Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project

U.S. Department of the Interior

Bureau of Reclamation

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Mission Statement

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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List of Abbreviations/Acronyms

°F	degrees Fahrenheit
°C	degrees Celsius
1995 Bay-Delta Plan	San Francisco Bay/Sacramento-San Joaquin Delta Estuary
8500 Banks	Banks Pumping Plant
ACID	Anderson-Cottonwood Irrigation District
af	acre-feet
af/yr	acre-feet per year
AFRP	Anadromous Fish Restoration Program
ALPI	aleutian low pressure index
ANN	Artificial Neural Network
ARG	American River Group
ASIP	Action Specific Implementation Plan
Authority	San Luis and Delta Mendota Water Authority
B2IT	CVPIA Section 3406 (b)(2) Implementation Team
BA	biological assessment
Banks	Banks Pumping Plant
BDCP	Bay Delta Conservation Plan
BO	biological opinions
BR	breached
BY	brood year
CA	California Aqueduct
Cal EPA	California Environmental Protection Agency
CALFED	CALFED Bay-Delta Program
CalSim II	California Simulation computer model
CAMP	Comprehensive Assessment and Monitoring Program
CCC	Contra Costa Canal

CCF	Clifton Court Forebay
CCWD	Contra Costa Water District
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFC	California Fish Commission
CFR	Code of Federal Regulations
cfs	cubic feet per second
CHO	Constant Head Orifice
City	City of Sacramento
cm	centimeters
CMARP	Comprehensive Monitoring Assessment and Research Program
COA	Coordinated Operation Agreement
Conjunctive Use Agreements	Principles of Agreement for Proposed Conjunctive Use Agreements
Corps	U.S. Army Corps of Engineers
cpm	catch per minute
CPUE	catch per unit effort
CRR	Cohort Replacement Rate
CRWQ CB-NCR	California Regional Water Quality Control Board-North Coast Region
CVOO	Bureau of Reclamation's Central Valley Operations Office
CVP	Central Valley Project
CVPA	Central Valley Project Act
CVPIA	Central Valley Project Improvement Act
CWA	Clean Water Act
CWT	coded-wire-tag
D-1485	SWRCB Decision 1485
DAT	CVPIA Section 3406 (b)(2) Data Assessment Team

DBEEP	Delta-Bay Enhanced Enforcement Program
DCC	Delta Cross Channel
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
DMC	Delta-Mendota Canal
DO	dissolved oxygen
DPS	Distinct Population Segment
DSM2	Delta Simulation Model 2
DSDT	delta smelt decision tree
DW	dewatered (at some point throughout the year)
DWR	California Department of Water Resources
E/I	export/inflow
EBMUD	East Bay Municipal Utility District
EC	electroconductivity
EFH	essential fish habitat
E/I	Export/Inflow Ratio
EID	El Dorado Irrigation District
EIR	Environmental Impact Report
EIR/EIS	Environmental Impact Report/Environmental Impact Statement
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERP	Ecosystem Restoration Program
ESA	(Federal) Endangered Species Act
ESU	Evolutionarily Significant Unit
EWA	Environmental Water Account
EWAT	Environmental Water Account Team
FB	flashboards removed during winter

FERC	Federal Energy Regulatory Commission
Fisheries Agreement	Principles of Agreement for Proposed Lower Yuba River Fisheries Agreement
FL	Fork length
FLD	fish ladder
FMWT	Fall Midwater Trawl Survey
FPA	Federal Power Act
FRH	Feather River Hatchery
FRWA	Freeport Regional Water Authority
FRWP	Freeport Regional Water Project
ft/s	foot/feet per second
FWS	U.S. Fish and Wildlife Service
GCID	Glenn-Colusa Irrigation District
GIS	geographic information system
GLM	Generalized Linear Models
GORT	Gate Operations Review Team
GS	Georgiana Slough
GSI	Genetic Stock Identification
HFC	high-flow channel
HGMP	Hatchery Genetics Management Plan
HORB	Head of Old River Barrier
IEP	Interagency Ecological Program
ID	Irrigation District
IFIM	Instream Flow Incremental Methodology
IHN	Infectious Hematopoietic Necrosis
Interior	U.S. Department of the Interior
IOS	Interactive Object-Oriented Salmon Simulation
IPO	Interim Plan of Operation

IWOFF	Integrated Water Operations Fisheries Forum
Jones	C.W. “Bill” Jones Pumping Plant. Formerly known as Tracy Pumping Plant
JPE	Juvenile Production Estimate
JPOD	joint point of diversion
KCWA	Kern County Water Agency
KFE	Kern Fan Element
km	kilometer
LFC	low-flow channel
LOD	Level of Development
LP	linear programming
LWD	large woody debris
M&I	municipal and industrial
maf	million acre-feet
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation and Management Act
MAs	Management Agencies (FWS, NOAA Fisheries, and DFG for EWA)
mg/L	milligrams per liter
mgd	millions of gallons per day
MIB	methylisoborneol
MIDS	Morrow Island Distribution System
MILP	mixed integer linear programming
MLR	multiple linear regression
mm	millimeters
mmhos/cm	millimhos per centimeter
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
mS/cm	milliSiemens per centimeter

msl	mean sea level
NBA	North Bay Aquaduct
NCCPA	Natural Community Conservation Planning Act
NCWA	Northern California Water Association
NDO	Net Delta Outflow
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
NMIPO	New Melones Interim Plan of Operation
NMFS	National Marine Fisheries Service
NOAA Fisheries	National Oceanic and Atmospheric Administration Fisheries (also know as National Marine Fisheries Service [NMFS])
NOD	North of Delta
NRC	National Research Council
OCAP	Operations Criteria and Plan
OFF	Operations and Fishery Forum
OID	Oakdale Irrigation District
ONCC	Oregon/Northern California Coast
Ops Group	CALFED Operations Coordination Group
PAs	Project Agencies (DWR and Reclamation)
PCBs	Polychlorinated biphenyls
PCWA	Olacer County Water Agency
PEIS	Programmatic Environmental Impact Statement
PFMC	Pacific Fishery Management Council
PG&E	Pacific Gas and Electric
PHABSIM	Physical Habitat Simulation
PIT	passive integrated transponder
POD	Pelagic Organic Decline
POP	Persistent organic pollutants

