, and flows entrained by the SWP and CVP water export facilities may affect homing of Tuolumne-River-origin Chinook salmon (TID/MID 2013f).

Fall-run Chinook salmon spawning escapement to the Tuolumne River has varied over a wide range. During some years it was larger than the escapement to any other Central Valley river, except for the mainstem Sacramento River, and was estimated at 122,000 spawners in 1940 and 130,000 spawners in 1944 (California Department of Fish and Game [CDFG] 1946; Fry 1961, as cited in Yoshiyama et al. 1996). In contrast, escapement was as low as 500, 200, and 100 returning adults in 1961, 1962, and 1963, respectively. Since the completion of Don Pedro Dam in 1971 (1971–2009), spawner estimates have ranged from 40,300 in 1985 to 77 in 1991 (TID/MID 2010). Recent escapement monitoring has been conducted at a counting weir established at RM 24.5, just below the downstream boundary of the gravel-bedded reach. Cumulative adult fall-run Chinook salmon counts at the weir from 2009–2016 are shown in Figure 4.3-1.

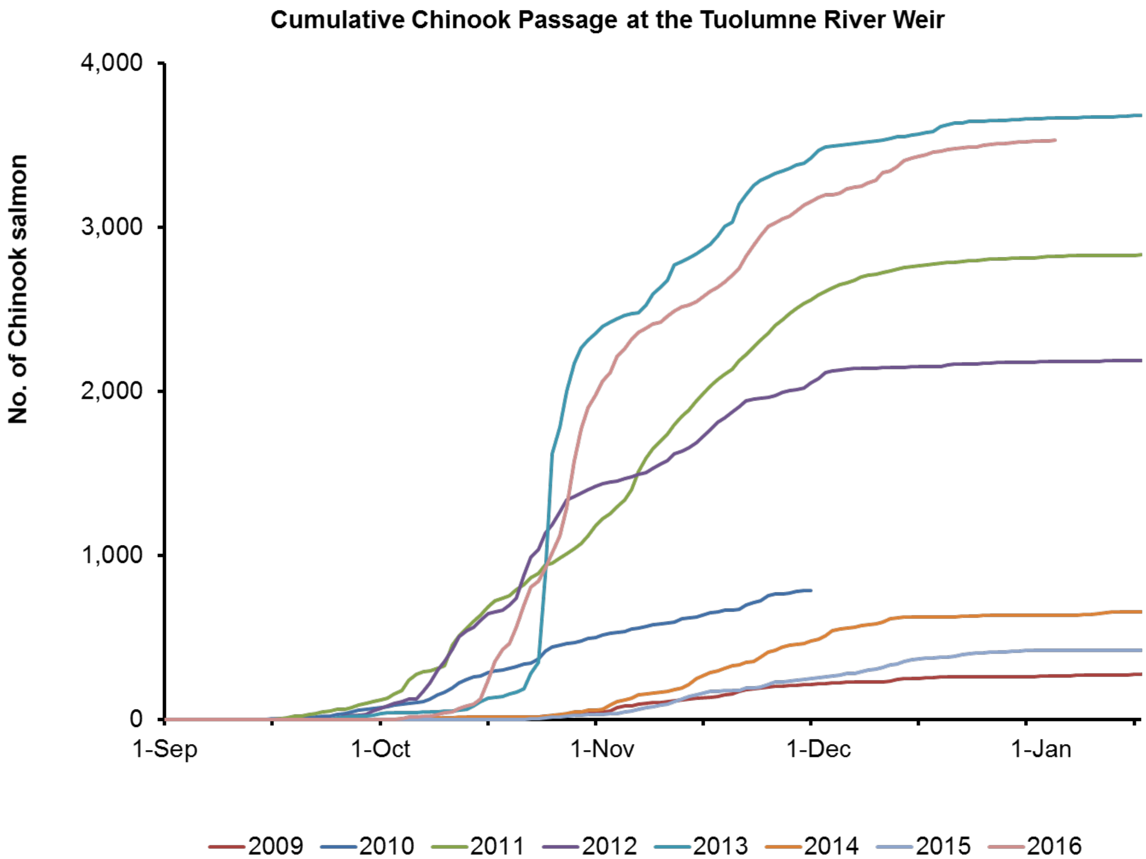

Figure 4.3-1. Cumulative adult fall-run Chinook salmon counts at the Tuolumne River weir (RM 24.5) 2009–2016.

Variations in ocean productivity and commercial harvest directly affect the number of fall-run Chinook salmon escaping the ocean troll fishery to spawn in the lower Tuolumne River (TID/MID 2013f). The Central Valley Harvest Rate Index (i.e., catch/[catch + escapement]) has been in excess of 70 percent in many years (TID/MID 2005), suggesting that year-to-year variations in ocean survival and harvest may affect Tuolumne River escapement and subsequent population levels (TID/MID 2013f). Commercial harvest in the Valley District[5], which includes rivers in San Joaquin, Stanislaus, and Tuolumne counties, is currently closed to the take of salmon. However, there are no available estimates of Chinook salmon lost to poaching in and downstream of the Tuolumne River (TID/MID 2013f).

Fall-run Chinook in the Tuolumne River have been heavily influenced by hatchery operations in the State of California. Straying of hatchery-origin fish has been documented in the Tuolumne River and has likely affected the numbers of fall-run Chinook salmon in annual spawning runs.

Although the proportions of adipose-fin-clipped Chinook salmon identified as hatchery-origin fish have been historically low in Tuolumne River spawning surveys, this proportion has increased dramatically from the 1990s to the present (TID/MID 2005; Mesick 2009; TID/MID 2012, Report 2011-8). Based on the results of the Chinook Salmon Otolith Study (TID/MID 2016), the estimated average hatchery contribution of adult Chinook salmon in the lower Tuolumne River during the years studied (i.e., 1998, 1999, 2000, 2003, and 2009) was 67 percent, and hatchery contribution generally increased in later years. Recognizing that some years in the otolith sample inventory over- or under-represent the typical age class structure in the escapement record, the overall proportion was estimated using only three-year old fish, which are expected to make up the bulk of the annual escapement. For these fish, hatchery contribution in the aforementioned years ranged from 36 to 90 percent, with a mean of 58 percent.

In 2015, the adult fall-run Chinook count at the lower Tuolumne River counting weir was 438 fish, of which 24 percent had adipose clips, and in 2016 the count was 3,555 fish, of which 24 percent had adipose clips. Under CDFW's constant fractional marking program (CFM), 25 percent of hatchery fish are adipose-clipped. CFM has not released an analysis of coded-wire tag data for 2015 or 2016. However, given that 25 percent of Central Valley fall-run Chinook salmon hatchery production is marked annually, and that there is no hatchery in the Tuolumne River, this suggests that nearly all Chinook salmon entering the lower Tuolumne River in 2015 and 2016 were hatchery strays (TID/MID 2017c).

Straying of hatchery Chinook can be linked to reduced fish size-at-return (Flagg et al. 2000) and as a result can reduce subsequent fry productivity per spawner. However, despite the high proportion of hatchery fish contributing to Chinook escapement into the Tuolumne River, Chinook size-at-return does not appear to be declining in response to hatchery introgression (TID/MID 2013f).

[5] Per the 2013-2014 California Freshwater Sport Fishing Regulations (http://www.dfg.ca.gov/regulations/), the Valley District consists of all of Butte, Colusa, Glenn, Kern, Kings, Merced, Sacramento, San Joaquin, Solano, Stanislaus, Sutter, Yolo and Yuba counties; Tulare County west of the west boundaries of Sequoia National Forest and Sequoia National Park; Fresno County west of the west boundaries of Sierra and Sequoia National Forests (including all of Pine Flat Lake); Madera County west of the west boundary of the Sierra National Forest; Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer and Tuolumne counties west of Highway 49 (including all of Don Pedro, McClure and New Melones lakes); that portion of Alameda County which is both east of Interstate 680 and north of Interstate 580; and all of Contra Costa County east of Interstate 680 and that portion of Contra Costa County which is both north of Highway 4 and east of Interstate 80; and all of Black Butte Lake.

4.3.2.2 Spawning and Incubation

Chinook salmon spawning in the lower Tuolumne River occurs primarily from October through December (with peak activity in November) in the gravel-bedded reach (RM 24 to 52), where water temperatures are suitably cool and spawning riffles are present (TID/MID 2013f). Egg incubation and fry emergence occur from October through January.

The Districts conducted redd mapping surveys during the winters of 2012-2013 and 2014-2015 to evaluate peak Chinook salmon spawning (TID/MID 2013g). In 2012-2013, 653 completed Chinook salmon redds were identified during the surveys, which were conducted between October 1 and April 19, with 622 (95 percent) of the completed redds observed between October 29 and November 29 (Table 4.3-2) (TID/MID 2013g). An additional 233 Chinook salmon redds were classified as incomplete. Peak spawning in all survey reaches occurred during the week of November 12, when 186 new redds were identified. Approximately 40 percent of Chinook salmon spawning occurred between October 1 and November 9, 2012, and more than 90 percent by November 18. Eight new Chinook redds were identified during January through the first week in February. These were classified as Chinook redds based either on the presence of fish or their similarity in size to Chinook redds identified earlier in the spawning season. During the 2012–2013 sampling season, evidence of superimposition was noted at 15.2 percent (99 of 653) of the observed Chinook salmon redds, and most (88 percent) superimposition was identified between November 5 and November 21, 2012. Most superimposition of Chinook salmon redds occurred upstream of RM 44 (TID/MID 2013g).

Table 4.3-2. New Chinook salmon redds identified by reach and date during the 2012–2013 survey period.

Week[1]	Survey Dates	Reach (RM)				Grand Total	Percent
		1 (52.0–47.4)	2 (47.4–42.0)	3 (42.0–31.6)	4 (31.6–22.0)		
1	10/1–10/4/12	7	1	1	0	9	1.4%
3	10/15–10/18/12	1	0	0	0	1	0.2%
5	10/29–11/2/12	28	13	30	5	76	11.6%
6	11/5–11/9/12	86	48	36	11	181	27.7%
7	11/12–11/15/12	87	48	37	14	186	28.5%
8	11/18–11/21/12	84	15	37	8	144	22.1%
9	11/26–11/29/12	14	9	4	8	35	5.4%
11	12/10–12/13/12	3	4	5	0	12	1.8%
14	1/2–1/5/13	0	1	2	0	3	0.5%
15	1/7–1/10/13	2	0	0	0	2	0.3%
17	1/21–1/24/13	0	0	1	0	1	0.2%
19	2/5–2/8/13	2	0	0	0	2	0.3%
21	2/18–2/21/13	0	0	0	0	0	0.0%
23	3/4–3/7/13	0	0	0	0	0	0.0%
25	3/18–3/21/13	1	0	0	0	1	0.2%
27	4/1–4/4/13	0	0	0	0	0	0.0%
29	4/17–4/19/13	0	0	0	0	0	0.0%
Grand Total		315	139	153	46	653	100%
Percent		48.2%	21.3%	23.4%	7.0%	100%	--

[1] Week refers to the number of weeks after the week of 10/1/12.

During the 2014-2015 run year, biweekly redd mapping surveys were conducted in Reaches 1 through 3 from October 7, 2014 to April 16, 2015. Surveys in Reach 4 were conducted opportunistically between October 18 and December 30, 2014. A total of 337 completed fall-run Chinook redds were documented, of which 307 (91.1 percent) were observed between November 2 and December 30, and only 5 redds (1.5 percent) were observed prior to November 2 (Table 4.3-3). An additional 70 Chinook salmon redds were classified as incomplete. Peak spawning in all survey reaches occurred during the week of November 16, when 142 new Chinook salmon redds were identified (Table 4.3-3). Redd superimposition was identified at 9.5 percent (32 of 337 total) of Chinook salmon redds. The highest number of superimposed redds was observed in Reach 1, accounting for 59.4 percent of the superimposition events. Spawning activity at recent gravel augmentation sites accounted for 16.3 percent (55 of 337 total) of the new fall-run Chinook redds observed during 2014-2015. The majority of these redds were observed at the CDFW augmentation sites near La Grange (RM 50.6 to 51).

Table 4.3-3. New Chinook salmon redds identified by reach and date during the 2014-2015 survey period.

Survey Week[1]	Survey Dates	Reach 1 (52.0-47.4)	Reach 2 (47.4-42.0)	Reach 3 (42.0-31.6)	Reach 4 (31.6-22.0)	Grand Total	Percent
6	10/7	2	--	--	--	2	0.6%
8	10/22–10/23	3	0	--	--	3	0.9%
10	11/3–11/6	13	6	7	--	26	7.7%
12	11/18–11/21	57	40	43	2	142	42.1%
14	12/1–12/5	15	19	34	10	78	23.1%
16	12/15–12/18	19	6	20	7	52	15.4%
18	12/28–12/30	7	1	0	1	9	2.7%
20	1/13–1/15	2	1	6	--	9	2.7%
23	1/26–1/28	0	1	5	--	6	1.8%
24	2/9–2/11	2	0	0	--	2	0.6%
26	2/24–2/26	1	0	0	--	1	0.3%
28	3/10–3/13	2	0	0	--	2	0.6%
30	3/24–3/26	0	0	2	--	2	1.6%
33	4/14–4/16	2	0	1	--	3	0.9%
Grand Total		125	74	118	20	337	--
Percent		37.1%	22.0%	35.0%	5.9%	--	--

[1] Survey week refers to the number of weeks starting the first full week of September (Week of September 7, 2014).

During the 2015-2016 run year, biweekly redd mapping surveys were conducted in Reaches 1 through 3 between October 14, 2015 and April 6, 2016. A total of 106 completed fall-run Chinook redds were documented, of which 101 (95.3 percent) were observed between November 3 and December 31, and no redds were observed prior to November 2, 2015 (Table 4.3-4). An additional 23 Chinook redds were classified as incomplete. Peak spawning in all survey reaches occurred during the week of November 30, when 37 new Chinook redds were identified (Table 4.3-4). The highest abundance of observed Chinook redds (45.3 percent) occurred in Reach 3 (RM 31.6 to RM 42.0). Reach 1 (RM 47.5 to 52.0) had the second highest abundance (37.7 percent). Five additional new Chinook redds were identified in January, and no Chinook redds were marked after January 26. Chinook redds marked after December 31 were classified as Chinook redds based on either the presence of fish or because redds were similar in size to Chinook redds identified earlier in the spawning season. Redd superimposition in 2015-2016 was observed at 4.7 percent (5 of

106 total) of the fall-run Chinook redds. Although there was a low sample size, 80 percent (n=4) of the superimposed redds were observed in Reach 4. Spawning activity at recent gravel augmentation sites accounted for 12.3 percent (13 of 106 total) of the new fall-run Chinook redds observed in the Tuolumne River during 2015-2016. The majority of these redds were observed at the CDFW augmentation sites near La Grange (RM 50.6 to 51).

Table 4.3-4. New Chinook salmon redds identified by reach and date during the 2015-2016 survey period.

Survey Week[1]	Survey Dates	Reach				Grand Total	Percent
		1 (52.0-47.4)	2 (47.5-42.0)	3 (42.0-31.6)	4[2] (31.6-21.6)		
7	10/14	0	--	--	--	0	0.0%
9	10/27–10/28	0	0	--	--	0	0.0%
10	11/3–11/5	2	1	3	--	6	5.7%
12	11/16–11/18	14	7	7	--	28	26.4%
14	11/30–12/2	15	8	14	--	37	34.9%
16	12/14–12/16	3	0	14	--	17	16.0%
18	12/30–12/31	3	2	8	--	13	12.3%
20	1/11–1/15	1	0	2	--	3	2.8%
22	1/26–1/28	2	0	0	--	2	1.9%
24	2/8–2/9	0	0	0	--	0	0.0%
26	2/22–2/23	0	0	0	--	0	0.0%
28	3/9–3/10	0	0	0	--	0	0.0%
30	3/21–3/22	0	0	0	--	0	0.0%
32	4/5–4/6	0	0	0	--	0	0.0%
Grand Total		40	18	48	0	106	--
Redd Density		8.7	3.33	4.6	--	--	--
Percent		37.7%	17.0%	45.3%	0.0%	--	--

[1] Survey week refers to the number of weeks starting the first full week of September (Week of September 6, 2015).
[2] Reach 4 was not surveyed due to excessive water hyacinth growth that blocked boat passage at various locations throughout the reach.

4.3.2.3 Juvenile Rearing, Smoltification, and Outmigration

Chinook salmon rearing in the Tuolumne River occurs primarily from January to May (TID/MID 2013f). However, low numbers of over-summering juveniles have been found downstream of the La Grange gage (RM 51.7) during snorkel surveys in most years (TID/MID 2013h). Based on seine and rotary screw trap monitoring, juvenile Chinook salmon fry (<50 mm) outmigrate from the lower Tuolumne River into the lower San Joaquin River and Delta as early as February in years with high flows, and smolts (>70 mm) emigrate during April and May in most years (TID/MID 2013f).

Results of the Tuolumne River Chinook Salmon Otolith Study (TID/MID 2016) indicate that the total number of days from formation of the otolith core to ocean entry for Tuolumne River juvenile Chinook was relatively constant at 99 (±20) days for each of the five outmigration years studied (1998, 1999, 2000, 2003, and 2009). During years when juvenile Chinook spent fewer days rearing in the Tuolumne River they spent a greater number of days rearing in the Delta. The study also indicated that the vast majority of adult Chinook returning to the Tuolumne River had emigrated as parr or smolts, suggesting that there is a survival advantage for fish emigrating at larger sizes from the Tuolumne River.

High levels of predation-related mortality have been documented by the Districts in multi-year smolt survival studies and by comparisons of upstream and downstream smolt passage at rotary screw traps (TID/MID 2013f). Predator distribution, year class success, habitat suitability, and activity all vary with differences in inter-annual runoff flows as well as seasonal variations in flow and water temperature. Historical changes in the Tuolumne River, primarily the creation of deep, low-velocity in-channel mining pits, have created suitable habitat for non-native predators over a wide range of river flows.

During previous predation studies in the lower Tuolumne River, 13 fish species[6] were identified that potentially prey on Chinook salmon fry and juveniles, and of these largemouth and smallmouth bass were found to be the primary predators (TID/MID 1992). Based on estimates of predator abundance from mark-recapture electrofishing surveys and estimated rates of consumption from gut samples, predation on juvenile Chinook salmon by largemouth bass was estimated to be approximately 8,600–14,300 individuals per day during the spring pulse flow period (300–600 cfs, USGS gage 11289650) (TID/MID 1992).

In 2012, the potential impact of predation was assessed by estimating the abundance of target predator species between RM 5.1 (location of the Grayson rotary screw trap) and RM 30.3 (location of the Waterford rotary screw trap). Predator abundance was estimated based on electrofishing survey results and reported as a function of shoreline lengths in this reach. Largemouth bass, smallmouth bass, and striped bass were the most abundant predator species identified in the 2012 study. Largemouth bass and smallmouth bass were estimated to have consumed about 37 percent and 49 percent, respectively, of the total potential juvenile Chinook salmon consumed by the three primary non-native predator species (i.e., largemouth bass, smallmouth bass, and striped bass). Despite making up only a small fraction (< 4 percent) of piscivore-sized fish (> 150 mm FL), striped bass were estimated to have consumed nearly 15 percent of the total potential juvenile Chinook salmon consumed by the three predator species. There was no evidence of consumption of Chinook salmon by Sacramento pikeminnow during either the 2012 study or the Districts' previous study (TID/MID 1992).

The total number of juvenile Chinook salmon potentially consumed was estimated by multiplying the estimated number of predators, the Chinook migration period (days), and the estimated predation rate (number of juvenile Chinook salmon consumed per day) (TID/MID 2013e). Average consumption rates on juvenile Chinook salmon (i.e., number of Chinook salmon per predator) by largemouth and smallmouth bass in the lower Tuolumne River (not scaled by gastric evacuation rates) ranged from 0–0.20 during the 2012 predation study (TID/MID 2013e). In 2012, predation rates averaged for all habitat types and sampling events were 0.07 Chinook salmon per largemouth bass per day and 0.09 per smallmouth bass per day. Striped bass predation rates in the lower river were generally higher than those of smallmouth bass and largemouth bass (TID/MID 2013e). In 2012, predation rate averaged for all habitat types and sampling events was 0.68 Chinook salmon per striped bass per day.

[6] The 13 fish species that potentially prey on Chinook salmon fry and juveniles in the lower Tuolumne River, as identified in TID/MID (1992a), are smallmouth bass, largemouth bass, striped bass, bluegill, redear sunfish, green sunfish, warmouth, channel catfish, white catfish, brown bullhead, Sacramento pikeminnow, riffle sculpin, and *O. mykiss*.

A conservative estimate of the total consumption of juvenile Chinook salmon by striped, largemouth, and smallmouth bass is about 42,000 during March 1-May 31, 2012, based on observed predation rates and estimated predator abundance. This suggests that nearly all juvenile Chinook salmon may be consumed by introduced predators between the Waterford and Grayson rotary screw traps. Only 2,268 Chinook salmon were estimated to have survived migration through the 25 miles between the screw-trapping sites (Robichaud and English 2013) during January through mid-June, making it plausible that most losses of juvenile Chinook salmon in the lower Tuolumne River between Waterford and Grayson during 2012 can be attributed to predation by non-native piscivorous fish species.

Acoustic tracking results revealed habitat overlap of juvenile Chinook and predators at three tested flows (280 cfs, 415 cfs, and 2,100 cfs) (TID/MID 2013e). Striped bass had the greatest overlap (18.4–46.3 percent) of habitat use with Chinook salmon, followed by largemouth bass (5.8–30.5 percent), and smallmouth bass (0.2–38.2 percent).

McBain & Trush and Stillwater Sciences (2006) hypothesized that at Tuolumne River flows exceeding 2,500 cfs, higher velocities would increase Chinook salmon migration rates through SRPs, and therefore reduce predation risk. However, the results of the 2012 Predation Study (TID/MID 2013e) showed that transit times across SRP 6 and SRP 10 were fastest at 280 cfs, suggesting that higher flows may decrease transit rates through SRPs due to eddy effects. Comparison of transit rates between sites showed no statistically significant difference at a given flow, suggesting that the results may apply more broadly to other SRP sites as well. Based on review of individual acoustic tracks, extended residence times were due to fish circling within the array rather than passing directly through the SRP; circling was likely caused by hydraulic conditions (i.e., eddies) within the SRPs.

Surveys to assess the impact of flow fluctuations on salmonids in the lower Tuolumne River were conducted from 1986 to 2002. Rapid flow reductions can cause stranding and entrapment of fry and juvenile salmon on gravel bars and floodplains and in off-channel habitats that may become cut off from the main channel when flows are reduced. A comprehensive evaluation of stranding was conducted in the lower Tuolumne River (TID/MID 2001) and is summarized in the 2005 Ten-Year Summary Report (TID/MID 2005). This evaluation indicated that the highest potential for stranding occurred at flows between 1,100 and 3,100 cfs, i.e., the range of flows under which the floodplain is inundated in several areas of the spawning reach. However, the 1995 Settlement Agreement established ramping rates developed to minimize the potential for salmonid stranding, and as a result the risk of salmonid stranding is considered to be low under current operations. As such, since 2002 there have been no requirements to monitor salmonid stranding, and all current floodplain restoration projects include design requirements for minimizing stranding potential.

Results of rotary screw trap monitoring and Delta outmigrant tracking and survival studies generally support the utility of increased spring pulse flows during April–May as a means of improving outmigrant salmonid survival from tributaries to the Delta (Stillwater Sciences 2012), if timed correctly. Based on rotary screw trap monitoring data from the Waterford (RM 29.8) and Grayson (RM 5.2) locations, Robichaud and English (2013) suggested that, on average, 35 percent of Chinook smolts moved during the first day of increased flows, and 66 percent moved within the first three days.

Although spring pulse flows appear to induce outmigration, overall flow regime may not be closely correlated with fish size at outmigration. Strontium (Sr) isotope ratios (87Sr/86Sr) and otolith microstructural features analyzed as part of the Chinook Salmon Otolith Study (TID/MID 2016) suggest that average fish size at exit from the Tuolumne River during the years analyzed (1998, 1999, 2000, 2003, 2009) was unrelated to water-year type, except for outmigration year 2000 (which had an above-normal [AN] WY classification), when average fish size was significantly smaller ($p<0.005$) than in years with high winter-spring outflows (i.e., 1998 [Wet] and 1999 [AN]) or below-normal [BN] water years (i.e., 2003 and 2009).

Reductions in marsh and floodplain habitats in the lower San Joaquin River and South Delta, along with changes in mainstem and tributary flow magnitudes and timing, have reduced access to Delta habitats historically used by rearing and emigrating Chinook salmon smolts from the Tuolumne River. Although warmer water in the Delta can increase juvenile Chinook growth rates relative to those in upstream tributary habitats, degradation of Delta habitat has reduced the primary and secondary productivity that support the food web (Durand 2008), resulting in low growth rates (MacFarlane and Norton 2002, Kjelson et al. 1982) of juvenile Chinook salmon.

Predation in the Delta and predation related mortality within the Clifton Court forebay of the SWP and CVP water export facilities affect the number of Chinook salmon recruited to the ocean fishery (TID/MID 2013f). For Chinook salmon outmigrants from the Tuolumne River, increased flows in the San Joaquin River at Vernalis have been shown to reduce predation-related mortality, but the relationship is highly dependent on the presence of the Head of Old River Barrier (HORB).[7] Salvage losses of Chinook entrained into the SWP and CVP export facilities increase with increasing export flows, and pre-screen losses of 63–99 percent have been estimated for fish entrained into the Clifton Court forebay. For juvenile Chinook salmon not entrained by the SWP and CVP export facilities, non-native fish introductions, levee construction, and changes in flow magnitudes and timing have increased predator ranges. In addition, water temperature related mortality during late spring explains much of the variation observed during past smolt survival studies in the Delta (TID/MID 2013f).

4.3.3 Threats and Stressors to Fall-Run Chinook Salmon in the EFH Action Area

Table 4.3-5 provides a summary, excerpted and abridged from TID/MID (2013f), of potential stressors on Tuolumne River fall-run Chinook salmon.

[7] For the protection of out-migrating fall-run Chinook salmon in years when spring flow in the San Joaquin River is less than 5,000 cfs, a temporary barrier has typically been placed at the head of Old River from April 15 to May 15 in most years to prevent drawing these fish towards the pumps near Tracy (TID/MID 2013,W&AR-05).

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Table 4.3-5. Potential stressors affecting Tuolumne River Chinook salmon populations.

Potential Stressor	Notes/Citations
Adult Homing and Timing of Arrival at Spawning Grounds	
Straying of hatchery origin salmon	Increased proportions of hatchery-origin fish found in the Tuolumne (e.g., TID/MID 2012, 2016) and in the Central Valley as a whole (Barnett-Johnson et al. 2007). Although no information is available to assess effects of hatchery-origin fish on run-timing in the Tuolumne River, hatcheries' broodstock selection practices can alter run timing (Flagg et al 2000).
Direct Mortality of Upmigrating Adults	
Ocean harvest	No San Joaquin basin-specific information available, but variations in ocean harvest indices (PFMC 2012) show broad effects on Central Valley population levels.
In-river harvest and poaching	Commercial harvest in the Valley District, which includes rivers in San Joaquin, Stanislaus, and Tuolumne counties, is currently closed to the take of salmon, but there are no available estimates of salmon lost to poaching in the Tuolumne or San Joaquin rivers.
Spawning Success	
Habitat availability	Evidence of competition for suitable spawning areas and exclusion of spawners at high escapement levels (TID/MID 1992, 2000, 2001) as well as gravel losses at upstream spawning riffles (McBain and Trush 2004). However, gravel losses have been offset by gravel augmentation in the Tuolumne River below La Grange Diversion Dam.
Direct Mortality of Eggs/Alevins	
Redd superimposition	Studies (TID/MID 1997, 1992, 2013g; FISHBIO 2017) suggest that redd superimposition has the potential to increase density-dependent egg mortality and delayed fry emergence at moderately high escapement.
Direct Mortality of Juveniles in the Tuolumne and San Joaquin Rivers	
Predation	Documented in direct surveys by Districts (TID/MID 1992), in multi-year smolt survival tests (TID/MID 2003) and by comparisons of upstream and downstream fish passage (TID/MID 2012, 2013e).
Habitat availability for predators	In-channel mining and reduced flood frequency have created suitable habitat for non-native predators (McBain and Trush 2000; Ford and Brown 2001; McBain and Trush and Stillwater Sciences 2006).
Flow and water temperature effects on predation	Predator distribution (Brown and Ford 2002), juvenile Chinook year-class success (McBain and Trush and Stillwater Sciences 2006), smolt survival (TID/MID 2003), and habitat suitability for salmon and predators (McBain and Trush and Stillwater Sciences 2006; Stillwater Sciences 2012) vary with flow and water temperature.
Water quality effects on predation	The lower Tuolumne River is currently listed for pesticides shown to impair olfactory sensitivity in laboratory studies (Scholz et al. 2000).
Juvenile Growth and Smoltification in the Delta	
Habitat availability	Reductions in marsh and floodplain habitats due to levees as well as changes in flow magnitudes and timing have affected growth opportunities and survival of juvenile Chinook salmon in the Delta (Kimmerer et al. 2008; Lund et al. 2007).
Water temperature	Juvenile Chinook metabolism in the Delta is likely higher than in upstream tributary habitats due to higher water temperatures (Kjelson et al. 1982), particularly on inundated floodplains (Sommer et al. 2001).

Potential Stressor	Notes/Citations
Food availability	Food web changes (Durand 2008) and growth rates (MacFarlane and Norton 2002; Kjelson et al. 1982) suggest limited food supplies in the Delta.
Direct Mortality of Juvenile Chinook Salmon in the Delta	
Water temperature	Temperatures at or above 25°C (77°F) associated with increased mortality (Myrick and Cech 2001) routinely occur in the South Delta by late-May. Baker et al. (1995) show water temperature explains much of the variation in Delta smolt survival studies.
Predation	Predation has been documented in the lower San Joaquin River (e.g., SJRGA 2011), in the Clifton Court Forebay (Gingras 1997), as well as near-shore and open water habitats (Lindley and Mohr 2003) of the Delta.
Habitat availability for predators	Levees and changes in flow magnitudes and timing have increased predator distribution (Kimmerer et al. 2008; Lund et al. 2007).
Flow effects on predation	Newman (2008) shows a significant Vernalis-flow-survival relationship to Jersey Pt. Although HORB improves survival through the Delta by 16–61%, a significant flow-survival relationship does not exist without HORB (Newman 2008).
Entrainment	Kimmerer (2008) shows salvage losses of Chinook salmon at the SWP and CVP increase with increasing export flows. Pre-screen losses of 63–99% for all fish entrained into the Clifton Court forebay (Gingras 1997).
Adult Growth in the Ocean	
Food availability	Pacific Decadal Oscillation and El Niño/Southern Oscillation influence coastal productivity and salmon abundance (MacFarlane et al. 2005; Mantua and Hare 2002). Central Valley Chinook salmon growth is dependent on prevailing coastal conditions (MacFarlane and Norton 2002; Lindley et al. 2009; Wells et al. 2007). Hatchery releases may result in density-dependent competition for food resources during early ocean rearing (Ruggerone et al. 2010).
Direct Mortality of Adults in the Ocean	
Harvest	Central Valley stocks have been exploited at average rates of more than 60 percent. Larger fish are selectively targeted, a practice that may reduce fish size and fecundity (Lindley et al. 2009; NMFS 2006).
Predation	Avian predation in San Francisco Bay (Evans et al. 2011) and pinniped predation along the California coast (Scordino 2010) have been documented, but population-level impacts have not been assessed.
Water quality	Early life history exposure to pesticides may affect predator avoidance (Scholz et al. 2000; NMFS 2006), but no reports have assessed predation effects due to contaminant exposure in the Central Valley or along the California Coast.

4.3.4 Conservation Initiatives

The Central Valley Project Improvement Act (CVPIA) was passed by Congress in 1992. The CVPIA directed the Secretary of the Interior to develop and implement a program that made all reasonable efforts to double natural production of anadromous fish in Central Valley streams (Section 3406(b)(1)) by 2002, and it dedicated up to 800,000 ac-ft of water annually for fish, wildlife, and habitat restoration (Section 3406(b)(2)), and provides for the acquisition of additional water to supplement the annual allotment (Section 3406(b)(3)). Since 1993, the USFWS has directed the use of this dedicated water.

The CALFED Bay-Delta Program (CALFED), a joint state/federal effort which commenced in June 1995, was charged with developing a "long-term Bay-Delta solution" (NMFS 2014). A primary component of CALFED is the Ecosystem Restoration Program, which was developed to provide a foundation for long-term ecosystem and water quality restoration and protection. Among the non-flow factors targeted by the program to reduce adverse effects on salmon are unscreened diversions, wastewater discharges, other water pollution, poaching, land-derived salts, introduced species, fish passage barriers, channel alterations, and loss of riparian wetlands.

As noted in Section 2.4.1, FERC's 1996 order (FERC 1996) amending the Don Pedro Project license required the incorporation of the lower Tuolumne River minimum flow provisions contained in the 1995 settlement agreement between the Districts, CCSF, resource agencies, and environmental groups. The revised minimum flows in the lower Tuolumne River vary from 50 to 300 cfs, depending on water year hydrology and time of year. The water year classifications are recalculated each year to maintain approximately the same frequency distribution of water year types. The settlement agreement and license order also specified certain pulse flows for the benefit of upstream migrating adult and downstream migrating juvenile Chinook salmon, the amount of which also varies with water-year type. The downstream flow schedule provided for by the settlement agreement and subsequent FERC Order is shown in Table 2.4.-1.

As noted in Section 2.4.2, conditions in the lower Tuolumne River have benefited from the involvement of the TAC, the role of which was formalized in the Districts' 1995 Settlement Agreement. As directed under the 1995 Settlement Agreement, the TAC developed 10 priority habitat restoration projects aimed at improving geomorphic and biological aspects of the lower Tuolumne River corridor (listed below), which in turn have the potential to benefit fall-run Chinook, at one or more times during the species' life cycle.

- Channel and Riparian Restoration Projects (RM 34.3-RM 40.3)
  - Gravel Mining Reach Phase I - 7/11 Gravel Mining Reach Restoration (restored channel and floodplain along 1.5 river miles) (RM 38-39.5) (completed in 2003)
  - Gravel Mining Reach Phase II (not completed)[8]
  - Gravel Mining Reach Phase III (not completed)

[8] By the terms of the 1995 Settlement Agreement, the Districts and CCSF pledged $500,000 and an additional $500,000 in matching funds for Tuolumne River restoration projects. Also by the terms of the agreement, CDFW and USFWS were

  - Gravel Mining Reach Phase IV (not completed)
- Predator Isolation Projects
  - SRP 9 Channel and Floodplain Restoration (restored channel and floodplain along 0.2 river miles) (RM 25.7-25.9) (completed in 2001)
  - SRP 10 (RM 25.5) (not completed)
- Sediment Management Projects (RM 43.0-RM 51.8)
  - RM 43 Channel Restoration (restored channel and floodplain along 0.5 river miles) (completed in 2005)
  - Gasburg Creek Fine Sediment Retention Project (RM 50) (completed in 2008)
  - Gravel Augmentation (coarse sediment) (not completed)
  - Riffle Cleaning (fine sediment) (not completed)

Other restoration efforts have been implemented in the lower Tuolumne River corridor by various groups, including Friends of the Tuolumne (FOT), Tuolumne River Conservancy (TRC), Tuolumne River Trust (TRT), Natural Resource Conservation Service (NRCS), East Stanislaus Resource Conservation District (ESRCD), USFWS, CDFW, Stanislaus County, and the cities of Waterford, Ceres, and Modesto.

CDFW placed about 27,000 yd^3 of gravel in the Tuolumne River near the town of La Grange from 1999 to 2003 to increase spawning gravel area to help offset gravel losses due to the 1997 flood. The FOT, TRT, NRCS, and ESRCD implemented several large floodplain restoration projects on the lower Tuolumne River near Modesto, including the Grayson River Ranch project, which resulted in the restoration of 140 acres of floodplain between RM 5 and RM 6. The TRT, in partnership with the NRCS, CDWR, the National Oceanic and Atmospheric Association (NOAA), and the ESRCD, acquired approximately 250 ac on both sides of the Tuolumne River from RM 5.8 to 7.4 (“Big Bend”). The Big Bend project site, which involved restoration of 240 acres of floodplain between RM 5.5 and RM 7.0, was completed from 2004 to 2006. FOT, funded by the California Bay-Delta Authority, acquired about 250 ac of river and floodplain habitat at Bobcat Flat (RM 42.4 to 44.6). A restoration plan was developed, with the goal of enhancing natural floodplain function at the parcel. The Bancroft-Ott Floodplain and Wetland project resulted in 56 acres of restored floodplain along 0.5 river miles (at approximately RM 4).

The Adaptive Management Forum (AMF) was initiated in 2001 to review designs for restoration projects in Central Valley rivers and assist resource agencies and tributary restoration teams. The AMF panel of technical experts reviewed and made recommendations concerning tributary restoration projects and made recommendations for incorporating monitoring and hypothesis-driven adaptive management into project implementation to maximize restoration success.

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responsible for actively pursuing state and federal funding. After securing funding and constructing the initial four priority projects identified by the TAC, CDFW, while supporting additional restoration projects at the TAC, actively opposed using CALFED funding for additional projects. Consequently, approved CALFED funding of over $14.75 million for three additional TAC projects, designed to benefit fall-run Chinook and *O. mykiss*, was never able to be used and the projects were never implemented due to factors outside the control of the Districts.

4.4 Habitat Conditions in the Action Area

4.4.1 Overview of Habitat Conditions in the Lower Tuolumne River

Physical habitat conditions in the lower Tuolumne River from La Grange Diversion Dam (RM 52.2) to the confluence with the San Joaquin River have been affected by a wide range of human actions conducted over many decades. Prior to widespread European settlement, channel form in the gravel-bedded zone of the lower Tuolumne River (RM 24.0–52.1) consisted of a combination of single-thread and split channels that migrated and avulsed (McBain and Trush 2000). Anthropogenic changes that have occurred in the lower Tuolumne River corridor since the mid-1800s include gold mining, aggregate mining, grazing, agriculture, water management, and urban encroachment. In 1993, the city of Modesto built Dennett Dam at RM 16 (Baggese 2009).

Riverbed material was excavated to depths well below the thalweg to mine gold and aggregate, eliminating active floodplains and terraces and creating large in-channel and off-channel pits. A historical timeline of mining in the San Joaquin River's tributaries includes placer mining (1848–1880), dredge mining (1880–1960s), and sand and gravel mining (1940s–present) (McBain and Trush 2000). On the Tuolumne River, dredge mining during the early 1900s resulted in the excavation of channel and floodplain sediments and left dredger tailings deposits between RM 38.0 and 50.5. Large-scale, off-channel aggregate mining continues today.

Historically, sand and gravel were mined directly from the active river channel, creating large, in-channel pits now referred to as Special Run Pools (SRPs). These SRPs are as much as 400 feet wide and 35 feet deep, occupying 32 percent of the channel length in the gravel-bedded reach of the lower Tuolumne River, and are characterized by much lower velocities and greater depths than the un-mined sections of river. More recent aggregate mining operations have excavated sand and gravel from floodplains and terraces immediately adjacent to the river channel at several locations downstream of Roberts Ferry Bridge (RM 39.5) (TID/MID 2011). Floodplain and terrace pits in this reach are typically separated from the channel by narrow berms that can breach during high flows, resulting in capture of the river channel. The January 1997 flood caused extensive damage to dikes separating deep gravel mining pits from the river, breaching or overtopping nearly every dike along a 6-mile-long reach (TID/MID 2011).

Agricultural and urban encroachment along the lower river, combined with a reduction in high flows and coarse sediment supply, have resulted in a relatively static channel within a floodway confined by dikes and agricultural uses. Many miles of river bank have been leveed and stabilized with riprap by agencies or landowners. Levees and bank revetment extend along portions of the river bank from near Modesto (RM 16) downstream through the lower San Joaquin River and Delta.

The relative abundances of habitat types documented in the lower Tuolumne River from RM 52–39 during the *Oncorhynchus Mykiss* Habitat Survey (TID/MID 2017f) were as follows: 14 percent riffle, 61 percent flat water, and 25 percent pool. Sediment modeling conducted as part of the Spawning Gravel in the Lower Tuolumne River study (TID/MID 2013h) indicate that without gravel augmentation, the channel bed from RM 52 to 39.7 would be slowly degrading and coarsening in response to a reduction in coarse sediment supply due to sediment retention in Don

Pedro Reservoir and other upstream reservoirs. Gravel augmentation, however, has helped to increase coarse sediment storage in this area. Although the results of sediment modeling and topographic differencing indicate little overall change in storage from RM 52 to 45.5 during the period 2000 to 2012, high flows in water year (WY) 2006 and WY 2011 resulted in substantial pool scour, with coarse sediment re-deposited in pool tails and riffles and fine bed material mobilized to channel margins (TID/MID 2013h). Most riffle mesohabitat units (i.e., 84 percent of total riffle habitat) mapped in 2012 from RM 52.1 to 23 contained spawning gravel suitable for use by salmonids (TID/MID 2013f).

Results of a recent study document amounts of LWD in the lower Tuolumne River from RM 52–24 (TID/MID 2017f). There was a total of 118 LWD pieces in the 16,905 linear feet of habitat surveyed in 2012, which when extrapolated to the reach extending from RM 39 to RM 52, is an estimated 453 pieces (TID/MID 2017f). The importance of LWD in habitat formation decreases with increasing channel width. The lower Tuolumne River between RM 26 and 52 has channel widths averaging 119 feet, and LWD has a limited effect on channel morphology in this reach (TID/MID 2017f). Compared to smaller streams, Bilby and Bisson (1998) observed that wood has less effect on channel form in larger streams, which is consistent with the W&AR-12 surveyors' observations that woody debris has a limited effect on channel morphology in the lower Tuolumne River.

Most woody debris captured in Don Pedro Reservoir originates upstream of the reservoir, and given the size of this woody debris, a majority of it would pass through the lower Tuolumne River during high flows if it were not trapped in the reservoir (TID/MID 2017f).

Although LWD provides habitat for salmonid in some systems, there are no data available for the Tuolumne River or neighboring Merced River that specifically address the role of LWD on salmonid abundance (TID/MID 2017f). Of the 121 locations within the W&AR-12 study reach where LWD was recorded, about 80 percent of it was located in or adjacent to runs or pools, which are not typically the preferred habitat of juvenile or adult salmonids in the lower Tuolumne River. Because most woody debris in the lower Tuolumne River is relatively small and positioned partially or wholly out of the channel, it does not provide significant cover for salmonids, which in turn limits its value as protection from avian and aquatic predators. Due to its generally small size, location, and lack of complexity, most woody debris from RM 24 to 52 provides little habitat value for salmonids.

The 2012 Lower Tuolumne River Riparian Information and Synthesis Study (TID/MID 2013c) shows that native riparian vegetation occupies 2,691 ac along a nearly continuous but variable-width band along the lower Tuolumne River corridor (TID/MID 2013c). In addition, the number of locations and areal extent of riparian land dominated by non-native plants has actually decreased over the past 15 years.

Overall, the areal coverage of native riparian vegetation along the lower Tuolumne River is increasing, with a 419-ac increase in the net extent of native vegetation documented between 1996 and 2012, brought about primarily through active restoration projects. The highest relative abundance of native riparian vegetation per river mile was mapped along the 12 miles immediately downstream of La Grange Diversion Dam. Closer to the confluence with the San Joaquin River, several large restoration projects have also increased the extent of native riparian vegetation. However, there is limited natural replacement of mature and senescent plants with younger cohorts outside the restored areas. Areas with the least riparian vegetation and narrowest riparian corridors occur from RM 10.5 to 19.3, i.e., the section of river that runs through the urban areas of Modesto and Ceres. The river corridor between RM 19.3 and 40.3 includes large areas that are sparsely vegetated due to historical mining and dredger tailings deposits.

4.4.1.1 Hydrology in the in the Lower Tuolumne River

Streamflows in the Tuolumne River have been altered by the cumulative influences of water storage and diversion projects in the watershed (McBain and Trush 2000). Analyses of streamflow records from the USGS gaging station at La Grange (Station 11289650) reveal the following: (1) annual water yield to the lower Tuolumne River below La Grange Diversion Dam has been reduced from an average unimpaired yield of 1,906,000 ac-ft to 772,000 ac-ft; (2) the magnitude and variability of winter base flows, fall and winter storms, and spring snowmelt runoff have been reduced; and (3) the magnitude, duration, and frequency of winter floods have been reduced (McBain and Trush 2000). Following completion of the Don Pedro Dam in 1971, compliance with ACOE flood control and other flow requirements reduced the estimated average annual flood (based on annual maximum series) from 18,400 cfs to 6,400 cfs. The 1.5-year recurrence event was reduced from 8,400 cfs to 2,600 cfs (McBain and Trush 2000).

Mean monthly flows in the lower Tuolumne River from 1975-2012 are shown in Table 4.4-1. Records for these locations are available from the USGS National Water Information System website for October 1, 1970 to September 30, 2012.

Table 4.4-1. Mean monthly flows from 1975-2012 in the lower Tuolumne River at four locations.

Month	Below La Grange Diversion Dam (cfs)	Modesto Canal near La Grange (cfs)	Turlock Canal near La Grange (cfs)	Don Pedro Project Release (cfs)
Jan	1,491	74	140	1,705
Feb	1,812	66	183	2,061
Mar	1,952	267	604	2,823
Apr	1,962	543	1,069	3,574
May	1,790	660	1,211	3,661
Jun	1,034	786	1,474	3,294
Jul	537	878	1,798	3,213
Aug	327	782	1,568	2,677
Sep	481	513	786	1,780
Oct	618	288	400	1,306
Nov	348	174	196	718
Dec	881	122	208	1,211

Source: USGS 11289650, USGS 11289000, USGS 11289500, and USGS 11289651.

USGS also reports flows for a gage located farther downstream, near the City of Modesto below Dry Creek (Table 4.4-2).

The unimpaired flow of the Tuolumne River is calculated on a daily basis at La Grange Diversion Dam (Station ID TLG) by the CDWR. The drainage area at this location, according to CDWR's

California Data Exchange Center system, is approximately 1,548 mi^2. Historical computed flows are available from the California Data Exchange Center on a daily basis beginning in April 1986, and on a monthly basis from October of 1900 through the present. Unimpaired flows are not intended to mimic or represent natural flows. Because these data are computed on a daily basis using a number of different gages for an arithmetic water-balance (including changes in storage in Don Pedro Reservoir), unimpaired flows for the Tuolumne River can vary considerably from day to day and occasionally show negative flows. Table 4.4-3 presents a summary of average monthly unimpaired flows for 1975 to 2012.

Table 4.4-2. Mean monthly flows for the 1975-2012 period for the Tuolumne River at Modesto, below Dry Creek.

Month	Mean Monthly Flow (cfs)	Lowest Mean Monthly Flow (cfs)	Highest Mean Monthly Flow (cfs)
Jan	1,837	154	15,500
Feb	2,138	166	8,782
Mar	2,293	239	7,658
Apr	2,192	169	9,268
May	1,992	138	10,420
Jun	1,216	95	5,683
Jul	716	79	4,244
Aug	501	68	2,415
Sep	680	73	4,041
Oct	848	78	4,760
Nov	647	93	2,089
Dec	1,129	110	5,431

Source: USGS 11290000.

Table 4.4-3. Tuolumne River at La Grange Diversion Dam mean monthly unimpaired flow, 1975-2012.

Month	Unimpaired Flow Monthly Average (ac-ft)
January	146,465
February	156,184
March	227,960
April	279,811
May	449,940
June	354,796
July	143,172
August	33,145
September	16,926
October	24,289
November	46,374
December	83,581
Total	1,946,116

Source: TID/MID 2017h.