ppm	parts per million
ppt	parts per trillion
Project	CVP and SWP (as in CVP and SWP water rights)
PSL	Pre-screen loss
psu	Practical Salinity Units
RBDD	Red Bluff Diversion Dam
Reclamation	U.S. Bureau of Reclamation
RM	River Marker (similar to mile marker)
RMIS	Regional Mark Information System
ROD	Record of Decision
RPA	reasonable and prudent alternative
RRDS	Roaring River Distribution System
RST	rotary screw (fish) trap
RWQCB	Regional Water Quality Control Board
SA	Settlement Agreement
SAFCA	Sacramento Area Flood Control Agency
Salmod model	A computer model that simulates the dynamics of freshwater salmonid populations
SCDD	Spring Creek Debris Dam
SCE	Southern California Edison
SCWA	Sacramento County Water Agency
SDFF	South Delta Fish Facility Forum
SDIP	South Delta Improvement Project
SDP	Station Development Plan
SDTB	South Delta Temporary Barriers
SJRA	San Joaquin River Agreement
SJRTC	San Joaquin River Technical Committee
SJRWR	San Joaquin River water rights

SL	sloped dam
SMPA	Suisun Marsh Preservation Agreement
SMSCG	Suisun Marsh Salinity Control Gates
SMWC	Sutter Mutual Water Company
SOD	South of Delta
SOD	Safety of Dams
SONCC	Southern Oregon/Northern California Coast
SPME	Solid Phase Micro-extraction
SRCD	Suisun Resource Conservation District
SRPP	Spring-run Chinook Salmon Protection Plan
SRTTG	Sacramento River Temperature Task Group
SRWQM	Sacramento River Water Quality Management
SSJID	South San Joaquin Irrigation District
SWP	State Water Project
SVWMP	Sacramento Valley Water Management Program (Phase 8)
SWRCB	(California) State Water Resources Control Board
SWRI	Surface Water Resources, Inc.
T&E	Threatened and Endangered
taf	thousand acre-feet
TAO	Thermalito Afterbay Outlet
TCCA	Tehama-Colusa Canal Authority
TCD	temperature control device
TDS	total dissolved solids
TFCF	Tracy Fish Collection Facility
TFFIP	Tracy Fish Facility Improvement Program
TFPL	Trust for Public Lands
TNS	Townet Survey

TU	temperature units
U.S.C.	United States Code
UN	unscreened diversion
USFC	U.S. Commission of Fish and Fisheries
USGS	U.S. Geological Survey
USRFRHAC	Upper Sacramento River Fisheries and Riparian Habitat Advisory Council
VAMP	Vernalis Adaptive Management Plan
VSP	Viable Salmonid Population
Water Purchase Agreement	Principles of Agreement for Proposed Long-term Transfer Agreement
WDSC	(Metropolitan) Water District of Southern California
Western	Western Area Power Administration
Westlands	Westlands Water District
WOMT	Water Operations Management Team
Working Group	Delta Smelt Working Group
WQCP	Water Quality Control Plan
WRESL	Water Resources Engineering Simulation Language
WTP	Water Treatment Plant
WUA	weighted usable (spawning) area
WY	water year
YCWA	Yuba County Water Agency
YOY	young-of-the-year

Preface

The Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR) propose to operate the Central Valley Project (CVP) and State Water Project (SWP) to divert, store, re-divert, and convey CVP and SWP (Project) water consistent with applicable law and contractual obligations. These operations are summarized in this biological assessment (BA) and described in more detail in Chapter 2.

This BA is intended to provide a thorough analysis of the continued long-term operations of the CVP and SWP and the effects of those operations on listed species and designated Critical Habitat. The document is divided into chapters. Chapter 1 outlines the statutory, regulatory and other parameters that influence Project operations. Chapter 2 is the complete project description. Chapters 3 and 4 address basic biology, life history, and baseline of Central Valley steelhead and factors that may influence their distribution and abundance. Chapters 5 and 6 address basic biology, life history, and baseline of winter-run Chinook and Coho salmon and factors that may influence their distribution and abundance. Chapter 7 addresses basic biology, life history, and baseline of delta smelt and factors that may influence their distribution and abundance. Chapter 8 addresses basic biology, life history, and baseline of green sturgeon and factors that may influence their distribution and abundance. Chapter 9 articulates the assumptions made in the modeling used in the effects analysis. Chapters 10 through 13 are the effects analyses. Chapter 14 addresses effects of Project operations on southern Killer Whales. Chapter 15 is the summary of the effects analyses and effects determinations. Chapter 16 addresses Essential Fish Habitat. Chapter 17 addresses technical assistance for longfin smelt. Chapter 18 is a discussion of ongoing actions to improve habitat and lessen Project impacts.

The CVP and the SWP are two major inter-basin water storage and delivery systems within California that divert and re-divert water from the southern portion of the Sacramento-San Joaquin Delta (Delta). Both CVP and SWP include major reservoirs upstream of the Delta, and transport water via natural watercourses and canal systems to areas south and west of the Delta. The CVP also includes facilities and operations on the Stanislaus and San Joaquin Rivers. The major facilities on these rivers are New Melones and Friant Dams, respectively.

The projects are permitted by the California State Water Resources Control Board (SWRCB) to store water during wet periods, divert water that is surplus to the Delta, and re-divert Project water that has been stored in upstream reservoirs. Both projects operate pursuant to water right permits and licenses issued by the SWRCB to appropriate water by diverting to storage or by directly diverting to use and re-diverting releases from storage later in the year. As conditions of their water right permits and licenses, the SWRCB requires the CVP and SWP to meet specific water quality, quantity, and operational criteria within the Delta and on various project-controlled rivers. Reclamation and DWR closely coordinate the CVP and SWP operations, respectively, to meet these conditions.

The project description for this BA includes the ongoing operations of the CVP and SWP and potential future actions that are foreseeable to occur within the period covered by the project description. Inclusion of future activities in the project description does not constitute agency approval of those actions. Any future actions will be required to comply with all applicable laws, including those regarding agency decision making, before those actions are approved or implemented. The Biological Opinions (BOs) issued by the United States Fish and Wildlife

Service (FWS) and National Marine Fisheries Service (NMFS) in compliance with the Federal Endangered Species Act (ESA) as a result of this Section 7 consultation will be considered in the decision making process on future actions as the BOs will analyze the effects of those potential actions on listed species.

The proposed action in this consultation includes activities undertaken by DWR in operating the SWP. As such, DWR will also consult with the California Department of Fish and Game (DFG), as may be appropriate, to address applicable requirements of the California Endangered Species Act (CESA). This BA will serve to describe the proposed SWP activities to be consulted under CESA.

The listed species and designated Critical Habitat to be analyzed in this document have been derived from species lists provided by FWS and NMFS. The species analyzed in this document under the jurisdiction of FWS are delta smelt. The species analyzed in this document under the jurisdiction of NMFS are: winter-run Chinook salmon, spring-run Chinook salmon, Coho salmon, Central Valley steelhead, green sturgeon, and southern Killer Whales. Supplemental information regarding longfin smelt is also provided.

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Chapter 1 Summary of Legal and Statutory Authorities, Water Rights, and Other Obligations Relevant to the Action

Introduction

The Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR) propose to operate the Central Valley Project (CVP) and State Water Project (SWP) to divert, store, and convey CVP and SWP (Project) water consistent with applicable law and contractual obligations. These operations are summarized in this biological assessment (BA) and described in more detail in Chapter 2.

The CVP and the SWP are two major inter-basin water storage and delivery systems that divert and re-divert water from the southern portion of the Sacramento-San Joaquin Delta (Delta). Both CVP and SWP include major reservoirs upstream of the Delta, and transport water via natural watercourses and canal systems to areas south and west of the Delta. The CVP also includes facilities and operations on the Stanislaus and San Joaquin Rivers. The major facilities on these rivers are New Melones and Friant Dams[1], respectively.

The projects are permitted by the California State Water Resources Control Board (SWRCB) to store water during wet periods, divert water that is surplus to the Delta, and re-divert Project water that has been stored in upstream reservoirs. Both projects operate pursuant to water right permits and licenses issued by the SWRCB to appropriate water by diverting to storage or by directly diverting to use and re-diverting releases from storage later in the year. As conditions of their water right permits and licenses, the SWRCB requires the CVP and SWP to meet specific water quality, quantity, and operational criteria within the Delta. Reclamation and DWR closely coordinate the CVP and SWP operations, respectively, to meet these conditions.

The project description for this BA includes the ongoing operations of the CVP and SWP and potential future actions that are foreseeable to occur within the period covered by the project description. Inclusion of future activities in the project description does not constitute agency approval of those actions. Any future actions will be required to comply with all applicable laws, including those regarding agency decision making, before those actions are approved or implemented. The Biological Opinions (BOs) issued as a result of this Section 7 consultation will be considered in the decision making process on future actions as the BOs will analyze the effects of those potential actions on listed species.

The proposed action in this consultation includes activities undertaken by DWR in operating the SWP that potentially affect State listed species under the California Endangered Species Act (CESA). CESA allows California Department of Fish and Game (DFG), upon request of DWR,

[1] While part of the CVP, the Friant Division operations are not included in the action for the purposes of Section 7 consultation.

to determine if Federal incidental take statements and biological opinions obtained through Federal consultation are consistent with State law. As such, DWR intends to submit the Biological Opinions to DFG for a consistency determination review pursuant to the California Endangered Species Act (CESA).

Relationship to CVP Operations Criteria and Plan

Reclamation periodically updates the CVP Operations Criteria and Plan (CVP-OCAP). The most recent CVP-OCAP, covering the years 1991-2003, was completed in 2004. The 2004 CVP-OCAP describes the laws, regulations and other criteria applicable to operations of the CVP that were in effect during the 1991-2003 period. In addition, the 2004 CVP-OCAP was used to guide development of the project description included in Chapter 2 of this BA. However, the project description included in Chapter 2 of this BA is different from the 2004 CVP-OCAP in that the project description in this BA looks at the present and future long-term operations of the CVP and SWP. While this process is often referred to as the OCAP consultation, that name is a misnomer. The consultation focuses on the effects of the continued long-term coordinated operation of the CVP and SWP. The laws, regulations, policies, guidelines and other criteria for operations described in the CVP-OCAP which are currently in effect are incorporated into the Project Description of this BA and accurately reflected in the modeling described in Chapter 9.

Legal and Statutory Authorities

Legal and statutory authorities and obligations, water rights, and other obligations guide the Project agencies' proposed action. This section of the BA elaborates on those authorities, responsibilities, and obligations.

CVP

The CVP is the largest Federal Reclamation project and was originally authorized by the Rivers and Harbors Act of 1935. The CVP was reauthorized by the Rivers and Harbors Act of 1937 for the purposes of "improving navigation, regulating the flow of the San Joaquin River and the Sacramento River, controlling floods, providing for storage and for the delivery of the stored waters thereof, for construction under the provisions of the Federal Reclamation Laws of such distribution systems as the Secretary of the Interior (Secretary) deems necessary in connection with lands for which said stored waters are to be delivered, for the reclamation of arid and semiarid lands and lands of Indian reservations, and other beneficial uses, and for the generation and sale of electric energy as a means of financially aiding and assisting such undertakings and in order to permit the full utilization of the works constructed." This Act provided that the dams and reservoirs of the CVP "shall be used, first, for river regulation, improvement of navigation and flood control; second, for irrigation and domestic uses; and, third, for power."