Since completion of the new Don Pedro Dam in 1971, the flood of record occurred in January 1997. The peak inflow was 120,935 cfs and peak outflow was 59,462 cfs, as measured at the La Grange gage. Prior to 1971, the unregulated historical flood of record occurred in January 1862, with an estimated discharge of 130,000 cfs. A more recent flood (post-original Don Pedro Dam construction) occurred in December 1950, with an estimated discharge of 61,000 cfs. On February

20, 2017, the reservoir level reached 830 feet and the Don Pedro Project spilled for just the second time, with the maximum release being 19,100 cfs.

The annual minimum unimpaired runoff of the Tuolumne River above Don Pedro Reservoir occurred in WY 1977, at 0.38 million ac-ft (0.34 cfs/mi^2), or just 19 percent of the mean value. Since 1971, several drought periods have occurred: water years 1976-1977, 1987-1992, 2001-2004, and 2012-2015. During the 1976-1977 drought, the combined two-year unimpaired flow was 1 million ac-ft, or 26 percent of the mean of 3.9 million ac-ft. These two years are the driest two consecutive years in recorded history. The longest drought occurred during WYs 1987-1992. The unimpaired flow over these six years averaged 0.9 million ac-ft, or 48 percent of the mean. In the entire WY 1987-1992 period, not a single year exceeded 70 percent of the long-term mean annual flow. The successive four-year low flow period from 2001-2004 had a mean unimpaired flow of 1.35 million ac-ft, or 69 percent of the mean, without a single-year's flow being above the mean.

The majority of groundwater recharge in both the Turlock and Modesto groundwater basins comes from groundwater storage provided by greater irrigation occurring during wet years. Recent studies have indicated that groundwater storage has been reduced and may no longer be in a state of equilibrium as it had been in the 1990s (TID 2008). Pumping of groundwater for irrigation has significantly increased in both the Turlock and Modesto groundwater basins, primarily due to the substantial increase in orchards in areas outside the surface-water irrigation territories served by the Districts.

Two years during the 2012–2015 drought were among the five driest years on record. During the 2012–2015 period, annual runoff was less than 60 percent of the average annual runoff for the basin. Water supply to the Districts' customers was cut back by up to 50 percent in 2015, and the reservoir level dropped to elevation 671.2 feet in October 2015. Groundwater use rose sharply during this period. However, this source of supplemental water supply is unlikely to be as available as it has been under the recently enacted Sustainable Groundwater Management Act regulations in California.

4.4.1.2 Temperature and Water Quality in the Lower Tuolumne River

4.4.1.2.1 Temperature

The Tuolumne River between Don Pedro Dam and La Grange Diversion Dam is directly affected by discharges from the Project. The La Grange headpond does not thermally stratify because of its small size relative to the flow passing through it. Releases from Don Pedro Dam reflect temperatures in the hypolimnion of Don Pedro Reservoir and generally do not exceed 13 ºC (55.4ºF) and are often much cooler.

The Basin Plan water quality objective (WQO) for temperature states that "at no time or place shall the temperature of any cold water be increased by more than 5°F above natural receiving water temperature" (Central Valley Regional Water Quality Control Board [CVRWQCB] 1998, as amended). Temperatures in the reach immediately downstream of the Don Pedro Project are dominated by the cold water released from deep in the reservoir. Comparison of modeled seven-day average of the daily maximum (7DADM) temperatures under with- and without-dams conditions indicate that immediately below Don Pedro Dam (RM 54), with-dams 7DADM temperatures are relatively cool year-round, with little variability (Figure 4.4-1), because water is released from the reservoir's hypolimnion. Because of the thermal mass of the reservoir, water at depth is to a large degree buffered from the influence of seasonal and diel variability in air temperature and other climatic factors. With-dams 7DADM temperatures immediately downstream of the Project are much cooler than without-dams temperatures in summer but are slightly warmer from November through February (Figure 4.4-1).

With-dams temperatures during summer rise significantly with increasing distance downstream of the Don Pedro Project. Under the current Project conditions, by RM 46, maximum summertime 7DADM temperatures have climbed back to 20°C (Figure 4.4-2), very close to the 7DADM temperatures experienced above Don Pedro Reservoir. However, this is still 5°C below those simulated under without-dams conditions. By RM 40 (near Roberts Ferry Bridge), with-dam 7DADM temperatures in July reach 22°C (Figure 4.4-3). By RM 34, thermal equilibrium has largely been restored under with-dams conditions, i.e., the maximum 7DADM temperatures in summer are around 24°C, very close to the maximum 7DADM without-dams conditions (Figure 4.4-4). From this point downstream to the confluence with the San Joaquin River (Figures 4.4-5 - 4.4-7), with-dam maximum summertime 7DADM temperatures exceed those simulated under without-dam conditions by 2 to 3°C. Also, at all locations in the lower river, except immediately below Don Pedro Dam, there is a decrease in daily average water temperatures from mid-April to mid-May under the with-dams condition, which is the result of pulse flow releases scheduled to benefit fall-run Chinook outmigration downstream of La Grange Diversion Dam. Without-dams temperatures are cooler from mid-May (following the Base Case pulse flow) through the end of June downstream of about RM 40.

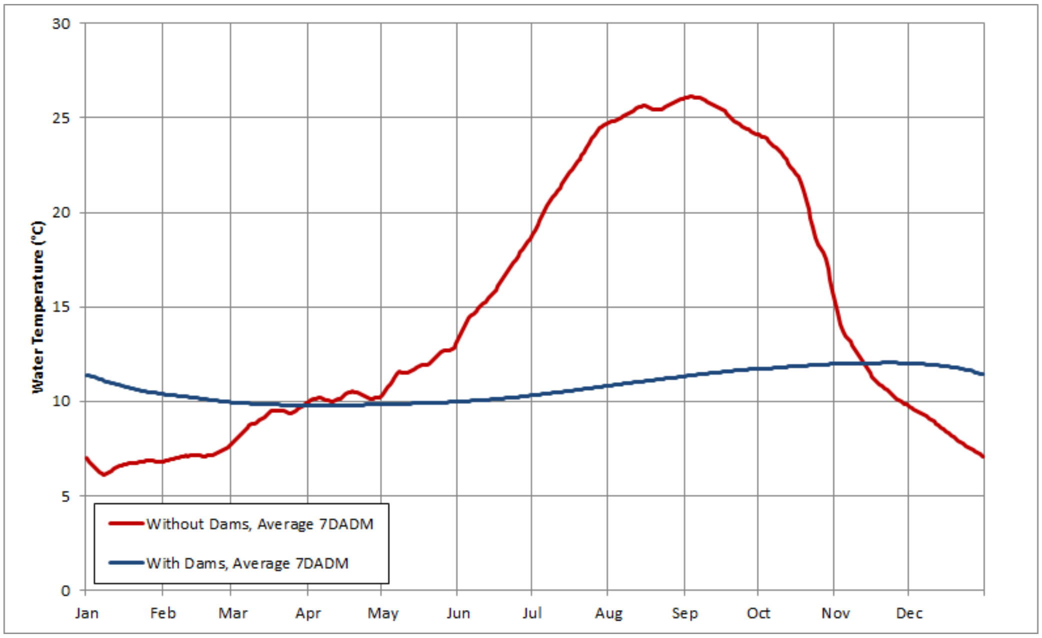

Figure 4.4-1. Comparison of modeled 7DADM water temperatures under with- and without-dams conditions in the Tuolumne River below Don Pedro Dam (≈RM 54). Without-dams temperatures (Jayasundara et al. 2017) and with-dams (Base Case) temperatures (TID/MID 2017e) are simulated based on the period 1970-2012. With-dams temperatures are based on current FERC-required instream flows.

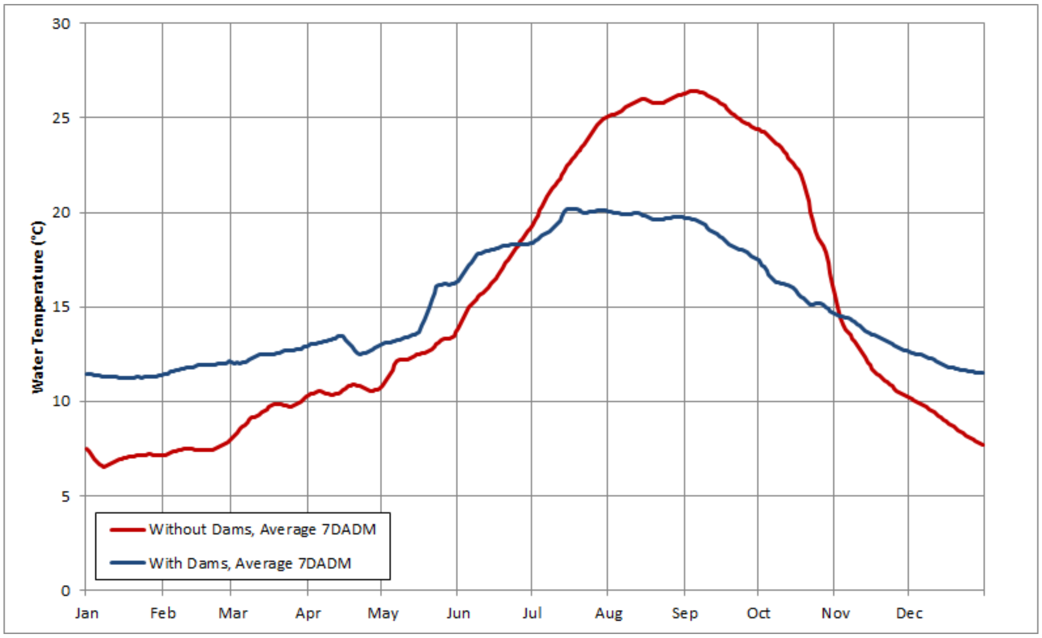

Figure 4.4-2. Comparison of 7DADM water temperatures under with- and without-dams conditions in the lower Tuolumne River at RM 46. Without-dams temperatures (Jayasundara et al. 2017) and with-dams (Base Case) temperatures (TID/MID 2017e) are simulated based on the period 1970 - 2012. With-dams temperatures are based on current FERC-required instream flows.

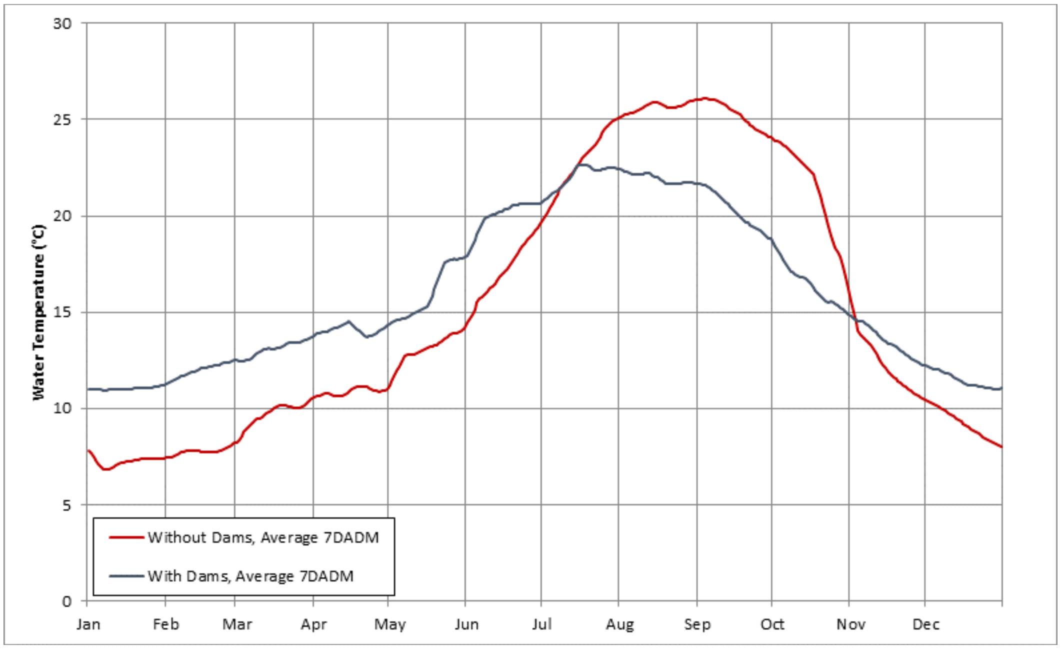

Figure 4.4-3. Comparison of 7DADM water temperatures under with- and without-dams conditions in the lower Tuolumne River at RM 40. Without-dams temperatures (Jayasundara et al. 2017) and with-dams (Base Case) temperatures (TID/MID 2017e) are simulated based on the period 1970 - 2012. With-dams temperatures are based on current FERC-required instream flows.

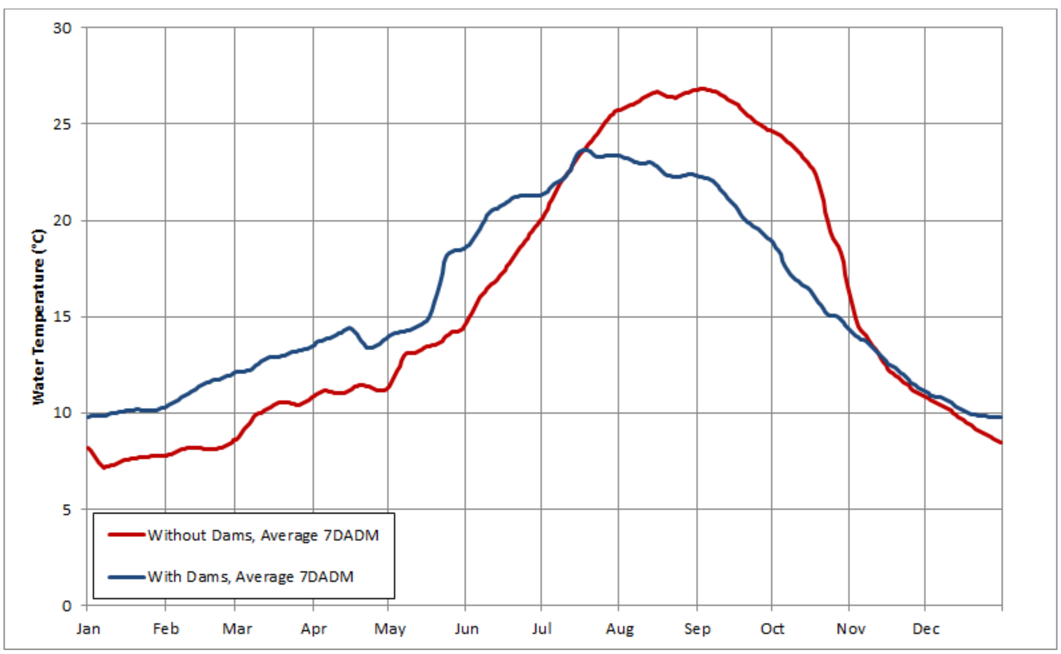

Figure 4.4-4. Comparison of 7DADM water temperatures under with- and without-dams conditions in the lower Tuolumne River at RM 34. Without-dams temperatures (Jayasundara et al. 2017) and with-dams (Base Case) temperatures (TID/MID 2017e) are simulated based on the period 1970 - 2012. With-dams temperatures are based on current FERC-required instream flows.

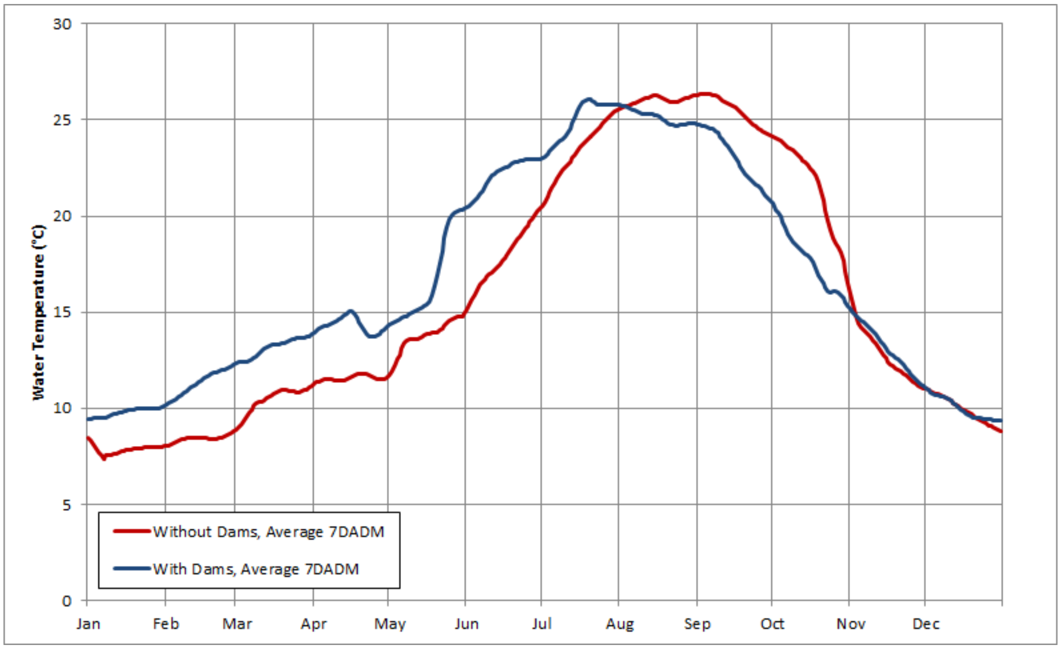

Figure 4.4-5. Comparison of 7DADM water temperatures under with- and without-dams conditions in the lower Tuolumne River at RM 24. Without-dams temperatures (Jayasundara et al. 2017) and with-dams (Base Case) temperatures (TID/MID 2017e) are simulated based on the period 1970 - 2012. With-dams temperatures are based on current FERC-required instream flows.

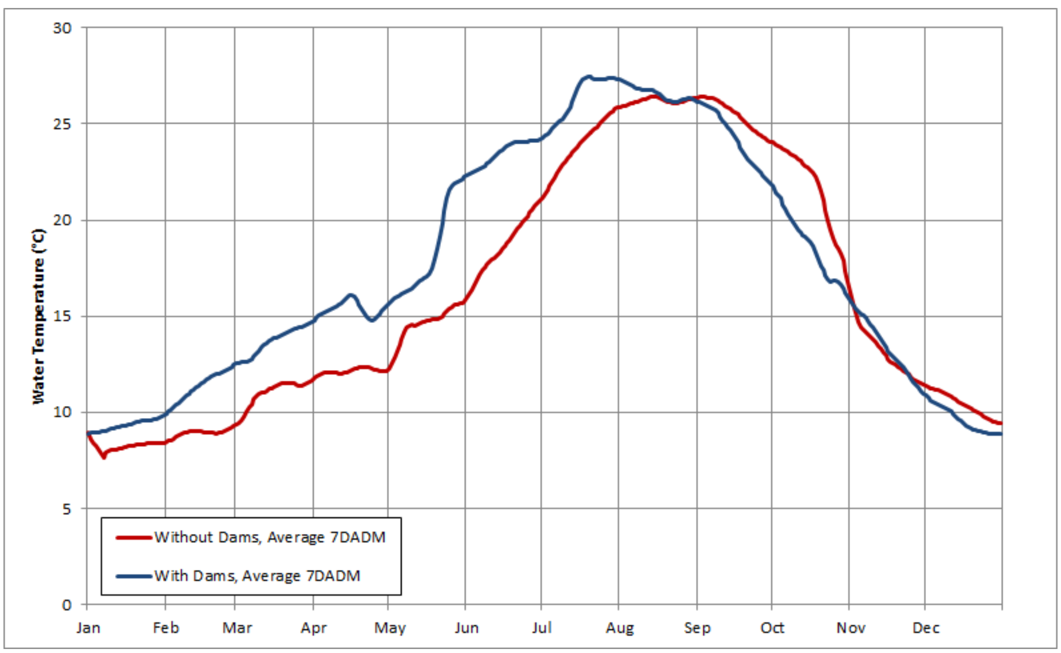

Figure 4.4-6. Comparison of 7DADM water temperatures under with- and without-dams conditions in the lower Tuolumne River at RM 10. Without-dams temperatures (Jayasundara et al. 2017) and with-dams (Base Case) temperatures (TID/MID 2017e) are simulated based on the period 1970 - 2012. With-dams temperatures are based on current FERC-required instream flows.

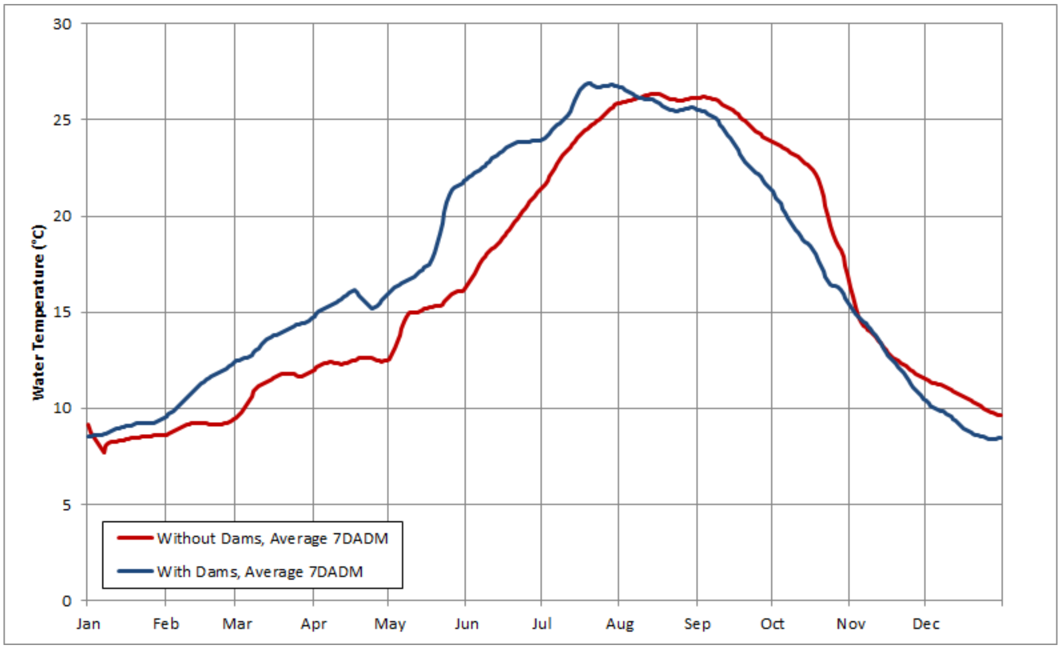

Figure 4.4-7. Comparison of 7DADM water temperatures under with- and without-dams conditions in the lower Tuolumne River at RM 1. Without-dams temperatures (Jayasundara et al. 2017) and with-dams (Base Case) temperatures (TID/MID 2017e) are simulated based on the period 1970 - 2012. With-dams temperatures are based on current FERC-required instream flows.

4.4.1.2.2 Water Quality

The Districts collected hourly dissolved oxygen (DO) data in the Tuolumne River downstream of Don Pedro Dam and powerhouse during 2012 (TID/MID 2013i) (Table 4.4-4). In all but two months, i.e., October and November, each hour's DO concentration measured downstream of the dam is above the Basin Plan WQO of 7 mg/L. In October and November there were 17 days when at least one hourly recording was below 7 mg/L, with the lowest concentration being 5.8 mg/L. However, there were zero days in 2012 when the average of the day's 24 hourly DO measurements was below 7 mg/L.[9]

[9] The Districts collected DO data in the La Grange Powerhouse tailrace channel as part of the Fish Barrier Assessment (FISHBIO 2017c) conducted in support of the La Grange Hydroelectric Project licensing. Data generally indicate satisfactory conditions for aquatic life. However, during the first year of the assessment (2015), there was a brief period from late September through October during which daily instantaneous measurements of DO as low as 4.3 mg/L were recorded at the La Grange Powerhouse tailrace channel weir location. The low instantaneous DO levels appeared to be a localized event because DO levels at the main channel weir ranged from 9.1-11.1 mg/L during the same time period.

Table 4.4-4. Monthly minimum, average and maximum dissolved oxygen concentrations (mg/L) in the Tuolumne River downstream of Don Pedro Dam and powerhouse in 2012.

Month	Minimum DO (mg/L)	Average DO (mg/L)	Maximum DO (mg/L)
2012			
January	8.6	10.1	11.4
February	8.2	10.0	12.4
March	8.4	9.2	12.1
April	8.4	9.3	10.9
May	8.8	9.6	10.6
June	8.6	9.6	10.7
July	8.3	9.2	10.3
August	8.2	9.1	10.4
September	7.4	8.8	10.3
October	6.8	8.4	10.7
November	5.8	8.7	11.0
December	8.6	8.9	9.1

Key: DO = Dissolved Oxygen
mg/L = milligram per Liter

Surface water quality data collected from 1952–2005 at a number of locations in the Tuolumne River downstream of La Grange Diversion Dam are summarized in Table 4.4-5.

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Table 4.4-5. Summary of water quality data downstream of La Grange Diversion Dam.

Location	Sampling Period	RM	Temperature (°C)	Turbidity NTU	Dissolved Oxygen (mg/L)	pH	Nitrate Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Orthophosphate (mg/L)	Source
Tuolumne River at Old La Grange Bridge	1952-1988; 2003-2004	51.4	7.0-15.0	0-18	7.3-12.7	6.4-8.4	0.01-1.20	0.00-0.20	0.00-0.46	0.00-0.10	EPA 2010 CVRWQCB 2010
Tuolumne River at Hickman Bridge near Waterford	1951-1977	31.6	7.8-29.4	--	5.3-19.4	6.0-8.6	0.00-6.00	--	0.08	0.04-0.16	EPA 2010
Tuolumne River at Legion Park	2003-2004	17.6	9.1-26	2.1-45	7.8-15.7	7.3-8.2	--	--	--	--	CVRWQCB 2010
Dry Creek at La Loma Road	2003-2004	18.7	5.8-26	1.2-54	6.0-16.0	7.2-8.1	--	--	--	--	CVRWQCB 2010
Dry Creek near Modesto	1976-1989	--	5.0-29.0	--	4.6-12.0	7.1-8.0	0.0-7.1	0.90	0.22-1.8	0.16-1.60	EPA 2010
Dry Creek at Gallo Bridge	2001	--	16.0-23.0	--	6.8-10.6	7.4-8.1	0.18-0.40	0.96-1.54	0.42-0.21	0.46-0.58	Kratzer et al. 2004
Tuolumne River at Modesto	1993-1995	16.0	8.0-27.2		8.2-11.6	6.3-8.4	--	--	--	0.01-0.41	USGS 2010
Tuolumne River at Audie Peeples	2003-2004	12.9	8.7-26	1.7-16	7.3-15.7	7.4-8.4	--	--	--	--	CVRWQCB 2010
Tuolumne River at Shiloh Road	2000-2005	3.7	7.7-27.9	0.8-52.3	7.8-15.1	6.7-9.0	--	0.30-3.69	0.06-0.40	0.04-0.50	CVRWQCB 2009 CVRWQCB 2010 Kratzer et al. 2004

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Section 303(d) of the federal Clean Water Act (CWA) requires each state to submit to the EPA a list of rivers, lakes, and reservoirs for which pollution control and/or requirements have failed to provide adequate water quality. Based on a review of this list, the surface water bodies identified by the State Water Resources Control Board (SWB) as CWA § 303(d) State Impaired in and adjacent to the lower Tuolumne are listed in Table 4.4-6. There are currently no approved Total Maximum Daily Load (TMDL) plans for the Tuolumne River.

Table 4.4-6. Clean Water Act Section 303(d) List for the lower Tuolumne River and associated water bodies.

Water Body	Pollutant	Final Listing Decision
Lower Tuolumne River (Don Pedro Reservoir to San Joaquin River)	Chlorpyrifos	List on 303(d) list (TMDL required list)
	Diazinon	Do Not Delist from 303(d) list (TMDL required list)
	Escherichia coli	List on 303(d) list (TMDL required list)
	Mercury	List on 303(d) list (TMDL required list)
	Temperature	List on 303(d) list (TMDL required list)
	Unknown Toxicity	List on 303(d) list (TMDL required list)
Turlock Lake	Mercury	List on 303(d) list (TMDL required list)
Modesto Reservoir	Mercury	List on 303(d) list (TMDL required list)
Dry Creek (tributary to Tuolumne River at Modesto)	Chlorpyrifos	List on 303(d) list (TMDL required list)
	Diazinon	List on 303(d) list (TMDL required list)
	Escherichia coli	List on 303(d) list (TMDL required list)
	Unknown Toxicity	List on 303(d) list (TMDL required list)

Source : http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2012.shtml (accessed June 2016).

4.4.1.3 Fall-Run Chinook Habitat in the Lower Tuolumne River

4.4.1.3.1 Spawning and Incubation

Results from the current PHABSIM study (Stillwater Sciences 2013) corroborate results of previous modeling efforts, i.e., Chinook salmon spawning habitat (as estimated by modeling of weighted usable area [WUA]) is maximized at flows between 175 and 400 cfs (Table 4.4-7).

Table 4.4-7. Comparison of flows providing >90 percent WUA in the lower Tuolumne River, based on instream flow studies conducted in 1981, 1995, and 2013.

Species/Life stage	Stillwater Sciences 2013 (cfs)	Stillwater Sciences 2013 (USFWS 1995 HSC)[1] (cfs)	USFWS 1995 (cfs)	CDFG 1981[2] (cfs)
Chinook fry	≤100	≤100	<75 cfs	40–280
Chinook juvenile	50–300	50–400	75–225	80–340
Chinook spawn	200–400	200–400	175–325	180–360

[1] These results reflect the current PHABSIM model run with the habitat suitability criteria (HSC) used in the USFWS 1995 study.
[2] The CDFG 1981 study (reported in TID/MID 1992) simulated results to 600 cfs. The study showed contrasting results for Chinook fry and juveniles between the two study reaches, with a 1991 reanalysis (TID/MID 1992) documenting that the lower reach (Reach 2) results were disproportionately due to the influence of a single transect. As a consequence, only the results from Reach 1 are included above to maximize comparability of the data.

The availability, distribution, and quality of gravel for Chinook salmon spawning in the lower river was assessed through a series of studies conducted by the Districts from 1986 to 1992, and more recently as part of relicensing (W&AR-04). Results showed that riffle areas extended downstream to approximately RM 23.0, although the actual area available for spawning was less extensive due to site-specific flow characteristics and gravel quality (TID/MID 1992). Redd superimposition was estimated to occur at 44 percent of all Chinook salmon redds within the study area (RM 48.8 to 51.6), with an estimated egg loss due to redd superimposition of about 20 percent (TID/MID 1992; McBain and Trush 2000). More recently, superimposition of 15 percent of mapped redds was documented as part of the 2012 Redd Mapping Study (TID/MID 2013g).

Gravel quality was poor in riffles, with an associated estimated survival-to-emergence of 16 percent (TID/MID 1992). Gravel quality in redd locations was better with an associated average estimated survival-to-emergence of 34 percent. Following the 1997 flood, which introduced large volumes of fine sediment to the lower Tuolumne River, an in-situ egg-survival-to-emergence study was conducted to assess the effects of various fine sediment levels within spawning gravels (TID/MID 2007). Study results included an estimated survival-to-emergence rate ranging from near zero to approximately 40 percent, depending on fine sediment levels and intra-gravel flows. Beginning in 2001, gravel augmentation projects were undertaken to improve the quality of spawning gravel in the lower Tuolumne River (see Fish Habitat Restoration Projects, below).

In June 2001, discrete fine sediment deposits in the lower Tuolumne River channel were mapped from RM 52.2 to RM 39.6 (Stillwater Sciences 2002). Results of the survey indicated that fine sediment constituted a large fraction of the channel bed surface, and the largest volumes of fine sediment were observed from RM 45.5 to RM 39.5. Subsequent field observations during the spring and summer of 2012 indicated that pool tails and riffle crests, where Chinook spawning preferentially occurs, contained little fine (<2 mm) bed material (TID/MID 2013h). Fine bed material was distributed nearly equally among pool margins, other channel margins, and alcoves and backwaters (Figure 4.4-8).

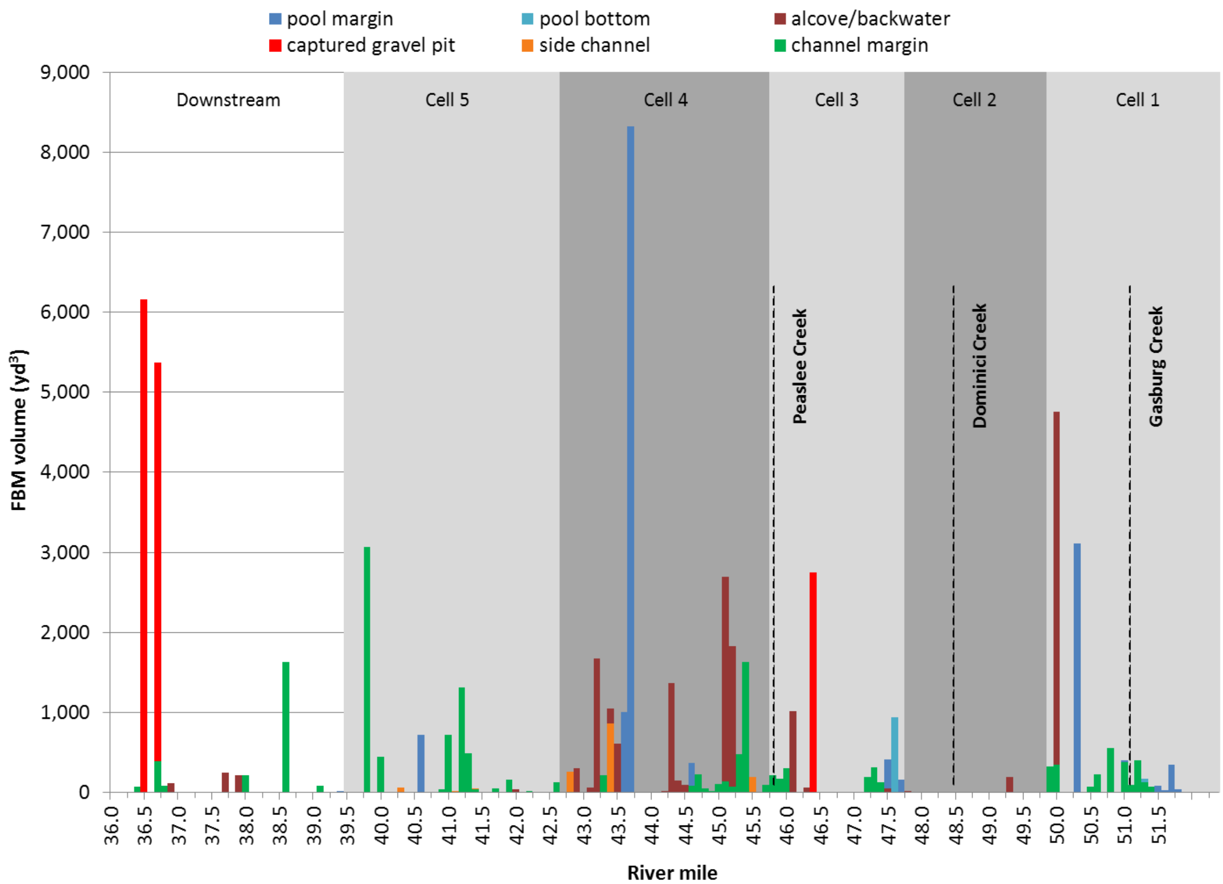

Figure 4.4-8. Distribution of fine (<2 mm) bed material deposits in geomorphic units from RM 52.2 to RM 36.3 (TID/MID 2013h).

4.4.1.3.2 Juvenile Rearing, Smoltification, and Outmigration

Results from the current PHABSIM study (Stillwater Sciences 2013) corroborate results of previous studies, indicating that WUA for Chinook fry and juveniles is maximized at lower flows, with juveniles maintaining high habitat values up to around 300 cfs (Table 4.4-7). Chinook salmon juvenile and fry WUA exhibits a similar pattern of annual fluctuation across all water year types, except for reductions in WUA that occur during high flows in wet years.

Results of the Pulse Flow Study (Stillwater Sciences 2012) show that flows above bankfull discharge at the locations studied were associated with increases in potential overbank habitat area. However, results of the Lower Tuolumne River Floodplain Hydraulic Assessment (TID/MID 2017d) confirm that only a portion of the inundated floodplain area provides suitable habitat for Chinook fry and juveniles. In addition, although some floodplain areas are present over the length of the lower Tuolumne River, not all sections of the floodplain are inundated at the same flows. In the uppermost reach (i.e., RM 51.7–40.0), the largest increase in inundated floodplain area occurs at low to moderate flows. However, the majority of available floodplain habitat in this reach is limited to several disturbed areas formerly overlain by dredger tailings (McBain and Trush 2000). These areas were also associated with the highest frequency of stranding and entrapment of juvenile Chinook salmon during historical stranding surveys at flows between 1,100–3,100 cfs

(TID/MID 2001). In the middle reach (i.e., RM 40.0–21.5), floodplain area is limited and so there is a minimal increase in inundated area with flow. In the lower reach (i.e., RM 21.5–0.9), little floodplain inundation occurs at flows less than 6,000 cfs. However, when flows exceed 7,000 cfs there are large increases in wetted floodplain area, primarily due to the inundation of low-gradient agricultural lands near the San Joaquin River confluence. Floodplain inundation in the lowermost reaches of the Tuolumne River also occurs as the result of backwater effects from the San Joaquin River (up to about RM 13 on the Tuolumne River).

Estimates of usable floodplain habitat for Chinook fry and juvenile life stages (Table 4.4-8) were developed as part of the floodplain modeling study (TID/MID 2017d) based on suitability indices from Stillwater Sciences (2013). Estimates of total usable habitat including both in-channel and floodplain areas steadily increased with increasing discharge in the upper reach (RM 52.2–40), but total habitat area became limited at intermediate discharges in the reaches downstream of RM 40. This occurred because reductions in suitable main channel habitat (primarily as the result of unsuitable water velocities) were not offset by increases in floodplain habitat.

In the upper reach (i.e., RM 51.7–40.0) modeled suitable habitat for Chinook fry ranged from 25 percent of the total inundated floodplain area at 9,000 cfs to 58 percent of the inundated area at 1,000 cfs. For juvenile Chinook in this reach, suitable habitat ranged from approximately 47 percent of the total inundated floodplain area at 1,000 cfs to 57 percent at 3,000 cfs.

In the middle reach (i.e., RM 40.0–21.5), suitable habitat for Chinook fry ranged from 16 percent of the total inundated floodplain area at 9,000 cfs to 58 percent of the inundated area at 1,000 cfs. For juvenile Chinook in this reach, suitable habitat ranged from approximately 35 percent of the total inundated floodplain area at 9,000 cfs to 54 percent at 3,000 cfs.

In the lower reach (i.e., RM 21.5–0.9), suitable habitat for Chinook fry ranged from 37 percent of the total inundated floodplain area at 7,000 and 9,000 cfs to 58 percent of the inundated area at 1,000 cfs. For juvenile Chinook in this reach, suitable habitat ranged from approximately 45 percent of the total inundated floodplain area at 7,000 cfs to 53 percent at 2,000 and 3,000 cfs.

On September 15, 2016, the SWB released for public comment the Revised Draft Substitute Environmental Document (SED) purporting to support the SWB's proposed amendment to the 2006 Water Quality Control, Plan, which, if adopted, would require that increased flows remain in the San Joaquin River and its three major tributaries–the Stanislaus, Tuolumne, and Merced rivers. One of SWB's justifications for higher flows is a need for increases in floodplain habitat. In its comments on the SED (TID/MID 2017b), the Districts pointed out that simply increasing floodplain area does not necessarily translate into increases in floodplain habitat that is usable by juvenile salmonids. The Districts' comments on the SED are attached to the AFLA for the Don Pedro Hydroelectric Project.

Although the lower Tuolumne River floodplain areas are relatively small when compared to large lowland flood bypasses of the Sacramento and San Joaquin river valleys, the results of the floodplain modeling study (TID/MID 2017d) show that extended periods of springtime floodplain inundation (e.g., 14 to 21 days) regularly occur at a 2- to 4-year recurrence interval on the lower Tuolumne River under the Base Case (WY 1971–2012) hydrology, and this floodplain inundation frequency is consistent with typical spawning return periods of fall-run Chinook salmon (Matella and Merenlender 2014).

Table 4.4-8. Hydraulic modeling results of total inundated floodplain area and usable habitat area for Chinook salmon fry and juveniles at selected flows in the lower Tuolumne River.

Modeled Flow (cfs)	1,000	2,000	3,000	5,000	7,000	9,000
Model A (RM 51.7-40) total inundated and usable rearing habitat areas (ft^2)						
Inundated Area	3,185,775	6,731,550	10,701,900	18,363,150	24,244,650	31,023,900
Chinook salmon fry	1,862,541	3,444,543	4,869,105	6,446,877	7,119,815	7,624,482
Chinook salmon juvenile	1,492,554	3,668,897	6,112,661	10,215,191	13,031,099	14,790,965
Model B (RM 40-21.5) total inundated and usable rearing habitat areas (ft^2)						
Inundated Area	1,720,350	3,716,550	5,685,525	9,722,700	13,187,925	15,403,950
Chinook salmon fry	996,093	1,720,727	2,124,633	2,796,063	2,974,076	2,393,577
Chinook salmon juvenile	845,844	1,970,584	3,069,094	4,545,171	5,636,807	5,398,679
Model C (RM 21.5-0.9) total inundated and usable rearing habitat areas (ft^2)						
Inundated Area	830,475	2,121,300	4,150,350	9,247,050	17,512,425	38,009,700
Chinook salmon fry	484,748	1,076,305	1,996,085	3,567,612	6,423,316	14,080,325
Chinook salmon juvenile	413,054	1,113,753	2,180,629	4,469,439	7,946,023	19,178,558

4.4.2 Habitat Conditions in the lower San Joaquin River and Delta

4.4.2.1 Lower San Joaquin River

The San Joaquin River basin has been significantly altered by dams and diversions that supply irrigation water to support a multi-billion dollar agricultural industry. Before dams altered the hydrology of the San Joaquin Basin rivers, large flow events annually mobilized the river bed and rejuvenated riparian forests along the bank and floodplain. Under current conditions, the once dynamic alluvial rivers have been largely converted to static channels that rarely change appreciably except during uncommon large floods. Other anthropogenic alterations have also affected the system including instream aggregate mining, construction of levees for flood control, removal of native vegetation for agriculture, urbanization, introduction of non-native species, and overharvest of anadromous salmonids.

Since the late 1800s there has been substantial draining, re-grading, and reclamation of flood basins, oxbow lakes, and tule marshes along the lower San Joaquin River, especially on the river's east side. Remnant flood basins, marshland, and open water/slough complexes within the river floodway have disappeared or been disconnected from the river by levees (Mussetter Engineering and Jones & Stokes Associates, Inc. 2000). Examples of sloughs still present outside the levee system include Walthall, Red Bridge, and Riley sloughs in San Joaquin County, Pear Slough in Stanislaus County, and the remnant San Joaquin River channel near Grayson. These slack-water habitats were part of an interconnected woodland complex within the meander-belt of the river. In contrast, under current conditions riparian forest and oak woodlands are largely contained within the levees and terraces, but many of the remaining aquatic and semi-aquatic habitats are outside the levee system.

4.4.2.1.1 Hydrology and Geomorphology of the Lower San Joaquin River

During the last 130 years, the flow regime of the San Joaquin River, including peak flow magnitudes and frequencies, has been significantly altered by water management, levee construction and channel modifications, flow bypasses, and local diversions (Mussetter Engineering and Jones & Stokes Associates, Inc. 2000). About 85 percent of the combined watershed area of the three main tributaries to the lower Jan Joaquin River is upstream of dams, which has had a significant effect on flow characteristics.

The median annual unimpaired flow in the San Joaquin River at Vernalis from WYs 1930 through 2009 was reportedly 5.6 million ac-ft (SWRCB 2012). The median annual actual flow was reportedly 1.9 million ac-ft, or 32 percent of the median annual unimpaired flow. This reduction in actual flow compared to unimpaired flow is attributable to exports of water to locations outside the basin and consumptive use of water within the basin. Unimpaired flow in the San Joaquin River at Vernalis is primarily attributable to flow from the Stanislaus, Tuolumne, and Merced rivers, and during wetter water years, the upper San Joaquin River.

The upstream water management projects have increased the duration of lower flows (less than about 3,000 cfs at Vernalis) and decreased the duration of intermediate flows (3,000 to 16,000 cfs at Vernalis) (Mussetter Engineering and Jones & Stokes Associates, Inc. 2000). Average annual hydrographs for the Vernalis gage show that prior to completion of Friant Dam in 1941, flows were relatively high during February and March but highest during the spring runoff in May and June. Under existing conditions, runoff volume during April and May has decreased significantly. Increases in channel depth (an effect of constraining the channel) have decreased the frequency of bankfull flows from two to four years, which in turn influences regeneration rates of riparian vegetation (Mussetter Engineering and Jones & Stokes Associates, Inc. 2000).

Cain et al (2003) list the following hydrologic alterations in the lower San Joaquin River between Newman and Vernalis:

- Flow depletions of 74-76 percent in May and June
- Substantial increases in the 1 to 7-day minima
- Substantial reductions in the 1 to 90-day maxima
- Shift in the timing of annual maxima, from April-May to late December-early January
- Reductions of 46-48 percent in high and low pulse durations.

Comparison of historical and current estimates indicates that sediment transport capacities have increased by about 60 percent upstream of the Tuolumne River confluence to about 185 percent downstream of the Stanislaus River confluence. This increase is caused primarily by increased hydraulic energy associated with channel deepening and narrowing.

Under existing conditions there are about 20,000 lineal feet of bank erosion (14 percent of total bank length) in the lower San Joaquin River between Old River (RM 54) and the Stanislaus River (RM 74.8) and 29,000 lineal feet (31 percent) between the Stanislaus River and Tuolumne River (RM 83.8) (Mussetter Engineering and Jones & Stokes Associates, Inc. 2000). Bank erosion upstream of the Tuolumne River confluence is a major source of sediment to the lower reaches of the San Joaquin River.

4.4.2.1.2 Temperature in the Lower San Joaquin River

The San Joaquin River from the confluence with the Tuolumne River to the Delta Boundary is included on the State's CWA Section 303(d) list for temperature impairment. Temperatures in the middle San Joaquin River are often above 25°C (77°F) for extended periods from the end of May through September (Cain et al. 2003) and at times, particularly during 2015, exceed 30°C (86°F). Water temperatures (2010-2016) measured at the USGS gage near Vernalis (11303500) are shown in Figure 4.4-9.