The CVP was reauthorized in 1992 through the Central Valley Project Improvement Act (CVPIA). The CVPIA modified the 1937 Act and added mitigation, protection, and restoration of fish and wildlife as a project purpose. Further, the CVPIA specified that the dams and reservoirs of the CVP should now be used "first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses and fish and wildlife mitigation, protection and restoration purposes; and, third, for power and fish and wildlife enhancement."

CVPIA includes authorization for actions to benefit fish and wildlife intended to implement the purposes of that Title. Specifically, Section 3406(b)(1) is implemented through the Anadromous Fish Restoration Program (AFRP). The AFRP objectives, as they relate to operations, are explained below. CVPIA Section 3406(b)(1) further provides for modification of the CVP operations to meet the fishery restoration goals of the CVPIA, so long as the operations are not in conflict with the fulfillment of the Secretary's contractual obligations to provide CVP water for other authorized purposes. The U.S. Department of the Interior's (Interior) decision on Implementation of Section 3406(b)(2) of the CVPIA, dated May 9, 2003, provides for the dedication and management of 800,000 acre-feet (af) of CVP yield annually by implementing upstream and Delta actions. Interior manages and accounts for (b)(2) water pursuant to its May 9, 2003 decision and the Ninth Circuit's decision in Bay Inst. of San Francisco v. United States, 66 Fed.Appx. 734 (9th Cir. 2003), as amended, 87 Fed. Appx. 837 (2004). Additionally, Interior is authorized to acquire water to supplement (b)(2) water, pursuant to Section 3406(b)(3).

There are several other statutes that have authorized the construction, operation, and maintenance of various divisions of the CVP. In these authorizations, Congress has consistently included language directing the Secretary to operate the CVP as a single, integrated project.

SWP

DWR was established in 1956 as the successor to the Department of Public Works for authority over water resources and dams within California. DWR also succeeded to the Department of Finance's powers with respect to State application for the appropriation of water (Stats. 1956, First Ex. Sess., Ch. 52; see also Wat. Code Sec. 123) and has permits for appropriation from the SWRCB for use by the SWP. DWR's authority to construct State water facilities or projects is derived from the Central Valley Project Act (CVPA) (Wat. Code Sec. 11100 et seq.), the Burns-Porter Act (California Water Resources Development Bond Act) (Wat. Code Sec. 12930-12944), the State Contract Act (Pub. Contract Code Sec. 10100 et seq.), the Davis-Dolwig Act (Wat. Code Sec. 11900-11925), and special acts of the State Legislature. Although the Federal government built certain facilities described in the CVPA, the Act authorizes DWR to build facilities described in the Act and to issue bonds. See Warne v. Harkness, 60 Cal. 2d 579 (1963). The CVPA describes specific facilities that have been built by DWR, including the Feather River Project and California Aqueduct (Wat. Code Sec. 11260), Silverwood Lake (Wat. Code Sec. 11261), and the North Bay Aqueduct (Wat. Code Sec. 11270). The Act allows DWR to administratively add other units (Wat. Code Sec. 11290) and develop power facilities (Wat. Code Sec. 11295).

The Burns-Porter Act, approved by the California voters in November 1960 (Wat. Code Sec. 12930-12944), authorized issuance of bonds for construction of the SWP. The principal facilities of the SWP are Oroville Reservoir and related facilities, and San Luis Dam and related facilities, Delta facilities, the California Aqueduct, and the North and South Bay Aqueducts. The Burns-Porter Act incorporates the provisions of the CVPA.

DWR is required to plan for recreational and fish and wildlife uses of water in connection with State-constructed water projects and can acquire land for such uses (Wat. Code Sec. 233, 345, 346, 12582). The Davis-Dolwig Act (Wat. Code Sec. 11900-11925) establishes the policy that preservation of fish and wildlife is part of State costs to be paid by water supply contractors, and recreation and enhancement of fish and wildlife are to be provided by appropriations from the General Fund.

ESA

Federal agencies have an obligation to ensure that any discretionary action they authorize, fund, or carry out is not likely to jeopardize the continued existence of any endangered or threatened species or destroy or adversely modify its critical habitat unless that activity is exempt pursuant to the Federal ESA 16 U.S.C. §1536 (a)(2); 50 Code of Federal Regulations (CFR) §402.03. Under Section 7(a)(2), a discretionary agency action jeopardizes the continued existence of a species if it "reasonably would be expected, directly or indirectly, to reduce appreciably the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of the species" 50 CFR §402.02.

Through this consultation, Reclamation will comply with its obligations under the ESA, namely, to: (1) avoid any discretionary action that is likely to jeopardize continued existence of listed species or adversely affect designated critical habitat; (2) take listed species only as permitted by the relevant Service; (3) and use Reclamation's authorities to conserve listed species. Reclamation also is proposing actions to benefit the species under its existing authorities and consistent with its 7(a)(1) obligation to conserve and protect listed species. Section 7(a)(1) alone does not give Reclamation additional authority to undertake any particular action, regardless of its potential benefit for endangered species. The SWP operations are coordinated with CVP operations and as such, are consulted on as part of the proposed action described in this BA. The coordinated operations of the CVP and SWP are subject to measures and/or alternatives required under the Federal biological opinions.

Recent Court Rulings

On December 14, 2007, the United States District Court for the Eastern District of California issued an Interim Remedial Order in Natural Resources Defense Council, et al. v. Kempthorne, 1:05-cv-1207 OWW GSA (E.D. Cal. 2007), to provide additional protection of the Federally-listed delta smelt pending completion of a new Biological Opinion for the continued operation of the CVP and SWP. The Interim Remedial Order remains in effect until the U.S. Fish and Wildlife Service (FWS) issues a new Biological Opinion for the continued operation of the CVP and SWP, which must be completed by September 15, 2008. A motion to extend the time for completion was filed on July 29, 2008. FWS has requested additional time to complete the Biological Opinions to December 15, 2008.

On April 16, 2008, the United States District Court for the Eastern District of California issued a Memorandum Decision and Order on the Cross-Motions for Summary Judgment filed in Pacific Coast Federation of Fishermen Association, et al. v. Gutierrez, 1:06-cv-245-OWW-GSA (E.D. Cal. 2008). The Court found that the Biological Opinion issued by the National Marine Fisheries Service (NMFS) in 2004 was invalid. An evidentiary hearing followed resulting in a Remedies

Ruling on July 18, 2008. The ruling concluded that the court needed further evidence to consider the Plaintiffs' proposed restrictions on CVP/SWP project operations. A Scheduling Order was filed by the court on July 24, 2008 and a further status conference is set for September 4, 2008 with evidentiary hearings to begin sometime in October 2008.

The California Endangered Species Act (CESA) provides the Department of Fish and Game (DFG) authority to authorize the take of endangered species incidental to an otherwise lawful activity. Pursuant to CESA, activities that impact State listed species must minimize and fully mitigate the impacts of the authorized take and the measures required to meet this obligation shall be roughly proportional in extent to the impact of the authorized taking on the species. Under Fish and Game Code Section 2080.1, DFG may determine that an incidental take statement and biological opinion issued pursuant to FESA is consistent with CESA and that no other State authorization or approval is required for the activity.

State-listed Species

On February 20, 2008, the California Fish and Game Commission issued an emergency regulation pursuant to Fish and Game Code section 2084 authorizing take of longfin smelt by the SWP and also imposing restrictions on the SWP under certain conditions for the purpose of protecting longfin smelt. Cal. Code Regs. tit. 14, § 749.3. Issuance of the emergency regulation followed the decision of the Commission to designate the longfin smelt as a candidate for listing under the California Endangered Species Act. The emergency regulation requires DWR to modify the operations of the SWP to meet prescribed flow ranges in Old and Middle Rivers that could go beyond the requirements imposed by the Interim Remedial Order described above and that are designed to protect larval and juvenile longfin smelt. The emergency regulation is effective until August 27, 2008 and has been extended into November 2008, with an option for one further extension into February 2009.

Federal Power Act

SWP

DWR operates Oroville's facilities as a multipurpose water supply, flood management, power generation, recreation, fish and wildlife enhancement, and salinity control project. The Federal Power Act (FPA) requires that DWR have a license from the Federal Energy Regulatory Commission (FERC) to operate the Oroville Facilities, FERC No. 2100. For the past 50 years, DWR has operated the Oroville Facilities under a license issued by the Federal Power Commission, precursor to FERC, that expired on January 31, 2007. Prior to expiration, DWR filed an application for a new license with FERC for the continued operation of the facilities, and FERC initiated a formal license proceeding on DWR's application. On March 24, 2006, DWR filed a comprehensive settlement agreement with FERC that is intended to result in the issuance of a new license for up to 50 years. Signatories to the agreement include: DWR, Interior, United States Forest Service, NMFS, Pacific Gas and Electric (PG&E), State Water Contractors, and American Rivers. The settlement agreement is currently pending before FERC. DWR is operating the Oroville Facilities pursuant to an annual license issued by FERC until such time as FERC issues a new license for the facilities.

Tribal Water Rights and Trust Resources

The Yurok and Hoopa Valley Tribes have fishing rights to take anadromous fish within their reservations. See Memorandum from the Solicitor to the Secretary, Fishing Rights of the Yurok and Hoopa Valley Tribes, M-36979 (October 4, 1993). These rights were secured to the Yurok and Hoopa Valley Tribes through a series of nineteenth century executive orders. Their fishing rights "include the right to harvest quantities of fish on their reservations sufficient to support a moderate standard of living." Id. at 3.

The executive orders that set aside what are now the Yurok and Hoopa Valley Reservations also reserved rights to an in-stream flow of water sufficient to protect the Tribes' rights to take fish within their reservations. See Colville Confederated Tribes v. Walton, 647 F.2d 42, 48 (9^{th} Cir.), cert. Denied, 454 U.S. 1092 (1981). Although the Tribes' water rights are presently unquantified, there are rights vested in 1891, at the latest, and perhaps as early as 1855. See, e.g., United States v. Adair, 723 F.2d 1394 (9^{th} Cir. 1983).

Water Rights

CVP

Federal law provides that Reclamation obtain water rights for its projects and administer its projects pursuant to State law relating to the control, appropriation, use, or distribution of water used in irrigation, unless the State law is inconsistent with clear Congressional directives. See 43 United States Code (U.S.C.) §383; California v. United States, 438 U.S. 645, 678 (1978); appeal on remand, 694 F.2d 117 (1982). Reclamation must operate the CVP in a manner that does not impair senior or prior water rights.

Reclamation was issued water rights by SWRCB to appropriate water for the CVP. Many of the rights for the CVP were issued pursuant to SWRCB Decision (D)-990, adopted in February 1961. Several other decisions and SWRCB actions cover the remaining rights for the CVP. These rights contain terms and conditions that must be complied with in the operation of the CVP. Over time, SWRCB has issued further decisions that modify the terms and conditions of CVP water rights. In August 1978, SWRCB adopted the Water Quality Control Plan (WQCP) for the Delta and Suisun Marsh, which established revised water quality objectives for flow and salinity in the Delta and Suisun Marsh. In D-1485, also adopted in August 1978, SWRCB required Reclamation and DWR to operate the CVP and SWP to meet all of the 1978 WQCP objectives, except some of the salinity objectives in the southern Delta. In addition, SWRCB, issued D-1594 in November 1983, and Order WR 84-2 in February 1984, defining Standard Permit Term 91 to protect CVP and SWP stored water from diversion by others. Permit terms and requirements, as they relate to operations, are discussed in the CVP-OCAP. In 1991, SWRCB adopted a WQCP that superseded parts of the 1978 plan, but SWRCB did not revise the water rights of DWR and Reclamation to reflect the objectives in the 1991 plan.