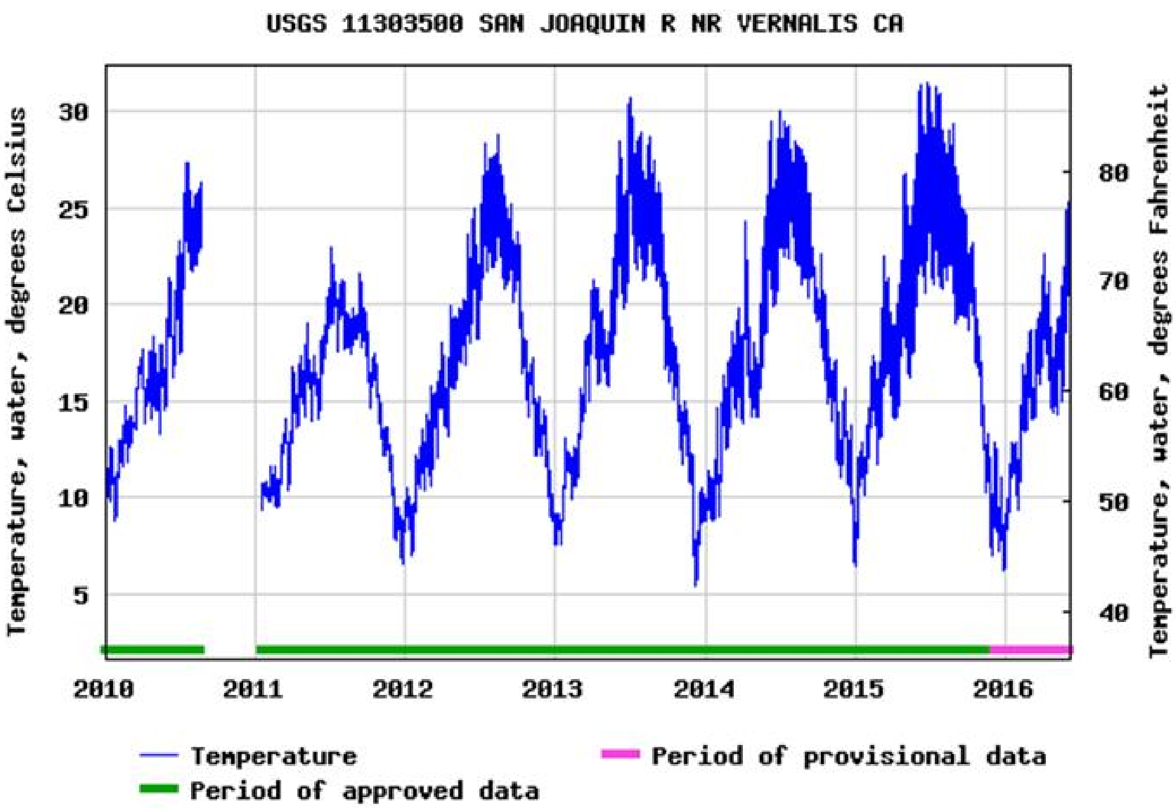

Figure 4.4-9. Water temperatures measured at the USGS gage near Vernalis (11303500) from 2010-2016.

4.4.2.1.3 Water Quality in the in the Lower San Joaquin River

The San Joaquin River downstream of the Tuolumne River confluence is CWA § 303(d) listed for a variety of pollutants (Table 4.4-9). The California Department of Pesticide Regulation (CDPR) has documented over 300 herbicides and pesticides that are discharged throughout agricultural regions of the Central Valley and Delta (Werner et al. 2008). Agriculture and urbanization are the primary land uses that act as sources of contaminants that have the potential to affect water quality and aquatic resources, primarily through water returns to the river. Hundreds of agricultural and urban drains discharge into the San Joaquin River downstream of the Merced River confluence, many of which are also designated as impaired water bodies, such as the Harding Drain, the Grayson Drain, the Newman Wasteway, and the Westley Waterway (SWRCB 2010).

The flow of subsurface drainage water from intensively irrigated agricultural land on the west side of the San Joaquin Valley has created a well-known water salinity and specific ion (selenium and boron) problem in the San Joaquin River. Discharges from the Tuolumne, Merced, and Stanislaus rivers dilute contaminant concentrations and improve the overall water quality, including the reduction of salinity levels, as the river flows downstream toward the Delta. Groundwater over-drafting is also thought to be affecting water quality, salt and boron concentrations in particular, in the San Joaquin River downstream of the Tuolumne River. Boron concentrations higher than about 2 parts per million have the potential to adversely affect riparian regeneration (Mussetter Engineering and Jones & Stokes Associates, Inc. 2000).

Table 4.4-9. Clean Water Act Section 303(d) List for the lower San Joaquin River.

Reach	Pollutant	Final Listing Decision
San Joaquin River (Tuolumne River to Stanislaus River)	Chlorpyrifos	Do Not Delist from 303(d) list (being addressed with EPA approved TMDL)
	DDT	List on 303(d) list (TMDL required list)
	Diazinon	Do Not Delist from 303(d) list (being addressed with EPA approved TMDL)
	Electrical Conductivity	List on 303(d) list (TMDL required list)
	Group A Pesticides	List on 303(d) list (TMDL required list)
	Mercury	List on 303(d) list (TMDL required list)
	Temperature, water	List on 303(d) list (TMDL required list)
	Unknown Toxicity	Do Not Delist from 303(d) list (TMDL required list)
San Joaquin River (Stanislaus River to Delta Boundary)	Chlorpyrifos	Do Not Delist from 303(d) list (being addressed with EPA approved TMDL)
	DDE	List on 303(d) list (TMDL required list)
	DDT	Do Not Delist from 303(d) list (TMDL required list)
	Diuron	List on 303(d) list (TMDL required list)
	Electrical Conductivity	Do Not Delist from 303(d) list (being addressed with USEPA approved TMDL)
	Escherichia coli	List on 303(d) list (TMDL required list)
	Group A Pesticides	List on 303(d) list (TMDL required list)
	Mercury	List on 303(d) list (TMDL required list)
	Temperature, water	List on 303(d) list (TMDL required list)
	Toxaphene	List on 303(d) list (TMDL required list)
	Unknown Toxicity	Do Not Delist from 303(d) list (TMDL required list)

Source : http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2012.shtml (accessed June 2016).

4.4.2.2 Sacramento-San Joaquin Delta

The Delta's boundaries are defined in Water Code §12220 and encompass a roughly triangular area extending from Chipps Island near Pittsburg on the west, to the City of Sacramento on the Sacramento River on the north, and to the Vernalis gaging station on the San Joaquin River on the south. The Delta is the transition zone between freshwater rivers of the Central Valley and the progressively more saline environments of Suisun, San Pablo, and San Francisco bays. Delta habitats are affected by tides, which result in daily and seasonal variability in flow patterns and water quality.

The Delta has been significantly altered from its historical condition by water diversions, levee construction, agricultural practices, and inputs of contaminants from a range of municipal, industrial, and agricultural sources. The Delta is interlaced with hundreds of miles of waterways and relies on more than 1,000 miles of levees for protection against flooding (Moore and Shlemon 2008). These levees have eliminated the majority of tidally exchanged marsh habitats in the Delta (Whipple et al. 2012). Under current conditions, only about 2 percent of historical tidal marsh habitat remains in the Delta (NMFS 2014). Tidal marsh is now restricted to remnant patches primarily in channels where the area between levees is sufficiently wide or where substrate deposits are deep enough to be suitable for tules and reeds (NMFS 2014). Historically, tidal marsh habitats were important nursery areas for a variety of Delta fish species (Kimmerer et al. 2008), but few locations in the eastern and central Delta now provide suitable habitat for many rearing fish, including Chinook salmon.

The combined effects of continued land subsidence, rising sea level, seismic risk, and winter flooding have increased the vulnerability of the Delta's extensive levee system. The breaching of levees has the potential to degrade water quality and expose habitats adjacent to islands to increased seepage and wave action (CDWR et al. 2013). Much of the rich Delta farmland has lost soil from oxidation, compaction, and wind erosion, resulting in lowered elevations of some islands, in some cases up to 25 feet below sea level.

The extent of historical flooding in Central Valley rivers was vast (Kelley 1989), resulting in prolonged periods of floodplain inundation. However, reductions in wetland and floodplain habitats in the lower San Joaquin River and South Delta, and changes in tributary flow magnitudes and timing, have reduced the amount of floodplain habitats (Whipple et al. 2012; TID/MID 2013f). Historically, the San Joaquin River was an important source of nutrients to the Delta. However, because most of the San Joaquin River's flow is now diverted from the south Delta by CVP/SWP operations, nutrient imports have declined (NMFS 2014). This reduction in nutrients has probably contributed to a decrease in food availability for fish in the Delta (NMFS 2014). Also, pumping operations may entrain zooplankton, another way in which food availability can be reduced for fish rearing in the Delta.

Water temperatures in the Delta during June and July are frequently warmer than 19°C (67°F) (NMFS 2014). The Delta is identified by the SWRCB as CWA §303(d) impaired for a number of contaminants (Table 4.4-10). As noted above, the CDPR has documented over 300 herbicides and pesticides that are discharged throughout agricultural regions of the Central Valley and Delta (Werner et al. 2008). The Stockton Deepwater Ship Channel (DWSC) portion of the San Joaquin River within the Delta is also §303(d) listed for chlorpyrifos, DDT, diazinon, dioxin, furan compounds, mercury, organic enrichment, PCBs, and pathogens. Heim et al. (undated) found that the highest methyl mercury (a biochemically active form of mercury) sediment concentrations were found in the central Delta. The central Delta was considered to have the greatest mercury methylation potential when compared to surrounding tributary streams.

Discharge of some nutrients, such as nitrogen and phosphorus from non-point-source runoff of agricultural fertilizer and from point sources such as water treatment facilities, stimulates algae growth, with attendant increases in the magnitude of diurnal DO variation. This has caused changes in the food webs of the Delta (Durand 2008), and as a result food availability for Delta fish populations (TID/MID 2013c).

There are periods of low DO concentrations in the DWSC during summer and fall upstream of Turner Cut. Because of these depressed DO levels, the reach fails to meet the Central Valley Basin Plan (Basin Plan) WQOs for DO (5 mg/l December - August and 6 mg/l September -November) (ICF International 2010). In 2008, the Department of Water Resources implemented the Stockton Deep Water Ship Channel Demonstration Dissolved Oxygen Aeration Facility Project (Aeration Facility) to increase DO levels and thereby potentially reduce adverse effects on biota, including migrating anadromous salmonids (Newcomb and Pierce 2010).

Table 4.4-10. Clean Water Act Section 303(d) List for the Sacramento-San Joaquin Delta.

Pollutant	Final Listing Decision
Chlordane	List on 303(d) list (TMDL required list)
DDT	List on 303(d) list (TMDL required list)
Dieldrin	List on 303(d) list (TMDL required list)
Dioxin compounds	List on 303(d) list (TMDL required list)
Furan Compounds	List on 303(d) list (TMDL required list)
Mercury	List on 303(d) list (being addressed by EPA approved TMDL)
PCBs	List on 303(d) list (TMDL required list)
Selenium	List on 303(d) list (TMDL required list)

Source : http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2012.shtml (accessed June 2016).

Water quality monitoring was conducted from Mossdale Crossing to Turner Cut to assess the benefit of installing the HORB (Brunell et al. 2010). The HORB is installed by CDWR in conjunction with reservoir releases to increase flow and DO concentrations in the DWSC for migrating fall-run Chinook salmon; these practices can temporarily increase DO. Since 2000, DO levels in the DWSC have been observed to increase about 2 to 3 mg/l with the increased DWSC flows associated with the placement of the HORB (Brunell et al. 2010). However, low DO may recur after removal of the HORB following the spring pulse flow releases from the San Joaquin River's tributaries (Brunell et al. 2010). The response of DO in the DWSC is complex and difficult to predict solely by flow management, and other factors, such as biological oxygen demand (BOD) and temperature, also influence DO.

5.0 EFFECTS OF PROPOSED ACTION

5.1 Interrelated and Interdependent Actions

As noted in Section 3.1 of this EFH Assessment, the Districts are seeking a new FERC license to allow for the continuation of hydroelectric power generation at existing facilities at Don Pedro Dam. Water storage and releases for irrigation, M&I uses, the CCSF's water bank, and flood control coordinated with the ACOE are in no way dependent on the issuance of a FERC license for the Project, and will occur with or without the licensing of the Proposed Action. As such, these uses are *not* interrelated or interdependent with the issuance of a FERC license for hydroelectric power generation.

Because the Districts are consulting with NMFS on the Proposed Action, and power would be generated under the new license as it has been historically (i.e., the effects of generation would be equivalent to those occurring under environmental baseline conditions, so there would be no incremental effects on resources in the lower river), the effects of the aforementioned non-hydropower water uses are addressed as independent actions in the cumulative effects analysis of this EFH Assessment (see Section 5.3). Other than their proposed aquatic resource measures (addressed below), the Districts are aware of no other actions that have the potential to affect fall-run Chinook salmon EFH in the Action Area that could be considered related to or interdependent with the Proposed Action to continue hydroelectric power generation at the Project.

5.2 Direct and Indirect Effects of the Proposed Action

There would be no direct or indirect adverse effects on fall-run Chinook EFH in the Action Area as the result of continued hydroelectric power generation at the Project. For the reasons described below, existing hydropower operations at Don Pedro Dam have no adverse effect on flows, temperature, water quality, or any other environmental conditions in the lower Tuolumne River, and as a result no effect on Chinook salmon or the species' EFH. There would, however, be direct effects on fall-run Chinook salmon EFH as the result of aquatic resource measures proposed by the Districts for implementation under the new FERC license (see Section 5.2.1).

Electric power is generated at the Don Pedro Hydroelectric Project using flows released for other purposes. Irrigation, municipal, and industrial water deliveries and high-flow releases are pre-scheduled based on forecasted demands and actual projected inflow and then released through the powerhouse up to its hydraulic capacity. Scheduling of these releases is adjusted, when consistent with water supply needs, to release flows with a preference for on-peak rather than off-peak hours. However, these "peaking" flows are modulated, being subject to water supply demand and limits on water fluctuations in the Districts main canals. Flows in the reach of the Tuolumne River below La Grange Diversion Dam are not subject to such fluctuations as the fluctuations travel down and are absorbed by the Districts' main canals and irrigation water needs, which are unrelated and non-interdependent actions, e.g., providing water for irrigation and M&I uses. Hydroelectric generation at the Don Pedro Project does not impact fall-run Chinook EFH in the Action Area, because the flows released into the lower Tuolumne River are not linked to power production and, absent power production at the Don Pedro Dam, reservoir operations and the flow release schedule would remain the same as they are under existing conditions, i.e., driven by uses other than hydroelectric power production.

5.2.1 Effects of Proposed Aquatic Resources Measures

As noted in Section 3.1, the Districts are proposing to implement a set of measures for the benefit of aquatic resources, including fall-run Chinook salmon, in the lower Tuolumne River. The effects of these measures are described in the following subsections.

5.2.1.1 Improve Spawning Gravel Quantity and Quality

5.2.1.1.1 Augment Current Gravel Quantities through a Coarse Sediment Management Program

The results of the Spawning Gravel in the Lower Tuolumne River report (TID/MID, 2013h) demonstrates that the Tuolumne River downstream of La Grange tailrace has enough gravel now, and for the foreseeable future, to provide sufficient habitat for fall-run Chinook spawning. However, although availability of spawning gravel is not currently a limiting factor, Don Pedro Reservoir's capture of gravel prevents its movement downstream, which has contributed to the net loss of gravel supply to the lower Tuolumne River. Based on the results of TID/MID (2013h) estimated total coarse sediment storage loss was approximately 8,000 tons, based on differencing of 2005 and 2012 DTM data over a 13-mile study reach, which included the reach of the lower Tuolumne River where nearly all salmonid spawning occurs. Distributed over the channel within the study area, this equates to an average bed lowering of 13 mm, or less than half the average median grain size of the coarse channel bed (approximately 51 mm). The total estimated gravel volume lost from storage in the reach is comparable in magnitude to the quantity of coarse sediment added during any one of the augmentation projects that have occurred since 2002 (approximately 7,000–14,000 tons). Also, the reservoir's ongoing operations affect flow magnitude and frequency downstream, and this affects gravel mobilization, which can lead to gravel filling in with fines, which in turn impacts the suitability of gravel for salmonid spawning (TID/MID 2013h).

To improve spawning conditions for fall-run Chinook, the Districts propose to conduct coarse sediment augmentation from RM 52 to RM 39 over a 10-year period following issuance of a new license. Because spawning preferences are more heavily weighted towards upstream habitats, the highest priority for the gravel augmentation is upstream of Old La Grange Bridge. Coarse sediment to be added to the river channel would range in size from 0.125 to 5.0 inches in diameter (Preliminary Gravel Augmentation Designs for Don Pedro Hydroelectric Project, as appended to Exhibit E of the AFLA). Taking biological needs, geomorphic needs, and sensitive habitat into consideration, the recommended short-term coarse sediment augmentation sites, in order of priority, would be (1) Riffle A3/4, (2) Riffle A5/6 (3) Basso Pool, and (4) and Riffle A1/2[10] (Stillwater Sciences 2017b). Preliminary gravel augmentation designs are provided in the Preliminary Gravel Augmentation Designs for Don Pedro Hydroelectric Project, and estimated gravel volumes and spawning gravel areas are shown in Table 5.2-1.

[10] Riffle A1/2 is located just downstream of the confluence of the mainstem Tuolumne River and the La Grange tailrace.

Table 5.2-1. Preliminary gravel augmentation volumes and spawning gravel areas (at 320 cfs) downstream of La Grange Diversion Dam (RM 52) in the Tuolumne River.

Riffle Location	RM	Volume (yd^3)	Tons	Wetted Area (ft^2)
A2	51.7	450	585	6,450
A3	51.5	4,300	5,590	43,640
A5	51.2	11,500	14,950	120,960
A6	51.0	18,600	24,180	100,460
Basso Upper	46.5	20,500	26,650	190,890
Basso Lower	46.2	2,300	2,990	80,269
Totals		57,650	74,945	542,669

Expected benefits of gravel augmentation in the future would include (1) an increase in fall-run Chinook egg-to-emergence survival, (2) reduced superimposition of fall-run Chinook redds, (3) increased benthic macroinvertebrate production, and (4) possibly improved hyporheic flow and cold water habitat downstream of LGDD.

Monitoring associated with this measure would include (1) a spawning gravel evaluation in Year 12 of the augmentation program using methods comparable to those employed for the Spawning Gravel in the Lower Tuolumne River Study (TID/MID 2013h) and (2) annual surveys of fall-run Chinook spawning use of new gravel patches for five years following completion of gravel augmentation.

5.2.1.1.2 Gravel Mobilization Flows of 6,000 to 7,000 cfs

Flows ranging from 6,000-7,000 cfs (measured at USGS gage 11289650 below La Grange Diversion Dam) would be released to mobilize gravel and fines. These operational flows would be provided for at least two days at an estimated average frequency of once every three to four years, i.e., during years when sufficient spill is projected to occur (see the Districts' Preferred Plan as appended to Exhibit E of the AFLA) (TID/MID 2017h). In years when the La Grange gage spring (March through June) spill is projected to exceed 100,00 ac-ft, the Districts would plan to release a flow of 6,500 cfs for two days within the spill period, with down-ramping not to exceed 300 cfs/hr.

Potential benefits of this measure would include (1) reduced fine sediment storage in the low-flow channel and in spawning gravels, which could increase fall-run Chinook egg-to-emergence survival and fry production and benthic macroinvertebrate production, (2) increased fine sediment storage on floodplains, which could improve regeneration of native riparian plant species during wetter water years, and (3) a net increase in lateral channel migration, bar formation, and large wood introduction, which together could create new floodplains and complex hydraulic environments resulting in improved fall-run Chinook adult holding, spawning, and juvenile rearing habitat.

Monitoring associated with this measure would consist of conducting substrate surveys at six test sites located upstream of RM 43 prior to a high-flow event, then examining the same test sites following the flow event to evaluate whether there are corresponding changes in channel morphology or improvements to the quality of spawning gravel, e.g., a reduction in interstitial fines. Flow magnitude and/or duration may be adjusted based on these observations.

This measure could cause localized, short-duration pulses in turbidity, which depending on the timing of releases, might benefit juvenile fall-run Chinook by decreasing predator sight-feeding effectiveness. Benefits to spawning habitat are expected to outweigh any short-term effects associated with turbidity increases.

5.2.1.1.3 Gravel Cleaning

The Districts would conduct a five-year program of experimental gravel cleaning using a gravel ripper and pressure wash operated from a backhoe, or equivalent methodology. Each year of the program would consist of two to three weeks of cleaning select gravel patches.

Gravel cleaning has the potential to expand the availability of high quality gravel, which would improve spawning success and egg incubation for fall-run Chinook. The Districts would conduct *O. mykiss* spawning and redd surveys in areas planned for gravel cleaning prior to commencing any gravel cleaning. Subject to the findings of these surveys, the gravel cleaning may coincide with May pulse flows to benefit Chinook smolt outmigration by providing increased turbidity to reduce predator sight feeding effectiveness.

During short periods, localized increases in turbidity might exceed state water quality standards, but the improvements in spawning gravel quality and potential increases in fall-run Chinook outmigrant survival due to short-duration reductions in predator efficiency are likely to significantly outweigh any short-term effects of increased turbidity. The Districts would coordinate with the SWRCB to secure necessary permits and conduct any required turbidity monitoring. If gravel cleaning is judged to be successful, the program would continue, adjusted as needed to comply with any water-quality related concerns of the SWRCB.

5.2.1.2 Improve Instream Habitat Complexity

Under this measure, $2 million would be provided for the collection and placement of boulder-size stone (approximately 0.7–1.5 yd^3) between RM 42 and RM 50. The boulder placement program would take place over four years and proceed by conducting placement in select sub-reaches each summer. Placement locations would be selected through collaboration with parties having fisheries and recreational interests in the lower Tuolumne River. A maximum of 200 boulders would be placed. The preferred locations for materials installation would be in run/glide habitats to create velocity diversity and feeding stations. Enhancing an area downstream of a riffle would likely have the greatest benefit. Smaller boulders (12-24 inch) may be placed along stream margins in similar run/glide habitat. This would provide interstitial velocity refuges for rearing juveniles during winter and high flows throughout the year. Locations between RM 48 and 50 that are run/glide habitats would be tested first.

This measure is designed primarily to provide favorable microhabitats for *O. mykiss* (TID/MID 2017f) by increasing structural and hydraulic complexity. However, improvements to spawning habitat occurring as localized scour displaces fines from gravel beds would benefit fall-run Chinook. Unlike the placement of large wood in the channel, suitably placed boulders would represent a minimal hazard to recreational boaters using the lower river.

Biological monitoring would consist of bounded count estimates in the treatment habitat units and untreated areas nearby that are hydraulically similar to the pre-treatment habitats. The Districts would collect data for at least two years prior to boulder placement and three years after placement. Annual snorkeling surveys would be conducted to assess differences in units with and without bordering boulders (see above), and evaluate changes in fish densities through time in response to boulder placement. In addition, a one-time monitoring event within five years following the completion of the boulder placement program would be conducted to examine the stability of the placed boulders and to map smaller gravel accumulations linked to the placement of the boulders.

5.2.1.3 Contribute to CDBW's Efforts to Remove Water Hyacinth

The Districts would contribute $50,000 per year to the California Division of Boating and Waterways (CDBW, the State agency responsible for implementing an Aquatic Pest Control Program to control hyacinth) to assist with the removal of water hyacinth and other non-native flora. The contribution would be made regardless of the level of water hyacinth infestation occurring in the lower Tuolumne River. The Districts would coordinate with CDBW when water hyacinth infestations occur on the Tuolumne River to schedule removal efforts.

There would be no monitoring conducted by the Districts in association with this measure. CDBW employs herbicides to treat water hyacinth and other invasive aquatic plants in Central Valley rivers and the Delta. CDBW uses herbicides that are registered for aquatic use with the EPA and the CDPR. Treated areas are typically monitored weekly to ensure that herbicide levels do not exceed allowable limits and that herbicide treatments have no adverse environmental impacts.

Because dense mats of water hyacinth can alter water quality by reducing dissolved oxygen and affecting pH and turbidity (Penfound and Earle 1948; Center and Spencer 1981, as cited in Cal-IPC 2014), removal of these introduced plants would likely benefit aquatic biota in the lower river, including fall-run Chinook salmon passing through the lowermost reaches of the river where water hyacinth infestations occur. Also, CDBW applies herbicide at levels that do not exceed allowable limits so that treatments have no adverse environmental impacts.

5.2.1.4 Fall-Run Chinook Spawning Improvement Superimposition Reduction Program

Redd superimposition occurs when newly arrived female fall-run Chinook select spawning sites on top of preexisting redds, and this superimposition can displace or damage eggs already in the gravel, thereby resulting in reduced fall-run Chinook productivity. To reduce this superimposition, the Districts propose to develop and install a temporary barrier to encourage spawning on less used, but still suitable, riffles. The temporary barrier would be installed each year below the new La Grange Bridge (RM 49.9) after November 15 once passage at the proposed RM 25.5 fish counting weir (see Section 5.2.1.5) exceeds 4,000 total spawners. The temporary barrier would be similar to the Alaska-type counting weir currently used on the Tuolumne River at RM 24.5 or a picket-weir type. Final design and configuration of the temporary barrier would be based on consultation with state and federal resource agencies.

Studies have shown (TID/MID 2013f, 2017a) that rates of spawning superimposition are relatively high for fall-run Chinook in the lower Tuolumne River at higher escapement levels (e.g., > 5,000 female spawners) due to a strong preference shown by fall-run Chinook to spawn upstream of RM 47. The reasons for this are uncertain, but may be correlated with the high percentage of out-of-basin hatchery strays contributing to the Tuolumne River escapement and their lack of site fidelity. Suitable spawning gravel exists in the lower Tuolumne River from RM 51.5 to approximately RM 30. Dispersing spawning activity more evenly throughout the reach containing suitable gravel is expected to improve fall-run Chinook productivity in high-escapement years.

5.2.1.5 Predator Control and Suppression Program

The Districts' proposed predator control and suppression program would consist of two elements: (1) construction and operation of a barrier weir and (2) active predator control and suppression (see descriptions of measures below).

Studies demonstrate that predation on juvenile fall-run Chinook by non-native black bass and striped bass has a substantial impact on smolt survival in the lower Tuolumne River (TID/MID 2013f, 2017a, 2013e; and results of rotary screw-trap monitoring). The Predator Suppression and Control Plan developed as part of the Districts' Proposed Action identifies a reduction in predation of 10 percent below RM 25.5 and 20 percent above RM 25.5. Modeling confirms that reducing predator-related mortality of Chinook salmon juveniles in proportion to these predator-reduction targets would have a greater beneficial effect on smolt survival than releasing to the river 40 percent of the unimpaired flow in the February 1–June 30 period.[11] An effective predator control and suppression plan, when combined with an appropriately-timed series of springtime pulse flows (see proposed flow releases described below), would dramatically improve juvenile fall-run Chinook salmon survival, especially during outmigration.

5.2.1.5.1 Construct a Fish Counting and Barrier Weir

The Districts are proposing to construct and operate a small barrier weir (less than 5 feet of head at normal flows) at approximately RM 25.5, about 1 mile upriver of the current counting weir. The barrier weir will be a reinforced concrete structure consisting of, from river-right to river-left (looking downstream), the components listed below. A planview of the weir is provided in Figure 5.2-1.

- A concrete abutment merging with natural grade;
- A fishway and counting structure equipped with a viewing window and fish sorting capability;
- A 8-foot long by 5-foot high bottom drop gate with a maximum hydraulic capacity of 75 cfs providing attraction flow to the fishway entrance;
- Spillway section;
- Middle abutment;

[11] Reducing predation rates by the amounts called for in the Proposed Action is projected to increase smolt production. Assuming a population of 2,000 female spawners, the Base Case smolt production estimate of 6.3 smolts per female spawner would increase to 11.4 smolts per female spawner (TID/MID 2013, W&AR-06). Increasing the February–June instream flows to 40 percent of the unimpaired flow is projected to produce 8.7 smolts per female spawner.

- Non-motorized craft (kayak/canoe/raft) bypass structure with flap gate control and concrete chute; and
- Left concrete abutment merging with natural grade.

The fish counting and barrier weir would serve the following purposes:

- Provide a permanent upstream migrant counting weir to replace the temporary seasonally-operated Alaska-type counting weir located at RM 24.5. The seasonal weir must be removed when flows reach 1,500 cfs; the new counting weir would be capable of being operated year-round and in river flows up to at least 3,000 cfs.
- Provide a Denil-type fishway and counting window to conduct fish counts, fish species separation, and potentially public viewing. The ability to collect fish would also permit broodstock selection, if desired by fisheries agencies.
- Provide an barrier to exclude striped bass from upstream habitats used for juvenile fall-run Chinook salmon rearing, while at the same time providing a location where striped bass are likely to congregate, which would enable their removal or isolation at key times during smolt outmigration. Striped bass are known to be voracious predators and have been observed in all seasons throughout the entire lower Tuolumne River. Keeping striped bass from extending their range into the prime fry and juvenile rearing habitat above RM 25.7 would reduce predation on these critical life stages.
- Provide for elimination of black bass movement into sections of river upstream of RM 25.7 and provide for long-term reduction in black bass populations above RM 25.7.

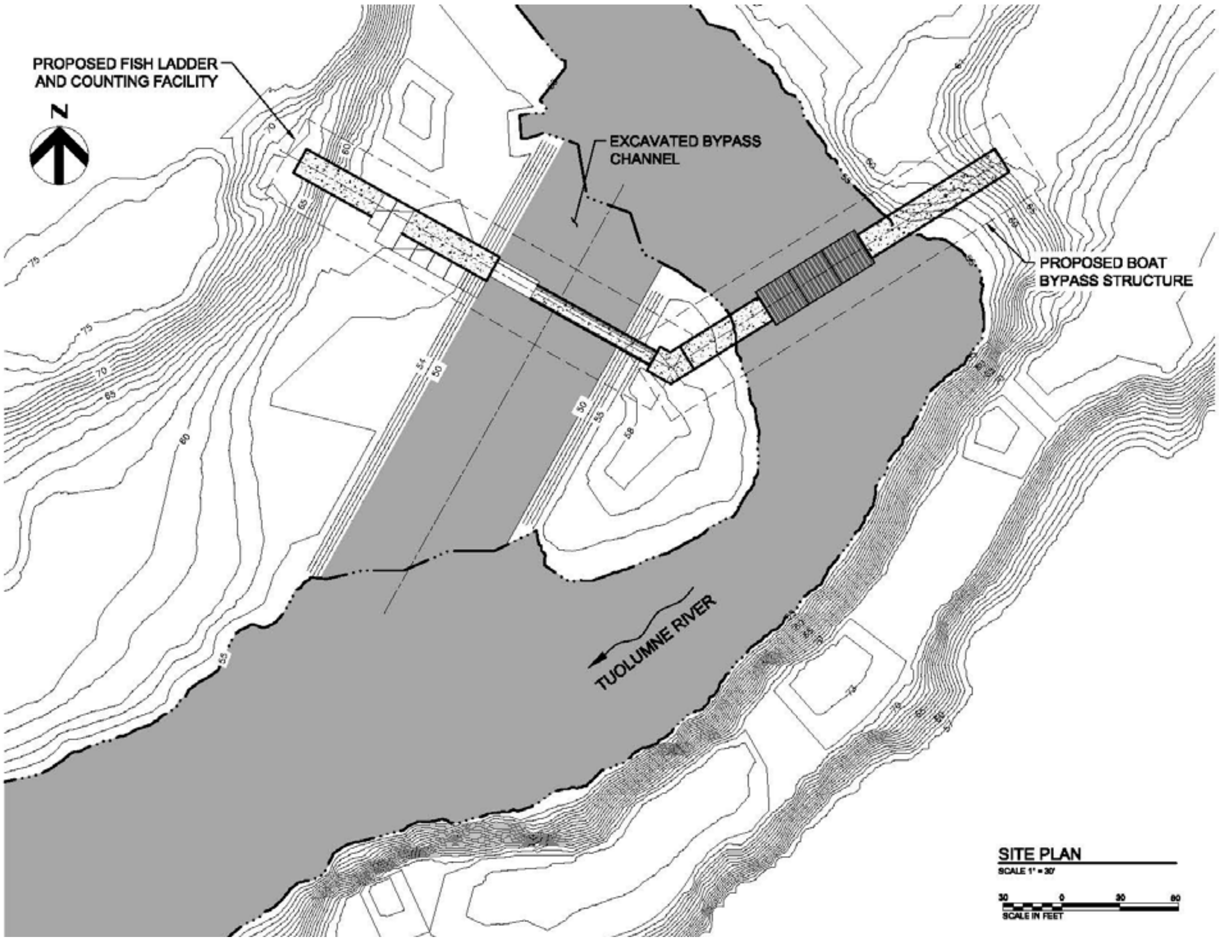

Figure 5.2-1. Planview of the fish counting and barrier weir at RM 25.5.

5.2.1.5.2 Predator Suppression and Removal

The Districts are proposing to implement a comprehensive predator suppression and control program consisting of the components described below.

- Specific incentives and measures to target an annual reduction in the population of black bass and striped bass, based on levels documented in 2012, by approximately 20 percent above the barrier weir (at RM 25.7) and 10 percent below the barrier weir. These measures would include, but would not be limited to, sponsoring and promoting black bass and striped bass derbies and reward-based angling in locations both above and below the barrier weir to substantially diminish the sizes of these populations over time. Other removal and/or isolation methods would include electrofishing, seining, fyke netting, and other collection methods.[12] Based on the 2012 population of black bass between the two Tuolumne River rotary screw-

[12] Such incentives could include expansion on the Tuolumne River of the current CDFW Free Fishing Days program, which currently allows free fishing on the Labor Day and July 4 holidays, expansion of CDFW's current Fishing in the City program to promote urban youth fishing, promotion of fishing derbies and competitions similar to the Nor-Cal Guides' and Sportsmen's Association (NCGASA) pikeminnow derby on the Feather River, and/or sport-reward program for striped bass and black bass similar to pikeminnow programs currently carried out in Washington and Oregon.

traps (RM 30 and RM 5), a 10 percent removal would amount to a total of about 660 fish (roughly equal numbers of smallmouth and largemouth bass).[13] To provide context, this level of removal would take four anglers about 80 days of fishing. There are more efficient means of removal, including electrofishing, and the seasonal timing of such removal would influence its effectiveness at increasing Chinook smolt survival. To ensure compliance with this measure, the Districts propose to file an annual report on black bass and striped bass reduction efforts undertaken during the prior calendar year. The Districts propose to conduct a survey every five years to identify the number of fish to be targeted in order to reduce the bass population by 10 percent in succeeding years.

- The Districts will seek and advocate for changes to current fishing regulations for the lower Tuolumne River (e.g., length of season, bag limit, catchable size, required removal of black bass/striped bass caught, allowing a bounty program) to reduce black and striped bass numbers. In addition, the Districts propose to establish a fund to carry out the activities contemplated above and to educate the public on the adverse effects of predation on fall-run Chinook in the Tuolumne River to encourage participation in the removal program and advocacy of changes to fishing regulations that facilitate such removal. Activities could include, but not be limited to, developing educational materials about the effects of predatory fish, community outreach, or kiosks. To monitor compliance with this measure, the Districts propose to file an annual report describing the specific educational and advocacy measures undertaken during a particular year.

Removal of striped and black bass would lead to substantial reductions in the abundance of non-native predators in the lower river, which in turn would lead to substantial increases in the survival of outmigrating juvenile fall-run Chinook salmon.

5.2.1.6 Fall-Run Chinook Salmon Restoration Hatchery Program

The Districts propose to build a fall-run Chinook restoration hatchery, in cooperation with CDFW, in the general vicinity of the current location of the CDFW offices below La Grange Diversion Dam. The restoration hatchery would be operated by CDFW. The Districts would pay for hatchery construction and O&M for the first 20 years, after which the success of the hatchery would be evaluated. The hatchery is not intended to be a permanent facility. The weir described above would allow for the collection of fall-run Chinook broodstock. The proposed supplementation program, like state and federal programs, would be implemented in accordance with procedures that prevent or minimize adverse impacts on the fitness, size, abundance, run-timing, and distribution of wild fish.

The fall-run Chinook population in the lower Tuolumne River has undergone significant genetic introgression in recent years, with progeny from out-of-basin strays accounting for much of the lower river's annual production. Recent estimates of the composition of fall-run Chinook salmon indicate that up to 50 percent of the escapement to the Tuolumne River is made up of hatchery-produced salmon from other rivers (Merced Irrigation District 2012). Barnett-Johnson et al. (2007) estimated that only 10 percent of Central Valley Chinook salmon captured in the ocean troll fishery

[13] See Districts' *Predator Control Plan* (appended to Exhibit E of the AFLA) for more details. The barrier weir will eliminate striped bass access to important Chinook rearing areas upstream of RM 25.5. Striped bass are estimated to be responsible for approximately 15-20 percent of the total predation on fall-run Chinook juveniles in the lower Tuolumne River.

were not raised in a hatchery setting. Assuming roughly equivalent survival of hatchery- and natural-origin fish from the fishery to the spawning grounds, up to 90 percent of annual escapement could consist of hatchery reared fish (TID/MID 2013f). Results of the Chinook Salmon Otolith Study (TID/MID 2016) indicate that the total estimated hatchery contribution of adult fall-run Chinook salmon in the Tuolumne River during the years studied (i.e., 1998, 1999, 2000, 2003, and 2009)[14] averaged 67 percent, and hatchery contribution generally increased in later years. Recognizing that some years in the otolith sample inventory over- or under-represent the typical age-class structure in the escapement record, the overall proportion was estimated using only three-year-old fish, which are expected to make up the bulk of the annual escapement. For three-year-old fish, hatchery contribution ranged from 36 to 90 percent, with a mean of 58 percent.

Stillwater Sciences (2017c) noted that a lack of genetic distinction between hatchery and naturally spawning fall-run Chinook salmon, along with loss of early life-history diversity due to inter-basin hatchery transfers and out-of-basin releases of hatchery-reared juveniles, are reducing the ability of fall-run Chinook to adapt to fluctuating environmental conditions, thereby contributing to a reduction in the Central Valley Fall, Late-Fall Run ESU's reproductive fitness. Observations that estuary releases of late-stage smolts provide the basis for the majority of adult harvest, and the fact that hatchery escapement results in high rates of straying, indicate that hatchery practices are increasingly producing salmon that survive at relatively high rates but are decoupled from basin-specific selective pressures that influence the adaptive capacity of the species' freshwater life-stages (Stillwater Sciences 2017c), presently and over the long-term.

The proposed supplementation program would be structured to attempt to counter these current adverse trends to the degree possible in the Tuolumne River through the spawning and rearing of fish selected by CDFW to best represent the wild Tuolumne River stock. The program would allow for the stocking of fish within the basin and as a result produce individuals that are adapted to the extent practicable to conditions in their natal environment.

5.2.1.7 Infiltration Galleries 1 and 2

The Districts are proposing to complete construction of TID's infiltration gallery (IG1) (at RM 25.9) and undertake construction of a second infiltration gallery (IG2) at the same general location. IG1 has a design capacity of approximately 100 cfs, and IG2 would have a capacity of 100-125 cfs. The purpose and operation of the infiltration galleries are discussed in Section 5.2.1.8 below. The locations of the proposed infiltration galleries are shown in Figure 5.2.2.

[14] The years evaluated for the Chinook Salmon Otolith Study, i.e., 1998, 1999, 2000, 2003, and 2009, were selected to represent "above normal" or "wet" and "below normal" or "dry" water-year types. These were also years during which the greatest number of otolith samples were available from the existing CDFW inventory.

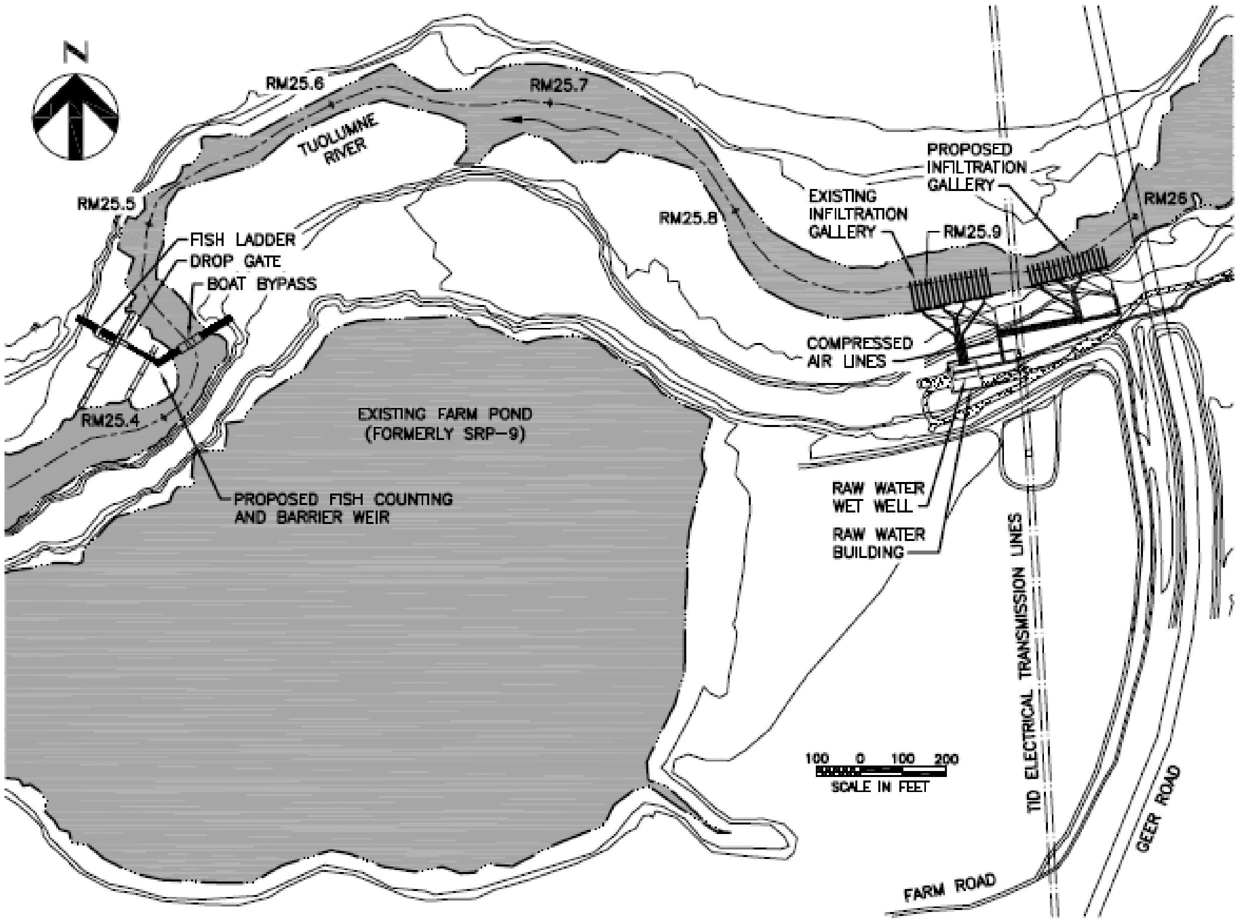

Figure 5.2-2. Site location of the infiltration galleries downstream of the Geer Road Bridge at approximately RM 25.9.

5.2.1.8 Flow-Related Measures for Fish and Aquatic Resources

The Proposed Action includes flow-related measures during all water-year types. The flow measures include a set of base flows designed for specific salmonid life stages in the Tuolumne River, and a set of pulse flows based on what is now 20 years of rotary screw-trapping results and other related studies specific to the Tuolumne River. An adaptive management approach to pulse flow timing and duration is part of these measures.

For all flow-related measures, the flow schedules are based on five water-year types determined using the 60-20-20 San Joaquin River Index (SJI). The five types are wet (W), above normal (AN), below normal (BN), dry (D), and critical (C). Table 5.2-2 provides the classification of each water year for the 1971–2012 modeling period of record.

All proposed flow-related measures identified below are based on five water-year types determined using the 60-20-20 San Joaquin River Index. The current method used by TID operators to determine the water-year type and required flow release schedule would remain unchanged.[15] There would be two flow monitoring locations for compliance: (1) the existing USGS Tuolumne River at La Grange gage and (2) a new USGS gage measuring the flow in the two infiltration gallery (see Figure 5.2-2) pipelines. The La Grange gage would be used to monitor compliance for flows between the La Grange gage and RM 25.5. Subtracting the infiltration gallery pipelines gage from the La Grange gage would yield the instream flows to be provided downstream of RM 25.5, and this difference would constitute the second point of compliance. Compliance would be achieved if flows equaled or exceeded the amounts identified below over monthly timeframes, with no deficit of more than 10 percent below the minimum for more than 60 minutes, and no deficit allowed that is greater than 20 percent below the flows described in the following sections and shown in Table 5.2-3. With the two compliance points being located 25 miles apart, during days where scheduled flow changes are to occur, time of travel would be taken into account when determining compliance. Any outage of the infiltration galleries that prevents the planned flow from being withdrawn and lasting for more than three consecutive days would result in the minimum instream flows required at the La Grange gage to be reduced by two-thirds of the amount that would have been withdrawn.

Table 5.2-2. Classification of each water year for the 1971–2012 modeling period of record.

Water Year	San Joaquin Index	Water Year	San Joaquin Index
1971	BN	1992	C
1972	D	1993	W
1973	AN	1994	C
1974	W	1995	W
1975	W	1996	W
1976	C	1997	W
1977	C	1998	W
1978	W	1999	AN
1979	AN	2000	AN
1980	W	2001	D
1981	D	2002	D
1982	W	2003	BN
1983	W	2004	D
1984	AN	2005	W
1985	D	2006	W
1986	W	2007	C
1987	C	2008	C
1988	C	2009	BN
1989	C	2010	AN
1990	C	2011	W
1991	C	2012	D

[15] TID operators currently determine the water-year type in early April and issue, after consultation with resource agencies, the schedule of releases for April 15 of the current year through April 14 of the next calendar year.

Table 5.2.3. Proposed lower Tuolumne River flows to benefit aquatic resources and accommodate recreational boating.

Water Year/Time Period	Flow (cfs)	
	La Grange Gage	RM 25.5
Wet, Above Normal, Below Normal		
June 1 – June 30	200	100[1]
July 1 – October 15[3]	350	150[2]
October 15 – December 31	275	275
January 1 – February 28/29	225	225
March 1 – April 15	250	250
April 16 – May 15[4]	275	275
May 16 – May 31[4]	300	300
Dry		
June 1 – June 30	200	75
July 1 – October 15	300	75[2]
October 15 – December 31	225	225
January 1 – February 28/29	200	200
March 1 – April 15	225	225
April 16 – May 15[4]	250	250
May 16 – May 31[4]	275	275
Critical		
June 1 – June 30	200	75
July 1 – October 15	300	75
October 15 – December 31	200	200
January 1 – February 28/29	175	175
March 1 – April 15	200	200
April 16 – May 15[4]	200	200
May 16 – May 31[4]	225	225

1 Cease IG withdrawal for one pre-scheduled weekend.
2 200 cfs for three-day July 4 holiday, for three-day Labor Day holiday, and for two pre-scheduled additional weekends in either June, July, or August.
3 1,000 cfs flushing flow (not to exceed 5,950 ac-ft) on October 5, 6 and 7, with appropriate up and down ramps and IGs shut off.
4 Fall-run Chinook outmigration pulse flows: 150,000 ac-ft (Wet, Above Normal), 100,000 ac-ft (Below Normal), 75,000 ac-ft (Dry), 45,000 ac-ft (sequential Dry[s]), 35,000 ac-ft (first Critical), and 11,000 ac-ft (sequential Critical[s]).[16]

5.2.1.8.1 Early Summer Flows (June 1–June 30)

Except for wet years, when high flows may extend well into June, most fall-run Chinook salmon juveniles have left the Tuolumne River by the end of May (Figure 5.2-3) (TID/MID 2013f), so increased summer flows are aimed at enhancing habitat conditions for *O. mykiss*. The Districts are proposing to provide an instream flow of 200 cfs (as measured at the La Grange gage) upstream of RM 25.9 from June 1–June 30 of all water year types to benefit *O. mykiss* fry rearing. Downstream of RM 25.5 (i.e., downstream of the infiltration galleries) instream flows would be 100 cfs during June of Wet, Above Normal, and Below Normal water years and 75 cfs in Dry and Critical years.

16 This reduced pulse flow, while still greater than or equal to Base Case pulse flows, would also occur in a sequence of "D" and "C" years. For example, in a sequence of the years C, D, C, D, C, D, the second and third "critical" years and the second and third "dry" years would each have pulse flows of 11 TAF and 45 TAF, respectively.

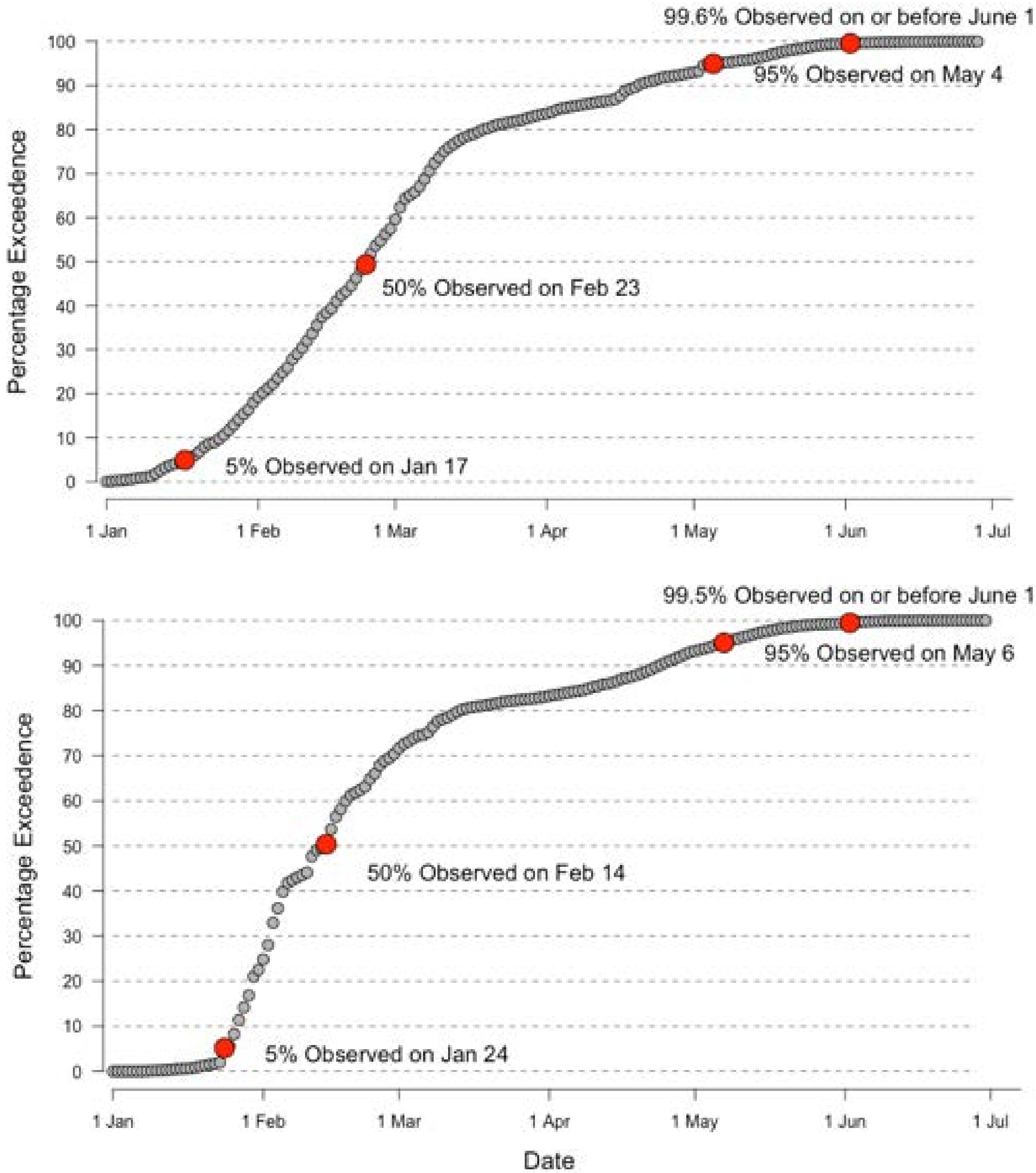

Figure 5.2-3 **Long-term migration pattern of observed juvenile Chinook salmon captured at the Waterford rotary screw-trap (top; RM 30) and the Grayson rotary screw-trap (bottom; RM 5) on the Tuolumne River (2006 – 2016). Key dates of passage are highlighted with red circles.**

However, low numbers of over-summering juvenile Chinook are observed downstream of the La Grange gage (RM 51.7) during most years (TID/MID 2013h) and would experience any flows released for the benefit of *O. mykiss*. IFIM study results (Stillwater Sciences 2013) indicate that a flow of 200 cfs provides nearly 100 percent of the maximum WUA for juvenile Chinook in the lower Tuolumne River (Figure 5.2-4). Water temperature modeling shows that at RM 47, a flow of 200 cfs would maintain average daily water temperatures at less than 18°C, and at RM 43, a flow of 200 cfs would maintain average daily water temperatures at less than 20°C, except when maximum daily ambient air temperatures exceed 100°F (38°C) (Figure 5.2-5), which on average occurs only one day in June (Figure 5.2-6). At 150 cfs, average daily water temperatures at RM 43 would be less than 20°C until maximum daily air temperature exceeds 95°F (Figure 5.2-5), which occurs on average three days in June (Figure 5.2-6). The TRCh (TID/MID 2017a) identifies an initial mortality threshold of 25°C (77°F) for Chinook salmon juveniles as a daily average water temperature, which is based on information reviewed for Chinook salmon fry mortality (Brett 1952, Orsi 1971). A flow of 200 cfs upstream of RM 25.7, although selected for the benefit of *O. mykiss*, would also benefit fall-run Chinook salmon. Juvenile Chinook salmon are not expected to over-summer downstream of RM 25.5.

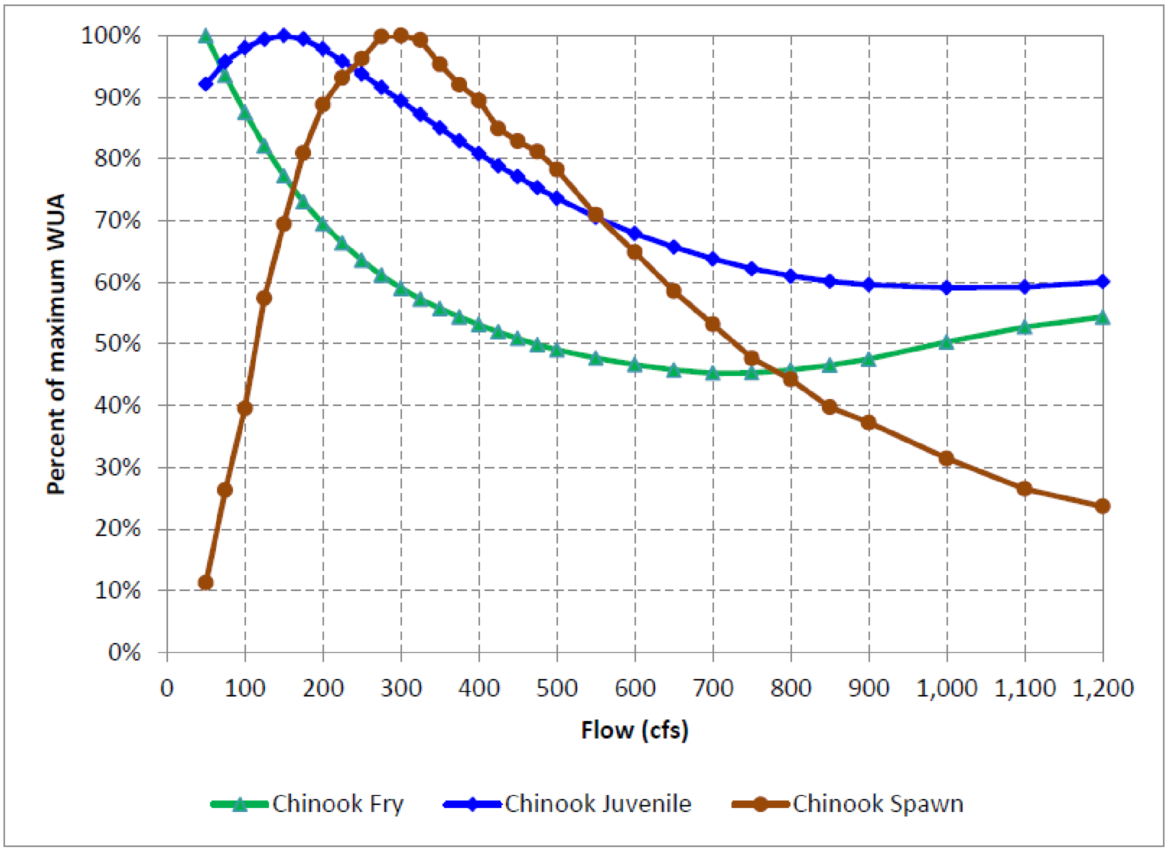

Figure 5.2-4. Chinook salmon WUA results for the lower Tuolumne River (source: Stillwater Sciences 2013).

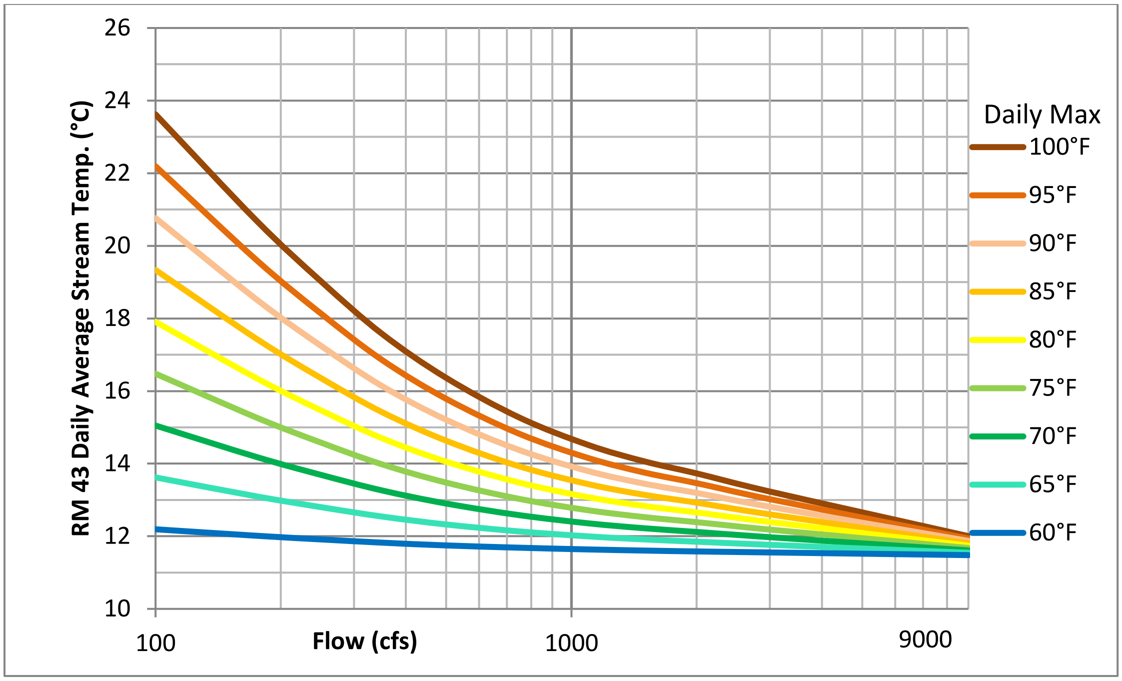

Figure 5.2-5. RM 43 daily average water temperatures versus flow and maximum air temperatures.

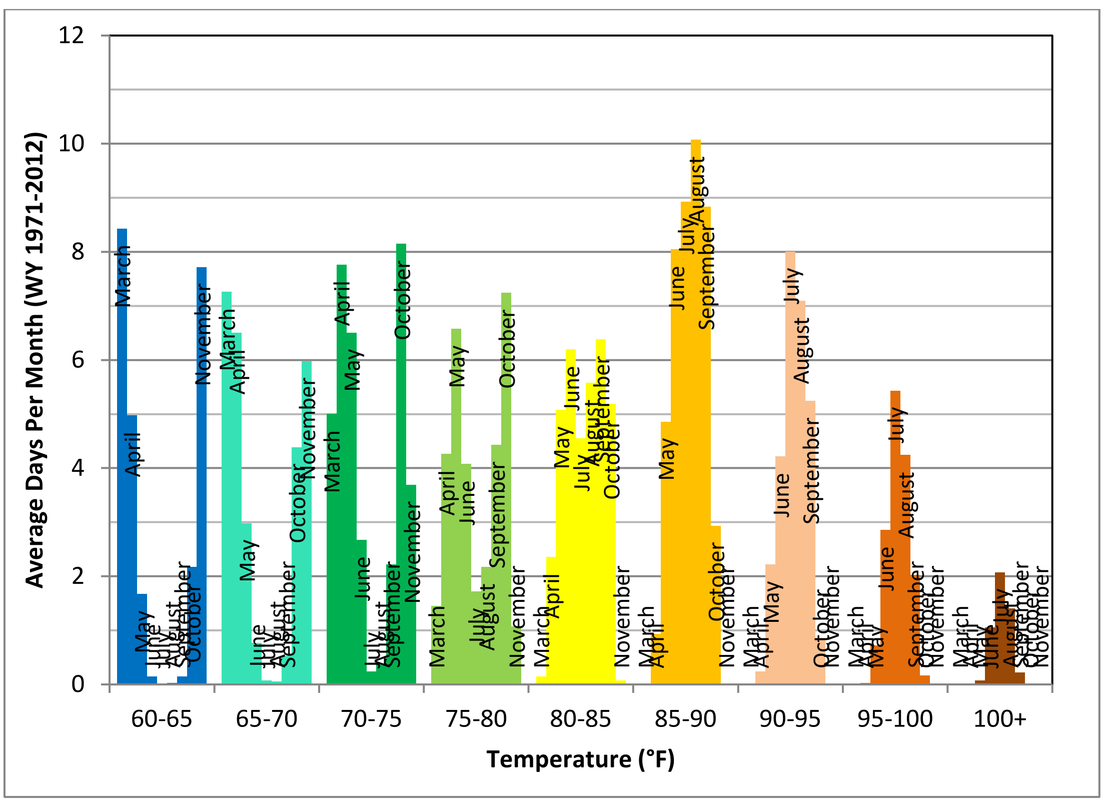

Figure 5.2-6. Frequency of occurrence of maximum daily air temperatures by month for the lower Tuolumne River (estimated for approximately RM 40).

5.2.1.8.2 Late Summer Flows (July 1–October 15)

The Districts are proposing to provide an instream flow of 350 cfs (as measured at the La Grange gage) upstream of RM 25.7 from July 1–October 15 of Wet, Above Normal, and Below Normal water year types to benefit *O. mykiss* juvenile rearing. During Dry and Critical water years, flow at the La Grange gage would be reduced to 300 cfs. Downstream of RM 25.5 (i.e., downstream of the infiltration galleries) instream flows during this period would be 150 cfs during Wet, Above Normal, and Below Normal water years and 75 cfs in Dry and Critical years.

During this period, the Districts would provide a flushing flow to clean gravels of accumulated algae and fines prior to the onset of substantial spawning. The Districts would provide an instream flow of 1,000 cfs (not to exceed 5,950 ac-ft) on October 5, 6 and 7, with appropriate up and down ramps and the infiltration galleries shut off. These flows would be provided in Wet, Above Normal, and Below Normal water years only. In Dry and Critical years, the flows at La Grange would continue to be 300 cfs, with withdrawals of 225 cfs at the infiltration galleries leaving 75 cfs in the river below RM 25.5.

Any over-summering juvenile fall-run Chinook would also benefit from these flows. IFIM study results (Stillwater Sciences 2013) indicate that flows between 300 cfs and 350 cfs provide between 85 and 90 percent of the maximum WUA for juvenile Chinook in the lower Tuolumne River (Figure 5.2-4), and water temperatures would be well below mortality thresholds. Juvenile Chinook salmon would not over-summer downstream of RM 25.5.

In early fall, Chinook salmon usually begin to enter the Tuolumne River. The Districts have maintained an adult counting weir at RM 24.5, near the downstream end of the gravel-bedded reach, since 2009. As indicated by Figure 5.2-7, the majority of adult fall-run Chinook enter the spawning reach above the counting weir after mid-October.

A flow of 350 cfs would maintain average daily water temperatures below 18°C at RM 43 until daily maximum air temperatures exceed 105°F (40.6°C) (Figure 5.2-5). During Dry and Critical years, flow at the La Grange gage would be reduced to 300 cfs, at which both juvenile and adult habitat is about 91 percent of maximum. Under these flows, average daily water temperatures would be maintained below 19°C at RM 43 until daily maximum air temperatures exceed 100°F (38°C) (Figure 5.2-5).

5.2.1.8.3 Fall-run Chinook Spawning Flows (October 16–December 31)

To provide habitat for fall-run Chinook spawning, the Districts propose to provide the following minimum instream flows for the October 16–December 31 spawning period: 275 cfs (BN, AN, and W water years), 225 cfs (D water years), and 200 cfs (C water years). Most fall-run Chinook spawning in the lower Tuolumne River occurs from mid-October through mid-December (TID/MID 2013g; FISHBIO 2017).

IFIM study results (Stillwater Sciences 2013) indicate that flows of 275 cfs, 225 cfs, and 200 cfs provide 100, 93, and 89 percent, respectively, of the maximum WUA for Chinook spawning in the lower Tuolumne River (Figure 5.2-4). At 275 cfs, average daily water temperatures at RM 43 would be less than 14.5°C until daily maximum air temperatures exceed 75°F, which is estimated to occur about one day in November on average (see Figures 5.2-5 and 5.2-6). Average daily water temperatures would generally remain below 14°C in December throughout the entire gravel-bedded reach of the lower Tuolumne River.

Although studies of spawning habitat indicate sufficient spawning gravels exist to accommodate between about 50,000 and 60,000 fall-run Chinook between RM 52 and RM 23 (TID/MID 2013h), improvements provided by operational flows (6,000-7,000 cfs) and the non-flow measures described previously would increase the quality and abundance of spawning gravels in the primary spawning reach located upstream of RM 45, thereby further reducing the rate of superimposition of Chinook redds (see also Superimposition Reintroduction Program above).

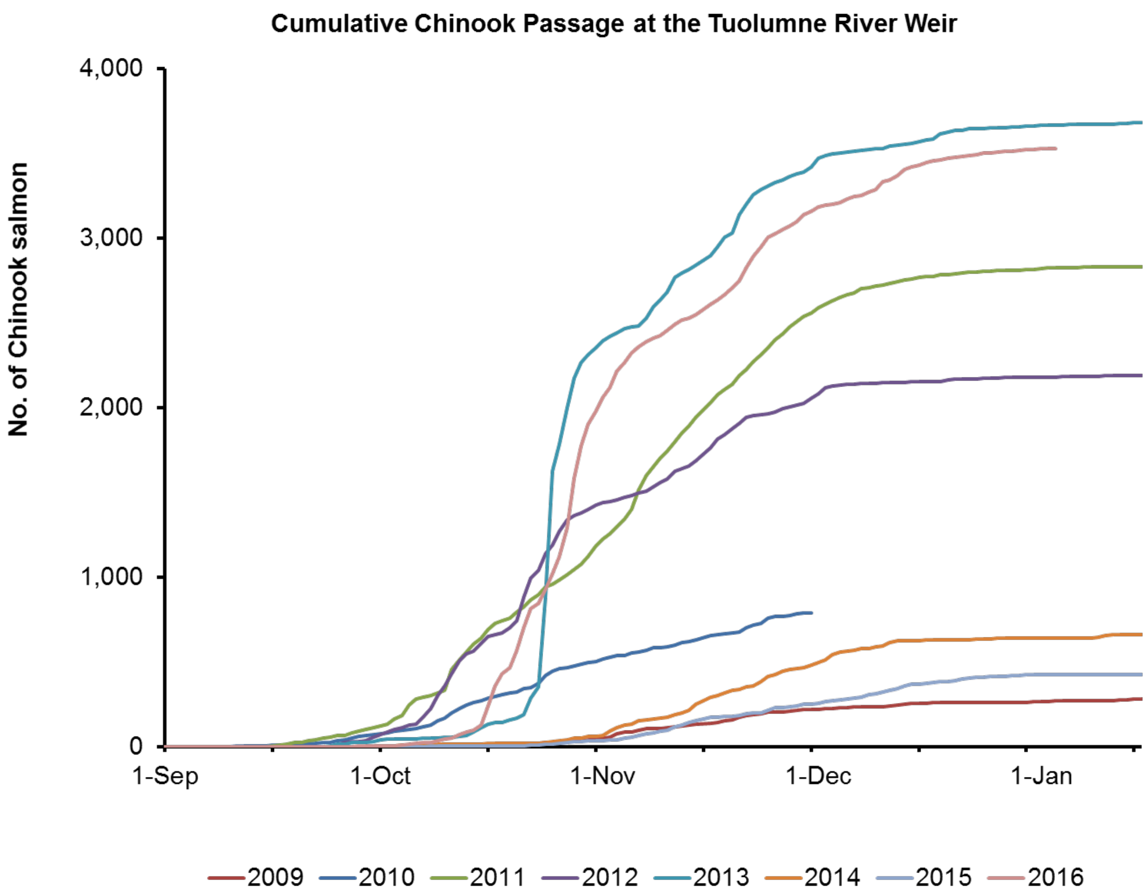

Figure 5.2-7. Cumulative adult fall-run Chinook salmon counts at the Tuolumne River weir (RM 24.5) 2009–2016.

5.2.1.8.4 Fall-run Chinook Fry Rearing (January 1–February 28/29)

To provide habitat for fall-run Chinook fry rearing, the Districts propose to provide the following minimum instream flows for the period of January 1–February 28/29: (1) 225 cfs (BN, AN, and W water years), (2) 200 cfs (D water years), and (3) 175 cfs (C water years). IFIM study results (Stillwater Sciences 2013) indicate that maximum fry WUA occurs at 50 cfs (Figure 5.2-4). At

100 cfs, Chinook salmon fry WUA is 88 percent of maximum, at 150 cfs it is 76 percent of maximum, and at 225 cfs it is about 67 percent of maximum.

Although the proposed flows would not maximize fry-rearing WUA, fry-rearing habitat is not limiting the Chinook population in the lower Tuolumne River. As shown in Figure 5.2-8, in-channel fry rearing capacity exceeds 13 million fry at lower river flows less than 200 cfs. Also, higher flows during early fry rearing (i.e., January–February) tend to promote downstream movement of fry, potentially into areas with higher densities of predatory fish species (TID/MID 2013f, 2017a), and fry that migrate out of the Tuolumne River basin account for only a small percentage (< 5 percent) of the adult Chinook escapement (TID/MID 2016). Moreover, there appears to be little benefit in attempting to provide floodplain habitat for Chinook fry rearing in the Tuolumne River. Based on the results of the Floodplain Hydraulic Analysis study (TID/MID 2017d), river flows exceeding 4,000 cfs would be required to provide the same level of in-channel plus floodplain juvenile rearing habitat as that provided by in-channel habitat alone at flows of 100 to 200 cfs (Figure 5.2-8).

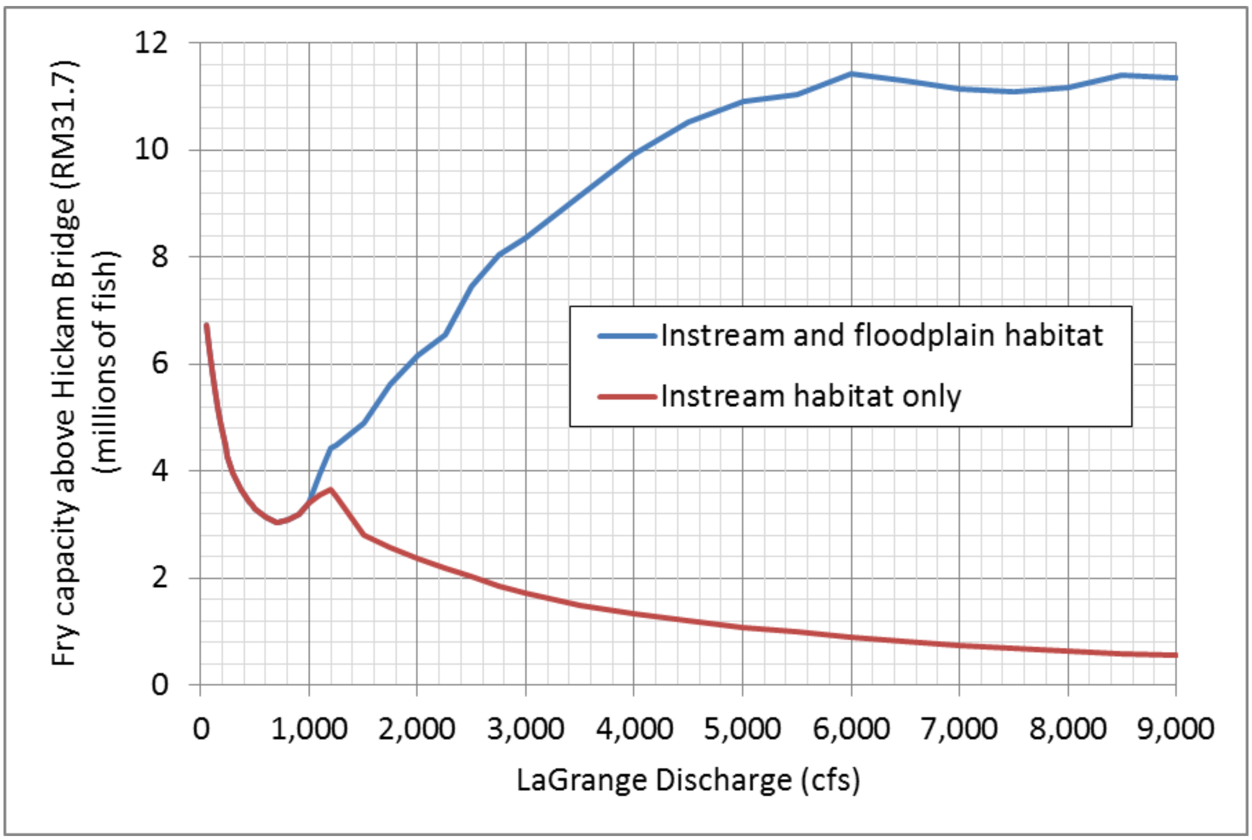

Figure 5.2-8. Chinook fry capacity (millions of fish) in the lower Tuolumne River for both in-channel and floodplain rearing above RM 31.7.

It is also important that flows do not decline substantially following the spawning period, which would result in the dewatering of established Chinook redds. The flows identified here represent a balance between protecting Chinook redds and providing substantial Chinook fry rearing habitat. The mean pot depth of Chinook redds during the 2012 redd survey was 1.8 feet, and the minimum observed depth to date is 0.9 feet (TID/MID 2013g) (Figure 5.2-9). Based on the rating curve for the USGS gage at La Grange, the change in flow from 275 cfs (i.e., spawning flow in BN, AN, and W water years) to 225 cfs (i.e., fry rearing flow in BN, AN, and W water years) would result in a 0.4-foot stage change, and from 225 cfs (spawning in D water years) to 200 cfs (rearing in D water years) a 0.2 foot stage change (Figure 5.2-10).

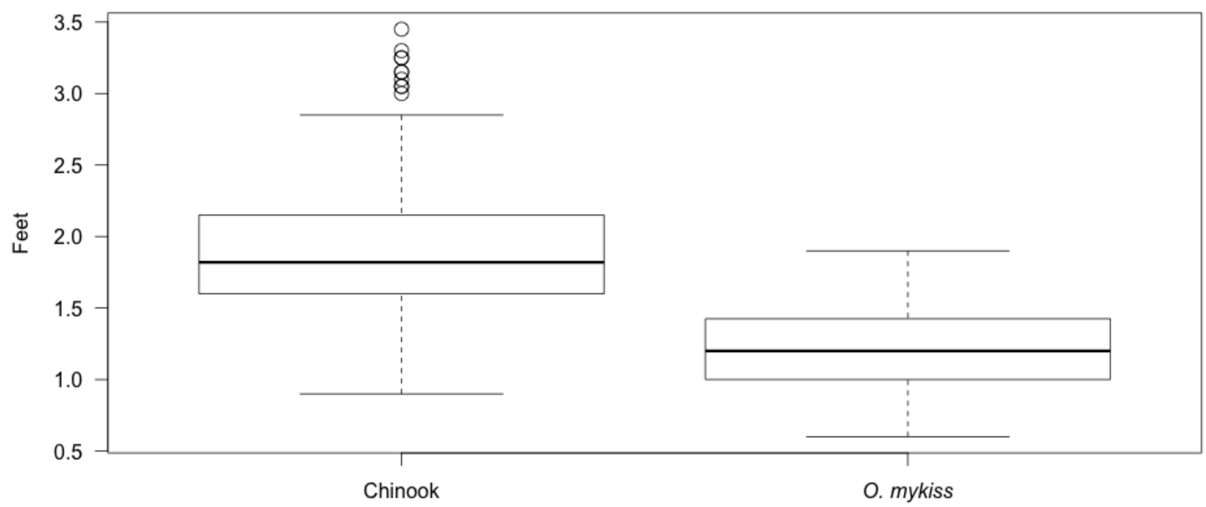

Figure 5.2-9. Boxplots of pot depths measured in Chinook salmon and O. mykiss redds surveyed on the lower Tuolumne River in 2012/2013 (source: TID/MID 2013g).

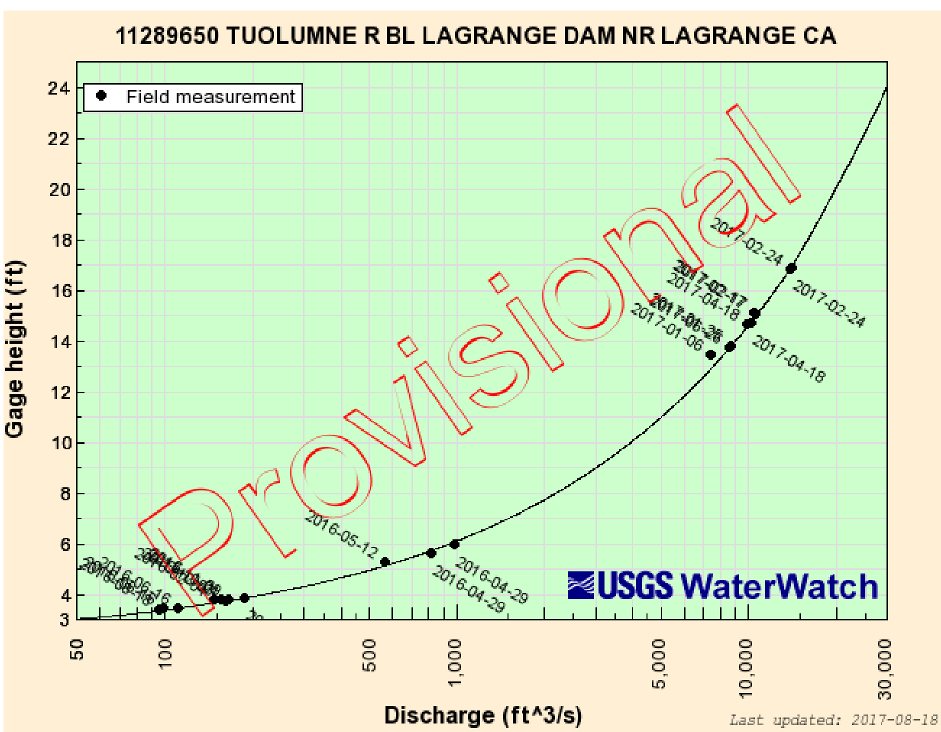

Figure 5.2-10. Stage-discharge rating curve of the USGS Tuolumne River at La Grange gage.[17]

[17] High flows occurring in 2017 may require adjustment to the rating curve. The control section at the gage has remained stable over previous high-flow periods. Minor adjustments to the rating curve have occurred from time to time.

5.2.1.8.5 Fall-run Chinook Juvenile Rearing (March 1–April 15)

In the lower Tuolumne River, juveniles constitute the predominant Chinook life-stage from March through mid-April, with many fish reaching parr-size (50-64 mm) by mid-March (FISHBIO 2015a, 2015b, 2016). To provide habitat for Chinook juvenile rearing, the Districts propose to provide the following minimum instream flows for the period of March 1–April 15: (1) 250 cfs (BN, AN, and W water years), (2) 225 cfs (D water years), and (3) 200 cfs (C water years).

IFIM study results (Stillwater Sciences 2013) indicate that WUA for fall-run Chinook juvenile rearing is maximized at 150 cfs and exceeds 97 percent of maximum at flows from 100 to 200 cfs (Figure 5.2-4). At 300 cfs, WUA declines to 90 percent of maximum (Figure 5.2-4). The flows proposed by the Districts would provide 90 and 97 percent of the maximum available WUA, which would have a beneficial effect on rearing juvenile fall-run Chinook in the lower river. As shown in Figure 5.2-11, in-channel juvenile rearing habitat is not a limiting factor for fall-run Chinook salmon in the Tuolumne River. At a flow of 250 cfs, in-channel rearing habitat supports 3 million juvenile fall-run Chinook salmon. When considering floodplain rearing habitat, a flow of 2,300 cfs is required to produce the same level of rearing habitat. Using a minimum time period of floodplain inundation of 14 days to be considered effective rearing habitat (Matella and Merenlender 2015), a flow of 7,000 ac-ft produces the same rearing habitat as a flow of 64,000 ac-ft.[18] Nevertheless, in W and AN water years, which in the 1971 to 2012 period occurred about 50 percent of the time, flows at the La Grange gage would frequently exceed minimum flows, and provide floodplain access for juvenile fall-run Chinook. Under the Proposed Action, flows of at least 3,000 cfs for 14 consecutive days in the February through June period would occur in 17 of the 42 year 1971-2012 period (see Exhibit E of the AFLA).

At 250 cfs, average daily water temperatures would remain below 18°C at RM 39.5 until maximum daily air temperatures exceed about 80°F (Figure 5.2-12), which occurs on average between three and four days in April (Figure 5.2-6), and would remain below 20°C at RM 39.5 until maximum daily air temperature exceeds 85°F (Figure 5.2-12), which occurs about one day in April on average (Figure 5.2-6).

[18] That is, 250 cfs for 14 days = 7,000 ac-ft and 2,300 cfs for 14 days = 64,000 ac-ft.

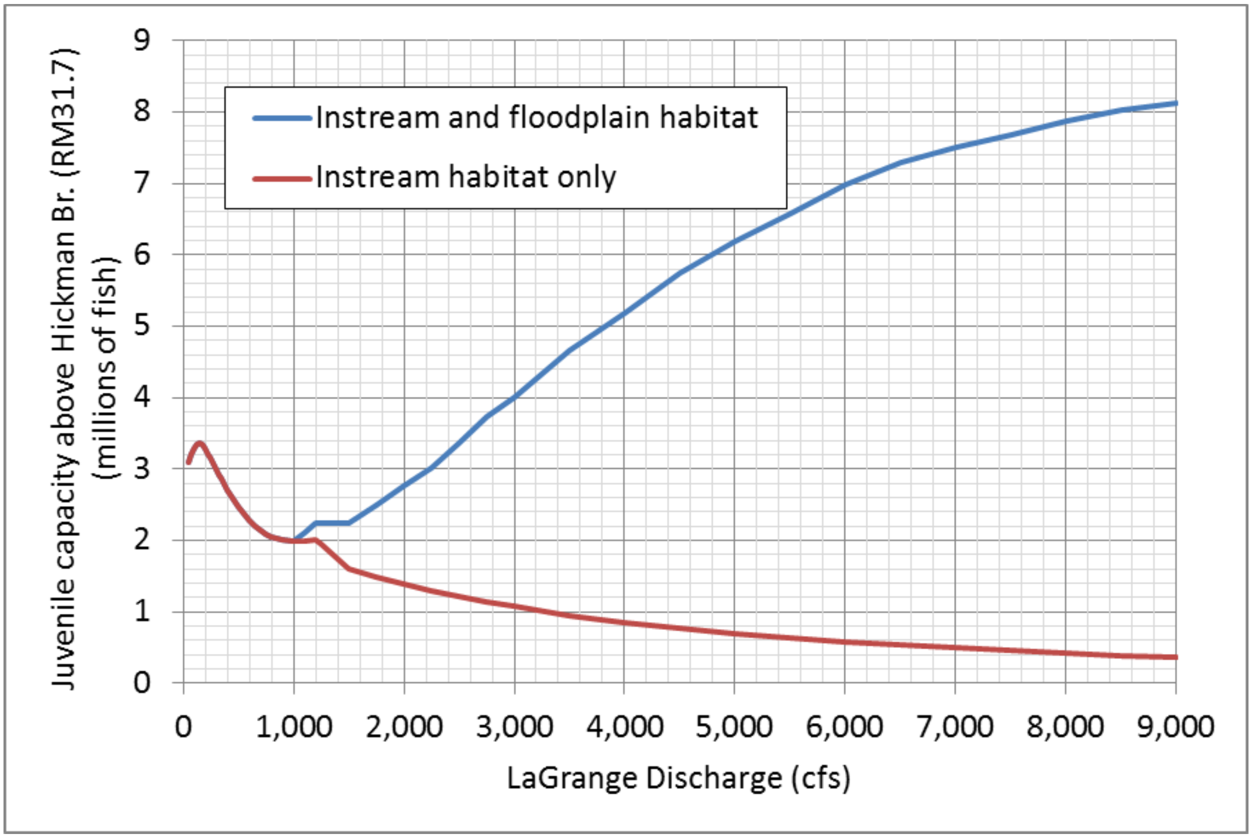

Figure 5.2-11. Juvenile Chinook capacity (millions of fish) in the lower Tuolumne River for both in-channel and floodplain rearing, above RM 31.7.

5.2.1.8.6 Outmigration Base flows (April 16–May 15)

The Districts propose to provide the following outmigration base flows for the period of April 16–May 15: (1) 275 cfs (BN, AN, and W water years), (2) 250 cfs (D water years), and (3) 200 cfs (C water years). These base flows could be augmented by outmigration pulse flows, depending on the timing of pulse flows, as explained below.

Fall-run Chinook salmon leaving the Tuolumne River as large parr or smolts display a much greater adult return rate (nearly a 20:1 ratio based on outmigration years 1998-2000, 2003, 2009; TID/MID 2016) than those leaving as fry (TID/MID 2016), so providing favorable growth conditions through smoltification is beneficial. Increasing base flows above those in the March 1–April 15 period would maintain favorable water temperatures during the mid-April through mid-May period, which is expected to benefit smolts. Water temperature modeling shows that at RM 43, a flow of 275 cfs would maintain average daily water temperatures at less than 20°C, even at maximum daily ambient air temperatures that exceed 100°F (38°C) (Figure 5.2-5). At RM 43, a flow of 275 cfs would maintain average daily water temperatures below 15°C until maximum daily air temperatures exceed 80°F (Figure 5.2-5), which, on average, occurs about three to four days in April and 15 in May (Figure 5.2-6). At RM 39.5, a flow of 275 cfs would maintain average daily water temperatures below 21°C until maximum daily air temperatures exceed 95°F (35°C) (Figure 5.2-12), which occurs on average about two days in May. At RM 39.5, a flow of 225 cfs would maintain average daily water temperatures below 21°C until maximum air temperatures exceed

95°F (32°C) (Figure 5.2-12), which occurs on average about two days in May (Figure 5.2-6).. As explained below, these base flows could be augmented by outmigration pulse flows, depending on the timing of pulse flows, which would further reduce water temperatures at a given location and extend the plume of colder water farther downstream.

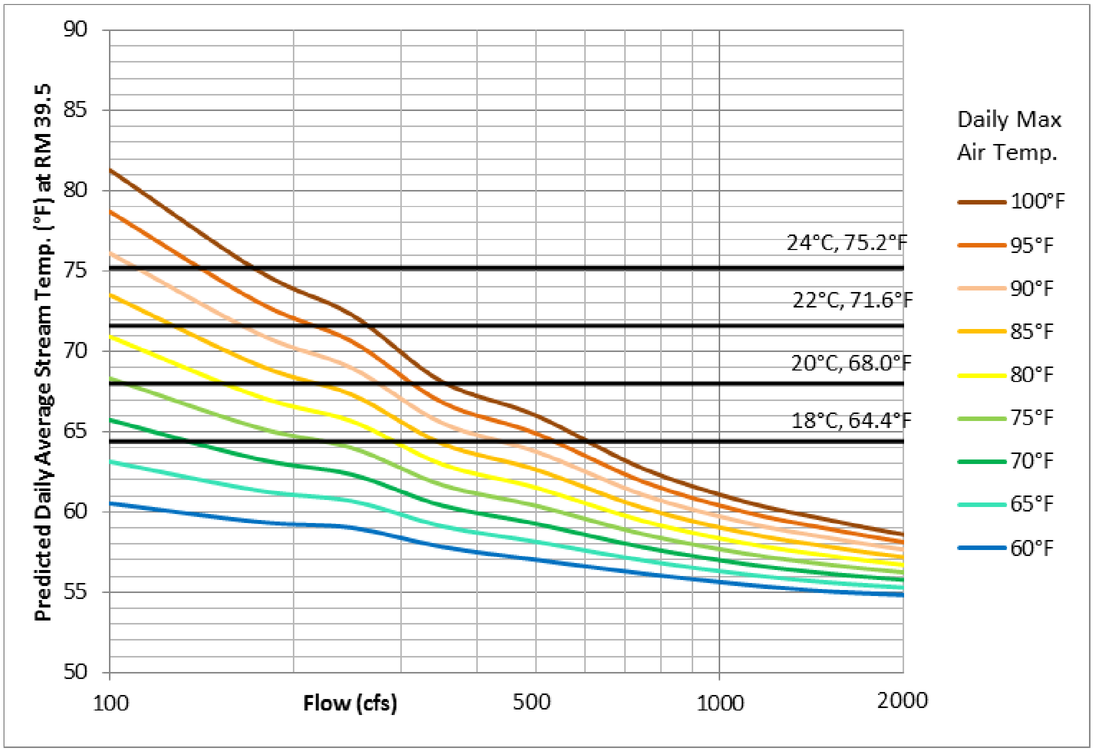

Figure 5.2-12. RM 39.5 daily average water temperatures versus flow and maximum air temperatures.

5.2.1.8.7 Outmigration Base flows (May 16–May 31)

Although during most years juvenile fall-run Chinook salmon have left the Tuolumne River by mid-May (Figure 5.2-3), in some years there are still parr and smolts in the river beyond May 15. To maintain lower water temperatures during this period, the Districts are proposing the following base flow releases: (1) 300 cfs (BN, AN, and W water years), (2) 275 cfs (D water years), and (3) 225 cfs (C water years). These base flows could be augmented by outmigration pulse flows, as explained below, which would further reduce water temperatures at a given location and extend the plume of colder water farther downstream.

5.2.1.8.8 Outmigration Pulse Flows (April 16–May 31)

Data collected since 2008 from the Districts' rotary screw traps suggest that fish identified as fall-run Chinook smolts are generally above 65 mm in size (Robichaud and English 2013, 2017; Sonke 2017). To encourage smolt outmigration and increase survival, pulse flows would be provided to coincide with periods when large numbers of parr- or smolt-size fish are present in the river. Active monitoring of spawn timing and river temperatures, supplemented by data from snorkel surveys or seining, would be used to track juvenile size and identify the best timing for spring pulse flow releases. The available pulse flow volumes would be substantially increased over baseline levels, except in the second (and subsequent to the second) Dry and Critical water years. The Districts are proposing to allocate the following volumes of water for pulse flow releases: 150,000 ac-ft (AN and W water years), 100,000 ac-ft (BN water years), 75,000 ac-ft (D water years), 45,000 ac-ft (in sequential D water years), 35,000 ac-ft (initial C water year), and 11,000 ac-ft (sequential C water years).[19]

The pulse flow volume would continue to be determined as it is under the current license, but using five water year types instead of 10 to reduce the frequency of the need for "interpolation water[20]." Since 1997, there has been "interpolation water" available in 11 of 18 years. Under the pulse flow schedule identified above, "interpolation water" would have been needed in only five of the 18 years (1997-2015) according to the Districts' Operations Model. Reducing the number of years in which "interpolation water" would occur increases the amount of water dedicated to spring outmigration pulse flows.

Rotary screw-trap data would continue to be used to estimate fall-run Chinook smolt survival in response to pulse flows. Timing pulse flows to coincide with periods when large numbers of juvenile Chinook are ready to outmigrate, combined with spawning gravel improvements, habitat improvements, and predator control measures, is expected to significantly improve Tuolumne River fall-run Chinook outmigration survival rates.

5.2.1.8.9 Flow Hydrograph Shaping

In spill years, the Districts would make reasonable efforts to shape the descending limb of the snowmelt runoff hydrograph to mimic natural conditions. Floodplain inundation along the lower Tuolumne River is initiated at a flow of approximately 1,100 cfs. Based on flows in the 1971–2012 period, the Proposed Action would result in flows at the La Grange gage greater than 1,500 cfs from February through July in 28 years (or more than 60 percent of the years). Flows exceeding 2,500 cfs would occur in 45 percent of the years in that period. Riparian recruitment streamflows timed to coincide with cottonwood seed dispersal would also benefit tree willows. Increasing natural recruitment of snowmelt-dependent hardwoods would increase stands of trees that could contribute large wood to the channel over the long-term and provide cover and shade for aquatic species.

5.2.1.9 Flows to Enhance Recreational Boating

The Districts would release the flows described below to enhance conditions for canoeing and kayaking on the lower Tuolumne River. The flow releases are based on the assumption that the lower river boating season extends from April 1–October 31. The results of the Districts' Lowest Boatable Flow Study (TID/MID/2013b) show that flows above 175 cfs on the lower Tuolumne River are considered boatable by those using non-motorized craft.

[19] This reduced pulse flow, while still greater than or equal to Base Case pulse flows, would also occur in a sequence of "D" and "C" years. For example, in a sequence of the years C, D, C, D, C, D, the second and third "critical" years and the second and third "dry" years would each have pulse flows of 11 TAF and 45 TAF, respectively.

[20] Article 37 of the existing Project license (FERC 2006) requires that between a Median Critical Water Year and an Intermediate Below Normal-Above Normal Water Year, the precise volume of flow to be released each fish flow year is to be determined using accepted methods of interpolation between index values.

From April 1–May 31 of all water years, a flow of 200 cfs or greater would be provided at the LaGrange gauge. During this time, the infiltration galleries would either be shut off or additional flows to be withdrawn for water supply purposes would be released at the La Grange gage.. Provision of these flows would be a byproduct of the flows provided for the benefit of aquatic resources, so no incremental effects would occur beyond those described above in Section 5.2.1.8.

From June 1–June 30, a flow of 200 cfs would be provided in all water years at the La Grange gage. Provision of this flow would be a byproduct of that provided for the benefit of aquatic resources, so no incremental effects would occur beyond those described above in Section 5.2.1.8. In Wet, Above Normal, and Below Normal water years, withdrawal of water at the infiltration galleries (described above) would cease for one pre-scheduled weekend in June to provide an additional 100 cfs (for a total of 200 cfs) downstream of RM 25.5. This short-duration incremental flow in the sand-bedded reach of the lower river would have no significant effects on fall-run Chinook. No juvenile (see Figure 5.2-3) or adult Chinook would be expected to occur downstream of RM 25.5 during the June 1–June 30 timeframe.

From July 1–October 15, a flow of 350 cfs in Wet, Above Normal, and Below Normal water years and 300 cfs in Dry and Critical water years would be provided at the La Grange gage. Provision of these flows would be a byproduct of those provided for the benefit of aquatic resources, so no incremental effects would occur beyond those described above in Section 5.2.1.8. In all but Critical water years, the Districts would provide a flow of 200 cfs below RM 25.5 for the three-day July 4 holiday, the three-day Labor Day holiday, and for two pre-scheduled additional weekends in either July or August. In Wet, Above Normal, and Below Normal water years this would represent an incremental increase of 50 cfs downstream of RM 25.5 (over the background of 150 cfs), and in Dry water years this would represent an incremental increase of 125 cfs (over the background of 75 cfs). In both cases, these short-duration incremental flows in the sand-bedded reach of the lower river would have no significant effects on fall-run Chinook. No juvenile fall-run Chinook would be expected to occur downstream of RM 25.5 during the July 1–October 15 timeframe (see Figure 5.2-3). Fall-run Chinook adults migrate upstream from late August through December, with peak migration in November, so individuals would be present in the Tuolumne River downstream of RM 25.5 during July 1–October 15. However, these adult fish can negotiate a wide range of hydraulic conditions and would not be adversely affected by shifts in flow brought about by occasionally providing recreational boating flows downstream of RM 25.5 during July 1–October 15. Flow increases associated with shutting off the infiltration galleries would effectively constitute a low-magnitude pulsed flow (i.e., an enhancement measure often recommended by fisheries agencies).