On May 22, 1995, SWRCB adopted a WQCP for the San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) Estuary (1995 Bay-Delta Plan). The 1995 Bay-Delta Plan superseded both the 1978 and 1991 plans. On December 29, 1999, SWRCB adopted (and then revised on

March 15, 2000) D-1641, amending certain terms and conditions of the water rights of the SWP and CVP. D-1641 substituted certain objectives adopted in the 1995 Bay-Delta Plan for water quality and flow objectives required to be met as terms and conditions of the water rights of the DWR and Reclamation. Permit terms and requirements, as they relate to operations, are discussed below. On December 13, 2006, SWRCB adopted an amended WQCP for the Bay-Delta, which became effective June, 2007. The SWRCB resolution adopting the WQCP stated that SWRCB did not believe there were any substantive changes to water quality standards from the 1995 Bay-Delta Plan.

SWP

Under California law, diversions of appropriated water since 1914 require a permit from the SWRCB. DWR has SWRCB permits and licenses to appropriate water for the SWP. These permits have terms that must be followed by DWR as the permit holder. The SWRCB has issued several decisions and orders that have modified DWR’s permits, many of which are the same decisions and orders that affect Reclamation CVP operations. These water right decisions, WR Order 98-09, D1485, and D1641 are described above and discussed below.

Water Contracts

CVP

As the divisions of the CVP became operational, Reclamation entered into long-term contracts with water districts, irrigation districts, and others for delivery of CVP water. Approximately 250 contracts provide for varying amounts of water. Most of these contracts were for a term of 40 years. The nature of the contracts vary, as some of the contracts were entered into with entities which claim water rights senior to the CVP, while other contracts are for water service. Some of the contracts, including the Sacramento River Settlement contracts, the San Joaquin Exchange Contracts, and certain refuge contracts, have defined minimum deliveries. The modeling described in Chapter 9 accurately represents CVP operations which incorporates Reclamation’s obligations and priorities for delivery under these different types of contracts.

Reclamation renewed numerous contracts in 2005 following issuance of the 2004 NMFS and 2005 FWS BOs regarding the long-term operations of the CVP and SWP. Following reinitiation of this Section 7 consultation, and as appropriate, Reclamation has executed interim water service contracts. Reclamation has an obligation to deliver water to the CVP contractors in accordance with contracts between Reclamation and the contractors. The execution of long-term CVP contracts in the future will be the subject of separate Section 7 consultations and, therefore, is not included as part of the current proposed action.

Pursuant to the Interim Remedial Order issued by Judge Wanger on December 14, 2007, Natural Resources Defense Council, et al. v. Kempthorne, 1:05-cv-1207 OWW GSA (E.D. Cal. 2007), Reclamation is prohibited from executing “any long-term water service contracts with CVP contractors until the [FWS’] New Biological Opinion” for the long-term operations of CVP and SWP is completed. Judge Wanger ordered that FWS complete the new BO by September 15, 2008.

SWP

In the 1960s, DWR entered into long-term water supply contracts with 32 water districts or agencies to provide water from the SWP. Over the years, a few of these water agencies have been restructured, and today DWR has long-term water supply contracts with 29 agencies and districts. These 29 contractors supply water to urban and agricultural water users in Northern California, the San Francisco Bay Area, the San Joaquin Valley, and Southern California. Of the contracted water supply, approximately three-quarters goes to municipal and industrial (M&I) users, and one-quarter goes to agricultural users. Through these contracts, the SWP provides water to approximately 23 million people in California, about 60% of the state's population. The contracts are in effect for the longest of the following periods: the project repayment period that extends to the year 2035; 75 years from the date of the contract; or the period ending with the latest maturity date of any bond issued to finance project construction costs.

Monterey Amendment

In 1994, DWR and most SWP contractors entered into an agreement known as the Monterey Amendment (a title based on the location of negotiations for the agreement). The agreement resolved long-term water allocation disputes and established a new water management strategy for the SWP. Key principles of the agreement include: (1) changes in allocation methods, including elimination of the agriculture-first-cut in times of shortage so that shortages are allocated proportionally to all SWP contractors based on Table A amounts; (2) water supply management measures including Castaic Lake and Perris reservoir management and out-of-service-area storage programs. The provisions of the SWP water supply contracts, including the Monterey Amendment, provide a means for facilitating the transfer and storage of water and for allocating water available to the SWP based on demand, water conditions, and regulatory constraints. As described in the Draft EIR for the Monterey Amendment (page 2-11), Article 6 of each contract includes a Table A amount which is used as a basis for determining the share of costs paid for by each contractor and for determining how to allocate the total SWP water supply among contractors in years when there is not enough water to meet all the contractors requests. Article 21 water is water that is excess to all other SWP needs and is available for allocation after all these needs have been met. It is still subject to all applicable regulatory constraints.

As used in the SWP water supply contracts, Article 21 water is water that is available after other priorities are fulfilled, such as filling of SWP reservoirs and Table A requested deliveries. Prior to the Monterey Amendment, there were several classifications of water surplus to these priorities. The Monterey Amendment deleted some of these classifications and consolidated others. Therefore it only changed the name of this class of water and how it is allocated among the SWP contractors; it did not create a new class of water.