5.3 Cumulative Effects of the Proposed Action

According to the Council on Environmental Quality's regulations for implementing NEPA (50 CFR §1508.7), cumulative effects on a resource are the result of the combined influence of past, present, and reasonably foreseeable future actions within a specified geographical range (FERC 2008), regardless of what agency (federal or non-federal) or person undertakes such actions. Cumulative effects may be beneficial or adverse.

Fall-run Chinook in the EFH Action Area are cumulatively affected by individually minor but collectively significant actions. Activities contributing to cumulative effects in the lower Tuolumne River include water storage and diversions for irrigation and M&I water supply, historical and ongoing mining activities, riparian water diversions, urbanization, other land and water development activities, the introduction and persistence of non-native species, channel modification by levees, recreation, flood control operations, wastewater treatment plant discharges, climate change, and other potential activities.

As described in Section 1.2 of this EFH Assessment, the EFH Action Area for fall-run Chinook salmon addressed herein includes the Tuolumne River from La Grange Diversion Dam (RM 52.2) to the confluence with the San Joaquin River and the San Joaquin River from RM 84 (i.e., the confluence with the Tuolumne River) downstream through the Delta.

5.3.1 Past, Present, and Future Actions in the EFH Action Area, other than the Proposed Action

5.3.1.1 Chronology of In-Basin and Out-of-Basin Actions

In accordance with the requirements of cumulative effects assessments provided under NEPA, the initial step of performing the analysis is to identify significant past, present, and foreseeable future actions that contribute to cumulative effects. The Tuolumne River basin has been affected by substantial resource use and land and water management activities over the past 150 years. Table 5-3.1 summarizes a chronology of major in-basin actions that contribute to varying degrees to cumulative effects on fall-run Chinook occupying the Action Area.

The information available on each of these potential contributors to cumulative effects varies greatly, ranging from very little (e.g., early to mid-1900s commercial and sport fish harvest) to large volumes of study (e.g., effects on flow-habitat relationships in the lower Tuolumne River over the past decade). This section includes operations and maintenance activities associated with the overall Don Pedro Project, i.e., those unrelated to the Proposed Action. A map of the San Joaquin River basin and Delta, showing the Project and other key features and facilities, is provided in Figure 5.3-1.

Table 5.3-1. Chronology of actions in the San Joaquin River Basin and Delta contributing to cumulative effects on fall-run Chinook salmon.

Action	Date
Dams, Diversions, Flow Regulation	
Tuolumne River Basin	
Wheaton Dam	1871
La Grange Mining Ditch (Indian Bar Diversion)	1871
Phoenix Dam	1880
La Grange Diversion Dam	1893
Modesto Reservoir	1911
Turlock Lake	1914
Eleanor Dam	1918
Old Don Pedro Dam	1923
O’Shaughnessy Dam (Hetch Hetchy)	1923
Priest Dam	1923
Early Intake	1924
Dennett Dam	1933
Hetch Hetchy Aqueduct completed; exports to San Francisco begin	1934
O’Shaughnessy Dam raised	1938
Cherry Lake	1956
Pine Mountain Dam	1969
New Don Pedro Dam	1971
Riparian water diversions along the Lower Tuolumne River	1870s – present
San Joaquin River Basin and Delta (excluding Tuolumne River)	
Central Valley Project	
Friant Dam	1942
Madera Canal	1945
Friant-Kern Canal	1951
Jones Pumping Plant	1951
Delta-Mendota Canal	1951
Delta Cross-Channel	1951
Hidden and Buchanan Projects	1962
San Felipe Division	1964 – 1987
Los Banos Detention Dam	1965
Little Panoche Detention Dam	1966
B.F. Sisk Dam	1967
O’Neill Pumping Plant	1967
William R. Gianelli Pumping-Generating Plant	1967
State Water Project	
Harvey O. Banks Pumping Plant	1968
Edmonston Pumping Plant	1971
Pyramid Dam	1973
Castaic Dam	1973
San Luis Drain	Halted in 1975
Warne Powerplant	1982
New Melones Dam	1983
Alamo Powerplant	1986
Coastal Branch Aqueduct	1997
Upper San Joaquin River	
Mendota Dam	1871
Sack Dam	Seasonal 1870s – 1946

Action	Date
Merced River Basin	
Robla Canal Company begin diverting Merced River	1870
Merced Canal and Irrigation Company forms	1883
Merced Falls Diversion Dam	1901
Crocker-Huffman Dam	1910
Exchequer Dam	1926
New Exchequer Dam	1967
Stanislaus River Basin	
Big Dam	1856
Herring Creek, Upper Strawberry, and Lower Strawberry reservoirs	1856
Lyons Reservoir	1898
Sand Bar Diversion Dam	1908
OID/SJID purchase Tulloch water rights/distribution system	1910
Relief Dam	1910
Goodwin Dam	1913
Philadelphia Diversion Dam	1916
Lower Strawberry Reservoir	1917
Old Melones Dam	1926
Spicer Meadow Dam	1929
Lyons Reservoir enlarged	1930
Tri-Dam Project (Donnells, Beardsley, and Tulloch dams)	1958
New Melones Dam (also in CVP section)	1983
New Spicer Dam	1989
In-Channel and Floodplain Mining	
Tuolumne River Basin	
Placer mining	1848 – 1890
Hydraulic mining (La Grange)	1871 - c.1900
Dredge mining of the Lower Tuolumne River (gold)	1908-1942, 1945-1951
Gravel and aggregate mining of the Lower Tuolumne River	1940s to present
San Joaquin River Basin and Delta (excluding Tuolumne River)	
Sand and gravel mining from Bay floor shoals begins	1915
Channel Alteration	
Begin large-scale construction of levees in San Joaquin River basin and Delta	1850s
Stockton Deep Water Ship Channel	1930s
San Joaquin River and Tributaries Project (> 100 miles of levees and bypasses)	1950s - 1960s
Non-Native Fish Species	
18 fish species introduced in Tuolumne River basin by state/federal agencies	1874 – 1954
4 additional fish species introduced in Tuolumne River basin	After 1954
Hatchery Practices	
CDFW begins stocking fish in the inland waters of California	Late 1800s
CDFW begins large-scale supplementation of anadromous fish stocks	1945
California's hatcheries at times use out-of-basin broodstocks/move fry to other basins	Before 1980s
Salmon from Central Valley hatcheries released in San Francisco Bay	Ongoing
Commercial and Sport Harvest	
Commercial salmon fishing begins in California	Early 1850s
Gill net salmon fisheries well established in lower San Joaquin River	1860
Well developed canning industry (20 canneries)	1880
12 million pounds of salmon landed and processed	1882
Ocean troll fishery dominates harvest	1917
Last inland cannery shutdown due to decline of inland fishery	1919
Last commercial river salmon fishery closed in Sacramento-San Joaquin basin	1957

Action	Date
Agriculture, Livestock, and Timber Harvest	
Timber operations begin in upper watersheds	Mid 1800s to present
Large-scale agriculture and livestock grazing begins in region	Mid 1800s to present
Urban Development	
Within Tuolumne River watershed and downstream	Mid 1800s to present
San Francisco Bay Area (Hetch Hetchy diversions)	1934 to present
MID M&I diversions	1995 to present
Climate Change	
Changes in global climate and weather patterns	Ongoing

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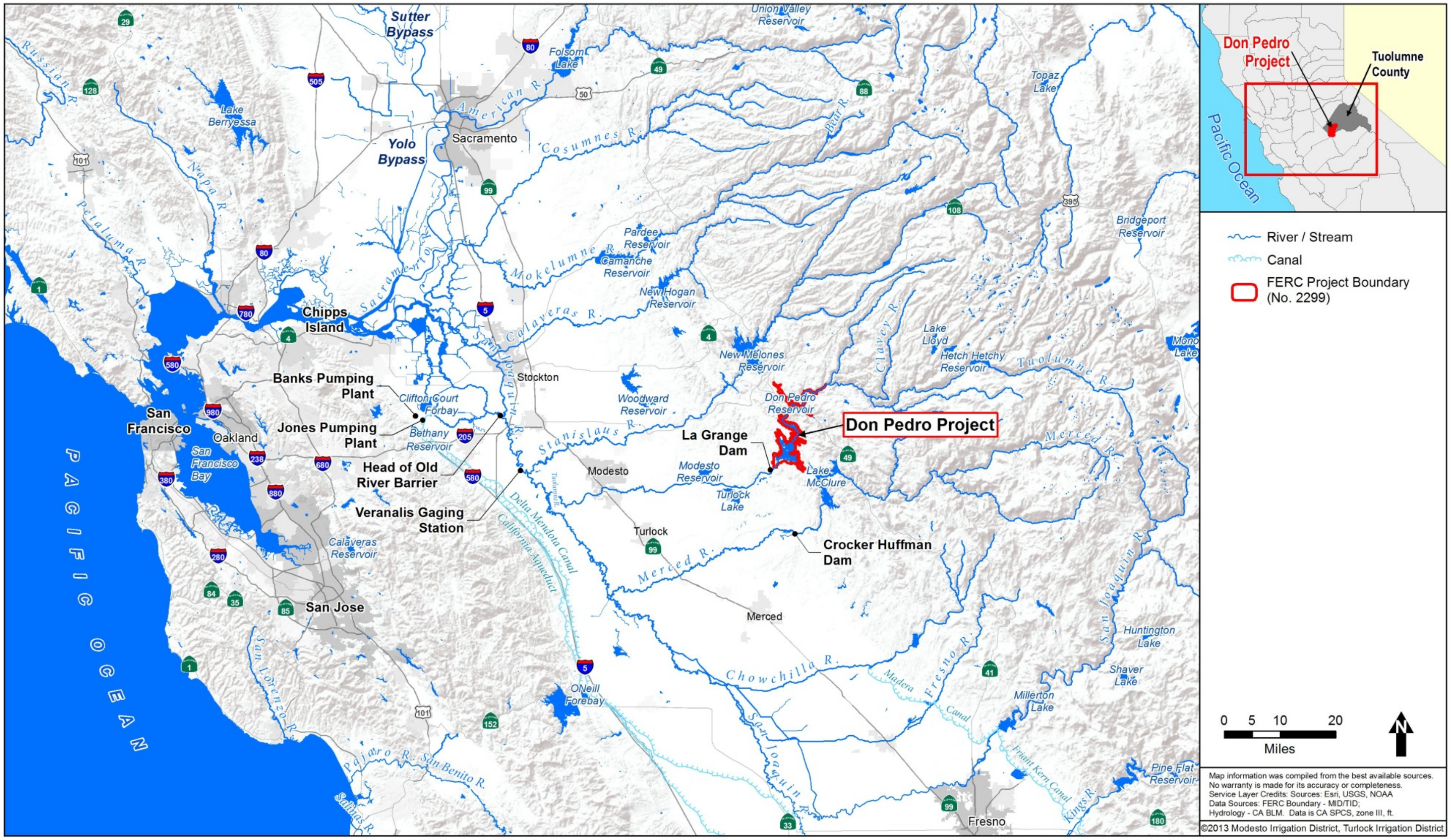

Figure 5.3-1. Map of the San Joaquin River basin and Delta.

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5.3.1.2 Don Pedro Project: Actions Independent of the Proposed Action

As noted previously, hydroelectric generation is a secondary purpose of the Don Pedro Project. With its license application to FERC, the Districts are seeking a new license to continue generating hydroelectric power. For this EFH assessment, the Districts are providing a complete description of the facilities and operation of the Don Pedro Project so the effects of the operation and maintenance of the Don Pedro hydroelectric facilities can be distinguished from the effects of the operation and maintenance activities of the overall Don Pedro Project's flood control and water supply/consumptive use purposes.

5.3.1.2.1 Project Dam and Reservoir

Don Pedro Dam is a 1,900-foot-long and 580-foot-high, zoned earth and rockfill structure. The top of the dam is at 855 feet (National Geodetic Vertical Datum of 1929). Don Pedro Reservoir extends upstream for approximately 24 miles at its normal maximum water surface elevation of 830 feet. In a typical year, water surface elevation in Don Pedro Reservoir peaks in late June/early July at the end of the snowmelt, and is then steadily drawn down over the summer and fall to serve water supply and lower Tuolumne River fish protection needs. Rainfall and snowmelt runoff resumes in December.

Although operation of the hydroelectric facilities at the Don Pedro Dam is an important function, it is a secondary function of the Project. The primary purposes of the Project are to provide water storage to meet the needs of irrigation and M&I water users and facilitate flood management in accordance with the ACOE flood control manual.

5.3.1.2.2 Timing and Magnitude of Flow Releases

Water is released from Don Pedro Reservoir for only three reasons: (1) to provide water needed to meet the Districts' irrigation and M&I demands, (2) for flood management purposes, and (3) to meet the FERC license requirements for fish protection flows in the lower Tuolumne River. In general, reservoir operations follow a relatively consistent annual cycle of water management for flood control; capturing runoff from snowmelt and seasonal rainfall; delivery of water to meet irrigation, municipal, and industrial needs; providing recreation opportunities; and providing scheduled releases for the protection of anadromous and resident salmonids in the lower Tuolumne River. The Districts possess senior water rights in the Tuolumne River, but Project operations must consider potential water availability over the course of multiple years, so that even in drier years the reservoir can retain a water supply that is sufficient to meet downstream users' needs.

Flows released at Don Pedro Dam to meet the Districts' irrigation and M&I water demands are all diverted from the Tuolumne River at La Grange Diversion Dam (the Districts' non-project Diversion Dam) to the TID and MID canal systems. From 1971 to 2012, the average annual water diversion at La Grange Diversion Dam to the Districts canals was approximately 900,000 ac-ft. Diversions for irrigation can occur year round, but generally occur from late February to early November. This water management contributes to cumulative effects on fall-run Chinook salmon in the lower Tuolumne River by storing water that is then scheduled for release into diversion canals. However, these effects due to diversion at La Grange Diversion Dam do not reflect outflow variability at the Don Pedro Project for the purpose of hydropower generation.

Flows released at Don Pedro Dam to comply with the ACOE's flood management guidelines consist of both pre-releases to create storage in anticipation of high runoff and releases during periods of high runoff to moderate downstream effects. Both of these release scenarios occur to balance reservoir levels, forecasted runoff, and downstream flows. "High" river flows can be defined as any flows released at Don Pedro Dam that are greater than those needed for irrigation and M&I purposes and aquatic resource protection purposes. The ACOE guidelines call for making 340,000 ac-ft of storage available for management of high-flow conditions. Flow releases for high-flow management purposes from March to July are affected by diversions at La Grange Diversion Dam for water supply purposes. High flows in the Tuolumne River are also affected by the operation of the upstream Hetch Hetchy system.

In addition to flood storage reservation within the reservoir, downstream flow restrictions also affect Project operations from a flood management perspective. The primary downstream flow guideline cited in the 1972 ACOE Flood Control Manual is that flow in the Tuolumne River at Modesto (as measured at the 9th Street Bridge) should generally not exceed 9,000 cfs. Flows in excess of 9,000 cfs have the potential to cause significant property damage in this area of the Tuolumne River basin, while also potentially contributing to flood flows in the San Joaquin River. If a large volume of water is forecasted that could result in flows higher than 9,000 cfs at Modesto, pre-flood releases may be made from Don Pedro Dam to create storage to prevent downstream flows from exceeding 9,000 cfs at a later time.

Between La Grange Diversion Dam and 9th Street in Modesto the single largest contributor of local flow to the Tuolumne River is Dry Creek. The Dry Creek watershed has its headwaters in the foothills just northeast of the Project. It is a "flashy" watershed, and once its soil is saturated any rainfall results in rapid runoff. Significant flows, i.e., 6,000 cfs or higher, can occur when significant rainfall occurs between Modesto and the upper end of the Dry Creek watershed. Because these flows from Dry Creek come in above the USGS's Tuolumne River 9th Street river gage, they must be taken into account when making releases from Don Pedro Reservoir to the lower river to avoid exceeding 9,000 cfs.

CCSF also contributed financially to the construction of the new Don Pedro Dam. In return for its financial contribution, CCSF obtained up to 570,000 ac-ft of water banking privileges in Don Pedro Reservoir, which allows CCSF to improve the reliability of its overall water supply management system for its Bay Area water users. CCSF pre-releases water from its upstream facilities into the water bank in the Don Pedro Reservoir so at other times it can hold back an equivalent amount of water that would otherwise have to be released to satisfy the Districts' water rights. Once the water enters Don Pedro Reservoir, the water belongs to the Districts, and the Districts have unrestricted entitlement to its use.

Prior to its construction, it was recognized that the new Don Pedro Project was necessary for the protection of Tuolumne River fall-run Chinook salmon because the original Don Pedro Reservoir built in the early 1920s, which had no downstream release requirements, would spill less and less water as CCSF increased its exports to the Bay Area. The Federal Power Commission, the predecessor to FERC, recognized that fisheries releases to the lower Tuolumne River, when combined with rising CCSF diversions, could ultimately undermine the economic feasibility of the new Don Pedro Project. To balance those factors, the Federal Power Commission's 1964 decision set normal-year releases for fish of 123,210 ac-ft for the first 20 years, and required the Districts to conduct studies that could be used to develop future fisheries requirements.

FERC's 1996 order (FERC 1996) amending the Don Pedro Project license required the incorporation of the lower Tuolumne River minimum flow provisions contained in the 1995 settlement agreement between the Districts, CCSF, resource agencies, and environmental groups. The revised minimum flows in the lower Tuolumne River vary from 50 to 300 cfs, depending on water year hydrology and time of year. The water year classifications are recalculated each year to maintain approximately the same frequency distribution of water year types. The settlement agreement and license order also specified certain pulse flows for the benefit of upstream migrating adult salmon and downstream migrating juveniles, the amount of which also varies with water-year type. The downstream flow schedule provided for by the settlement agreement and subsequent FERC Order is shown in Table 5.3.-2. These flows are a required element of the environmental baseline, and would continue regardless of whether or not the Proposed Action is licensed, i.e., the existing flow regime required by the settlement agreement and license is not part of the Districts' Proposed Action.

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Table 5.3-2. Schedule of flow releases from the Don Pedro Project to the lower Tuolumne River by water year type contained in FERC's 1996 order.

Schedule	Units	# of Days	Critical and Below	Median Critical[1]	Interm. CD	Median Dry	Interm. D-BN	Median Below Normal	Interm. BN-AN[1]	Median Above Normal	Interm. AN-W	Median Wet/Max
Occurrence	%		6.4%	8.0%	6.1%	10.8%	9.1%	10.3%	15.5%	5.1%	15.4%	13.3%
October 1-15	cfs	15	100	100	150	150	180	200	300	300	300	300
	AF		2,975	2,975	4,463	4,463	5,355	5,950	8,926	8,926	8,926	8,926
Attraction Pulse	AF		none	none	None	none	1,676	1,736	5,950	5,950	5,950	5,950
October 16-May 31	cfs	228	150	150	150	150	180	175	300	300	300	300
	AF		67,835	67,835	67,835	67,835	81,402	79,140	135,669	135,669	135,669	135,669
Outmigration Pulse Flow	AF		11,091	20,091	32,619	37,060	35,920	60,027	89,882	89,882	89,882	898
June 1-Sept 30	cfs	122	50	50	50	75	75	75	250	250	250	250
	AF		12,099	12,099	12,099	18,149	18,149	18,149	60,496	60,496	60,496	60,496
Volume (total)	AF	365	94,000	103,000	117,016	127,507	142,502	165,003	300,923	300,923	300,923	300,923

[1] Between a Median Critical Water Year and an Intermediate Below Normal-Above Normal Water Year, the precise volume of flow to be released by the Districts each fish flow year is to be determined using accepted methods of interpolation between index values.

Source: FERC 1996.

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5.3.1.3 Non-Project In-Basin Actions

The first dam built on the Tuolumne River, Wheaton Dam, was constructed in 1871 near the current location of the La Grange Diversion Dam at approximately RM 52.2. There are currently a number of dams in the mainstem Tuolumne River and its tributaries, some of which are used for storage and others that are primarily diversion dams. Table 5.3-3 lists the owners of the dams in the Tuolumne River basin and the capacities of their associated impoundments, if known. Dates for completion of construction of select impoundments are also provided in Table 5.3-3. Table 5.3-4 provides information on known hydropower facilities in the Tuolumne River basin, including both small and conventional hydroelectric generation facilities.

Table 5.3-3. Owners and capacities of dams or diversion facilities and their associated reservoirs in the Tuolumne River basin.

Owner	FERC Project No.	Stream	Dam or Diversion Dam	Reservoir or Impoundment Name (date completed)	Capacity (ac-ft)
CCSF	None	Tuolumne River	O'Shaughnessy Dam / diversion to Mountain Tunnel	Hetch Hetchy Reservoir (1923)	360,360 (USGS 1999)
CCSF	None	Eleanor Creek	Eleanor Dam	Lake Eleanor (1918)	26,146 (USGS 1999)
CCSF	None	Cherry Creek	Cherry Dam	Cherry Lake (1956)	274,2520 (USGS 1999)
CCSF	None	Tuolumne River	Early Intake (facility only used by CCSF for infrequent diversion from Cherry watershed)	n/a (1924)	<100
CCSF	None	Off-stream	Priest Dam	Priest Forebay (1923)	1,500
CCSF	None	Off-stream (Moccasin Creek and all local runoff diverted under or around impoundment)	Moccasin Dam	Moccasin Afterbay	Approx. 500
Private	None	Big Creek	Pine Mountain Dam	Pine Mountain Lake (1969)	7,700 (USGS 1999)
Private	None	Sullivan Creek (receives diversion from SF Stanislaus River)	Phoenix Dam	Phoenix Lake (1880)	612 (USGS 1999)
TID/MID	2299	Tuolumne River	Don Pedro Dam	Don Pedro Reservoir	2,030,000
TID/MID	None	Tuolumne River	La Grange Diversion Dam	La Grange Pool	100
MID	None	Off-stream	Modesto Reservoir Dam	Modesto Reservoir (1911)	28,000
TID	None	Off-stream	Turlock Lake Dam	Turlock Lake (1914)	48,000
TID	None	Off-stream	Dawson Dam	Dawson Lake	< 100

Source: USGS 1999; CCSF 2006.

Table 5.3-4. Hydropower generation facilities in the Tuolumne River watershed.

Owner	FERC Project No.	Powerhouse	Location / Description
CCSF	None	Robert C. Kirkwood Powerplant	124 MW; Completed 1967; water diverted from Hetch Hetchy Reservoir to powerhouse via Canyon Tunnel (CCSF 2006)
CCSF	None	Dion R Holm Powerplant	169 MW; Completed 1960; water diverted from Lake Lloyd via Cherry Power Tunnel (CCSF 2006)
CCSF	None	Moccasin Powerhouse (off-stream)	110 MW; water diverted to powerhouse via CCSF Mountain Tunnel by way of Priest Forebay (CCSF 2006)
MID TID	2299	Don Pedro Powerhouse	Immediately downstream of Don Pedro Dam; 4 units, authorized capacity 168 MW.
TID	14581	La Grange Powerhouse	4.5 MW Powerhouse; water source is TID Upper Main Canal.
TID	4450	Dawson Power Plant (off-stream)	5.5 MW; Small hydro located on TID Upper Main Canal between La Grange Diversion Dam and Turlock Lake
TID	3261	Turlock Lake (off-stream)	3.3 MW; Small hydro located at the outflow of the District's Turlock Lake
MID	290	Stone Drop (off stream)	230 kW; small hydro located on the MID main canal just below Modesto Reservoir
TID	1000	Hickman (off stream)	1.1 MW, first built 1979 on the TID Main Canal

5.3.1.3.1 Dam and Reservoir Operations Upstream of the Don Pedro Project

CCSF's Hetch Hetchy Water and Power Division maintains and operates several reservoirs in the middle-elevation band of the Tuolumne River watershed upstream of the Don Pedro Project, including CCSF's Cherry Lake (elevation 4,700 feet), Lake Eleanor (elevation 4,660 feet), and Hetch Hetchy Reservoir (elevation 3,800 feet) (CCSF 2006). The primary purposes of these projects are to provide water storage for purposes of water supply and hydropower generation. CCSF stores and diverts water from the upper Tuolumne River for use outside of the Tuolumne River basin. CCSF provides potable water to approximately 2.6 million Bay Area residents and serves much of the Bay Area's commercial, manufacturing, and industrial enterprises. The Hetch Hetchy system includes the San Joaquin Pipeline, which transports about 85 percent of CCSF's total water supply needs. The Hetch Hetchy system is an indispensable component of the welfare and economy of the Bay Area. The Hetch Hetchy system also produces about 1,700,000 MWh of renewable hydroelectric energy in an average year. The maximum rate of diversion from of the upper Tuolumne River to the San Francisco Bay Area is about 465 cfs. The average annual use is about 230,000 ac-ft, or about 12 percent of the average annual runoff.[21]

Another user of water in the upper Tuolumne River is CDFW, which operates the Moccasin Fish Hatchery below CCSF's Moccasin Reservoir, a 505-AF water supply reservoir. Water flow to the hatchery is estimated to be about 15 million gallons per day (23 cfs) or about 11,000 ac-ft per year. Water from the hatchery is discharged into Moccasin Creek. Water from Moccasin Reservoir also feeds CCSF's Foothill Tunnel.

[21] For the period 1987 - 2012.

5.3.1.3.2 Dam and Reservoir Operations Downstream of the Don Pedro Project

Water released through the Don Pedro powerhouse or outlet works discharges into the Tuolumne River and about 1 mile downstream enters the La Grange headpond. At La Grange Diversion Dam, an irrigation diversion dam owned by the Districts, water is diverted into MID's canal system on the north side of the Tuolumne River and into TID's canal system on the south side of the river. Flows greater than the Districts' irrigation and M&I needs continue on to the lower Tuolumne River by passing over the dam's spillway, through TID's La Grange powerhouse located off the TID main canal, or through sluice gates associated with the La Grange facilities.

La Grange Diversion Dam is located near the border of Stanislaus and Tuolumne counties at RM 52.2. Originally constructed by TID and MID between 1891 and 1893, the primary purpose of the dam is to raise the level of the Tuolumne River to permit diversion of water, by means of gravity, into the Districts' canal systems. La Grange Diversion Dam, which replaced Wheaton Dam (built by other parties in the early 1870s), was constructed at the downstream end of a narrow, steep-sided canyon. Operation of La Grange Diversion Dam results in very little fluctuation of water surface elevation in the La Grange headpond. When not in spill mode (i.e., above elevation 296.5 feet, which occurs about 30 percent of the time), the pool operates between elevation 296 feet and 294 feet about 90 percent of the time. The volume of storage in this 2-foot operating band is less than 100 ac-ft. La Grange Diversion Dam is the most downstream dam on the Tuolumne River. Flows in the lower Tuolumne River are recorded at the USGS's La Grange gage located about 0.3 miles below La Grange Diversion Dam.

5.3.1.3.3 Diversions Downstream of the Don Pedro Project

There are at least 26 points of water diversion along the lower Tuolumne River between La Grange Diversion Dam and the San Joaquin River (with an estimated total combined withdrawal capacity of 76.6 cfs [CDWR 2013]), and four diversions along Dry Creek (Figure 5.3-2). The diversions along the lower Tuolumne River typically occur during irrigation season.

5.3.1.3.4 Accretion Flows

Runoff from Dry Creek, agricultural return flows, groundwater seepage, and operational spills from irrigation canals all enter the lower Tuolumne River. Average monthly accretion flows in the lower Tuolumne River range from 40 cfs to 200 cfs, with an estimated annual average accretion from water years 1970-2010 of 152 cfs (TID/MID 2017h).

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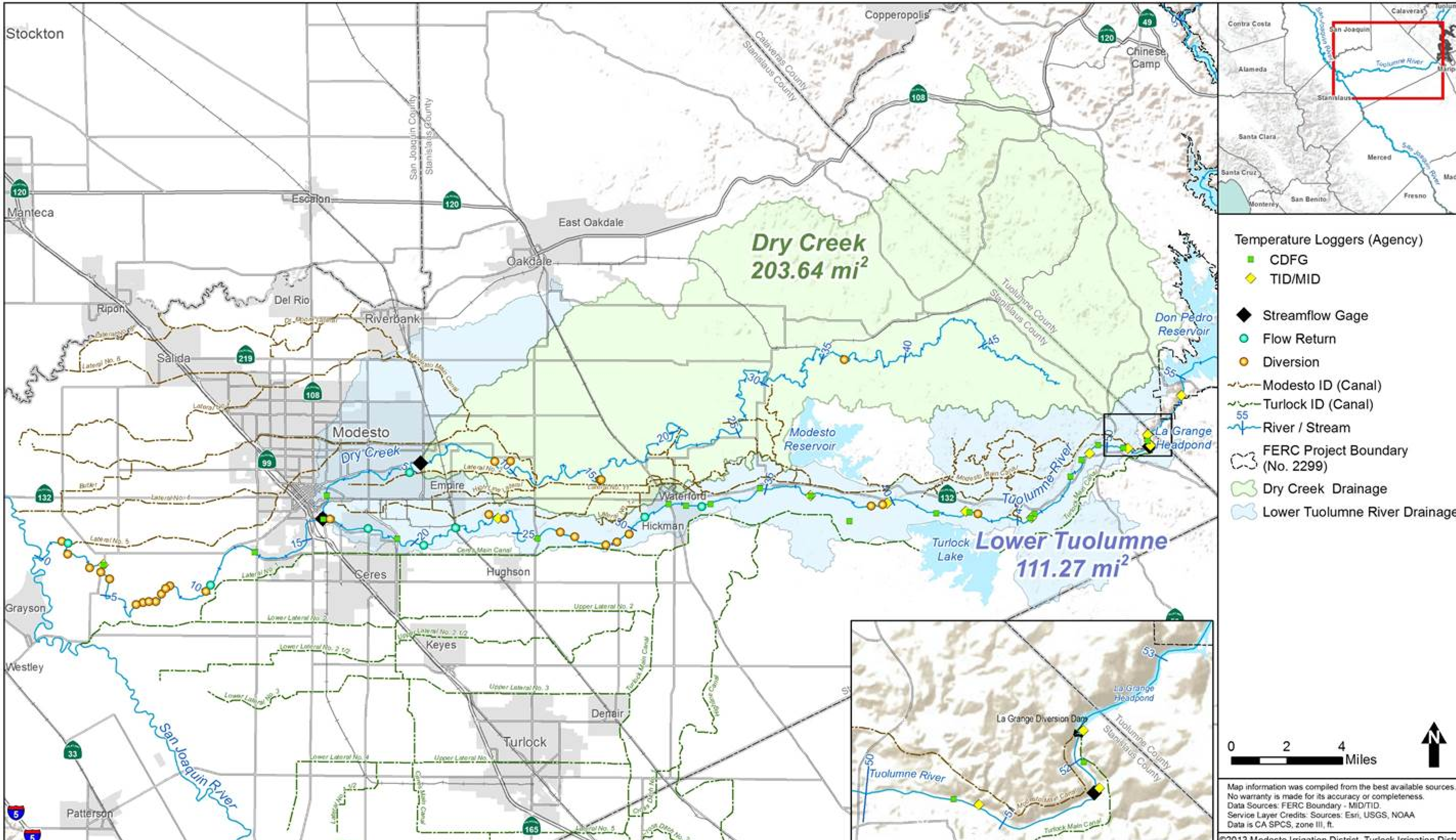

Figure 5.3-2. Locations of riparian diversions along the lower Tuolumne River and Dry Creek.

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5.3.1.3.5 Resource Extraction, Development, and Land Uses along the Tuolumne River

In-Channel and Floodplain Mining

The chief mining commodities in the vicinity of the Project are gold and aggregate. Mining-related impacts on the mainstem of the Tuolumne River corridor began with the California Gold Rush in 1848. A historical timeline of mining activities in the San Joaquin River's tributaries, including the Tuolumne River, comprises placer mining (1848–1880), hydraulic mining in the La Grange vicinity (1871 to about 1900), dredge mining (1908-1942, 1945-1951), and gravel and aggregate mining (1940s to present) (McBain and Trush 2000). Decades of dredge mining in the main channel of the Tuolumne River resulted in the excavation of channel and floodplain sediments and a legacy of significant channel modifications and dredger tailings deposits between RM 50.5 and 38.0. Gravel and aggregate mining, with their attendant floodplain modifications, continue alongside the river corridor.

The Columbia and Springfield placer mining operations northwest of the Project produced approximately $55 million in gold prior to 1899 (TID/MID 2011). The pocket mines of Sonora and Bald Mountain, as well as others in their vicinity, have been highly productive and long-lived. Marble and limestone products have been second in value to gold. The Columbia marble beds northwest of the Project had a long history of production prior to 1941, and two plants are currently processing stone from these deposits (TID/MID 2011). From the 1860s to the 1940s, roughly 10,000 tons of chromite ore and several hundred tons of crude magnesite ore were mined in the Project vicinity (TID/MID 2011). Most of the chromite came from the McCormick Mine, located northwest of the Project. All magnesite production in Tuolumne County occurred in the 1920s and came from two sites in the northern portion of the Red Hills located northwest of the Project (TID/MID 2011).

Gold mined in Stanislaus County has come predominantly from placers. Quaternary gravels of the lower Tuolumne River channel near Waterford were among the most productive (TID/MID 2011). In the early 1900s, large-scale dredging of Quaternary gravels began in the Tuolumne River between La Grange and Waterford, and most of the gold produced in Stanislaus County from 1932 through 1959, came from this area. In the late 1940s, gold mining declined sharply (Koschmann and Bergendahl 1968).

California leads the United States in aggregate production, and virtually all aggregate is removed from alluvial deposits (Kondolf 1995). As of 1994, sand and gravel mining exceeded the economic importance of gold mining in the state. Large-scale, in-channel aggregate mining began in the Tuolumne River corridor in the 1940s, when aggregate mines extracted sand and gravel directly from large pits excavated in the active river channel. Off-channel and floodplain aggregate mining along the Tuolumne River have also been extensive.

Aggregate in Stanislaus County is currently classified as aggregate resources (potentially useable aggregate that may be mined in the future but for which no mining permit has been granted) and aggregate reserves (aggregate resources for which mining and processing permits have been granted) (Higgins and Dupras 1993). An estimated 540 million tons (338 million yd^3) of aggregate resources are located in six different geographic areas of Stanislaus County (Higgins and Dupras

1993). The lower Tuolumne River corridor is the largest of the six areas and contains an estimated 217 million tons (135 million yd^3) of material in its channel and terraces (Higgins and Dupras 1993). The Gravel Mining Reach of the lower Tuolumne (RM 34.2 to 40.3) is currently the focus of development by commercial aggregate producers.

Much of the residual dredger tailings upstream of RM 45 were removed from the floodplain downstream of La Grange Diversion Dam as part of the construction of the new Don Pedro Dam in the 1960s. Reaches of the Tuolumne River between RM 47 and 50 that had been affected by gold dredger mining in the early 1900s were reconfigured following removal of the dredger tailings.

Agriculture, Livestock Grazing, and Timber Harvest

After the Gold Rush, there was a substantial increase in crop production and ranching in the Central Valley (TID/MID 2013c). During this period, woody vegetation along the Tuolumne River was cleared to allow for crop production in the rich alluvial soils of the bottomlands. Levees were constructed to protect the new farmlands from flooding in spring, and irrigation canals were constructed to provide water during the growing season (Thompson 1961; Katibah 1984). Of the estimated 4 million acres of wetland that occurred historically in the Central Valley, only about 300,000 acres remained in 1990. The conversion of wetlands to agricultural uses accounts for much of this reduction in wetland area.

Land in the lower Tuolumne River watershed is primarily privately owned, including that used for agriculture and livestock grazing (Stanislaus County 2006). Primary agricultural land uses along the gravel-bedded reach include orchards and row crops (RM 24.0-40) and livestock grazing (RM 40-51) (McBain and Trush 2000).

Timber operations have existed throughout the Sierra Nevada range since the mid-1800s. The Gold Rush of 1849 fueled a human migration into California that resulted in dramatic increases in the demand for timber. The indirect effects of gold mining included steamship transportation along the major rivers of the Central Valley, which was fueled by cordwood harvested from adjacent lands, which likely resulted in the first wave of riparian forest clearing in some areas of the Tuolumne River basin (Rose 2000, as cited in McBain and Trush 2002).

In recent times, timber harvest in the Tuolumne River watershed has typically been limited to lands in the upper basin. The Yosemite Stanislaus Solutions (YSS) collaborative group was formed in December 2010 to assist the Stanislaus National Forest in developing restoration plans across the landscape, regardless of ownership patterns, in the southern part of the Forest. One critical area within the YSS collaborative is Hetch Hetchy Reservoir. Approximately one third of the land within the YSS boundary burned in 1987 and succeeding years. After 1987, the majority of this land was successfully reforested. The 2013 Rim Fire (which burned from August 17, 2013 through September 20, 2013) burned a total of 253,360 acres (U.S. Department of Agriculture - Forest Service 2013). Much of the burn occurred in the Tuolumne River watershed.

Industrial, Urban, and Residential Development

Privately owned land in the lower Tuolumne River watershed is also used for rural residential purposes or for denser residential, municipal, and industrial purposes in communities such as Waterford and Modesto (Stanislaus County 2006). Many miles of river bank have been leveed and stabilized with riprap by agencies or landowners. Levees and bank revetment extend along portions of the river bank from the area near Modesto (RM 16) downstream to the San Joaquin River. Following the 1997 flood, some subdivisions that had been inundated in the Modesto area were found to have been constructed within the Federal Emergency Management Agency floodplain area designated prior to 1997 (TID/MID 2013c).

Four wastewater treatment plants (e.g., Tuolumne County Water District #1, Jamestown, Sonora, and Tuolumne) contribute a little over 19 percent of the total phosphorus to Don Pedro Reservoir. The Sonora Wastewater Treatment Plant accounts for about 11 percent of the phosphorus input (TID/MID 2011). Urban runoff to the lower Tuolumne River from the Modesto area has been shown to contain pesticides (Dubrovsky et al. 1998). A total of 15 pesticides were detected, and chlorpyrifos, diazinon, DCPA, metolachlor, and simazine were detected in almost every sample (Dubrovsky et al. 1998).

The CVRWQCB has issued various Cleanup and Abatement Orders for the Tuolumne River and its tributaries (TID/MID 2011). For example, in 2004, the CVRWQCB issued Order No. R5-2004-0718 for a discharger within the City of Hickman because a water retention pond at a nursery failed and caused 2,000 yd^3 of sediment and rock to enter the Tuolumne River. In 2008, the CVRWQCB issued Order No. R5-2008-0701 because two dischargers graded over 1,000 acres of land and caused significant discharges of sediment (11,200 NTU) into Peaslee Creek and the Tuolumne River. In 2009, the CVRWQCB issued Order No. R5-2009-0707 because a discharger graded over 76 acres of land and caused significant discharges of sediment into Peaslee Creek and one of its unnamed tributaries.

5.3.1.3.6 Fish Hatchery Practices

The following paragraphs relate to fish hatchery practices as they pertain specifically to the Tuolumne River and Don Pedro Reservoir. For a discussion of hatchery practices in the State of California, see Section 5.3.1.4.8 of this EFH Assessment.

Fall-run Chinook salmon are raised at five major Central Valley hatcheries, which release more than 32 million smolts each year. Hatchery-origin fish contribute disproportionately to the salmon runs of the Central Valley (Barnett-Johnson et al. 2007, Johnson et al. 2011), and adipose-fin-clipped fish from hatcheries have been found in high percentages in Tuolumne River carcass surveys in some years (e.g., TID/MID 2005, 2012). Recent studies have provided local evidence of high rates of straying into the Tuolumne River resulting from off-site hatchery releases by the Merced River Fish Facility and Mokelumne River Hatchery (Mesick 2001; ICF Jones & Stokes and Associates, Inc. 2010).

CDFW manages the Don Pedro Reservoir fishery as a put-and-grow resource with substantial stocking and appropriate fishing regulations. As part of its Inland Salmon Program, CDFW generally plants rainbow trout (*O. mykiss*), kokanee (*O. nerka*), and land-locked Chinook salmon in Don Pedro Reservoir annually. Don Pedro Reservoir is also managed by CDFW as a year-round fishery for black bass. No known fish stocking has occurred in the reach of the Tuolumne River between Don Pedro Dam and La Grange Diversion Dam (TID/MID 2013a).

In response to legislation codified in the Fish and Game Code in 2012, CDFW now raises and stocks sterile (triploid) trout in most areas where native trout occur, including the upper Tuolumne River watershed. Therefore, Moccasin Creek Hatchery currently stocks triploid rainbow trout and triploid brown trout in the upper Tuolumne River watershed.

5.3.1.3.7 Freshwater Salmonid Harvest

CDFW implemented sport catch limits on salmon in the early 2000s within a portion of the Tuolumne River. Salmon fishing is currently banned in the lower Tuolumne River and San Joaquin River upstream of the Delta. No estimate of salmon lost to poaching is available (TID/MID 2013f). However, poaching of Chinook salmon, to the extent that it occurs in the Tuolumne River, would likely only take place during the adult upstream migration period.

It is unclear to what degree historical commercial harvest took place in the Tuolumne River, but based on the scale of harvest within the San Joaquin River basin as a whole, past harvest, especially in the late 1800s and early 1900s, was likely significant. Currently, commercial harvest in the Valley District, which includes rivers in San Joaquin, Stanislaus, and Tuolumne counties, is closed to the take of salmon.

5.3.1.3.8 Non-Native Fish Species

Of the 23 non-native fish species documented in the lower Tuolumne River, 19 were introduced by state or federal agencies (CDFW, NMFS, USFWS, and the State Board of Human Health) between 1874 and 1954, and one was introduced with permission from CDFW in 1967 (Dill and Cordone 1997; Moyle 2002). The remaining three species were introduced by aquarists, catfish farms, or private individuals (Dill and Cordone 1997). Sixteen of the fish species released by state or federal agencies were introduced intentionally for sport or commercial fisheries, as a prey base for sportfish, or for mosquito control; two were introduced incidentally with shipments of sportfish (Dill and Cordone 1997). The most abundant and widespread non-native fish species in the lower Tuolumne River–bluegill, redear sunfish, and green sunfish–were first released in California between 1891 and 1954. Other introduced fish species in the lower Tuolumne River include threadfin shad, black and brown bullhead, white and channel catfish, common carp, fathead minnow, red shiner, golden shiner, goldfish, striped bass, largemouth bass, smallmouth bass, spotted bass, black and white crappie, warmouth, bigscale logperch, western mosquitofish, and inland silversides.

Black Bass and Striped Bass

Largemouth, smallmouth, and spotted bass (collectively black bass) were all introduced into California waters by CDFW and are now actively managed by CDFW in many locations. Largemouth and smallmouth bass were first released in California by CDFW between 1874 and

1891 (Dill and Cordone 1997; TID/MID 1992), and spotted bass were introduced in 1976. According to CDFW (2014), "Bass angling provides recreation and economic value to the state of California." Also according to CDFW (2014), "…California has been the center of attention for producing trophy-sized black bass. In a list of the top 25 largest largemouth bass caught in the U.S., 21 of the bass are from California waters." The California state record smallmouth bass is 9 pounds 13 ounces (CDFW 2014). Angler catches of Alabama spotted bass over six pounds have been verified by CDFW biologists for many California water bodies, including one spotted bass that weighed 10 pounds 4 ounces (CDFW 2014). All three species of black bass can be highly piscivorous and prey heavily on salmonids and other fish species (see below).

In 1990, largemouth bass abundance estimated for the lower Tuolumne River (RM 0.0 to RM 52.0) based on shoreline lengths was 11,074 individuals (TID/MID 1992). During 2012, the abundance of largemouth bass from RM 0.0 to RM 39.4 was estimated to be 3,323 based on shoreline length, and 3,891 based on habitat area (TID/MID 2013e). However, differences in study methods between the 1990 and 2012 sampling years preclude comparison of these estimates. For largemouth bass, site-specific density estimates ranged from 0 to 218 fish per mile (collected in 1998, 1999, and 2003) (McBain & Trush and Stillwater Sciences 2006) and 4 to 196 per mile in 2012.

Smallmouth bass density estimates for the lower Tuolumne River (converted to fish per mile) from McBain & Trush and Stillwater Sciences (2006) (collected in 1998, 1999, and 2003) ranged from 2 to 97 fish per mile. In 2012, site-specific density estimates of smallmouth bass ranged from 0 to 251 fish per mile (TID/MID 2013e).

The Districts' 2012 Predation Study represented the first year that abundance estimates were produced by the Districts for smallmouth bass, largemouth bass, and striped bass, because only the abundance of largemouth bass was estimated during the 1990 study. Additional years of study are likely necessary to understand the population dynamics of these species in relation to river conditions.

There is limited information regarding the abundance of striped bass in the Tuolumne River. However, there is anecdotal evidence of large numbers of striped bass being found in the Tuolumne River as far back as 1903 (State Board of Fish Commissioners 1904). Striped bass were captured by electrofishing in the lower Tuolumne River in 1989 (TID/MID 1992) and during predator surveys in 1998, 1999, and 2003 (McBain & Trush and Stillwater Sciences 2006). The Districts' 2012 Predation Study estimated striped bass abundance in the lower river to be in the range of 500-750 individuals during summer 2012.

5.3.1.3.9 Management and Recovery Activities

Native Salmonid Management and Recovery Programs

The Ecosystem Restoration Program[22] is designed to improve the ecological health of the Bay-Delta watershed through restoring and protecting habitats, ecosystem functions, and native species. The Watershed Program Element specifically works in tandem with the Ecosystem Restoration

[22] (http://www.dfg.ca.gov/ERP)

Program Element to ensure that the ecological health of the Delta is restored and that water management is improved by working with communities at the watershed level.

The California Advisory Committee on Salmon and Steelhead Trout was established by California legislation in 1983 to develop a strategy for the conservation and restoration of salmon and steelhead in California. The committee's recommendations were advanced and discussed in the related publications described in the following paragraphs.

The Central Valley Salmon and Steelhead Restoration and Enhancement Plan (CDFG 1990) was intended to outline CDFW's restoration and enhancement goals for salmon and steelhead resources of the Sacramento River and San Joaquin River systems and to provide direction for various CDFW programs and activities.

The Restoring Central Valley Streams (CDFG 1993) plan identifies the following goals to benefit anadromous fish: restore and protect California's aquatic ecosystems that support fish and wildlife, protect threatened and endangered species, and incorporate the state legislature's mandate and policy to double the size of populations of anadromous fish in California. The plan encompasses only Central Valley waters accessible to anadromous fish, excluding the Delta.

The Final Restoration Plan for the Anadromous Fish Restoration Program (USFWS 2001) identifies restoration actions that may increase natural production of anadromous fish in the Central Valley. This plan is divided to address different watersheds within the Central Valley, and restoration actions are identified for each watershed. It also identifies involved parties, priority ratings, and evaluation tools associated with various restoration actions. The plan addresses only Central Valley waters accessible to anadromous fish.

Habitat Protection, Restoration, and Enhancement Projects

As directed under the 1995 Settlement Agreement, the TAC developed the following 10 top priority habitat restoration projects aimed at improving geomorphic and biological conditions in the lower Tuolumne River corridor, which in turn would benefit fish and aquatic resources (completion status in parentheses):

- Channel and Riparian Restoration Projects (RM 34.3-RM 40.3)
    - Gravel Mining Reach Phase I - 7/11 Gravel Mining Reach Restoration (restored channel and floodplain along 1.5 river miles) (RM 38-39.5) (completed in 2003)
    - Gravel Mining Reach Phase II (not completed)[23]
    - Gravel Mining Reach Phase III (not completed)

[23] By the terms of the 1995 Settlement Agreement, the Districts and CCSF pledged $500,000 and an additional $500,000 in matching funds for Tuolumne River restoration projects. Also by the terms of the agreement, CDFW and USFWS were responsible for actively pursuing state and federal funding. After securing funding and constructing the initial four priority projects identified by the TAC, CDFW, while supporting additional restoration projects at the TAC, actively opposed using CALFED funding for additional projects. Consequently, approved CALFED funding of over $14.75 million for three additional TAC projects, designed to benefit fall-run Chinook and *O. mykiss*, was never able to be used and the projects were never implemented due to factors outside the control of the Districts.

  - Gravel Mining Reach Phase IV (not completed)
- Predator Isolation Projects
  - Special Run Pool (SRP) 9 Channel and Floodplain Restoration (restored channel and floodplain along 0.2 river miles) (RM 25.7-25.9) (completed in 2001)
  - SRP 10 (RM 25.5) (not completed)
- Sediment Management Projects (RM 43.0-RM 51.8)
  - River Mile 43 Channel Restoration (restored channel and floodplain along 0.5 river miles) (completed in 2005)
  - Gasburg Creek Fine Sediment Retention Project (RM 50) (completed in 2008)
  - Gravel Augmentation (coarse sediment) (not completed)
  - Riffle Cleaning (fine sediment) (not completed)

Other restoration efforts have been implemented in the lower Tuolumne River corridor by various groups, including FOT, TRC, TRT, NRCS, ESRCD, USFWS, CDFW, Stanislaus County, and the cities of Waterford, Ceres, and Modesto.

To improve salmonid spawning and rearing conditions in the lower Tuolumne River, several coarse sediment augmentation and habitat restoration projects have been completed (TID/MID 2005, 2013f). CDFW placed approximately 27,000 yd^3 of gravel in the river near Old La Grange Bridge (RM 50.5) from 1999 to 2003 (TID/MID 2007). Riffle and floodplain reconstruction projects have also been completed at Bobcat Flat (RM 43.5), near the site of 7/11 Materials (RM 40.3–37.7), and at SRPs 9 and 10 (approximately RM 25.7) (TID/MID 2007), with designs and preliminary permitting completed for additional gravel augmentation projects at upstream locations.

Riparian restoration projects along the Tuolumne River include Grayson River Ranch, Big Bend, SRP 9, 7/11 Mining Reach Segment #1, and RM 43 at Bobcat Flat. Floodplain restoration was conducted at Grayson River Ranch (located approximately 4 miles upstream of the San Joaquin River confluence) by FOT in 2000. Anecdotal evidence indicates that some recovery of riparian vegetation has occurred on the floodplain and along newly constructed sloughs. The TRT and other partners acquired approximately 250 acres on both sides of the Tuolumne River at Big Bend (RM 5.8 to 7.4). Restoration was completed in 2005, and monitoring results suggest that planting to reestablish native, woody riparian species has been effective. In 2001, restoration of river and floodplain habitat was completed at SRP 9 (RM 25.7 to 25.9). A brief survey conducted in 2002 indicated that tree survival typically exceeded 60 percent for most species one year after planting. In 2003, restoration of river and floodplain habitat was completed at the 7/11 site (RM 34.4 to 40.3). Post-project monitoring of planted vegetation has been limited to quantifying survival of planted vegetation and replacing plants as stipulated in the construction contract. The Bobcat Flat restoration site includes 303 acres of riparian and instream habitat owned by FOT. Restoration was conducted in 2005-2006, and anecdotal evidence and site photos indicate some success in restoring riparian vegetation at the site.

The AMF was initiated in 2001 to review designs for restoration projects in Central Valley rivers and assist resource agencies and tributary restoration teams. The AMF panel of technical experts made recommendations concerning tributary restoration, including the incorporation of adaptive management into projects and proposing approaches that would maximize restoration success.

As noted above, The Ecosystem Restoration Program[24] is designed to improve the ecological health of the Bay-Delta watershed through restoring and protecting habitats and ecosystem functions.

5.3.1.4 Past, Present, and Future Actions in the lower San Joaquin River and Delta

The San Joaquin River originates in the high Sierra Nevada range, flows northward, and enters the legally-defined Delta near the USGS Vernalis gaging station (RM 73). The drainage area of the San Joaquin River above the Vernalis gage is 13,539 mi^2. The average annual flow at Vernalis was 3.26 million ac-ft from WY 1924 through WY 2012 (3.19 million ac-ft for WY 1971–WY 2012). The three main tributaries to the San Joaquin River above Vernalis are the Merced (drainage area 1,726 mi^2), Tuolumne (drainage area 1,960 mi^2), and Stanislaus (drainage area 1,075 mi^2) rivers.

The Sacramento and San Joaquin rivers meet at the western boundary of the Delta. Freshwater from the rivers mingles with saltwater from the Pacific Ocean, creating the West Coast's largest estuary. Under historical conditions, the south Delta and lower San Joaquin River were composed of tidal wetlands merging southward into floodplain wetlands interspersed with complex side-channel habitats, lakes, and ponds, with seasonal wetlands bordering upland habitats (Whipple et al. 2012). As summarized by Lund et al. (2007), the present day Delta encompasses about 60,000 acres of open water (exclusive of Suisun Bay), 520,000 acres of agricultural lands, 64,000 acres of towns and cities, and 75,000 acres of undeveloped areas.

For the purposes of documenting out-of-basin actions influencing the EFH Action Area, the following sections focus on water management and other past, present, and reasonably foreseeable actions in the lower San Joaquin River basin, including the mainstem San Joaquin River below Friant Dam, two of the three major San Joaquin River tributaries, i.e., the Merced and Stanislaus rivers (actions on the Tuolumne River are discussed in previous sections of this EFH Assessment), and the Delta.

5.3.1.4.1 CCSF Regional Water System

CCSF, through the San Francisco Public Utilities Commission (SFPUC), owns and operates a regional water system that extends from the Sierra Nevada to San Francisco and serves retail and wholesale customers in San Francisco, San Mateo, Santa Clara, Alameda, and Tuolumne Counties. The regional water system consists of water conveyance, treatment, and distribution facilities. The regional system includes over 280 miles of pipelines, over 60 miles of tunnels, 11 reservoirs, five pump stations, and two water treatment plants. The source of the water supply is a combination of local supplies from streamflow and runoff in the Alameda Creek watershed and in the San Mateo Creek and Pilarcitos Creek watersheds (referred to together as the Peninsula watersheds),

[24] (http://www.dfg.ca.gov/ERP)

along with imported supplies from the Tuolumne River watershed. Local watersheds provide about 15 percent of total supplies, with the Tuolumne River providing the remaining 85 percent.

The SFPUC provides about one-third of its water supplies directly to retail customers, primarily in San Francisco, and about two-thirds of its water supplies to wholesale customers by contractual agreement. The wholesale customers are largely represented by the Bay Area Water Supply and Conservation Agency (BAWSCA), which consists of 26 member agencies in Alameda, San Mateo, and Santa Clara Counties. Some of these wholesale customers have other sources of water in addition to what they receive from the SFPUC, while others rely completely on the SFPUC for supply.

5.3.1.4.2 Central Valley Project and State Water Project

The development and management of California's surface water is a process that has spanned decades and has involved the participation of private companies and local, state, and federal agencies (CDWR et al. 2013). Irrigated agriculture in the San Joaquin Valley proliferated after the Gold Rush and again in 1857, when the California State Legislature passed an act to promote the drainage and reclamation of floodplains (Galloway and Riley 1999). By 1900, much of the flow of the Kern River and all flow from the Kings River were diverted and routed through canals and ditches to irrigate fields in the southern part of the San Joaquin Valley (Nady and Laragueta 1983, as cited in Galloway and Riley 1999). Because early diversions did not have associated storage facilities, agricultural water supply was limited by low summer flows.

By 1910, almost all available surface water in the San Joaquin Valley was diverted, which led to the development of groundwater for irrigation (Galloway and Riley 1999). The first groundwater development took place in areas where shallow groundwater was abundant, particularly in the central part of the valley where flowing wells were common. When the output from the flowing wells declined, pumps were installed to maintain flows. Around 1930, the development of an improved deep-well turbine pump, along with a reliable electrical supply in rural areas, allowed for further groundwater development.

The cities of Los Angeles and San Francisco began to have water shortages early in the 1900s. They recognized the need to augment local water supplies and were the first to develop distant water sources for this purpose. As California's population grew, existing projects could not meet the demand for water. As a result, the federal CVP and the California SWP were initiated in 1937 and 1957, respectively (CDWR et al. 2013). These two major statewide projects were developed to serve agricultural, environmental, and municipal water users throughout California.

The SWP and CVP water infrastructure is operated in a coordinated manner, with joint locations of diversion that allow one project to use the other's diversion facility under certain conditions (CDWR et al. 2013). To some degree, both the SWP and CVP systems rely on runoff and upstream reservoir releases from the Sacramento and San Joaquin River basins to deliver contracted water via the Delta export pumps located in the south Delta to deliver water to project customers. The CDWR exports water through the Harvey O. Banks Pumping Plant (Banks pumping plant, completed in 1968), which supplies the California Aqueduct. The U.S. Department of the Interior, Bureau of Reclamation (USBR) exports water into the Delta-Mendota Canal (completed in 1951) through the C. W. "Bill" Jones Pumping Plant (Jones pumping plant, completed in 1951). The history and structure of the CVP and SWP facilities are described in the following subsections.

Central Valley Project

The CVP is the largest water supply project in the United States. It includes 18 reservoirs with a combined storage capacity of more than 11 million ac-ft, 11 hydroelectric power plants, and more than 500 miles of major canals and aqueducts (CDWR et al. 2013). The USBR operates and maintains the CVP as an integrated project and coordinates operations with the SWP. Authorized project purposes include flood management, navigation; water supply for irrigation and domestic uses, fish and wildlife protection, restoration and enhancement, and power generation. However, not all facilities are operated to meet each of these purposes. The USBR has entered into approximately 250 long-term contracts with water districts, irrigation districts, and others for delivery of CVP water. Currently, there are eight divisions of the project and 10 corresponding units. Of the contracted water supply, approximately 70 percent goes to agricultural users, almost 20 percent is dedicated to fish and wildlife habitat, and nearly 10 percent is allocated to M&I water users. In addition to water storage and regulation, the system has a hydroelectric capacity of over 2,000 MW, provides recreation, and enables flood control with its dams and reservoirs.

There are five CVP divisions/units south of the Delta in the San Joaquin River basin: Friant Division, New Melones Unit, San Luis Unit, San Felipe Division, and Hidden Unit on the Chowchilla and Fresno rivers (described below).

Friant Division[25]

The Friant Division transports surplus water from northern California through the southern part of the Central Valley. The major facilities of this division are Friant Dam, Friant-Kern Canal, and Madera Canal, all constructed and operated by the USBR.

Friant Dam, located on the San Joaquin River 25 miles northeast of Fresno, was completed in 1942. The dam is a concrete gravity structure, 319 feet high, with a crest length of 3,488 feet. The dam controls San Joaquin River flows, provides downstream releases to meet water requirements above Mendota Pool, provides flood control and conservation storage, provides diversion into the Madera and Friant-Kern Canals; prevents saltwater from degrading thousands of acres of lands in the Delta, and delivers water to 1 million acres of agricultural lands in Fresno, Kern, Madera, and Tulare Counties. The reservoir, Millerton Lake, which first stored water in 1944, has a total capacity of approximately 520,500 ac-ft, a surface area of 4,900 acres, and an approximate length of 15 miles.

Friant Dam`s spillway was designed to pass flood water into Millerton Lake. However, due to frequent drought cycles in central California over the past 50 years, water has seldom spilled at Friant Dam. The outlet works consist of four steel pipes through Friant Dam that are controlled by four hollow-jet valves at the outlet ends. The capacity of the jet valves is 16,400 cfs; but flow through the valves rarely exceeds 100 cfs. Small releases are made to the river through two pipes branching from Penstocks 3 and 4.

[25] Source: http://www.usbr.gov/projects/Project.jsp?proj_Name=Central+Valley+Project

Construction of the Friant-Kern Canal began in 1945 and was completed in 1951. The canal has an initial capacity of 5,000 cfs that gradually decreases to 2,000 cfs at its endpoint in the Kern River. The canal outlet works consist of a stilling basin and four steel pipes through the dam. The canal carries water 151.8 miles from Millerton Lake to the Kern River, 4 miles west of Bakersfield. Along a 113-mile reach between Friant Dam and the White River, the canal has more than 500 different structures, including overchutes, drainage inlets, irrigation crossings, and turnouts. The water is used for supplemental and new irrigation supplies in Fresno, Tulare, and Kern Counties.

The 35.9-mile-long Madera Canal carries water north from Millerton Lake to lands in Madera County to provide supplemental and new irrigation supply. The canal, which was completed in 1945, has an initial capacity of 1,250 cfs, which decreases to 625 cfs at the Chowchilla River. The outlet works consists of two pipes that discharge into a stilling basin at the upstream end of the Madera Canal. Water ran for the first time through the canal's entire length on June 10, 1945. The John A. Franchi Diversion Dam, formerly the Madera Diversion Dam, on the Fresno River, is operated by the Madera Irrigation District. Built by the USBR, the facility was completed in 1964.

In 1947, riparian landowners sued the United States government under the California Fish and Game Code, stating that Friant Dam deprived them of commercial and recreational uses related to salmon fishing. The State Attorney General concluded the United States was not required by California law to discharge water to preserve fisheries downstream of the dam. In 1988, when the first contracts for the Friant Division came up for renewal, 15 environmental groups sued the federal government, maintaining that contract renewals should be subject to environmental review under NEPA and the ESA. The lawsuit culminated in the signing of the San Joaquin River Restoration Settlement Act and development of the associated San Joaquin River Restoration Program.

Hidden and Buchanan Units

The Hidden and Buchanan Units, located on the Chowchilla and Fresno Rivers, provide flood control and water supply to the Chowchilla and Madera irrigation districts. The Hidden Unit provides 24,000 ac-ft annually from Hensley Lake to the Madera Irrigation District, and the Buchanan Unit provides 24,000 ac-ft annually from Eastman Lake to the Chowchilla Water District.

New Melones Unit[26]

The New Melones Dam and Power Plant are located on the Stanislaus River, about 60 miles upstream of its confluence with the San Joaquin River. The dam is a 625-foot-high earth and rockfill structure that impounds New Melones Lake, which has a capacity of 2.4 million ac-ft at a pool elevation of 1,088.0 feet. Construction of the New Melones Dam project began in 1966, about 0.75 miles downstream of the original Melones Dam, which was built by the Oakdale and South San Joaquin Irrigation Districts in 1926. Construction of the diversion tunnel was completed in 1973. Construction of the main dam began in 1974, and initial filling of the reservoir took place in 1983.

[26] Source: http://www.water.ca.gov/swp/swptoday.cfm

The outlet works consist of a 3,774-foot-long, 23-foot-diameter tunnel and two conduits for emergency releases. Releases for flood control and irrigation are made through a branch of the multipurpose tunnel. The outlet works have a capacity of 8,300 cfs. The spillway has an uncontrolled concrete crest, with a capacity 112,600 cfs. The New Melones Power Plant, located immediately downstream of the dam, has a dependable capacity of about 279 MW, producing about 455 million KWh of energy annually. The New Melones Unit was officially transferred to the USBR in 1979 for integrated operation as part of the CVP.

An original purpose of the New Melones Dam was flood control. New Melones Lake includes a flood control reservation of 450,000 ac-ft. Under flood control conditions, release operations are designed not to exceed a flow of 8,000 cfs (channel capacity) in the Lower Stanislaus River from Goodwin Dam downstream to the San Joaquin River. Unit operations provide releases for downstream fisheries requirements, water quality, water rights, and a water supply yield estimated at about 180,000 ac-ft to meet present and projected agricultural and M&I needs in the service area.

Water availability for the New Melones Project has proven to be significantly different from what had originally been expected. The USBR found that previous modeled estimates of drought and demand were significantly inaccurate. As a result, contracts negotiated with the Stockton East Water District and the Central San Joaquin Water Conservation District have not always been met during drought years, and the USBR has had to purchase water from the Tri-Dam Project to meet the release requirements for the fall Chinook salmon run.

When the lake levels are lower, the old Melones Dam, which is now submerged, prevents cold water at the bottom of the lake from reaching the outlet works of the new dam, resulting in temperatures that are too high for salmonids downstream of the dam. The situation becomes most critical when the volume of the lake drops below 350,000 ac-ft.

San Luis Unit[27]

Authorized in 1960, the San Luis Unit was constructed by the USBR and the State of California. It is now jointly operated by the USBR and State of California, with some facilities operated by Westlands Water District (see below).

The joint-use facilities of the San Luis Unit include O'Neill Dam and Forebay, B.F. Sisk San Luis Dam and Reservoir, William R. Gianelli Pumping-Generating Plant, Dos Amigos Pumping Plant, Los Banos and Little Panoche reservoirs, and San Luis Canal from O'Neill Forebay to Kettleman City, together with the associated switchyard facilities. The federal/private facilities include the O`Neill Pumping Plant and Intake Canal, Coalinga Canal, Pleasant Valley Pumping Plant, and the San Luis Drain.

Los Banos (completed in 1965) and Little Panoche (completed in 1966) detention dams are located southwest of the town of Los Banos on Los Banos and Little Panoche Creeks, respectively. B.F. Sisk Dam and Reservoir, a 382-foot-tall zoned earthfill structure located on San Luis Creek near

[27] Source: http://www.water.ca.gov/swp/swptoday.cfm

Los Banos, were completed in 1967. The reservoir has a capacity of 2,041,000 ac-ft. O'Neill Dam, an 87-foot-high zoned earthfill structure located on San Luis Creek about 2.5 miles downstream of San Luis Dam, was completed in 1967. The O'Neill Pumping Plant was also completed in 1967. The William R. Gianelli Pumping-Generating Plant, located at San Luis Dam, was completed in 1967. The San Luis Canal, the largest earth-moving project in USBR history, extends 102.5 miles from the O'Neill Forebay to a location west of Kettleman City. Water was first released into the canal in 1967. The Dos Amigos Pumping Plant is located 17 miles south of the O'Neill Forebay.

The Pleasant Valley Pumping Plant, operated by Westlands Water District, lifts water at an intake channel leading from the San Luis Canal at mile 74. Coalinga Canal, also operated in part by Westlands Water District, extends from the turnout structure on the San Luis Canal to the Coalinga area in Fresno County. Construction of the San Luis Drain, designed to convey and dispose of subsurface irrigation return flows from the San Luis service area, began in April 1968. Construction was halted in 1975 because of high costs and concerns about the quality of the agricultural drainage that would enter the Delta.

San Luis Reservoir serves as the primary storage reservoir, and O'Neill Forebay serves as an equalizing basin for the pumping-generating plant. Pumps at the base of O'Neill Dam take water from the Delta-Mendota Canal through an intake channel and release it into the O'Neill Forebay. The California Aqueduct flows directly into O'Neill Forebay. The pumping-generating units take water from the O'Neill Forebay and discharge it into the main reservoir. When not pumping, the units generate electric power by reversing flow through the turbines. Water used for irrigation is discharged into the San Luis Canal and flows via gravity to Dos Amigos Pumping Plant, where it is elevated to allow for gravity flow to its terminus at Kettleman City.

A state canal system extends to southern coastal areas. During the irrigation season, water from the California Aqueduct flows through O'Neill Forebay into San Luis Canal rather than being pumped into San Luis Reservoir. The Los Banos and Little Panoche reservoirs are used to control cross drainage along the San Luis Canal and also provide flood control benefits. B.F. Sisk Reservoir is used to store surplus water of the Delta. A hydraulic junction for federal and state waters, B. F. Sisk Reservoir acts as a forebay for the Gianelli Pumping-Generating Plant. The primary purpose of the federal portion of the San Luis Unit facilities is to furnish approximately 1.25 million ac-ft of water to supplement irrigation supply to approximately 600,000 acres in western Fresno, Kings, and Merced counties.

San Felipe Division[28]

Initial authorization for construction of elements of the San Felipe Division occurred in 1960, and the division was fully authorized in 1967. Construction began in 1964 and was completed in 1987. The division consists of the Pacheco Tunnel, 48.5 miles of closed conduits, the Pacheco and Coyote pumping plants, San Justo Dam and Reservoir, and two associated switchyards. The Santa Clara Valley Water District manages the Santa Clara Tunnel and Conduit, Pacheco Tunnel and Conduit, and Pacheco and Coyote Pumping Plants. The Western Area Power Administration

[28] Source: http://www.water.ca.gov/swp/swptoday.cfm

manages Pacheco Switchyard, and San Benito County Water District manages San Justo Dam and Reservoir and Hollister Conduit.

Water from the Delta is transported through the Delta-Mendota Canal to O'Neill Forebay (see San Luis Unit, above), pumped into San Luis Reservoir, and then diverted through the Pacheco Tunnel Reach 1 to the Pacheco Pumping Plant. At the pumping plant, water is lifted to the Pacheco Tunnel Reach 2. The water flows through the tunnel and the 7.92-mile-long Pacheco Conduit, which extends to the bifurcation of the Santa Clara and Hollister conduits. The 22-mile-long Santa Clara Tunnel and Conduit convey water from the Pacheco conduit to the Coyote Pumping Plant, which is located at the end of the Santa Clara Conduit, near Anderson Dam. The 19.5-mile-long Hollister Conduit extends from the Pacheco Conduit to San Justo Reservoir. San Justo Dam, located about 3 miles southwest of Hollister, is a 151-foot-high earthfill structure that impounds a reservoir with a capacity of 9,785 ac-ft.

The primary recipients of water from the San Felipe Division are municipal and industrial users. The San Felipe Division provides supplemental irrigation to 63,500 acres and about 132,400 ac-ft of water annually for municipal and industrial uses.

State Water Project

The SWP is a complex system composed of pumping plants, hydroelectric power plants, water storage facilities with a combined capacity of approximately 5.8 million ac-ft, and approximately 700 miles of pipelines and canals (CDWR et al. 2013). It is the largest state-built water storage and conveyance project in the United States. The CDWR operates and maintains the SWP, which delivers water to 29 agricultural and municipal and industrial contractors in northern California, the San Joaquin Valley, the Bay Area, the Central Coast, and southern California.

SWP facilities south of the Delta in the San Joaquin River basin include the following: (1) the San Luis Area, which includes the Gianelli Pumping-Generating Plant and the Dos Amigos Pumping Plant, (2) the Coastal Branch Area, which consists of the Devil's Den, Bluestone, and Polonio Pass pumping plants and the Las Perillas and Badger Hill pumping plants, (3) the South San Joaquin Area, which includes the Buena Vista, Teerink and Chrisman, and Edmonston pumping plants, (4) the West Branch Area, which includes the Oso and Alamo pumping plants and the Warne and Castaic power plants, and (5) the East Branch Area, which includes Lake Perris, the Pearblossom Pumping Plants, and the Mojave and Devil Canyon power plants. The Gianelli Pumping-Generating Plant and Dos Amigos Pumping Plant are joint-use facilities, described above in the context of the CVP (see preceding section). The remaining facilities are described below.[29]

As noted above, water is pumped into the California Aqueduct at the Banks Pumping Plant and flows south by gravity to the San Luis Joint-Use Complex. After leaving the San Luis Joint-Use Complex, water travels through the California Aqueduct in the central San Joaquin Valley, until it reaches the bifurcation near Kettleman City, which conveys a portion of the water into the Coastal Branch Aqueduct (completed in 1997) to serve San Luis Obispo and Santa Barbara counties. The water remaining in the mainstem of the California Aqueduct is pumped uphill by the Buena Vista, Teerink, and Chrisman pumping plants until it reaches Edmonston Pumping Plant (operational

[29] Source: http://www.water.ca.gov/swp/swptoday.cfm

beginning in 1971), the SWP's largest pumping facility and the world's largest water lift. The Edmonston Plant pumps water nearly 2,000 feet up and over the Tehachapi Mountains through approximately 10 miles of tunnels. In so doing, it consumes 40 percent of the electricity used by the SWP.

As the water reaches the bottom of the mountain, it bifurcates into the West Branch and the East Branch aqueducts (the latter is the mainstem). Water in the West Branch is pumped by the Oso Pumping Plant into Quail Lake, from where it enters a pipeline leading into Warne Powerplant (operating since 1982). Water is then discharged into Pyramid Lake (Pyramid Dam was completed in 1973) and through Angeles Tunnel to the Castaic Powerplant (the latter two facilities are jointly operated by CDWR and the Los Angeles Department of Water and Power, which owns the facilities). At the end of the West Branch is Castaic Lake (Castaic Dam was completed in 1973) and Castaic Lagoon.

Water flowing down the East Branch generates power at Alamo Powerplant (completed in 1986) and is then pumped uphill by the Pearblossom Plant, from where it flows downhill through an open aqueduct, linked at its end to four underground pipelines that carry the water into the Mojave Siphon Powerplant, which discharges the water into Lake Silverwood. When water is needed, it is discharged into Devil Canyon Powerplant and its two afterbays. The 28-mile-long Santa Ana Pipeline then conveys the water underground to Lake Perris, the southernmost SWP facility.

The SWP's most recently constructed facility, the East Branch Extension, conveys water from Devil Canyon Powerplant's afterbay to Yucaipa Valley and the San Gorgonio Pass area in San Bernardino and Riverside counties. The project, which consists of 13 miles of buried pipeline, three pump stations, and a 90 ac-ft regulatory reservoir, is expected to meet the region's water needs for 40 years. SWP water will be used to recharge groundwater basins and allow greater flexibility for local water systems. The extension, completed in 2003, is a cooperative project between CDWR, the San Bernardino Valley Municipal Water District, and the San Gorgonio Pass Water Agency.

SWP deliveries provide water to 25 million Californians and about 750,000 ac of irrigated farmland. Other project functions include flood management, water quality maintenance, power generation, recreation, and fish and wildlife enhancement. The SWP operates under long-term contracts with public water agencies throughout California from counties north of the Delta to southern California. These public water agencies in turn deliver water to wholesalers or retailers or deliver it directly to agricultural and M&I water users (USBR and CDWR 2005). Of the contracted water supply, approximately 75 percent goes to M&I users and 25 percent to agricultural users.

5.3.1.4.3 Water Management in the San Joaquin, Merced, and Stanislaus Rivers

There are currently more than 80 dams on the San Joaquin, Merced, Tuolumne, and Stanislaus rivers, with a total storage capacity of over 7.7 million ac-ft. Combined, these facilities have the capacity to capture and control the entire average annual yield of the rivers they dam for the primary purposes of water supply, flood control, and hydroelectric power generation. The relatively large flows from the eastside tributaries, i.e., the Merced, Tuolumne, and Stanislaus rivers, strongly influence flow and water quality in the mainstem San Joaquin River. The westside tributaries are ephemeral, so water entering the San Joaquin River from the west side of the basin consists largely of agricultural return flows, which strongly influences the quality of water in the river.

San Joaquin River Mainstem

The flow regime downstream of Friant Dam (described as part of the Friant Division) has been managed since the implementation of the CVP (Cain et al. 2003). Friant Dam and its associated infrastructure irrigate approximately 1 million acres of agricultural land along the San Joaquin Valley's east side (Cain et al. 2003). In most years, these diversions take 95 percent of the river's average annual yield. A small fraction of the water is released according to a 1957 legal settlement to maintain flows (typically 250 cfs or less) during the irrigation season to support agricultural diversions by riparian water rights holders in the 36-mile reach between Friant Dam and the Gravelly Ford Canal. As a result, this reach of the river is wetted all year.

Below the Gravelly Ford Canal, the river channel is underlain by highly permeable bed material, and there are high rates of flow losses to infiltration. This reach has been allowed to go dry to avoid losing valuable surface water to groundwater infiltration (Cain et al. 2003). Riparian water rights holders downstream of Gravelly Ford have been served by the Delta-Mendota Canal, which delivers water from the Delta to the San Joaquin River at Mendota Pool. Mendota Pool is formed behind Mendota Dam and was originally constructed in the 1800s to divert irrigation water from the San Joaquin River to several irrigation districts now known as the San Joaquin River Exchange Contractors (Exchange Contractors). The Exchange Contractors agreed not to exercise their historic rights to the San Joaquin River's water in exchange for Sacramento River water delivered via the Delta- Mendota Canal. Today, Mendota Pool has a storage capacity of 3,000 ac-ft and distributes Delta water into a system of irrigation canals. Some water is released downstream of Mendota Pool into the historical channel of the San Joaquin River for subsequent diversion into Arroyo Canal at Sack Dam, 22 miles downstream of the Mendota Pool.

The San Joaquin River between Gravelly Ford and the Merced River has an unusually complex system of flood bypasses, which route most flood flows around the historical river channel and flood basin of the San Joaquin River (Cain et al. 2003). Authorized by the Flood Control Act of 1944, the San Joaquin River and Tributaries Project was constructed in the 1950s and 1960s and includes over 100 miles of levees and bypasses. Starting 35 miles downstream of Friant Dam, a levee-confined floodway between Gravelly Ford and the Chowchilla bypass is designed to convey 12,000 cfs, but due to channel aggradation and levee instability may only be able to safely convey 8,000 cfs. Approximately 45 miles downstream of Friant, large flood releases are diverted into the Chowchilla and Eastside Flood bypass systems, which route most of the river's floodwaters around the historical flood basin downstream of Mendota Pool.

There are hundreds of entities with rights to divert water from the San Joaquin River between the mouth of the Merced River and the Delta. Many of these are small, unscreened private irrigation diversions. Some diversions, such as those of the Patterson Irrigation District (at which a new fish screening facility was constructed in 2011) and the West Stanislaus Irrigation District, are capable of diverting hundreds of cfs of water.

The median annual unimpaired flow in the San Joaquin River at Vernalis from WY 1930 through 2008 was reportedly 5.9 million ac-ft (Cain et al. 2003). The median annual actual flow was reportedly 1.9 million ac-ft, or 32 percent of the median annual unimpaired flow. This reduction in actual flow compared to unimpaired flow is attributable to exports of water to locations outside the basin and consumptive use of water within the basin. Unimpaired flow in the San Joaquin River at Vernalis is primarily attributable to flow from the Stanislaus, Tuolumne, and Merced rivers, and during wetter water years, the upper San Joaquin River. In flood years, water from the Kings River also contributes to the flow in the San Joaquin River.

The San Joaquin River Restoration Program includes flow releases at Friant Dam to restore and maintain fish populations in good condition in the mainstem San Joaquin River. Interim flows were first released from Friant Dam on October 1, 2009. In 2013, interim flows between 350 and 400 cfs were released from Friant Dam to maintain the flow target at Gravelly Ford.[30] Up to 1,060 cfs was released from Friant Dam in 2013 as part of spring pulse flows. On January 2, 2014, flows released from Friant Dam were increased to 475 cfs to maintain the flow target at Gravelly Ford. However, beginning in February 2014, flows released from Friant Dam were decreased to 360 cfs to begin ceasing restoration flows because of drought conditions (i.e., a critical low-water year beginning March 1, 2014). Flows were reduced in 50-cfs increments until all restoration flows were discontinued. On February 15, 2016 flows released from Friant Dam were increased to 168 cfs to begin restoration flows. Flows released from Friant Dam increased to 235 cfs on February 16, to 285 on February 19 to meet the flow target at Gravelly Ford, and then decreased to 270 cfs on February 26 to maintain the flow target at Gravelly Ford.

Merced River

In about 1870, the Robla Canal Company, a private water company, began diverting water from the Merced River to eastern Merced County (Merced Irrigation District 2012). The Robla Canal Company was succeeded by the Farmers Canal Company, which was acquired by the Merced Canal and Irrigation Company in 1883 (Merced Irrigation District 2012).

Currently, four dams control the majority of flow in the Merced River: Merced Falls Diversion Dam, New Exchequer Dam, McSwain Dam, and Crocker-Huffman Dam (Cain et al. 2003). Merced Falls Diversion Dam (RM 55.0), constructed in 1901 by Pacific Gas and Electric Company, generates hydroelectric power and diverts flow into the Merced Irrigation District's (Merced ID) Northside Canal, which has a capacity of 90 cfs. In 1910, the Merced ID constructed Crocker-Huffman Dam (RM 52.0), which diverts flow into the Main Canal. The Main Canal has a capacity of 1,900 cfs and delivers water to lands south of the Merced River.

Exchequer Dam, the first major storage facility on the Merced River, was constructed in 1926 by the Merced ID. It stored flows during the high spring run-off period and released them during the irrigation season into the North and Main Canals at Merced Falls and at the Crocker-Huffman Diversion Dam. Due to its limited capacity of 281,000 ac-ft, Exchequer Dam did not capture all spring runoff and therefore did not allow for inter-annual water storage. Exchequer Dam, now

[30] Source: http://restoresjr.net/activities/if/index.html

known as Old Exchequer Dam, was inundated in 1967 by Lake McClure, when the Merced ID constructed New Exchequer Dam immediately downstream of the old dam (RM 62.5).

New Exchequer Dam and its downstream counterpart, McSwain Dam (RM 56.0), are the primary components of the Merced River Development Project, which is owned by the Merced ID and licensed by FERC. Lake McClure, the reservoir created by New Exchequer Dam, has a storage capacity of 1.03 million ac-ft and enables the Merced ID to store water in wet years for use during subsequent dry years. Lake McSwain, located 6.5 miles downstream of New Exchequer Dam, has a capacity of 9,730 ac-ft and is operated as a re-regulation reservoir and hydroelectric facility. Together, the New Exchequer and McSwain projects have a combined storage capacity of 1.04 million ac-ft, which amounts to 102 percent of the average annual runoff from the Merced River watershed. The Merced River Development Project provides agricultural water supply, hydroelectric power, flood control, recreation, and some water to maintain minimum instream flows for fish in the Merced River.

The ACOE regulates flood control operations on the New Exchequer Dam and Reservoir. According to the ACOE Water Control Manual, which dictates operations of the dam for flood control, a maximum of 400,000 ac-ft of space is dedicated to flood control during the winter runoff season, i.e., November 1 through March 15 (Stillwater Sciences 2001). A flood reservation storage capacity of 350,000 ac-ft is maintained for the rain flood pool between October 31 and March 15, and an additional 50,000 ac-ft is reserved for the forecasted spring snowmelt after March 1. The ACOE limits maximum reservoir releases to 6,000 cfs, measured at Stevinson gage near the confluence with the San Joaquin River. The maximum physical release from the New Exchequer outlet structure is 12,400 cfs.

The Merced River between Crocker-Huffman Dam (RM 52.0) and Shaffer Bridge (RM 32.5) has been extensively affected by alteration of the flow regime, water withdrawals, agricultural water returns, and land use activities (Stillwater Sciences 2001). The major water withdrawals are associated with the Cowell Agreement water users and riparian water users. These water users have maintained seven main channel diversions in this reach since the mid-1800s and have the right to divert annually up to approximately 94,000 ac-ft of water. The users divert water to private canals via small wing dams constructed in the channel each year with rock and gravel excavated from the river. Most of these diversions are unscreened. There are numerous agricultural water returns in this section of river as well. Downstream of Shaffer Bridge, CDFW identified 238 diversions, generally small pumps that deliver water for agricultural purposes (Stillwater Sciences 2001).

Stanislaus River

There are more than 30 dams in the Stanislaus River watershed, with a combined storage capacity of approximately 2.7 million ac-ft, more than 220 percent of the river basin's average annual runoff (Cain et al. 2003). Development of dams and diversions for both mining and irrigation began soon after the Gold Rush. Beginning in 1856, a series of water and power companies constructed several water supply and power facilities in the Stanislaus River Watershed. On the South Fork Stanislaus River, Big Dam and Herring Creek, Upper Strawberry, and Lower Strawberry reservoirs were constructed in 1856, Lyons Reservoir was constructed in 1898, and Philadelphia Diversion Dam

(11-foot-high concrete face rock masonry overflow spillway dam) in 1916. The Oakdale Irrigation District and San Joaquin Irrigation District were formed in 1909 and bought the Tulloch water rights and physical distribution system in 1910. The Sand Bar Diversion Dam (24-foot-high timber crib overflow spillway dam) and the Stanislaus Forebay (60-foot-high shotcrete face earthfill compacted rock overlay dam) were constructed on the Middle Fork Stanislaus River in 1908, and Relief Dam (144.5-foot-high concrete face rock masonry dam) in 1910. In 1917, Lower Strawberry Reservoir was enlarged from 1,190 ac-ft to 17,900 ac-ft (Strawberry Dam is a 133-foot-high concrete face rock masonry dam).

The Oakdale and San Joaquin irrigation districts built the original 80-foot Goodwin Dam in 1913 to divert water into the Oakdale and South San Joaquin Irrigation Canals. Despite its height, Goodwin Diversion Dam provided no usable storage. Oakdale Canal, with a capacity of 560 cfs, diverts water to the south, and the South San Joaquin Canal diverts up to 1,320 cfs to the north. The height of Goodwin Dam was increased in the late 1950s to create a re-regulating reservoir for the New Tulloch Dam.

In 1926, Oakland Irrigation District and San Joaquin Irrigation District constructed Melones Dam and its associated 112,500 ac-ft reservoir 15 miles upstream of Goodwin Dam to store spring runoff and release it downstream for diversion at Goodwin Dam (Cain et al. 2003). In 1929, Spicer Meadow Dam (with a reservoir capacity of 4,060 ac-ft) was completed on the North Fork Stanislaus River, and in 1930, Lyons Reservoir was enlarged from 839 to 5,508 ac-ft.

In 1948, the Oakdale and San Joaquin irrigation districts agreed to investigate the cost and feasibility of constructing additional dams to increase water supply and provide power production, and in 1955 the districts agreed to construct the Tri-Dam Project, including the Donnells Dam (483 feet high) and Reservoir (64,325 ac-ft) and Beardsley Dam (280 feet high) and Reservoir (97,802 ac-ft) on the Middle Fork Stanislaus River upstream of Melones Dam, and the Tulloch Dam (205 feet high) and Reservoir (66,968 ac-ft) downstream of Melones Dam. Construction of the three facilities was completed in 1957 and the facilities became operational in 1958. As part of the construction of the Tri-Dam Project, the height of Goodwin Diversion Dam was increased to 87 feet to create an afterbay to regulate discharge from Tulloch Dam. From 1985–1990, the Calaveras County Water District constructed the North Fork Stanislaus Hydroelectric Project, which included the construction of New Spicer Dam (265 feet high) and Reservoir (189,000 ac-ft) in 1989.

Melones Dam, now known as Old Melones Dam, was replaced and inundated in 1979 when the ACOE constructed New Melones Dam. New Melones Dam impounds the largest reservoir in the San Joaquin River Basin, with a storage capacity of 2.4 million ac-ft or 2.4 times the Stanislaus River's average annual runoff. New Melones Dam is operated and maintained by the USBR for flood control, to provide water for CVP contractors in the watershed, and to maintain water quality in the Stanislaus River and Delta.

5.3.1.4.4 Stockton Deep Water Ship Channel

The lower San Joaquin River flows north past the City of Stockton and into the Delta. The river connects the global economy to the Port of Stockton (Port) through a 78-mile-long DWSC

(Newcomb and Pierce 2010). The DWSC, which was first dredged in the 1930s, terminates at the Deep Water Turning Basin adjacent to the Port. The channel serves as a shipping corridor for cargo ships traveling from San Francisco Bay to the Stockton Port.

Periods of low DO concentrations have historically been observed in the DWSC; the majority of these low DO periods have occurred during summer and fall upstream of Turner Cut. In January 1998, the SWRCB adopted the CWA Section 303(d) list that identified this DO impairment, and the CVRWQCB initiated development of a TMDL to identify factors contributing to the DO impairment and assign responsibility for correcting the low DO problem (ICF International 2010).

Since the approval of the San Joaquin River DO TMDL Basin Plan Amendment in 2005, two actions have been implemented to alleviate low DO conditions in the DWSC: (1) the City of Stockton added engineered wetlands and two nitrifying bio-towers to the Stockton Regional Wastewater Control Facility to reduce ammonia discharges to the San Joaquin River and (2) the CDWR constructed the Demonstration Dissolved Oxygen Aeration Facility (Aeration Facility) at Rough and Ready Island to evaluate its applicability for improving DO conditions in the DWSC (ICF International 2010).

A full-scale aerator was constructed (using public grant funds) in the Stockton DWSC by CDWR and was operated by CDFW until 2011. In 2011, CDWR deeded the aerator to the Port of Stockton, which now owns and operates the facility. The annual cost of operating the aerator is the subject of a multi-party agreement. Twenty five percent of the cost is provided by the San Joaquin Tributaries Authority and San Joaquin River Group Authority, a joint powers authority that includes the Districts. The other cost-share partners in the operating agreement, and their cost-share percentages, are the CDWR jointly with the State Water Contractors (17 percent), the San Luis Delta Mendota Water Authority (12.5 percent), the San Joaquin Valley Drainage Authority (12.5 percent), and the Port of Stockton (33 percent). Upon completion of the operation agreement, the Port of Stockton will continue to own and operate the aerator.

5.3.1.4.5 Delta Water Management and Diversions

The Delta's boundaries are defined in Water Code § 12220, and encompass a roughly triangular area extending from Chipps Island near Pittsburg on the west, to the City of Sacramento on the Sacramento River on the north, and to the Vernalis gaging station on the San Joaquin River on the south. With the construction of the CVP and SWP, the Delta became a critical link in California's complex water distribution system (CDWR et al. 2013). Delta channels transport water mostly from upstream Sacramento Valley reservoirs to the South Delta, where the Banks and Jones pumping plants divert water into the California Aqueduct and the Delta Mendota Canal, respectively. The Delta is currently a conduit for water that is used for a wide range of instream, riparian, and other beneficial uses, including critical habitat for several native aquatic and terrestrial species, drinking water for more than 25 million people, and irrigation water for 4 million acres of farmland throughout the Delta and San Joaquin Valley.

The water balance in the Delta—i.e., total inflow versus total outflow—is controlled by supply from the Sacramento and San Joaquin rivers, eastside tributary rivers and streams, contributions from Coast Range watersheds, upstream diversions, demand from in-Delta water users, outflows from the Delta to the San Francisco Bay and Pacific Ocean, and exports to agricultural and M&I users outside the Delta (CDWR et al. 2013). Precipitation in the Delta region and small tributary inflows provide some water to the Delta, but these are minor compared to the flow contributions of the large rivers. The largest volume of water exiting the Delta is outflow, which is the water that travels through the Delta, contributes to in-channel and wetland coverage, and exits through the San Francisco Bay to the Pacific Ocean. Exports of water through the SWP and the CVP, followed by in-Delta use and local diversions, constitute the next largest volumes of water exiting the Delta.

There are over 3,000 diversions that remove water from upstream and in-Delta waterways for agriculture and M&I use (CDWR et al. 2013). Of these, 722 are located in the mainstem San Joaquin and Sacramento rivers, and 2,209 diversions are in the Delta (Herren and Kawasaki 2001). Of the 2,209 diversions in the Delta, most are unscreened and used for in-Delta agricultural irrigation (Herren and Kawasaki 2001). There are also numerous water management activities and diversions in eastside rivers that affect inflows to the Delta (e.g., to support M&I uses, hydroelectric generation, agriculture, and flood control in the Calaveras and Mokelumne river watersheds).

Population Growth and Water Demand

In the first decade of this century, California's population increased by 25 percent, double the national average (CDWR et al. 2013). The California Department of Finance estimates that the population will exceed 52 million by 2030 and reach nearly 60 million by 2050. In its 2009 update of the California Water Plan, CDWR used three possible future scenarios to forecast water demands up to the year 2050. It is estimated that water demands will be as high as 10 million ac-ft per year. In addition to the increased demand for Delta water resulting from population growth, established flow release requirements and restrictions on project operations for the protection of certain fish and wildlife species with critical life stages that depend on freshwater flows are expected to increase in the future. These current and projected future requirements all increase the competition for water supplies in the State of California.

With forecasts of reduced precipitation, shifts in timing of peak flow and runoff periods, reductions in snowpack, and impacts from a rising sea level resulting from global climate change, the struggle to meet the divergent demands for water will increase in the future. Nevertheless, the Delta will remain the center of California's water system, because the economies of major regions of the state depend on the water flowing through the Delta.

5.3.1.4.6 San Joaquin River and Delta Levee Construction and Maintenance

Beginning in the 1850s, the construction of levees around the San Joaquin River and Delta facilitated the conversion of lands to agricultural and other human uses. Combined with the straightening, widening, and dredging of channels, levee construction increased shipping access to the Central Valley and increased the ability to control water conveyance and prevent flooding (CDWR et al. 2013). Currently, the Delta is a highly engineered environment, composed of 57 leveed island tracts and 700 miles of sloughs and winding channels. Over 1,100 miles of levees protect 738,000 acres of Delta islands, tracts, and population centers from flooding and safeguard a large portion of California's water supply (CDWR et al. 2013). The extensive levee system supports widespread farming throughout the Delta. This has allowed farmers to drain and farm a large portion of the Delta, which in its natural state was a tidal marsh.

Most of the levees protecting the Delta (approximately 65 percent) are not part of the federal/state Sacramento Flood Control Project system and were constructed and are now maintained by island landowners or local reclamation districts (CDWR et al. 2013). These levees were generally built to an agricultural standard and may be less stable than those constructed and maintained to protect urban areas. Improvement and maintenance of these "non-project" levees can be challenging; the peat deposits that made the Delta a fertile farming location make poor materials for constructing levees and/or their foundations. Oxidization of these peat soils has led to island and levee subsidence, which has increased the burden on the levee system. Another way that the Delta levees are distinguished from levees along rivers such as the Sacramento and San Joaquin rivers is that they are constantly exposed to water, so they often act more as dams than levees, although they are not constructed or regulated to the same engineering standards as dams.

Currently, California has several programs in place to help manage risk and improve the environment in the Delta (CDWR et al. 2013). Local reclamation districts are responsible for maintaining their levees but may be reimbursed for a portion of the cost of maintenance under the State's Delta Levees Subvention Program, which was established in 1973. The Delta Flood Protection Fund Act of 1988 and the Delta Levee's Special Project program also provide financial assistance to local levee maintenance programs.

5.3.1.4.7 Land Use

Mining

Known mineral resources in the western Delta are primarily sand and gravel deposits that are valuable as construction aggregate or as construction fill material (California State Lands Commission [CSLC] 2012). Since 1915, millions of cubic yards of sand and gravel have been mined from Bay floor shoals. Sand mining in recent decades has been conducted under mining leases granted by the CSLC.

Based on the 2006 California Geological Survey study of aggregate availability, estimates of demand for construction aggregate in California over the next 50 years will total approximately 13.5 billion tons (Kohler 2006), not including increased demand following major bond initiatives (e.g., for public infrastructure projects, reconstruction following a major earthquake, etc.). Under the latest mining leases, an average of approximately 135,700 yd^3 per year were mined from the Delta and Carquinez Strait lease areas. Recently proposed 10-year mineral extraction leases that would enable continuation of dredge mining in the western Delta have been reviewed and approved by the CSLC.

Agriculture and Livestock Grazing

Agriculture is the primary land use along the lower San Joaquin River from its confluence with the Tuolumne River to Vernalis, with uses including fruit and nut orchards, field crops, vegetables, seed and other row crops, vineyards, and pastures (Mintier Harnish et al. 2009). The Delta's combination of highly productive soils, a climate conducive to agriculture, and readily available high quality irrigation water support a broad range of agriculture, including high value crops (CDWR et al. 2013). According to the Farmland Mapping and Monitoring Program classifications, Delta land used for agricultural purposes totals more than 575,000 acres, including approximately 395,000 acres of Prime Farmland, 33,000 acres of Farmland of Statewide Importance, 41,000 acres of Unique Farmland, 44,000 acres of Farmland of Local Importance (including locally-designated Farmland of Local Potential), and 63,000 acres of Grazing land (CDWR et al. 2013).