Availability of Article 21 water in the Delta usually occurs during the January to April period and is dependent on hydrology and allowable pumping from the Delta. For example, Article 21 water was limited by hydrology from 1988 to 1995 due to the 1987-1992 drought and a dry year in 1994. However, due to a more favorable hydrology from 1996 through 2005 and due to increased water demands overall, Article 21 deliveries averaged 163,000 acre feet. This increase was not caused by the change in name of "surplus water" but to hydrologic conditions and overall water demand. A portion of this increased demand is due to the fact that the Monterey

Amendment did “pre-approve” storage of SWP supplies in locations outside of the SWP contractors’ service areas. It is this linkage between additional storage opportunities that is related to the impact of the Monterey Amendment on Delta pumping amounts and timing.

Power Contracts

CVP

In 1978, Contract 8-07-20-P0004 between the Western Area Power Administration (Western) and PG&E was entered into to provide transmission wheeling services from the Reclamation’s New Melones generators to the CVP transmission system at the Tracy Substation. This contract expires in 2028.

A second contract with PG&E (Contract #14-06-200-2207A) provides for transmission wheeling of CVP generation to Reclamation’s share of the San Luis Facilities that include Dos Amigos, Gianelli, and O’Neill Pumping Plants as well as many small canal-side pumping plants. In addition, this contract provides transmission-wheeling services from Reclamation’s share of the Gianelli and O’Neill Pumping Plants (when they are operating as generators) to the Tracy Substation. This contract expires in 2016.

SWP

DWR has authority to include as part of SWP facilities the construction of such plants and works for generation of electric power and distribution and to enter into contracts for the sale, use, and distribution of the power as DWR may determine necessary (Wat. Code Sec. 11295 and 11625). The SWP power plants generate about half of the energy it needs to move water within the State. Because the SWP consumes more power than it generates, it meets its remaining power needs by purchasing energy or making energy exchanges with other utilities.

Other Agreements

The CVP and SWP divert water from the Sacramento River and the Delta. Reservoir releases and Delta exports must be coordinated to ensure that the projects operate within agreed upon procedure and in a manner consistent with terms and conditions imposed in the Projects’ water right permits and licenses. Below are summaries of agreements that impact operations of the CVP and/or the SWP.

Coordinated Operations Agreement (COA)

The Coordinated Operation Agreement (COA) between the United States of America and DWR to operate the CVP and the SWP was signed in November 1986. Congress, through Public Law 99-546 authorized and directed the Secretary to execute and implement the COA.   The COA defines the rights and responsibilities of the CVP and SWP with respect to in-basin water needs and provides a mechanism to account for those rights and responsibilities.

Under the COA, Reclamation and DWR agree to operate the CVP and SWP under balanced conditions in a manner that meets Sacramento Valley and Delta needs while maintaining their respective annual water supplies as identified in the COA. Balanced conditions are defined as periods when the two Projects agree that releases from upstream reservoirs, plus unregulated flow, approximately equal water supply needed to meet Sacramento Valley in-basin uses and Project exports. Coordination between the two projects is facilitated by implementing an accounting procedure based on the sharing principles outlined in the COA. During balanced conditions in the Delta when water must be withdrawn from storage to meet Sacramento Valley and Delta requirements, 75 percent of the responsibility to withdraw from storage is borne by the CVP and 25 percent by the SWP. The COA also provides that during balanced conditions when unstored water is available for export, 55 percent of the sum of stored water and the unstored export water is allocated to the CVP, and 45 percent is allocated to the SWP. Although the principles were intended to cover a broad range of conditions, changes introduced by past BOs, SWRCB D-1641, and CVPIA were not specifically addressed by the COA. However, these variances have been addressed by Reclamation and DWR through mutual informal agreements.

The COA is the federal nexus for ESA Section 7 consultation on operations of the SWP. Because of commitment expressed in the COA and the Congressional mandate to Reclamation to operate the CVP in conjunction with the SWP, the operations of the two projects are linked and are best analyzed together.

CALFED

In the August 28, 2000, CALFED Bay-Delta Program (CALFED) Record of Decision (ROD), Reclamation, DWR and other State and Federal agencies committed to implementing a long-term plan to restore the Bay-Delta. CALFED is a 30-year Program guided by four major resource management objectives in achieving a Delta that has a healthy ecosystem and can supply Californians with the water they need—water supply reliability, ecosystem restoration, water quality, and levee system integrity. These objectives are further addressed through 11 Program elements as a way of sustaining CALFED’s long-held approach of fulfilling its objectives in a concurrent and balanced manner—water management, storage, conveyance, ecosystem restoration, environmental water account, levee system integrity, watershed management, water supply reliability, water use efficiency, water quality, water transfers, and science.

The ROD describes a strategy for implementing an overall plan to fix the Delta and identifies complementary actions the CALFED Agencies will also pursue in coordination with programs developed in the plan and in support of the stated goals. Nothing in the ROD is intended to, nor does, affect the regulatory responsibilities of individual CALFED Agencies (ROD, page 5).

A legal action was filed in September 2000 challenging the ROD where a judgment resulted holding the PEIS/R satisfied the requirements of CEQA. An appeal followed and the trial court ruling was reversed. The Appellate Court decision was appealed to the California Supreme Court that issued a decision on June 5, 2008 holding the CALFED final PEIS/R complied with CEQA. A second case was filed in Federal court; however, that litigation has been stayed pending resolution of the State court case.

Several forums and teams developed under the CALFED collaborative agreements and resulting ROD continue to progress and contribute to the adaptive water management in the Delta. These include the Water Operations Management Team (WOMT), Integrated Water Operations and

Fisheries Forum (IWOFF), Data Assessment Team (DAT), Salmon Decision Tree and the Delta Smelt Working Group (DSWG). Although many of these entities originated from CALFED, they are included in regulatory requirements of the SWRCB and previous BOs.