Over 30 types of crops are grown in the Delta region, including alfalfa, almonds, apples, apricots, asparagus, cherries, corn, squashes and melons, dry beans, grain and hay, wine and table grapes, miscellaneous truck crops, olives, peaches and nectarines, pears, rice, safflower, subtropical trees, Sudan grass, sugar beets, sunflowers, tomatoes, turf, and walnuts (CDWR et al. 2013). Areas with less productive soils such as hard pan or areas with high water tables or poor drainage are often used as pasture.

Delta agricultural production relies heavily on irrigation because there is low rainfall during the majority of the growing season (CDWR et al. 2013). Irrigation and drainage practices vary depending on the kind of crop being irrigated. Methods include drip, sprinkler, furrow, flood, border strip, basin, sub-irrigation, or a combination of these. Most crops produced in the Delta require weekly or biweekly irrigation throughout the growing season until a few weeks before harvest. In-season irrigation quantities depend on crop type, stage of crop growth, soil moisture profile, management of plant pests and diseases, and weather conditions. Generally, irrigation water is diverted directly from Delta waterways and transported to agricultural lands via canals. In some cases water is pumped directly into field furrows. Irrigation and drainage canals are operated and maintained in the Delta by reclamation districts, irrigation districts, and water agencies. Some of the agricultural surface water diversions are screened to protect fish, but many are not (CDWR et al. 2013).

Fertilizers, pesticides, and herbicides are commonly used to maximize yields and protect crops (CDWR et al. 2013). Fertilizers are used to replenish soil nutrients and may be composed of natural and/or synthetic materials with varying concentrations of plant nutrients. Although pesticides are designed to break down after a period of time, spray drift and groundwater contamination are common problems associated with applied pesticides (CDWR et al. 2013). Application methods for fertilizers, pesticides, and herbicides vary by crop and chemical type and include: chemigation (i.e., application through the irrigation system), orchard spray rigs, spray booms, brush brooms, broadcast spreaders, chemically coated seeds, and aerial applicators (crop dusters). The CDPR has documented over 300 herbicides and pesticides that are discharged throughout agricultural regions of California's Central Valley and Delta (Werner et al. 2008).

Delta agricultural runoff percolates into the water table or is discharged into Delta waterways (CDWR et al. 2013). Within the Delta, reclamation district canals and ditches frequently function as both water supply and drainage conveyance facilities, and they are typically kept at low water levels during the drainage season and pumped out by the reclamation districts to remove drainage and stormwater. During the crop irrigation season in subsurface irrigated areas, water is diverted from the Delta into these same ditches. Agricultural drainage water is captured in the canals and ditches and reused in subsequent irrigation. Most reclamation district drainage discharged into Delta waterways is for stormwater and flood management (CDWR et al. 2013).

Industrial and Residential Development

There are no incorporated cities along the lower San Joaquin River from its confluence with the Merced River to Vernalis. Rural residential use is typically the only type of development, and much of the population resides in surrounding cities (Mintier Harnish et al. 2009).

California is presently losing agricultural land at a rate of 49,700 ac annually, due in part to urban development fueled by population growth, housing prices, and commuting patterns (Kuminoff and Sumner 2001) as well as drainage problems, loss of reliable or affordable water supply, and conversion to wildlife habitat. These circumstances suggest that the existing land use patterns in the Delta and surrounding areas (including the lower San Joaquin River watershed) may experience continuing changes in the future, with a shift to more industrial, commercial, and residential land uses. Currently, there are 64,000 ac in the Delta that support urban and commercial land uses, although this is expected to increase due to population growth and the concomitant conversion of agricultural land to urban and residential uses.

There is little infrastructure along the lower San Joaquin River aside from that which supports agriculture and rural residential development. The Delta, on the other hand, contains much infrastructure of statewide importance, including transportation facilities and power generation and transmission facilities (Mintier Harnish et al. 2009). Three interstate highways (I-5, I-80, and I-580) pass along the periphery of the Delta; Interstate-5 is one of the most important north-south transportation routes on the west coast, running from the Mexican border to the Canadian border. It also runs along the entire eastern edge of the Delta. On an average day, the segments of I-5 that pass through Stockton carry approximately 130,000 vehicles. Ship traffic in the Delta supports interstate and international commerce. More than 300 ships and barges used the Stockton DWSC in 2005.

Electricity, gasoline, and other energy supplies for the region are provided by pipelines and transmission facilities that cross the Delta, and in 2004, there were approximately 240 operating natural gas wells in the Delta (Mintier Harnish et al. 2009). In addition, a large Pacific Gas & Electric Company gas storage facility is located under McDonald Island within the San Joaquin County portion of the Delta (Mintier Harnish et al. 2009). More than 500 miles of electrical transmission lines run through the Delta, portions of which carry power to other parts of the western United States. The petroleum pipelines that cross the Delta provide approximately 50 percent of the transportation fuel used in Northern California and Nevada (Mintier Harnish et al. 2009).

Recreation

Recreational use is a critical asset to the San Joaquin River watershed and Delta region. Visitors include local residents, residents from nearby communities, and many visitors from the Bay Area and other parts of the state (CDWR et al. 2013). Along the San Joaquin River and Delta waterways and on Delta islands, activities include picnicking, swimming, fishing, boating, waterskiing, nature study, sightseeing, horseback riding, tent and RV camping, biking, hunting, and hiking. Although these recreational activities contribute to local economies, they also increase pressure on an already fragile environment.

To support the high levels and diversity of recreational use, an extensive infrastructure of public (county, state, and federal) and private providers has been established within the region (CDWR et al. 2013). Tent and RV camping sites are located throughout the area. Most of the camping areas are privately owned at marinas around the Delta. There are, however, publicly owned camping sites such as Dos Reis Park on the San Joaquin River and Caswell Memorial State Park on the Lower Stanislaus River (near its confluence with the San Joaquin River). Public picnic areas along Delta waterways can be found at Buckley Cove Park (on the DWSC), Dos Reis Park, Mossdale Crossing (on the San Joaquin River), and Westgate Landing (on the Mokelumne River).

Habitat preserves and state and county parks (Dos Reis and Mossdale Crossing regional parks and Durham Ferry State Recreation Area) along the San Joaquin River provide recreational access (CDWR et al. 2013). The 7,000-ac San Joaquin River National Wildlife Refuge supports a mix of habitats that provide excellent conditions for wildlife and plant diversity. Visitor activities at the refuge include wildlife viewing, interpretation and environmental education, and photography. Formal fishing access and hunting opportunities are generally available in publicly owned parks or wildlife areas. Along some waterways, particularly along the DWSC, there are sandy beaches that are heavily used by boaters. Public boat launch facilities are available throughout the Delta, but a significant number of launches are associated with private marinas.

Changes in Land Use

With population growth in California above the national average, i.e., 2.1 percent versus 1.7 percent between 2010 and 2012,[31] changes in land use in the lower San Joaquin and Delta area are likely, but the nature and extent of those changes are uncertain. Urban development to accommodate population growth continues to occur in the counties of the Delta (CDWR et al. 2013). Limited housing supply and high home prices in the Bay Area have induced many Bay Area residents to relocate to Delta counties and commute long distances to work. As an example, since 1992, cities in San Joaquin County have annexed 27,769 acres, or 3 percent of the total area for urban development (CDWR et al. 2013). Additionally, population growth within and outside the Delta region will inevitably increase the amount of infrastructure that is required to support increases in residential, commercial, and industrial land development. Much of the land that will support this development will be acquired by conversion of agricultural lands.

California's focus on climate change and greenhouse gas reduction could also dramatically change the form of land use in the future (CDWR et al. 2013). Adopted on September 30, 2008, Senate Bill 375 is the State's first attempt to control greenhouse gas emissions by reducing urban sprawl. Senate Bill 375 links land use and transportation planning and encourages more compact, higher-density development through various incentives, including transportation funding and streamlined California Environmental Quality Act review. The bill has the potential to significantly change land use planning and growth patterns in and around the Delta region.

[31] http://quickfacts.census.gov/qfd/states/06000.html

Increasing environmental management and recovery activities in the San Joaquin and Sacramento river basins and in the Delta region (e.g., related to water management, water quality, conservation/recovery of rare, threatened, and endangered or commercially-viable species, etc.) may also impact patterns of land use change (CDWR et al. 2013).

5.3.1.4.8 Fish Hatchery Practices

CDFW is the principal agency responsible for managing and conserving fisheries and aquatic resources in California. As part of its responsibility, CDFW operates a statewide system of fish hatcheries that rear and subsequently release millions of trout, salmon, and steelhead of various age and size classes into state waters. These fish are reared and released for recreational fishing and commercial harvest, conservation and restoration of native fish species, mitigation for habitat losses caused by development, and mitigation for fish lost at pumping facilities in the Delta.

Anadromous fish hatcheries have been present in California since the first one was established by the United States Commission of Fish and Fisheries on the McCloud River in 1872 (JHRC 2001). In the early 1900s, CDFW assumed responsibility for stocking hatchery trout into state lakes and rivers. Since 1945, CDFW has reared inland and anadromous fish species at 21 hatcheries throughout California. CDFW currently stocks trout in high mountain lakes, low elevation reservoirs, and various streams and creeks. Salmon have been stocked primarily in rivers and direct tributaries to the Pacific Ocean, with the exception of kokanee, Coho, and Chinook salmon planted in reservoirs for sport fishing. Currently, California operates both trout (14) and salmon and steelhead (10) hatcheries throughout the state (ICF Jones & Stokes Associates, Inc. 2010). In addition to anadromous fish releases in the San Joaquin River basin, discussed below, fish are released from CDFW facilities in the Sacramento River basin, including fall-run Chinook salmon produced at the Nimbus Hatchery.

In the 1970s CDFW began stocking Chinook salmon in some California lakes and reservoirs (JHRC 2001). Initially, out-of-state sources of eggs were used, but subsequently, because none of these sources could provide disease-free eggs, eggs that were in excess of CDFW hatcheries' needs were used (JHRC 2001). Salmon, often from out-of-basin stocks, may have escaped downstream from the lakes and reservoirs in which they were planted and later returned as adults to that stream, possibly interbreeding with wild adult salmon from that stream (JHRC 2001). Until the early 1980s, California's hatcheries occasionally used broodstock from other basins or moved fry to other basins (JHRC 2001). This practice could have affected the genetics of fish naturally occurring in the receiving basins or resulted in the transfer of diseases from the hatchery to the wild populations (JHRC 2001).

Significant numbers of salmon from Central Valley hatcheries have been transported by truck to San Francisco Bay and released (JHRC 2001). For example, in 1999 the following releases of fall Chinook smolts were made downstream of the Delta: 5.88 million from the Feather River Hatchery; 3.8 million from the Nimbus Hatchery, and 1.72 million from the Mokelumne River Hatchery (JHRC 2001). Also in 1999, the Feather River Hatchery released 2.12 million of its spring Chinook smolts in San Pablo Bay (JHRC 2001). Releasing hatchery salmon downstream of the Delta improves their survival and contribution to fisheries and reduces the potential for competition of hatchery smolts with naturally produced fish (JHRC 2001). However, off-site releases may also increase the straying rate of returning adult salmon. Dettman and Kelley (1987) (as cited in JHRC 2001) estimated that 46 percent of Feather River Hatchery fish released in the Delta returned to rivers other than the Feather River. Releases that substantially increase the rate of straying fish, and likely increase interbreeding between natural and hatchery populations of different watersheds, are inconsistent with the CDFW and NMFS goal of maintaining the genetic integrity of wild salmon stocks (JHRC 2001).

The Merced River Fish Hatchery, located just downstream of the Crocker-Huffman Diversion Dam and operated by CDFW, began production in 1970 (Merced Irrigation District 2012). The hatchery rears fall-run Chinook salmon and follows an integrated broodstock strategy. Broodstock consists of unsegregated, natural and hatchery-produced Chinook salmon that volitionally enter the hatchery's facilities. Average annual production (from 2004–2008) was 972,344 fish, with most fish stocked as smolts. Most Merced River Hatchery fish are released from the hatchery from April through June, at 70 to 90 fish per pound. A Hatchery Genetic Management Plan (HGMP) has not been prepared for the Merced River Fish Hatchery, and until a HGMP is completed, the hatchery will continue to operate according to the existing hatchery and stocking plan.

Chinook salmon produced at the Merced River Fish Hatchery are routinely used for investigations in the San Joaquin River watershed, such as the previously conducted Vernalis Adaptive Management Plan smolt survival evaluations, and have been stocked in the Stanislaus and Tuolumne rivers. The Merced Irrigation District and others voluntarily fund the coded-wire tagging of smolts produced at the hatchery.

The Mokelumne River Fish Hatchery was built in 1963 by the East Bay Municipal Utilities District (and is operated by CDFW) to offset impacts to fisheries due to construction of Camanche Dam (ICF Jones & Stokes Associates, Inc. 2010). The hatchery is located on the south bank of the Mokelumne River immediately downstream of Camanche Dam and raises fall-run Chinook salmon and steelhead with water from Camanche Reservoir. In addition to mitigation responsibilities, the Mokelumne River Hatchery has an enhancement program supported by commercial salmon trollers. The Mokelumne River Hatchery receives its steelhead broodstock from the Feather River Hatchery or from adults returning to the hatchery, and has received broodstock fish from the American River, and Battle Creek (CDFW 2012). The Chinook salmon broodstock is of Central Valley origin. Average annual fish production at the Mokelumne River Hatchery from 2004 through 2008 was 5,351,901 fish. The normal Mokelumne River Hatchery release schedule is as follows: (1) fall-run Chinook salmon smolts are released from May through July into San Pablo Bay at 40–60 fish per pound and (2) steelhead yearlings are released from January through February into the lower Mokelumne River at four fish per pound.

5.3.1.4.9 Freshwater Salmonid Harvest

Commercial salmon fishing in California began in the early 1850s, coinciding with the influx of miners associated with the Gold Rush. By 1860, gill net salmon fisheries were well established in the lower San Joaquin River. Growth of this fishery was enhanced by the canning industry (CDFW 2013), and by 1880 there were 20 salmon canneries operating in the Sacramento and San Joaquin rivers, which increased fishing effort to maintain the supply of salmon. The salmon fishery reached its peak in 1882 when about 12 million pounds were landed and processed. Shortly thereafter, the fishery collapsed due to a sudden decline in salmon stocks caused by the pollution and degradation of rivers from mining, agriculture, and timber operations, combined with excessive fishing pressure. By 1919 the last inland salmon cannery had shut down, and in 1957 the last remaining commercial river fishery closed in the Sacramento-San Joaquin basin (CDFW 2013).

In past years, sport fishing for trout, steelhead, and salmon was closed from the I-5 bridge at Mossdale upstream on the San Joaquin River (CDFG 2011). However, 2013–2014 regulations allowed two hatchery trout or hatchery steelhead (four total possession limit) to be taken year round (CDFW 2013). Salmon fishing remains closed in the San Joaquin River, although some sport harvest takes place in the Delta.

5.3.1.4.10 Non-Native Species

Non-native species enter a region's aquatic systems in a variety of ways, most prominently through historical stocking by state resource management agencies, illegal introductions by anglers, ballast water discharged from ships, and boating activities. Introduction of non-native species has resulted in large changes in the fish community structure of the Central Valley (Moyle 2002). Non-native fish introductions in California date back to European settlement, and current fish communities in the lower reaches of the San Joaquin River tributaries and Delta are dominated by non-native taxa. Over 200 non-native species have been introduced in the Delta and become naturalized (Cohen and Carlton 1995), including many fish (e.g., smallmouth bass, largemouth bass, and striped bass) that prey on juvenile salmonids.

CDFW continues to manage some non-native fish species for recreational angling, such as black bass (open year round in the Delta with a five fish daily bag limit), striped bass (open year round in the Delta and lower San Joaquin River with a two fish limit), sunfish and crappie (open year round in the Delta with no size limit and a combined bag limit of 25), and catfish and bullhead (open year round in the Delta with no size or catch limit) (CDFG 2011).

The Delta, particularly the San Joaquin River between the Antioch Bridge and the mouth of Middle River and other channels in this area, are important spawning grounds for striped bass (CDFW 2014). Another important spawning area is the Sacramento River between Sacramento and Princeton (CDFW 2014). Sublegal striped bass, under 18 inches long, are found all year in large numbers upstream of San Francisco Bay, but their migratory patterns are poorly understood. After spawning, most adult striped bass move out of the rivers and into brackish and salt water for the summer and fall. However, some adult fish remain in freshwater during summer, and many anglers have caught striped bass at unexpected times and places (CDFW 2014).

5.3.1.4.11 San Joaquin River and Delta Aquatic Resources Management and Recovery Activities

There are numerous programs and efforts in the San Joaquin River Basin and Delta that have been completed, are currently underway, or are planned for the foreseeable future. These programs are likely to result in the establishment of new environmental mandates such as streamflow requirements, aquatic habitat restoration measures, and fish protection and recovery objectives.

Cumulatively, these requirements could have effects on aquatic resources and threatened and endangered species in the lower San Joaquin River and the Delta.

Final Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead

In 2014, NMFS issued a final Recovery Plan (NMFS 2014) for the endangered Sacramento River winter-run Chinook salmon ESU, threatened Central Valley spring-run Chinook salmon ESU, and threatened Central Valley steelhead DPS. Implementation of the recovery plan is intended to improve the viability of these species so they can be removed from federal protection under the ESA. The recovery plan describes the steps, strategies, and actions projected to return the three species to viable status in the Central Valley, thereby ensuring their long-term (i.e., greater than 100 years) persistence and evolutionary potential.

The recovery plan establishes watershed- and site-specific recovery actions. Watershed-specific actions address threats occurring in each of the rivers or creeks that support spawning populations of the ESUs and/or DPS. Site-specific actions address threats to these species occurring within a migration corridor (e.g., the Delta). Recovery actions were identified using two recovery planning public workshops and a number of ecosystem and/or anadromous fish enhancement plans. Recovery actions that have been identified in the Delta include development of alternative water diversion operations and conveyance systems, large-scale habitat restoration, integration of existing restoration programs, non-native predatory fish control, Yolo Bypass floodplain and fish passage enhancements, modifications to long-term operations of the CVP and SWP, and new stream flow requirements. Recovery actions that have been identified in the mainstem San Joaquin River include restoring floodplain habitat, implementing ecological flow schedules, reducing contaminants and improving water quality, and improving juvenile outmigration for steelhead and future spring-run Chinook salmon at CVP and SWP facilities.

San Joaquin River Restoration Settlement Act

The San Joaquin River Restoration Program (SJRRP) is a direct result of a settlement reached in September 2006 to provide sufficient fish habitat in the San Joaquin River below Friant Dam. Parties to the Settlement include the U.S. Departments of the Interior and Commerce, the Natural Resources Defense Council, and the Friant Water Users Authority. The settlement received federal court approval in October 2006. Federal legislation was passed in March 2009 authorizing federal agencies to implement the settlement.

The settlement is based on two goals: (1) to restore and maintain fish populations in "good condition" in the mainstem of the San Joaquin River below Friant Dam to the confluence of 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 could result from the interim flows and restoration flows provided for in the settlement.

The SJRRP outlines a comprehensive long-term effort to provide flows in the San Joaquin River from Friant Dam to the confluence of the Merced River to restore a self-sustaining spring-run Chinook salmon fishery while reducing or avoiding adverse water supply impacts. The program calls for full restoration flows beginning in 2014.

Implementation of the 2009 San Joaquin River Restoration Settlement Act and SJRRP has had significant effects on stream flows in the basin.[32] Annual restoration flows in the San Joaquin River vary between 0 ac-ft in dry years to more than 550,000 ac-ft in wet years. Combined with other flows in the watershed upstream of the Merced River confluence, these restoration flows are anticipated to provide 275,000 to 750,000 ac-ft of water in the San Joaquin River as measured at the confluence with the Merced River, depending on hydrologic conditions. The flow schedule is designed to support spring-run Chinook salmon reintroduction and may not be compatible with efforts to improve conditions for other salmonid species in the Merced River and other tributaries in the San Joaquin River basin.

The first interim water releases from Friant Dam in support of the SJRRP began on October 1, 2009. In 2013, interim flows between 350 and 400 cfs were released from Friant Dam to maintain the flow target at Gravelly Ford.[33] Up to 1,060 cfs was released from Friant Dam in 2013 as part of spring pulse flows. On January 2, 2014, flows released from Friant Dam were increased to 475 cfs to maintain the flow target at Gravelly Ford. However, beginning in February 2014, flows released from Friant Dam were decreased to 360 cfs to begin ceasing restoration flows because of drought conditions (i.e., a critical low-water year beginning March 1, 2014). Flows were reduced in 50-cfs increments until all restoration flows were discontinued. On February 15, 2016 flows released from Friant Dam were increased to 168 cfs to begin restoration flows. Flows released from Friant Dam increased to 235 cfs on February 16, to 285 on February 19 to meet the flow target at Gravelly Ford, and then decreased to 270 cfs on February 26 to maintain the flow target at Gravelly Ford.

Delta Water Quality Control Planning

Recognizing that many water issues in California involve both water quantity and quality, the California Assembly Committee on Water Pollution proposed a coordinated water regulatory program.[34] Concomitant statutory changes enacted in 1967 merged the State Water Quality Control Board and State Water Rights Board to form the SWRCB. In 1969, the California State Legislature enacted the Porter-Cologne Water Quality Control Act, which is the basis of current water protection efforts in California. In 1972, the State assumed responsibility for enforcing the federal CWA, which involved blending state and federal processes to regulate activities such as setting water quality standards and issuing discharge permits.

On August 16, 1978, the SWRCB adopted the 1978 Delta Plan and Decision 1485 (D-1485). The 1978 Delta Plan included WQOs intended to protect M&I, agricultural, and fish and wildlife beneficial uses in the Delta, and fish and wildlife beneficial uses in Suisun Marsh. The 1978 Delta Plan and D-1485 standards were based on the principle that Delta water quality should be at least

[32] Source: www.restoresjr.net
[33] Source: http://restoresjr.net/activities/if/index.html
[34] Source: http://www.swrcb.ca.gov/about_us/water_boards_structure/history_water_policy.shtml

as good as it would have been had the state and federal water projects not been constructed. The fish and wildlife standards in the 1978 Delta Plan and D-1485 were based on an agreement developed by CDWR, CDFW (then CDFG), the USBR, and USFWS. It was acknowledged that these standards did not afford a "without-project" level of protection for salmon, but the level of protection was believed to be reasonable until determinations regarding Delta mitigation measures were finalized.

D-1485 added conditions to the CVP's and the SWP's operating permits requiring that the projects meet applicable WQOs. In all SWP and CVP permits affecting the Delta, the SWRCB reserved jurisdiction to formulate or revise terms and conditions for salinity control and fish and wildlife protection, and to coordinate the terms and conditions between the two projects.

In 1985, some D-1485 standards were amended to modify or omit some monitoring stations in Suisun Marsh and to revise the schedule for implementation of salinity objectives. In May 1991, the SWRCB adopted the 1991 Bay-Delta Plan, which superseded WQOs in the 1978 Delta Plan and the San Francisco Bay and the Sacramento-San Joaquin Delta regional water quality control plans in instances where the existing plans conflicted with the 1991 Bay-Delta Plan. The 1991 Bay-Delta Plan contained a range of WQOs aimed at protecting beneficial uses. These objectives addressed (1) salinity levels for municipal and industrial intakes, Delta agriculture, water export agriculture, and estuarine fish and wildlife resources, (2) an expanded period of protection for striped bass spawning, and (3) temperature and DO levels for Delta fisheries. The 1991 Bay-Delta Plan did not include Delta outflow objectives and operational constraints. The flow and operational objectives in the 1978 Delta Plan remained in effect, implemented via D-1485. Beneficial uses and WQOs in the 1991 Bay-Delta Plan were submitted to EPA, which approved the objectives for M&I uses, agricultural uses, and DO for Fish and Wildlife in the San Joaquin River. However, all other fish and wildlife objectives were not approved by EPA, so relevant standards in D-1485 remained in effect.

In May 1995, the SWRCB adopted the 1995 Bay-Delta Plan, which was superseded by the 2006 Bay-Delta Plan, in instances where the 1995 plan conflicted with the 2006 plan. The 2006 Bay-Delta Plan included updates to address emerging issues that, because of changing circumstances or increases in scientific understanding, were either unregulated or not fully regulated by preceding plans. These issues included pelagic organism decline (pelagic fishes in the Delta Estuary and Suisun Bay), climate change, Delta and Central Valley salinity, and San Joaquin River flows. The 2006 Bay-Delta Plan included specific objectives related to the following variables: Delta outflow, flows in the Sacramento River at Rio Vista, flows in the San Joaquin River at Vernalis, export limits, Delta cross channel gates operation, and salinity.

Beginning on February 13, 2009, the SWRCB began updating and implementing the 2006 San Francisco Bay/Sacramento-San Joaquin Delta Estuary Plan (Bay-Delta Plan), particularly with regard to water quality and flow objectives and changes to water rights and water quality regulation consistent with the program of implementation. A technical report on the first phase of the project, Southern Delta Salinity and San Joaquin River flow objectives, was peer reviewed, and a final report was scheduled for release in early 2012. On January 24, 2012, the SWRCB issued a notice requesting additional information for the review of the Bay-Delta Plan.

The Bay-Delta Plan identifies beneficial uses of the Bay-Delta, WQOs for the reasonable protection of those beneficial uses, and a program of implementation for achieving the WQOs. The SWRCB recognizes that changing conditions may alter the flows needed to protect beneficial uses in the Bay-Delta. Changes in conditions that could affect flow needs include, but are not limited to, reduced reverse flows in Delta channels, increased tidal habitat, improved water quality, reduced competition from invasive species, changes in the points of diversion of the SWP and CVP, and climate change. The SWRCB will consider whether certain WQOs should be phased in over time and under what conditions that phasing should occur, in addition to what type of contingencies should be provided in the program if expected habitat improvements do not occur or if actions do not produce the expected results.

San Joaquin River and Bay Delta TMDL Plans

Adoption of TMDLs required under the CWA §303(d) has the potential to affect stream flows in the San Joaquin River. The SWRCB has initiated a comprehensive effort to address salinity and nitrate problems in the Central Valley and to adopt long-term solutions that will lead to enhanced water quality and economic sustainability. The Central Valley Salinity Alternatives for Long-Term Sustainability effort is a collaborative basin planning effort aimed at developing and implementing a comprehensive salinity and nitrate management program.

Additional San Joaquin River flows are being targeted to help dilute saline agricultural return waters and naturally occurring saline waters, pesticides, and other potentially toxic compounds and to reduce temperatures throughout the watershed. A partial list of San Joaquin River TMDLs that may directly or indirectly affect flows and water quality is shown below (SWRCB 2010):

Reach	Pollutant	Final Listing Decision
San Joaquin River (Tuolumne River to Stanislaus River)	Chlorpyrifos	Do Not Delist from 303(d) list (being addressed with EPA approved TMDL)
	DDT	List on 303(d) list (TMDL required list)
	Diazinon	Do Not Delist from 303(d) list (being addressed with EPA approved TMDL)
	Electrical Conductivity	List on 303(d) list (TMDL required list)
	Group A Pesticides	List on 303(d) list (TMDL required list)
	Mercury	List on 303(d) list (TMDL required list)
	Temperature, water	List on 303(d) list (TMDL required list)
	Unknown Toxicity	Do Not Delist from 303(d) list (TMDL required list)
San Joaquin River (Stanislaus River to Delta Boundary)	Chlorpyrifos	Do Not Delist from 303(d) list (being addressed with EPA approved TMDL)
	DDE	List on 303(d) list (TMDL required list)
	DDT	Do Not Delist from 303(d) list (TMDL required list)
	Diuron	List on 303(d) list (TMDL required list)
	Electrical Conductivity	Do Not Delist from 303(d) list (being addressed with EPA approved TMDL)
	Escherichia coli	List on 303(d) list (TMDL required list)
	Group A Pesticides	List on 303(d) list (TMDL required list)
	Mercury	List on 303(d) list (TMDL required list)
	Temperature, water	List on 303(d) list (TMDL required list)
	Toxaphene	List on 303(d) list (TMDL required list)
	Unknown Toxicity	Do Not Delist from 303(d) list (TMDL required list)

Reach	Pollutant	Final Listing Decision
Sacramento-San Joaquin Delta	Chlordane	List on 303(d) list (TMDL required list)
	DDT	List on 303(d) list (TMDL required list)
	Dieldrin	List on 303(d) list (TMDL required list)
	Dioxin compounds	List on 303(d) list (TMDL required list)
	Furan Compounds	List on 303(d) list (TMDL required list)
	Mercury	List on 303(d) list (being addressed by EPA approved TMDL)
	PCBs	List on 303(d) list (TMDL required list)
	Selenium	List on 303(d) list (TMDL required list)

Bay-Delta Conservation Plan

The Bay-Delta Conservation Plan (BDCP) was developed to provide for water supply reliability and recovery of listed species through a Habitat Conservation Plan under federal law and a Natural Community Conservation Plan under state law. The BDCP includes a wide range of actions related to habitat restoration, protection, and enhancement; water conveyance facilities; water operations and management; monitoring, assessment, and adaptive management; costs and funding; and governance structure and decision-making.

The BDCP was developed to address ecological needs of at-risk Delta species, primarily fish, while improving and securing a reliable water supply. The BDCP was structured to be a comprehensive restoration program, consisting of conservation measures designed to improve the state of natural communities, and in so doing, improve the overall health of the Delta ecosystem. The BDCP attempted to balance species conservation with a variety of other important uses in the Delta. A draft of the BDCP was issued but withdrawn and replaced by the California Water Fix and EcoRestore programs (see below).

Delta Stewardship Council

In November 2009, the Sacramento-San Joaquin Delta Reform Act was passed by the California Legislature and signed by the governor. It established a State policy of coequal goals (i.e., providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem) for the Delta and created the Delta Stewardship Council as a new, independent agency to determine how goals would be met through development and implementation of the Delta Plan. The BDCP (see preceding section) is to be included in the Delta Plan providing it is approved by state regulatory agencies and meets certain additional criteria. Because the Delta is linked to many statewide issues, the Plan will address decisions pertaining to statewide water use, flood management, and the Delta watershed.

Biological and Conference Opinion on the Long-Term Operation of the CVP and SWP

On June 4, 2009, NMFS released the Biological and Conference Opinion on the Long-Term Operation of the CVP and SWP. The opinion included a series of alternatives to avoid jeopardy of the continued existence of Central Valley steelhead, among other species, and adverse modification of its designated critical habitat. Among the alternatives identified are significantly higher instream flows in the Stanislaus River, San Joaquin River minimum flow requirements at Vernalis, and Delta export limitations to protect out-migrating anadromous salmonids.

Although the opinion addressed only the combined CVP and SWP operations, it concluded that "the long-term viability of this diversity group [steelhead] will depend not only on implementation of this reasonable and prudent alternative, but also on actions outside this consultation, most significantly increasing flows in the Tuolumne and Merced rivers." On September 20, 2011, the U.S. District Court invalidated the Biological and Conference Opinion and remanded it to NMFS for further consideration in accordance with the court's decision and the requirements of law. Since then, the 9th Circuit court overturned the lower court's opinion, and the 2009 BiOp is in effect and parties are complying with its directives.

The Central Valley Project Improvement Act

As noted previously, the Ecosystem Restoration Program[35] has funded projects involving habitat restoration, floodplain restoration and/or protection, instream habitat restoration, riparian habitat restoration and protection, fish screening and passage projects, research on and eradication of non-native species and contaminants, research on and monitoring of fisheries, and watershed stewardship and outreach. An Environmental Water Account is used to offset losses of juvenile fish at the Delta pumps, and to provide higher instream flows in the Yuba, Stanislaus, American, and Merced rivers to benefit salmonids.

The CVPIA added the purposes of fish and wildlife protection, restoration, and mitigation to the original CVP purposes of irrigation, domestic water use, fish and wildlife enhancement, and power augmentation. As part of the CVPIA, the following actions have been implemented: modifications of CVP operations, management and acquisition of water for fish and wildlife needs, flow management for fish migration and passage, increased flows, replenishment of spawning gravels, restoration of riparian habitats, screening of water diversions, and habitat restoration.

The Delta Pumping Plant Fish Protection Agreement and Tracy Fish Collection Mitigation Agreement

The Delta Pumping Plant Fish Protection Agreement and Tracy Fish Collection Mitigation Agreement mitigate for SWP pumping plant impacts by screening water diversions, enhancing law enforcement efforts to reduce illegal fish harvest, installing seasonal barriers to guide fish away from undesirable spawning habitat or migration corridors, and restoring salmon habitat. Mitigation has also included the removal of four dams to improve Chinook and steelhead passage on Butte Creek. Approximately one-third of the approved funding for salmonid projects specifically targets spring-run Chinook salmon and steelhead in upper Sacramento River tributaries.

CCSF Water System Improvement Program

On October 30, 2008, the SFPUC adopted a system-wide program, the Water System Improvement Program (WSIP, also known as the "Phased WSIP Variant") (SFPUC Resolution No. 08-200). The WSIP is a comprehensive program designed to improve the regional system with respect to water quality, seismic response, and water delivery based on a planning horizon through the year

35 http://www.dfg.ca.gov/ERP

2030. The WSIP also aims to improve the regional system with respect to water supply to meet water delivery needs in the service area through the year 2018.

The overall goals of the WSIP are to: maintain high-quality water, reduce vulnerability to earthquakes, increase delivery reliability and improve the ability to maintain the system, meet customer water supply needs, enhance sustainability in all system activities, and achieve a cost effective, fully operational system. To further these program goals, the WSIP also includes objectives that address system performance in the areas of water quality, seismic reliability, delivery reliability, and water supply.

Under the WSIP, the SFPUC established the year 2018 as an interim mid-term planning horizon for its water supply strategy. Thus, the SFPUC made a decision about a water supply strategy to serve its customers through 2018, and is deferring a decision regarding long-term water supply after 2018 and through 2030 until it undertakes further water supply planning and demand analysis.

The WSIP includes the following key program elements:

- Full implementation of all 17 proposed WSIP facility improvement projects described in the Program Environmental Impact Report.
- Water supply delivery of 265 million gallons per day (mgd) (average annual target delivery) to regional water system customers through 2018, with water supplies originating from the Tuolumne, Alameda, and Peninsula watersheds. This includes 184 mgd for wholesale customers (including 9 mgd for the cities of San Jose and Santa Clara) and 81 mgd for retail customers.
- Development of 20 mgd of conservation, recycled water, and groundwater within the SFPUC service area (10 mgd in the retail service area and 10 mgd in the wholesale service area).
- Dry-year transfer from the Modesto and/or Turlock Irrigation Districts of about 2 mgd coupled with the a conjunctive-use project to meet the drought year goal of limiting rationing to no more than 20 percent on a system-wide basis.
- Reevaluation of 2030 demand projections, potential regional water system purchase requests, and water supply options by 2018, as well as a separate SFPUC decision in 2018 regarding regional system water deliveries after 2018.

Under the WSIP, the SFPUC will deliver to customers up to 265 mgd from the SFPUC watersheds on an average annual basis. While average annual deliveries from the SFPUC watersheds would be limited to 265 mgd, such that there would be no increase in diversions from the Tuolumne River to serve additional demand, there would be a small increase in average annual Tuolumne River diversions of about 2 mgd over existing conditions to meet delivery and drought reliability goals through 2018.

Day-to-day operation of the regional water system under the WSIP would be similar to existing operations, but would provide for additional facility maintenance activities and improved emergency preparedness. This would allow the SFPUC to meet its WSIP objectives and provide for increased system reliability and additional flexibility for scheduling repairs and maintenance. The proposed operations strategy would also include a multistage drought response program.

Under the WSIP, regional water system operations would continue to comply with all applicable institutional and planning requirements, including complying with all water quality, environmental and public safety regulations; maximizing the use of water from local watersheds; assigning a higher priority to water delivery over hydropower generation; and meeting all downstream flow requirements.

The California Water Fix

The California Water Fix is a proposal to improve the SWP and CVP freshwater storage and delivery systems, and involves the following primary elements: (1) construction and operation of new water conveyance facilities in the Delta, including three intakes, two tunnels, appurtenant structures, a permanent head of Old River gate, and expansion of the Clifton Court Forebay, (2) coordinated operation and maintenance of existing and new SWP and CVP Delta facilities, (3) resource conservation measures, and (4) a monitoring and adaptive management program. These improvements are being undertaken to help protect California's water supply from the effects of earthquakes, flooding, and rising sea levels; reduce waste of fresh water; and improve habitat for fish and wildlife.

California EcoRestore

The California Natural Resources Agency is implementing EcoRestore in coordination with other state and federal agencies to contribute to the restoration of at least 30,000 acres of Delta habitat by 2020. The science-driven objectives will be guided by an adaptive management program to pursue habitat restoration projects with well-defined goals and objectives and the financing needed to successfully implement the projects. Habitat types identified for restoration include tidal wetlands, floodplains, riparian areas, and uplands. Fish passage improvements and other projects are also elements of the program.

SWB Revised Draft Substitute Environmental Document

The SWB protects beneficial uses of water in the Bay-Delta via the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). The SWB is proposing to amend two elements of the Bay-Delta Plan: (1) San Joaquin River flow objectives to protect fish and wildlife and (2) Southern Delta salinity objectives for the protection of agriculture. On September 15, 2016, the SWB released for public comment the Revised Draft SED, which provides a description of these proposed amendments and the SWB's analysis of their potential effects. The flow element of the proposed amendments would, if adopted, require that increased flows remain in the San Joaquin River and its three major tributaries–the Stanislaus, Tuolumne, and Merced rivers–and would establish flow-related compliance locations on each of these major tributaries, in addition to the current flow compliance point located on the San Joaquin River at Vernalis.

5.3.2 Assessment of Cumulative Effects on Fall-Run Chinook Salmon

The following cumulative effects assessment section is organized according to the types of effects resulting from the actions described in the previous sections. Topics include (1) hydrologic and physical habitat alteration, (2) temperature and water quality, (3) connectivity and entrainment, (4) hatchery propagation and stocking, (5) introduced species and predation, (6) benthic invertebrates and fish food availability, and (7) freshwater harvest and poaching, and (8) effects of ocean conditions. The geographic scope of the assessment, as noted above, includes the Tuolumne River from La Grange Diversion Dam to its confluence with the San Joaquin River and the San Joaquin River downstream through the Delta.

The Don Pedro Project contributes to cumulative effects on fall-run Chinook salmon EFH, in the lower Tuolumne River and downstream in the San Joaquin River and Delta. Other actions conducted within the Tuolumne River basin that contribute to cumulative effects include CCSF's operations of the Hetch Hetchy system, water diversions at La Grange Diversion Dam, riparian withdrawals by water users, discharge of irrigation return flows, historic and current mining activities, agricultural and urban land uses, the presence of non-native species, stocking of hatchery salmonids, and measures (both existing and proposed) undertaken to benefit aquatic resources, Chinook salmon in particular. In addition, ongoing operation of reservoir and diversion facilities in the San Joaquin River and its tributaries, along with an array of other actions (see previous section), also contribute to cumulative effects on fall-run Chinook EFH in the Action Area.

5.3.2.1 Hydrologic and Physical Habitat Alteration

5.3.2.1.1 Lower Tuolumne River

Prior to widespread European settlement, the channel form of the lower Tuolumne River consisted of a combination of single-thread and split channels that migrated and avulsed (McBain & Trush 2000). Variation in hydrologic and geological controls, primarily valley width and the location and elevation of underlying bedrock, resulted in variable and complex localized channel morphologies (McBain & Trush 2000). The riparian corridor was miles wide in places where the river lacked confinement (McBain & Trush 2000). More than a century of cumulative impacts have transformed the lower Tuolumne River from a dynamic, alluvial system capable of forming its own bed and bank morphology to a river highly constrained between either man-made dikes or agricultural fields, or constrained by riparian vegetation that has encroached into the low water channel (McBain & Trush 2000).

Hydrologic Alteration

Over the past 120 years, each increment of flow regulation (Wheaton, La Grange, Dennett, O'Shaughnessy, old Don Pedro, and new Don Pedro dams along the mainstem and dams constructed along tributaries above O'Shaughnessy Dam, including Cherry and Eleanor Creeks) has modified the lower Tuolumne River's flow regime. Historically, Wheaton Dam and the present day La Grange Diversion Dam lacked the storage capacity needed to affect high flow conveyance to the lower Tuolumne River during winter and spring (McBain & Trush 2000). CCSF's Hetch Hetchy Project, the Districts' new Don Pedro Dam, and CCSF's Cherry Lake combined to reduce the magnitude and frequency of flood flows and snowmelt runoff to the Tuolumne River downstream of La Grange Diversion Dam. Indeed, reducing flood flows was an intended purpose of the Project at the time of its construction. The ACOE contributed financially to the construction of the new Don Pedro Dam to aid in the implementation of the basin's federally orchestrated flood control program.

Analyses of streamflow records from the USGS gaging station at La Grange (Station 11-289650) reveal the following alterations of hydrologic conditions: (1) reduction of the magnitude and variability of summer and winter base flows and spring snowmelt runoff and (2) the magnitude, duration, and frequency of winter floods (McBain & Trush 2000). Following completion of the new Don Pedro Dam in 1971, compliance with ACOE flood control and other flow requirements reduced the estimated average annual flood (based on annual maximum series) from 18,400 cfs to 6,400 cfs.

Physical Habitat and Riparian Alteration

Gravel and gold mining, as well as other land uses, adversely affected aquatic habitat prior to the construction of dams on the Tuolumne River (TID/MID 2005) (see Table 5.3-1 for a summary of the chronology of actions within the defined geographic scope for cumulative effects). The presence of dams, aggregate extraction, agricultural and urban encroachment, and other land uses, including hydraulic mining practices near La Grange, have resulted in imbalances of sediment supply and transport in the lower Tuolumne River channel (McBain & Trush 2000). Don Pedro Dam and La Grange Diversion Dam, combined with other dams upstream of the Project Boundary, trap all coarse sediment and LWD that would otherwise pass downstream. In the lower river, in-channel excavation of bed material to depths well below the river thalweg for gold and aggregate has significantly reduced available spawning habitat, eliminated active floodplains and terraces, and created large in- and off-channel pits that provide favorable habitat for non-native predator species.

The cumulative effect of sediment trapping by upstream reservoirs, mining, and other land uses has altered the channel downstream of La Grange Diversion Dam (CDWR 1994; McBain and Trush 2004). Sequences of historical photos show that channel corridor width has been progressively reduced by land use (McBain and Trush 2000). Sediment model simulations indicate that without gravel augmentation, the channel bed from RM 52 to 39.7 would undergo a slow loss of gravel and increased coarsening (armoring) in response to the reduction in sediment supply (TID/MID 2013, WA&R-04). Gravel augmentation, however, has helped to increase coarse sediment storage in this area (TID/MID 2013h). The current rate of gravel transport in this reach is low compared to the stores of gravel.

Large in-channel pits (SRPs) were created where sand and gravel aggregate were extracted. Historical deposits of dredger tailings (RM 50.5–38.0) confined the active river channel, preventing sediment recruitment that would otherwise have resulted from the normal process of channel migration (McBain and Trush 2000). Under current conditions, channel migration has been substantially curtailed.

More recent aggregate mining operations have excavated sand and gravel from floodplains and terraces immediately adjacent to the river channel at several locations downstream of Roberts Ferry Bridge (RM 39.5). Floodplain and terrace pits in this reach are typically separated from the channel by narrow berms that can breach during high flows, resulting in capture of the river channel. The January 1997 flood caused extensive damage to dikes separating deep gravel mining pits from the river as water breached or overtopped nearly every dike along a 6-mile-long reach (TID/MID 2011).

Most woody debris captured in Don Pedro Reservoir is small, and it appears that the majority of it would pass through the lower river during normal high flows if it were not trapped in the reservoir (TID/MID 2017f). The lower Tuolumne River between RM 52 and 26 has channel widths averaging 119 feet, and woody debris would have a limited effect on channel morphology in this reach (TID/MID 2017f).

Clearing of riparian forests in the Tuolumne River basin has modified vegetation and associated habitat, altering many attendant ecosystem processes (Katibah 1984; Naiman et al. 2005). Urban and agricultural encroachment have resulted in the direct removal of large tracts of riparian vegetation in the lower Tuolumne River corridor. Livestock selectively graze younger vegetation, which limits the establishment of riparian plants (McBain and Trush 2000). Clearing woody plant cover has also created openings in the riparian corridor where non-native plant species have become established and proliferated (McBain and Trush 2000). Land conversion and levee construction that constrained channel migration, including alteration of meander bends and cutoff/oxbow formations, have reduced riparian complexity (McBain and Trush 2000; Grant et al. 2003).

Mining has also substantially altered riparian conditions along the lower Tuolumne River. Aggregate mining leaves large pits in the floodplain, converting floodplain vegetation to open water. Levees built to isolate mining pits from the river constrain lateral movement of the river (TID/MID 2013c). These activities preclude regeneration of riparian vegetation by eliminating habitat and limit lateral movement of the river, reducing the amount and diversity of riparian habitat surfaces (TID/MID 2013c). Dredger tailings of unconsolidated sediments on the floodplain have replaced rich soils with poor ones, resulting in changes in riparian species composition and a reduced extent and diversity of riparian vegetation (TID/MID 2013c). The reduced development of riparian vegetation on dredger spoil piles has diminished riparian habitat connectivity (TID/MID 2013c).

Flow regulation and sediment trapping associated with upstream dams indirectly affected riparian vegetation by modifying the hydrologic and fluvial processes that influence survival and mortality of riparian vegetation. As noted above, each increment of flow regulation (La Grange Diversion Dam, O'Shaughnessy Dam, Old Don Pedro Dam, New Don Pedro Dam) successively reduced the magnitude, duration, and frequency of flood flows, and removed key mortality agents, including scour, channel migration, flood-induced toppling, and inundation (McBain and Trush 2000). In some areas, reduced flood scour has allowed riparian vegetation to encroach along the low water channel, where historically vegetation would have been absent. In other areas, as noted above, the legacy of impacts has altered the structure of the floodplain and reduced the potential for establishment.

The lateral extent of riparian vegetation along the Tuolumne River is greatly diminished from what it was prior to large-scale settlement along the river. Currently, less than 15 percent of the historical riparian forests remain along the Tuolumne River (McBain and Trush 2000). However, over the past 15 years the areal extent and location of lands dominated by non-native plants has actually decreased (TID/MID 2013c). Overall, the 52-acre average of native riparian vegetation per river mile is slowly changing, with a 419-acre increase in the net extent of native vegetation between 1996 and 2012 (an average increase of about 8 acres/mile), assisted by active restoration projects (TID/MID 2013c).

Effects on Fall-Run Chinook EFH

Fall-run Chinook abundance in the Tuolumne River has been reduced by habitat degradation and extensive instream and floodplain mining beginning in the mid-1800s (McBain and Trush 2000). Dams and water diversions associated with mining had affected fish migration as early as 1852 (Snyder 1993 unpublished memorandum, *as cited* in Yoshiyama et al.1996). Access to historic spawning and rearing habitat was restricted beginning in the 1870s, when a number of dams and irrigation diversion projects were constructed. Wheaton Dam, built in 1871 near the site of the present-day La Grange Diversion Dam, was a barrier to salmon migration. In 1884, the California Fish and Game Commission reported that the Tuolumne River was "dammed in such a way to prevent the fish from ascending" (California Fish and Game Commission 1884, *as cited* in Yoshiyama et al. 1996).

During their upstream migration, Tuolumne River flows may affect homing of Tuolumne River origin Chinook salmon, and may also affect straying of salmonids from other rivers into the Tuolumne River (TID/MID 2013f). However, weir counts suggest that after adult Chinook enter the Tuolumne River, fall pulse flows are not necessary to enhance upstream migration.

Studies conducted in the Tuolumne River indicate that a lack of spawning gravel and curtailed sediment recruitment, due to in-river and floodplain mining, trapping by upstream dams, and other land uses, may result in density-dependent competition and exclusion from suitable spawning sites and may limit the number of female Chinook salmon that successfully spawn in the lower Tuolumne River (TID/MID 1992, 2000, 2001). TRCh results indicate that Chinook salmon are limited by spawning habitat availability at high spawning fish densities in wet years but at both low and high fish densities during dry years (TID/MID 2017a). Upstream reaches affected by gold dredger mining in the early part of the century (RM 50–47) were "reconfigured" following removal of dredger tailings for construction of the new Don Pedro Dam, and this reach currently supports the majority of fall-run Chinook salmon spawning activity (TID/MID 2013f).

Although there is the potential for Chinook redd scouring to occur during flood events, minimum spawning flows required by FERC have reduced the risk of redd dewatering (TID/MID 2013f). The risk of mortality due to redd scour, redd dewatering, and entombment is considered to be low in the Tuolumne River due to current operations and reduced fine sediment supply in much of the spawning reach (TID/MID 2013f).

Floodplain access for rearing juvenile Chinook salmon is limited in the lower Tuolumne River due to flows and habitat modification. Section 4.4 of this EFH Assessment provides a summary of the results of floodplain habitat modeling conducted by the Districts (TID/MID 2017d). Results of this study show that estimates of total usable habitat including both in-channel and floodplain areas steadily increases with increasing discharge in the upper reach (RM 52.2–40), but total habitat area becomes limited at intermediate discharges in the reaches downstream of RM 40, because reductions in suitable main channel habitat (primarily as the result of unsuitable water velocities) are not offset by increases in floodplain habitat.

Because current Don Pedro Project operations do not include power peaking, potential risk of juvenile Chinook salmon stranding and entrapment are low. Some stranding may occur during flow reductions following flood control releases; however, the low frequency of these flood events in combination with ramping rate restrictions required by the current FERC license likely result in a low risk of fish mortality due to stranding and entrapment (TID/MID 2013f). A comprehensive evaluation of stranding surveys was conducted on the lower Tuolumne River (TID/MID 2000) and is summarized in the 2005 Ten-Year Summary Report (TID/MID 2005). This evaluation indicated that the highest potential for stranding occurred at flows between 1,100 and 3,100 cfs, i.e., the range of flows under which the floodplain is inundated in several areas of the Chinook spawning reach.

Although increased structure often increases the quality of salmonid habitat in streams, it is unlikely that the alluvial portions of the Tuolumne River downstream of La Grange Diversion Dam historically supported the large wood or boulder features that are more typically found in high-gradient streams of the Central Valley and along the coasts of California and Oregon (TID/MID 2013f), so it is unclear to what degree LWD retention by upstream dams has contributed to adverse habitat effects in the lower river. Although LWD provides habitat for salmonids in some systems, there are no data available for the Tuolumne River or neighboring Merced River that specifically address the role of LWD on salmonid abundance (TID/MID 2017f). Of the 121 locations within the W&AR-12 study reach where LWD was recorded, about 80 percent of it was located in or adjacent to runs or pools. Because most LWD in the lower Tuolumne River is partially or wholly out of the channel, and due to its small size, it does not provide significant cover for fish, which in turn limits its value as protection from avian and aquatic predators.

SRPs, created by in-channel mining, can be up to 400 feet wide and 35 feet deep and occupy approximately 32 percent of the length of the channel in the gravel-bedded zone (RM 52–24). These habitat features harbor non-native fish, such as introduced largemouth and smallmouth bass, that prey on juvenile salmonids (see Introduced Fish Species, below). Introduced predators have been, and continue to be, most abundant in large, slow-moving areas prevalent in the middle section of the lower river, downstream of the major Chinook salmon spawning areas (Orr 1997). It is likely that the present pattern and degree of predation mortality for Chinook juveniles in the Tuolumne River is to a large extent a result of past sand and gravel mining coupled with the introduction by CDFW of non-native piscivorous fish species (Orr 1997).

Continued hydroelectric power generation at the Project as part of the Proposed Action would not contribute to cumulative effects on fall-run Chinook EFH in the lower Tuolumne River, because the lower river flow regime is dictated by the independent, non-interrelated primary purposes of the Don Pedro Project (i.e., water supply, flood control, CCSF's water bank) and releases to protect aquatic resources. However, some of the Districts' proposed measures for the lower Tuolumne River would contribute positively to cumulative effects on flow regime and physical habitat, which would influence fall-run Chinook, as described below. Greater detail on the measures listed below, and their direct effects, can be found in Section 5.2.

- **Gravel Augmentation**: Gravel augmentation at discrete locations from RM 52–RM 39 would enhance the quality and quantity of fall-run Chinook spawning habitat. Adding coarse sediment (0.125–5.0 inches in diameter) to the river channel at locations selected based on biological and geomorphic needs, would result in the following expected benefits (1) an increase in fall-run Chinook egg-to-emergence survival, (2) reduced superimposition of fall-run Chinook redds, (3) increased benthic macroinvertebrate production, and (4) potentially improved hyporheic flow and cold water habitat downstream of La Grange Diversion Dam.
- **Gravel Mobilization Flows**: Flow releases ranging from 6,000–7,000 cfs (measured at USGS gage 11289650 below La Grange Diversion Dam) would provide the following expected benefits (1) reduced fine sediment storage in the low-flow channel and in fall-run Chinook spawning gravels, which could increase egg-to-emergence survival and fry production, and could improve benthic macroinvertebrate production, (2) increased fine sediment storage on floodplains, which could improve regeneration of native riparian plant species during wetter water years, and (3) a net increase in lateral channel migration, bar formation, and large wood introduction, which together could create new floodplains and complex hydraulic environments resulting in improved fall-run Chinook adult holding, spawning, and juvenile rearing habitat.
- **Gravel Cleaning:** Experimental gravel cleaning to flush fine sediments from gravel interstices has the potential to expand the availability of high quality gravel, which would improve spawning success and egg incubation for fall-run Chinook. Gravel cleaning would coincide with the May pulse flows (see below) to aid fall-run Chinook smolt outmigration by providing increased turbidity to reduce predator sight-feeding effectiveness.
- **Improve Instream Habitat Complexity**: Boulders (approximately 0.7-1.5 yd^3 in size) placed between RM 50 and RM 42 are expected to increase structural and hydraulic complexity, and improve spawning habitat for fall-run Chinook as localized scour displaces fines from gravel beds. This measure could also result in local increases in benthic macroinvertebrate production, through substrate improvements due to the scouring of fines.
- **Contribute to CDBWs Efforts to Remove Water Hyacinth**: Providing matching funds to California DBW for the removal of water hyacinth in the lower Tuolumne River would likely benefit aquatic biota in the lower river, possibly including fall-run Chinook salmon passing through the lowermost reaches of the river where water hyacinth infestations occur.
- **Fall-Run Chinook Spawning Improvement Superimposition Reduction Program**: Installation of a temporary barrier in the lower river channel is expected to reduce rates of fall-run Chinook redd superimposition. Rates of redd superimposition are relatively high for fall-run Chinook in the lower Tuolumne River due to a strong preference for spawning upstream of RM 47 (TID/MID 2013f, 2017a), even though suitable spawning gravel exists in the lower Tuolumne River downstream to approximately RM 30.
- **Flow-Related Measures for Fish and Aquatic Resources in the Lower Tuolumne River**: The Districts are proposing to implement the flow regime summarized in Table 5.2.3 and described in greater detail in Section 5.2 for the following objectives: (1) flows from June 1–June 30 to benefit *O. mykiss* fry rearing (2) flows from July 1–October 15 to benefit *O. mykiss* juvenile rearing, (3) flows from October 16–December 31 to provide habitat for fall-run Chinook spawning, (4) flows from January 1–February 28/29 to provide habitat for fall-run

Chinook fry rearing, (5) flows from March 1–April 15 to provide habitat for fall-run Chinook juvenile rearing, (6) fall-run Chinook outmigration base flows from April 16–May 31, and (7) outmigration pulse flows from April 16–May 31. The direct benefits of these flows on fall-run Chinook are described in Section 5.2. These flows would contribute positively to cumulative effects on fall-run Chinook EFH.

- **Flow Hydrograph Shaping**: Shaping the descending limb of the snowmelt runoff hydrograph to mimic natural conditions to facilitate cottonwood seed dispersal would increase natural recruitment of snowmelt-dependent hardwoods that could contribute woody debris to the channel over the long-term and provide cover and shade for aquatic organisms, including fall-run Chinook.

5.3.2.1.2 San Joaquin River and Delta

Flows in the San Joaquin River and its tributaries, combined with flow diversions at the SWP and CVP water export facilities, may affect homing of Tuolumne River-origin Chinook salmon during their upstream migration (TID/MID 2013f). Homing fidelity of Chinook salmon to their natal streams is related to the sequence of olfactory cues imprinted during rearing and outmigration, so attraction flows and entrainment of flows into the SWP and CVP may affect the numbers of Chinook salmon returning to the Tuolumne River. However, other than the broad relationships between Vernalis flows, water exports at the SWP and CVP facilities, and subsequent recoveries of hatchery-reared, code-wire-tagged fish recovered in Sacramento and San Joaquin River basin hatcheries (Mesick 2001), the relationship between San Joaquin River tributary homing and attraction flows remains poorly understood. Flow alterations may also affect straying of salmonids from other rivers into the Tuolumne River (TID/MID 2013f), which could in turn affect fall-run Chinook.

The extent of historical flooding in Central Valley rivers was vast (Kelley 1989), and the timing of Chinook salmon outmigration would have allowed juveniles to exploit habitats provided by prolonged periods of floodplain inundation. Reductions in wetland and floodplain habitats in the lower San Joaquin River and South Delta, and changes in tributary flow magnitudes and timing, have reduced access to Delta floodplain habitats used by rearing and emigrating Chinook salmon from the Tuolumne River (Whipple et al. 2012; TID/MID 2013f).

Few locations in the eastern and central Delta provide suitable habitat for rearing salmonids (TID/MID 2013f). Because extended periods of floodplain inundation do not occur in most areas of the lower San Joaquin River and Delta, except as the result of large flood control releases from tributaries, it is likely that changes in Delta habitats have affected the number and growth of rearing Chinook salmon, resulting in a reduction in the number and size of smolts entering the ocean and potential reduction in ocean survival (TID/MID 2013f). However, winter inundation of some flood bypasses and floodplains along the lower portions of some San Joaquin River tributaries still provides some juvenile Chinook salmon rearing habitat (Feyrer et al. 2006; Sommer et al. 2001; Sommer et al. 2005; Moyle et al. 2007).

The Delta is interlaced with hundreds of miles of waterways, and relies on more than 1,000 miles of levees for protection against flooding (Moore and Shlemon 2008). These levees have eliminated the majority of tidally exchanged marsh habitats in the Delta (Whipple et al. 2012), areas historically used as nursery areas for a variety of Delta fish species (Kimmerer et al. 2008), and few locations in the eastern and central Delta now provide suitable habitat for rearing Chinook salmon. The combined effects of continued land subsidence, rising sea level, increased seismic risk, and increased winter flooding increase the vulnerability of the extensive Delta levee system, which can result in degradation of water quality and exposure of habitat adjacent to islands to increased seepage and wave action (CDWR et al. 2013). Much of the rich Delta farmland has lost soil from oxidation, compaction, and wind erosion, resulting in lowered elevations of some islands, in some cases up to 25 feet below sea level.

Measures have been undertaken to address conditions for migratory salmonids in the lower San Joaquin River and Delta. The results of south Delta survival studies indicate that installation of the HORB increases salmon smolt survival through the Delta by 16 to 61 percent (TID/MID 2013f) (see also Temperature and Water Quality, below).

5.3.2.2 Water Quality

5.3.2.2.1 Water Temperature

Water temperatures in the lower Tuolumne River are unlikely to result in mortality of upstream migrating adult salmonids, either directly or as the result of increased susceptibility to pathogens (TID/MID 2013f). No evidence of Chinook salmon pre-spawning mortality has been identified in the lower Tuolumne River (TID/MID 2013f). Fall-run Chinook adults must first traverse the warmer waters of the Delta and San Joaquin River before encountering the Tuolumne River, which often has cooler temperatures during the late September through November peak migration periods than the San Joaquin River. Despite being warmer than the Tuolumne River at times, water temperature in the lower San Joaquin River and Delta are considered unlikely to result in direct mortality of upstream migrating adult Chinook salmon or increase their susceptibility to disease (TID/MID 2013f).

Based on assessments of seasonal water temperatures and typical spawning periods, fall-run Chinook salmon in San Joaquin River basin tributaries are unlikely to encounter unsuitable water temperatures leading to reduced egg viability (TID/MID 2013f), and Myrick and Cech (2001) stated that only the earliest spawners arriving in San Joaquin River basin tributaries during September might encounter unsuitable temperatures. Intragravel water temperatures measured during February and March 1991 at several locations in the lower Tuolumne River ranged from 11 to 15°C (TID/MID 1997), indicating that water temperature conditions are suitable for Chinook salmon egg incubation.

Rotary screw trap data indicate that two juvenile outmigration life-history strategies exist for Tuolumne River fall-run Chinook salmon: winter outmigration of fry in January-February and spring outmigration of subyearling smolts (>70 mm) from late March through June. During January and February, water temperatures are suitable for rearing Chinook salmon in the lower Tuolumne River. In March through June temperatures are warm at times, but in most years water temperatures for spring outmigrants remain below 25°C, although temporally isolated events of high water temperature can occur. In general, flow releases resulting from the 1996 FERC Order help maintain appropriate water temperatures during Chinook salmon rearing and outmigration.

In the San Joaquin River, suitable water temperatures for Chinook smolt emigration in the range of 18 to 21°C exist at Vernalis as late as mid-May in most years, and it is likely that Delta conditions are suitable for smolt emigration as late as June in some years (TID/MID 2013f). There are, however, periods when elevated water temperatures in the lower San Joaquin River and Delta likely have substantial effects on juvenile salmonids. Unsuitable temperature conditions in excess of 25°C are exceeded at Vernalis by late June in many years, limiting successful emigration, and temperatures associated with increased salmonid mortality (Myrick and Cech 2001) routinely occur in the south Delta (TID/MID 2013f). Baker et al. (1995) showed that water temperature explains much of the variation in Delta smolt survival studies from 1983–1992, and by examining the relationship between water temperature in the Delta and predation-related mortality, it is clear that high water temperatures reduce juvenile Chinook salmon survival (Williams 2006).

5.3.2.2.2 Dissolved Oxygen

Measurements of water column and intragravel DO in artificial Chinook salmon spawning redds (TID/MID 2007) indicate that DO concentrations in the lower Tuolumne are generally suitable during the egg incubation period.

In the lower San Joaquin River, beginning in the 1960s, CDFW documented potentially adverse effects of low DO levels on adult salmon. Hallock et al. (1970) documented that low DO areas in the Delta blocked adult Chinook salmon upstream migration into the San Joaquin River. More recent water quality data and literature reviews by Newcomb and Pierce (2010) indicate that low DO at Stockton may adversely affect adult salmon in September and October during the upstream migration period and juvenile anadromous salmonids in June during the downstream migration period. For juvenile salmonids, literature reviews by Newcomb and Pierce (2010) suggest that low DO levels can lead to decreased swimming performance, reduced growth, impaired development, and increased susceptibility to predation, pathogens, and contaminants.

Periods of low DO concentrations observed in the Stockton DWSC in the summer and fall months upstream of Turner Cut show that this portion of the lower San Joaquin River does not meet Central Valley Basin Plan (Basin Plan) WQOs for DO (5 mg/l December - August and 6 mg/l September -November) (ICF International 2010). In 2008, the Department of Water Resources implemented the Stockton Deep Water Ship Channel Demonstration Dissolved Oxygen Aeration Facility Project (Aeration Facility) to increase DO levels and thereby potentially reduce adverse effects on migrating anadromous salmonids (Newcomb and Pierce 2010).

Testing showed that operating strategies for the Aeration Facility can be developed for a range of DWSC flows, depending on inflowing DO and BOD (ICF International 2010). At times, water column BOD exceeds the capacity of the Aeration Facility to help meet the DO objective in some portions of the DWSC. Evaluating fisheries data over time will allow researchers to assess trends in Chinook salmon populations and the respective timings of their upstream migration runs. If populations increase and fish begin to arrive in the San Joaquin River earlier, it will be reasonable to infer that low DO may no longer be a considerable stressor for migrants in the DWSC (Newcomb and Pierce 2010).

Water quality monitoring was conducted on the San Joaquin River from Mossdale Crossing to Turner Cut to assess the benefit of installing the HORB (Brunell et al. 2010). The HORB is installed by CDWR in conjunction with reservoir releases to increase flow and DO concentrations in the DWSC for migrating fall Chinook salmon; these practices can temporarily increase DO. Since 2000, DO levels in the DWSC have been observed to increase about 2 to 3 mg/l with the increased DWSC flows associated with the placement of the HORB (Brunell et al. 2010). However, low DO may recur after removal of the HORB following the spring pulse flow releases from the San Joaquin River's tributaries (Brunell et al. 2010). The response of DO in the DWSC is complex and difficult to predict solely by flow management; other factors, such as BOD (see above) and temperature, also influence DO.

5.3.2.2.3 Nutrients and Contaminants

Agriculture is the primary land use adjacent to the lower Tuolumne River, and agricultural chemicals have the potential to affect water quality and aquatic resources primarily through water returns to the river. The return water often contains pollutants, which affect fish, benthic macroinvertebrates, and other aquatic species. The CDPR has documented over 300 herbicides and pesticides that are discharged throughout agricultural regions of the Central Valley and Delta (Werner et al. 2008). Six pesticides were detected in runoff from agricultural and urban areas during a study conducted in the lower Tuolumne River, and chlorpyrifos, DCPA, metolachlor, and simazine were detected in almost every sample (Dubrovsky et al. 1998). Peak diazinon concentrations measured in the lower Tuolumne River have frequently exceeded levels that can be acutely toxic to some aquatic organisms (Dubrovsky et al. 1998).

Large numbers of pesticides are used on lands upstream of and adjacent to the lower San Joaquin River and Delta (Brown 1996; Kuivala and Foe 1995), and they have been shown to inhibit olfactory-mediated alarm responses in salmonids (Scholz et al. 2000). The lower San Joaquin River has been identified by the SWRCB as CWA § 303(d) State Impaired for chlorpyrifos, DDE, DDT, diazinon, diuron, electrical conductivity, *Escherichia coli*, group a pesticides, mercury, and toxaphene. Reduction in flows in the San Joaquin River, particularly between Gravelly Ford Canal and the Merced River, has increased the concentration of pesticides and fertilizers in the river, which has contributed to pollution that has impacted aquatic species (Cain et al. 2003). Hundreds of agricultural and urban drains discharge into the San Joaquin River downstream of the Merced River confluence, many of which are also designated as impaired water bodies, such as the Harding Drain, the Grayson Drain, the Newman Wasteway, and the Westley Waterway (SWRCB 2010).

It is unknown whether pesticide levels in Delta waters affect rearing or out-migrating Chinook salmon, and no studies of increased predation related mortality due to chemical contaminants are available for Central Valley rivers (TID/MID, W&AR-05). A range of literature sources suggests that early life history exposure to trace metals, herbicides, and pesticides may impair olfactory capabilities required for homing sensitivity in salmonids (Hansen et al. 1999; Scholz et al. 2000; Tierney et al. 2010), which could affect arrival of adult fish in their natal streams.

The flow of subsurface drainage water from intensively irrigated agricultural land on the west side of the San Joaquin Valley into the San Joaquin River has created a well-known water salinity and specific ion (selenium and boron) problem in the river. Flow from the Tuolumne River (and the

Merced and Stanislaus rivers) dilutes ion concentrations and improves the overall water quality of the San Joaquin River as it moves downstream toward the Delta.

Discharge of nutrients such as nitrogen and phosphorus from non-point runoff of agricultural fertilizer and point sources, such as water treatment facilities, stimulates algae growth, with attendant increases in the magnitude of diurnal DO variation. This has caused changes in the food webs of the San Joaquin River and Delta (Durand 2008), and as a result food availability for Delta fish populations (TID/MID 2013f).

5.3.2.2.4 Water Quality Related Effects on Fish and Aquatic Resources Resulting from the Districts Proposed Measures

Some of the Districts' proposed measures for the lower Tuolumne River would contribute to cumulative effects on water quality, which would influence fall-run Chinook EFH, as described below. Greater detail on the measures listed below, and their direct effects, can be found in Section 5.2.

Gravel Mobilization Flows of 6,000–7,000 cfs

Flow releases ranging from 6,000–7,000 cfs (measured at USGS gage 11289650 below La Grange Diversion Dam) could result in short-duration pulses of turbidity, which, depending on the timing of releases, could benefit outmigrating juvenile fall-run Chinook by decreasing predators' sight-feeding effectiveness. Benefits to spawning habitat and possibly Chinook outmigration survival would outweigh any short-term effects on water quality associated with turbidity increases. Such turbidity increases are not expected to contribute significantly to cumulative effects on water quality in the basin.

Gravel Cleaning

Experimental gravel cleaning undertaken to flush fine sediments from gravel interstices and expand the availability of high quality gravel for fall-run Chinook has the potential to result in short-duration, localized increases in turbidity that might exceed state water quality standards. However, improvements in spawning gravel quality and potential increases in fall-run Chinook outmigrant survival due to short-duration reductions in predator efficiency are likely to significantly outweigh any short-term effects of increased turbidity. As noted in Section 5.2, the Districts would coordinate with the SWRCB to secure necessary permits and conduct any required turbidity monitoring. If gravel cleaning is judged to be successful, the program would continue, adjusted as needed to comply with any water-quality related concerns of the SWRCB.

Contribute to CDBW's Efforts to Remove Water Hyacinth

The Districts propose to provide matching funds to the CDBW for the removal of water hyacinth in the lower Tuolumne River. Partial removal of these introduced invasive plants could improve water quality in the lower river, particularly during summer when plant densities and background water temperatures are higher, which would have a beneficial effect on aquatic resources, including fall-run Chinook passing through the lower Tuolumne River, thereby resulting in a positive contribution to cumulative effects.

Early Summer Flows (June 1–June 30)

Instream flows provided from June 1–June 30 to benefit *O. mykiss* fry rearing would reduce water temperatures in the lower river relative to baseline conditions. Water quality modeling shows that these flow releases would maintain favorable average daily water temperatures. Cooler water would benefit fall-run Chinook, thereby resulting in a positive contribution to cumulative effects in the lower Tuolumne River.

Late Summer Flows (July 1–October 15)

Instream flows provided from July 1–October 15 to benefit *O. mykiss* juvenile rearing would also reduce water temperatures in the lower river relative to baseline conditions. Water quality modeling shows that these flow releases would maintain favorable average daily water temperatures. Cooler water would benefit fall-run Chinook, thereby resulting in a positive contribution to cumulative effects in the lower Tuolumne River.

During this period, the Districts would provide a flushing flow to clean gravels of accumulated algae and fines prior to the onset of substantial spawning. The Districts would provide an instream flow of 1,000 cfs (not to exceed 5,950 ac-ft) on October 5, 6 and 7, with appropriate up and down ramps and the infiltration galleries turned off. These flows would be provided in Wet, Above Normal, and Below Normal water years only. In Dry and Critical years, the flows at La Grange would continue to be 300 cfs, with withdrawals of 225 cfs at the infiltration galleries leaving 75 cfs in the river below RM 25.5. These flushing flows would not be expected to have significant effects on water quality.

Outmigration Base flows (April 16–May 15)

Instream flows provided from April 16–May 15 to facilitate fall-run Chinook outmigration would maintain favorable lower river water temperatures. Water quality modeling shows that these flow releases would maintain favorable average daily water temperatures. Base flows would at times be augmented by outmigration pulse flows, which would further reduce water temperature at a given location and extend the plume of colder water farther downstream. Providing lower water temperatures relative to baseline conditions would benefit fall-run Chinook, thereby contributing positively to cumulative effects in the lower Tuolumne River.

Outmigration Base Flows (May 16–May 31)

Although during most years juvenile fall-run Chinook salmon have left the Tuolumne River by mid-May, in some years there are still parr and smolts in the river beyond May 15. To maintain lower water temperatures during this period, the Districts are proposing the following base flow releases: (1) 300 cfs (BN, AN, and W water years), (2) 275 cfs (D water years), and 225 cfs (C water years). These base flows would, depending on environmental conditions, be augmented by outmigration pulse flows, which would further reduce water temperature at a given location and extend the plume of colder water farther downstream, thereby benefitting fall-run Chinook and resulting in a positive contribution to cumulative effects in the lower Tuolumne River.

5.3.2.3 Flow Hydrograph Shaping

In spill years, the Districts would make reasonable efforts to shape the descending limb of the snowmelt runoff hydrograph to mimic natural conditions to promote seed dispersal and germination of cottonwoods and native willows. Increasing natural recruitment of snowmelt-dependent hardwoods would increase stands of trees that would eventually provide shade, which could over the long-term contribute to water temperature reduction, thereby contributing positively to cumulative effects on water quality in the lower Tuolumne River.

5.3.2.4 Connectivity and Entrainment

5.3.2.4.1 Upstream Migration Barriers

The La Grange Diversion Dam is identified by the PFMC (2014) as a human-made barrier to Chinook salmon upstream migration. However, prior to the dam's existence fall-run Chinook would have preferentially used the middle reaches of the Tuolumne River, so reductions in habitat access for this species are likely less substantial than they would be for other anadromous fish species that spawn and rear at higher elevations in Central Valley tributaries.

Dams and water diversions associated with mining adversely affected fish migration in the Tuolumne River as early as 1852 (Snyder 1993 unpublished memorandum, *as cited* in Yoshiyama et al. 1996). Access to historic spawning and rearing habitat was significantly restricted beginning in the 1870s, when a number of dams and irrigation diversion projects were constructed. Wheaton Dam, built in 1871 at the site of the present-day La Grange Diversion Dam (RM 52.2), was identified as a barrier to anadromous salmonid migration in 1884, as noted by the California Fish and Game Commission (California Fish and Game Commission 1884, *as cited* in Yoshiyama et al. 1996).

5.3.2.4.2 Entrainment

Anadromous fish downstream of the Faraday Diversion Dam are subject to entrainment in numerous intakes along the river. However, irrigation withdrawals for frost protection at diversions along the lower reaches of the Tuolumne River are rare during the Chinook salmon in-river rearing period (TID/MID 2013f), and as a result significant mortality of juvenile Chinook due to entrainment in the lower Tuolumne River is considered unlikely (TID/MID 2013f).

Juvenile salmonid entrainment and increased exposure to predation occur at major diversion facilities on the lower San Joaquin River and in the Delta. Although entrainment in smaller irrigation diversions has not been well quantified, entrainment into the SWP and CVP export facilities is considered a major source of mortality for rearing and out-migrating Chinook salmon, with effects on the number of Chinook recruits to the ocean fishery (TID/MID 2013f).

Based on paired releases of tagged Chinook salmon in the Clifton Court forebay of the SWP, Gingras (1997) estimated pre-screen mortality to be between 63 and 99 percent. Fish entrained in the Clifton Court forebay experience stress and may undergo physical damage during salvage operations (TID/MID 2013f), and salvage losses of Chinook salmon entrained into the SWP and CVP increase with increasing export flows (TID/MID 2013f).

5.3.2.5 Hatchery Propagation and Stocking

Recent studies have increasingly demonstrated potentially adverse effects of hatchery-reared salmonids on co-occurring wild stocks with which they may interact via interbreeding, competition, or predation. An issue of concern is genetic introgression of hatchery stocks with "natural" stocks, resulting in a decrease in the biological fitness of the natural stocks (e.g., ISAB 2003; Berejikian and Ford 2004; Kostow 2004; Araki et al. 2007; Lindley et al. 2007; CDFG and NMFS 2001).

Hatchery-origin fish represent a large proportion of the Central Valley fall-run Chinook salmon harvest (TID/MID 2013f). Although the proportion of adipose-fin-clipped Chinook salmon identified as originating from hatcheries has been historically low in Tuolumne River spawning surveys, this proportion has increased dramatically from the 1990s to the present (TID/MID 2005, 2012; Mesick 2009). Recent estimates of the composition of Chinook salmon indicate that up to 50 percent of the escapement to the Tuolumne River is made up of hatchery-produced salmon from other rivers (Merced Irrigation District 2012). In the Central Valley as a whole, it is estimated that hatchery production has provided over half of the Central Valley harvest and escapement of salmon in some years (CDFG and NMFS 2001). Barnett-Johnson et al. (2007) recently estimated that only 10 percent of Central Valley Chinook salmon captured in the ocean troll fishery were not raised in a hatchery setting. Assuming roughly equivalent survival of hatchery- and natural-origin fish from the fishery to the spawning grounds, these results imply that up to 90 percent of annual escapement could consist of hatchery reared fish (TID/MID 2013f).

Facilities that produce anadromous fish whose life histories could overlap temporally or spatially with Tuolumne River fall-run Chinook include the Feather River Hatchery, Nimbus Hatchery, Mokelumne River Hatchery, Merced River Hatchery, and the Coleman National Fish Hatchery, a federal facility that produces fall-run Chinook (ICF Jones & Stokes Associates, Inc. 2010). Fish from the Merced and Mokelumne hatcheries, because of the proximity of these facilities to the Tuolumne River, may be more likely than fish from other facilities to stray into the lower Tuolumne River, and thereby potentially contribute to cumulative adverse effects on Chinook salmon.

To provide more accurate estimates of the proportions of hatchery reared and naturally produced Chinook salmon in Central Valley rivers, a CFM Program was initiated by the Pacific States Marine Fisheries Commission in spring 2007, with an adipose fin clip and coded-wire tag applied to at least 25 percent of the fish released from 2007 through 2012 (Buttars 2011). Although the Merced River Fish Facility does not participate in the CFM Program, observations of adipose-fin-clipped salmon have steadily risen in the Merced, Tuolumne, and Stanislaus rivers since 2007, reflecting a higher proportion of adipose-fin-clipping at the participating hatcheries[36].

In the absence of appropriate hatchery management practices, hatcheries may select for early run timing by spawning a disproportionately higher percentage of earlier returning fish (Flagg et al. 2000), resulting in reduced spawning success (TID/MID 2013f). There is, however, no evidence that the introduction of hatchery fish has altered the run timing of fall-run Chinook salmon in the Tuolumne River. Although the proportion of hatchery-origin Chinook salmon in Tuolumne River spawning runs has increased in recent years, size-at-return does not appear to have decreased in response to hatchery introgression for the period 1981–2010, suggesting that any hatchery influences on Tuolumne River spawner fecundity and spawning success are minor (TID/MID 2013f).

In a recent review, Stillwater Sciences (2017c) summarized some of the effects of hatchery supplementation on fall-run Chinook salmon in the Central Valley. Stillwater Sciences (2017a) noted that a lack of genetic distinction between hatchery and naturally spawning fall-run Chinook and loss of early life-history diversity, due to inter-basin hatchery transfers and out-of-basin releases of hatchery-reared juveniles, are reducing the ability of fall-run Chinook to adapt to fluctuating environmental conditions. This inability is contributing to a reduction in the ESU's reproductive fitness on a large scale. Because estuary releases of late-stage smolts provide the basis for most adult harvest, and hatchery escapement results in high rates of straying, hatchery practices are increasingly producing salmon that survive at high rates but are decoupled from basin-specific selective pressures that influence the adaptive capacity of the species' freshwater life-stages (Stillwater Sciences 2017a).

HGMPs are being prepared pursuant to Section 7 of the ESA for salmon and steelhead hatcheries in California to guide the propagation of Chinook salmon. The goal of the plans is to prevent adverse impacts on the genome of federally-listed fish and any potential effects of stocking on the size, abundance, run-timing, and distribution of wild fish.

As part of their suite of measures, the Districts are proposing to fund a fall-run Chinook salmon restoration hatchery, which would improve Chinook smolt production in critically dry years. The Districts propose to build, in cooperation with CDFW, a fall-run Chinook restoration hatchery to be operated by CDFW (see Section 5.2). The proposed supplementation program, like state and federal programs, would be implemented in accordance with procedures that prevent or minimize adverse impacts on the fitness, size, abundance, run-timing, and distribution of wild fall-run Chinook.

The proposed supplementation program would be structured to attempt to counter the current adverse effects of hatchery supplementation on fall-run Chinook in the Tuolumne River through the spawning and rearing of fish selected by CDFW to best represent the wild Tuolumne River stock. The program would allow for the stocking of fish within the basin and as a result produce individuals that are adapted to the extent practicable to conditions in their natal environment.

[36] Hatcheries participating in the PFMC CFM Program include the Coleman National Fish Hatchery, Feather River Hatchery, Feather River Hatchery Annex, Nimbus Hatchery, and Mokelumne River Hatchery.

Implementation of a properly managed restoration hatchery would benefit the fall-run Chinook population, and as a result contribute positively to cumulative effects in the lower Tuolumne River.

5.3.2.6 Introduced Species and Predation

Predation on native salmonids by non-native fish introduced into the lower Tuolumne River is influenced by channel modifications that have created habitats favorable to non-native piscivores. Inter-annual variations in flows and water temperatures have been associated with variations in river-wide predator distribution (Ford and Brown 2001) and year-class strength in multi-year surveys conducted as part of the SRP 9 habitat restoration project at RM 25.7 (McBain & Trush and Stillwater Sciences 2006).

High levels of predation related mortality have been documented in direct surveys by the Districts, in multi-year Chinook smolt survival tests, and by comparisons of upstream and downstream fish passage at rotary screw traps (TID/MID 2013f). Apparent variations in the relationship between spring flows and Chinook smolt outmigration (Mesick et al. 2008) and subsequent adult Chinook escapement (TID/MID 1992; Speed 1993; TID/MID 1997; Mesick and Marston 2007; Mesick et al. 2008) suggest that predation, primarily by introduced fish species, is a major source of salmonid mortality, with effects on long-term Chinook population levels in the Tuolumne River (TID/MID 2013f). Studies conducted in the lower Tuolumne River identified 12 fish species that potentially prey on Chinook salmon fry and juveniles, but largemouth, smallmouth, and striped bass (all of which are introduced species) are the primary predators (TID/MID 1992, 2013e).

Average consumption rates of juvenile Chinook salmon (i.e., number of Chinook salmon per predator per day) by largemouth and smallmouth bass in the lower Tuolumne River (not scaled by gastric evacuation rates) ranged from 0–0.20 during the 2012 predation study (TID/MID 2013e) and from 0–1.7 in an earlier study conducted by the Districts (TID/MID 1992). In 2012, predation rates averaged for all habitat types and sampling events were 0.07 Chinook salmon per largemouth bass per day and 0.09 per smallmouth bass per day. Striped bass predation rates in the lower river were generally higher than those of smallmouth bass and largemouth bass (TID/MID 2013e). In 2012, the predation rate averaged for all habitat types and sampling events was 0.68 Chinook salmon per striped bass per day. Table 5.3-1 shows the estimated effect on fall-run Chinook predation associated with removal of black and striped bass (i.e., 10–15 percent) between the Grayson (RM 5.1) and Waterford (RM 30.3) rotary screw-traps.

Table 5.3-1. Estimated effect on fall-run Chinook predation rates associated with the removal of black and striped bass between the Grayson and Waterford rotary screw-traps (RM 5.1–30.3).

Species	10 Percent Removal Target	15 Percent Removal Target	Potential Reduction in Fall-Run Chinook Salmon Predation (salmon/day)
Largemouth bass	301	452	30-45
Smallmouth bass	363	544	40-60
Striped bass	24	35	26-39

Largemouth bass and smallmouth bass were estimated to have consumed about 37 percent and 48 percent, respectively, of the total potential juvenile Chinook salmon consumed by the three primary non-native predator species (i.e., largemouth bass, smallmouth bass, and striped bass). Despite making up only a small fraction (< 4 percent) of the total number of piscivore-sized fish (> 150 mm FL), striped bass were estimated to have consumed nearly 15 percent of the total potential juvenile Chinook salmon consumed by the three predator species. There was no evidence of consumption of Chinook salmon by the native Sacramento pikeminnow during either the 2012 study or the Districts' previous study (TID/MID 1992).

A conservative estimate of the total consumption of juvenile Chinook salmon by striped, largemouth, and smallmouth bass is about 42,000 during March 1-May 31, 2012 based on observed predation rates and estimated predator abundance. This suggests that nearly all juvenile Chinook salmon may be consumed by introduced predators between the Waterford and Grayson rotary screw traps. Only 2,268 Chinook salmon were estimated to have survived migration through the 25 miles between the screw-trapping sites (Robichaud and English 2013) during January through mid-June, making it plausible that most losses of juvenile Chinook salmon in the lower Tuolumne River between Waterford and Grayson during 2012 can be attributed to predation by non-native piscivorous fish species.

Predation in the lower San Joaquin River, Delta, and at the SWP and CVP export facilities is considered a primary cause of mortality for Chinook salmon, with effects on long-term population levels (TID/MID 2013f). The SWP and CVP facilities create lentic habitats that support the persistence of non-native fish species. Delta water exports, in combination with non-native species introductions, have resulted in dramatic changes in the Delta fish species assemblage, with numerous predatory fish species benefitting from current Delta hydrology (Lund et al. 2007). It is likely that predation has its greatest impact on Chinook salmon populations in the lower San Joaquin River and Delta, when juveniles and smolts out-migrate during the spring through the lower reaches of rivers and estuaries on their way to the ocean (Mather 1998). Based on review of available information, predation in the lower San Joaquin River and Delta, as well as predation related mortality in the Clifton Court forebay of the SWP and CVP water export facilities, are key factors affecting the numbers of Chinook salmon recruited to the ocean fishery (TID/MID 2013f). For Chinook salmon outmigrants from the Tuolumne River, increased flows at Vernalis have been shown to reduce predation related mortality, but the relationship is highly dependent on the presence of the HORB (TID/MID 2013f).

Avian and pinniped (seals and sea lions) predation on juvenile Chinook salmon has been documented in San Francisco Bay (Evans et al. 2011) and along the California coast (Scordino 2010), respectively, and it is likely that at least avian predation occurs to some extent in or near the Delta as well. Whether and to what extent such predation is mediated by anthropogenic influences in the region is unknown.

Predation on juvenile salmonids is not the only adverse effect associated with introduced species. Introduced zooplankton species and the overbite clam (*Corbula amurensis*) in the lower Tuolumne and San Joaquin rivers (Brown et al. 2007) may have affected the availability of suitable prey for rearing salmonids (see also, Benthic Invertebrates and Fish Food Availability, below).

As explained in Section 5.2, the Districts' proposed predator control and suppression program would consist of constructing and operating a barrier weir coupled with active predator control and suppression. The barrier weir, which would be located at RM 25.7, would prevent striped and black bass from moving into upstream habitats used by rearing juvenile Chinook salmon. The weir would also provide a location where striped bass would likely congregate, thereby allowing them to be removed or isolated during Chinook smolt outmigration.

The Districts proposed comprehensive predator suppression and control program would consist of three components: (1) isolating, collecting, and/or relocating striped bass prior to spring pulse-flow releases to reduce predation on juvenile fall-run Chinook during outmigration, (2) sponsorship and promotion of black bass and striped bass fishing derbies and reward-based angling at locations above and below the barrier weir to diminish population sizes over time; other removal and/or isolation methods would include, but not be limited to, electrofishing, seining, and fyke netting, and (3) seeking and advocating for changes to current fishing regulations for the lower Tuolumne River (e.g., length of season, bag limit, catchable size, requested removal of black bass/striped bass caught, allowing a bounty program) to reduce black and striped bass numbers and educate the public on the adverse effects of predation on fall-run Chinook in the Tuolumne River to encourage participation in the removal program and advocacy of changes to fishing regulations.

The proposed removal of striped and black bass would lead to substantial reductions in the abundance of non-native predators in the lower river, which in turn would lead to substantial increases in the survival of outmigrating juvenile fall-run Chinook salmon. Removing these non-native predatory fish from the system would result in a significant increase in survival of fall-run Chinook outmigrants, and as a result a substantial positive contribution to cumulative effects in the lower Tuolumne River.

5.3.2.7 Benthic Invertebrates and Fish Food Availability

Analysis of historical drift samples and stomach contents of rearing juvenile Chinook salmon indicates that there are adequate food resources for rearing in the Tuolumne River (TID/MID 2013f), and analysis of long-term Hess sampling data gathered from 1988–2009 at RM 48.8 indicates that increased summer flows since 1996 have resulted in beneficial shifts in the invertebrate food supply of fishes. Overall invertebrate abundances in the samples declined slightly from 1996 to the present. However, community composition shifted away from pollution-tolerant invertebrate taxa and toward those with higher food value for juvenile Chinook salmon (TID/MID 2010).

A number of factors affect aquatic food sources available to rearing juvenile Chinook salmon in the Delta: changes in flow magnitudes and timing, water exports at the SWP and CVP facilities, construction of levees and the resulting conversion of marsh habitats to agricultural and urban land uses, and anthropogenic introductions of agricultural fertilizers, contaminants, and non-native species (TID/MID 2013f).

Although warmer waters in the Delta provide a higher growth rate potential for juvenile salmonids than that associated with cooler upstream tributary habitats, degradation of Delta habitat conditions has adversely affected the primary and secondary productivity that support Delta food webs, resulting in low growth rates of Chinook salmon juveniles (TID/MID 2013f).

As noted above, introduced zooplankton species and the overbite clam in the lower Tuolumne and San Joaquin rivers (Brown et al. 2007) may compete with native fauna and thereby affect the availability of suitable prey for rearing salmonids in these areas.

The following resource measures proposed by the Districts for the lower river have the potential to increase benthic macroinvertebrate abundance: gravel augmentation, operational flows, experimental gravel cleaning, scour associated with placement of boulder-size stones, and increases in riparian vegetation and associated large wood recruitment resulting from shaping the descending limb of the snowmelt runoff hydrograph to mimic natural conditions. It is not clear, however, that such increases would translate into significant benefits for fall-run Chinook, because fish population modeling suggests that food availability in the lower Tuolumne River is not limiting fall-run Chinook rearing under current conditions (TID/MID 2017a, 2017g).

5.3.2.8 Freshwater Harvest and Poaching

CDFW implemented sport fishing catch limits on salmon in the early 2000s within a portion of the Tuolumne River, and salmon fishing is currently banned in the lower Tuolumne River and San Joaquin River upstream of the Delta. There is no available estimate of the number of Chinook salmon lost to poaching in the Tuolumne or San Joaquin rivers (TID/MID 2013f). However, poaching of Chinook salmon, to the extent that it occurs, would take place during the adult upstream migration period (September–December).

Because the Tuolumne River downstream of La Grange Diversion Dam supports a catch-and-release recreational trout fishery from January 1 through October 15, it is possible that some Chinook redds in the lower Tuolumne River are at times inadvertently disturbed (Chinook egg incubation extends into January) by wading anglers (NMFS 2014).

5.3.2.9 Effects of Ocean Conditions on Fall-Run Chinook Salmon

As noted previously, the EFH Action Area for Tuolumne River fall-run Chinook salmon includes the Tuolumne River from La Grange Diversion Dam to the confluence with the San Joaquin River and the San Joaquin River from RM 84 (i.e., the confluence with the Tuolumne River) downstream through the Delta to San Francisco Bay. Although the Pacific Ocean is outside the geographical limits of the analysis, environmental conditions and commercial harvest of Chinook salmon in the ocean exert a strong influence on the abundance and health of the Chinook salmon population in the Tuolumne River, in some years potentially overwhelming the effects of many in- and out-of-basin actions in the rivers or Delta (128 FERC ¶ 61,035 [2009]).

In the open ocean, seasonal and longer-term changes in meteorological and oceanographic conditions determine water temperature and coastal circulation patterns, with effects on nutrient upwelling and primary and secondary productivity of the marine food web that supports ocean feeding and growth of Tuolumne River fall-run Chinook salmon. Major climate-ocean factors such the Pacific Decadal Oscillation and shorter-term El Niño/Southern Oscillation influence ocean productivity, and consequently salmon numbers through a series of complex processes (Pearcy 1992; Williams 2006). For example, the recent dramatic collapse of Sacramento fall-run Chinook stocks during the 2007 and 2008 spawning years was attributed to highly anomalous coastal ocean conditions during 2005 and 2006, i.e., late and weakened seasonal upwelling associated with warmer sea surface temperatures led to the deterioration of coastal food webs on which juvenile salmon depend (CalCOFI 2006, 2007; NMFS 2009).

Ocean harvest has the potential to reduce the number of adult Chinook salmon migrating into the Tuolumne River (Williams 2006; PFMC 2013). For many years, an annual average of 60 percent of the Central Valley Chinook salmon population has been taken in the ocean fishery, directly affecting the species' escapement to fresh water (TID/MID 2013f). The Central Valley Harvest Rate Index (i.e., catch/[catch + escapement]) has been in excess of 70 percent in many years (TID/MID 2005), suggesting that year-to-year variations in ocean survival and harvest affect Tuolumne River escapement and subsequent population levels (TID/MID 2013f).

Harvest mortality of larger fish generally reduces the age and size, and consequently the fecundity, of upstream migrating spawners (Williams 2006; TID/MID 2013f). The transition from inland gill net fishing to an ocean troll fishery at the end of the nineteenth century had significant impacts on Central Valley salmon populations; fish are exposed to trolling over a period of years, resulting in younger and smaller salmon returning to California streams. There is evidence that such a reduction in the age-distribution of Central Valley fall-run Chinook salmon has occurred (Williams 2006). Chinook harvest management by the PFMC is based exclusively on meeting escapement goals for the hatchery-supported Sacramento River fall run. Because "mixed stock fisheries supported by strong stocks may overharvest weaker ones," (Williams 2006) there is a potential to overharvest already diminished San Joaquin River Basin stocks. The PFMC dropped its San Joaquin Basin escapement goal in 1984 because of the effects of Delta export pumps on those runs (Boydstun 2001).

6.0 CONCLUSIONS

Table 6.0-1 summarizes the potential effects of the Districts' Proposed Action on fall-run Chinook salmon EFH in the Action Area. Section 5.2 provides a description of the direct effects of the Districts' proposed measures on fall-run Chinook salmon in the Tuolumne River, and Section 5.3 provides a discussion of the proposed measures' contributions to cumulative effects.

Table 6.0-1. Effects determinations associated with the Proposed Action, including the Districts' proposed measures for the lower Tuolumne River, for fall-run Chinook EFH in the Action Area.

Action	EFH Effect Determination
Continued generation of hydroelectric power	Insignificant
Augment current gravel quantities through a coarse sediment management program	Beneficial
Gravel mobilization flows of 6,000 to 7,000 cfs	Beneficial
Gravel cleaning	Beneficial
Instream habitat improvement (boulder placement)	Beneficial
Contribute to CDBW's efforts to remove water hyacinth	Beneficial
Fall-run Chinook spawning improvement superimposition reduction program	Beneficial
Predator control and suppression program	Beneficial
Fall-run Chinook salmon restoration hatchery program	Beneficial
Flows to enhance habitat for *O. mykiss* fry rearing	Beneficial
Flows to enhance habitat for *O. mykiss* juvenile rearing	Beneficial
Flows to enhance habitat for fall-run Chinook spawning	Beneficial
Flows to enhance habitat for fall-run Chinook fry rearing	Beneficial
Flows to enhance habitat for fall-run Chinook juvenile rearing	Beneficial
Fall-run Chinook outmigration base flows	Beneficial
Fall-run Chinook outmigration pulse flows	Beneficial
Hydrograph shaping	Beneficial
Flows to enhance recreational boating	Insignificant

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