Coordinated Water Operations

The Implementation Memorandum of Understanding (MOU), also signed on August 28, 2000, memorialized the operations decision-making process that had evolved through the CALFED Operations Coordination Group (Ops Group) process, including an Operations Decision Making Process (Attachment D of the ROD). This process consists of staff-, stakeholder-, and policy-level forums for addressing operational issues. This MOU was amended in September 2003, but the Ops Group process was not affected.

One of these forums, the Water Operations Management Team (WOMT), consists of managers of Reclamation, FWS, NMFS, DFG, DWR, and the U.S. Environmental Protection Agency (EPA). WOMT provides a frequent opportunity for managers to discuss CVP/SWP operations and related fishery issues. WOMT typically meets weekly to discuss current fishery data, staff and group recommendations on fish protections and CVP/SWP operations. In the case of operations or actions affecting Federally listed fish species, WOMT makes recommendations to the appropriate fishery regulatory agency for a final determination on fishery protection actions. The WOMT decisions are posted on-line and any change from formal recommendations is described in the notes.

The Ops Group was established by the 1994 Framework Agreement. The Ops Group (consisting of DWR, DFG, SWRCB, Reclamation, FWS, NMFS, and EPA) coordinates the operations of the projects with fisheries protection and implementation of the CVPIA. Shortly after its formation, the Ops Group provided a forum for stakeholders to provide input into the operations decision process. The Ops Group also established three teams to facilitate the decision-making process, data exchange, and information dissemination. The CVPIA Section 3406(b)(2) Implementation Team (B2IT) assists Interior with implementation of CVPIA Section 3406(b)(2). The DAT is an agency-driven group that includes stakeholder participation to review biological data and provide input to Reclamation and DWR on potential actions that could be implemented to protect fish. The IWOFF is a stakeholder-driven forum to aid information dissemination and facilitate discussion regarding operation of the CVP and SWP, and has been meeting since 1995.

The Ops Group developed and implements the Chinook Salmon Protection Decision Process. The process includes monitoring of environmental conditions and salmon movement, data assessment procedures, specific indicators that spring-run Chinook are entering the Delta from upstream or being entrained at the SWP or CVP export facilities, and operational responses to minimize the effects of SWP and CVP facilities on emigrating spring-run salmon. The Ops Group's decision-making process is also used for protection of other Chinook salmon runs.

The Ops Group also created the DSWG, a team of fish biologists from participating agencies who review current data on delta smelt and longfin smelt, and make recommendations to FWS and DFG for the protection of the delta smelt and longfin smelt respectively.

Environmental Water Account

The Environmental Water Account (EWA) is a cooperative management program described in the CALFED ROD. The purpose of EWA is to provide protection to the fish of the Bay-Delta estuary through environmentally beneficial changes in SWP/CVP operations at no uncompensated water cost to the Projects' water users.

The use of EWA assets used historically and projected in a limited use has been included in some operations studies to reflect current operational flexibility to reduce incidental take of listed species and to provide for restoration and recovery of such species. Inclusion of the EWA in this description of present and future actions for CVP and SWP operations does not represent a decision on the future implementation of EWA. Federal funding of EWA is authorized through 2010 and DWR anticipates allocation of Yuba Water (See Yuba Accord section below) for EWA purposes and continuation of the use of operational flexibility, calling this a "limited EWA" in this BA. The EWA agencies have completed an EIR/EIS for the potential extension of an EWA to 2011, but have yet to decide on its size and scope.

Trinity River

In December 2000, Interior signed the Record of Decision (ROD) for the Trinity River Mainstem Fishery Restoration Environmental Impact Statement (EIS) and EIR. The ROD was the culmination of years of studies on the Trinity River. The ROD adopted the preferred alternative, a suite of actions that included a variable annual flow regime, mechanical channel rehabilitation, sediment management, watershed restoration, and adaptive management.

The EIS/EIR was challenged in Federal District Court. (Westlands Water District, et al. v. United States Dept. of the Interior, 275 F.Supp.2d 1157 (E.D. Cal, 2002)). Initially, the District Court limited increased flows to the Trinity River called for by the ROD until preparation of a supplemental environmental document was completed. On July 13, 2004, the Ninth Circuit reversed that part of the decision, ruling that Reclamation did not need to prepare a supplemental environmental document. (Westlands Water District, et al. v. United States Dept. of the Interior, 376 F.3d 853 (9th Cir. 2004)). Consequently, Reclamation has been and continues to implement the flows described in the Trinity ROD and has included the Trinity ROD flows as part of this proposed action on which Reclamation is consulting. In the same decision, the Ninth Circuit affirmed the District Court's ruling invaliding certain terms and conditions imposed in the biological opinions applicable to the ROD (Id.)

San Joaquin River Agreement

The San Joaquin River Agreement (SJRA) includes a 12-year experimental program providing for increased flows and decreased Delta exports in the lower San Joaquin River during a 31-day pulse flow period during April-May. It also provides for the collection of experimental data during that time to further the understanding of the effects of flows, exports, and the Head of Old River Barrier on salmon survival. This experimental program is commonly referred to as the Vernalis Adaptive Management Program (VAMP). The SJRA also provides water for flows at other times on the Stanislaus, Merced, and lower San Joaquin Rivers. The SJRA establishes a management and technical committee to oversee, plan, and coordinate implementation of activities required under the SJRA. Reclamation, DWR, FWS, DFG, and NMFS are signatories to the SJRA; other signatories include San Joaquin River water rights (SJRWR) holders, CVP and SWP water contractors, and other stakeholders. The signatory SJRWR holders formed the San Joaquin River Group Authority to coordinate implementation of their responsibilities under the SJRA. Under the SJRA, Reclamation and DWR purchase water for VAMP flows from the SJRWR holders of up to 110,000 af may be provided for VAMP during April-May with an additional 27,500 af that may be provided at other times. In certain "double-step" years, up to an additional 47,000 af may need to be acquired to fully meet VAMP flow objectives. This water would be provided under supplemental agreements separate from the SJRA. The SJRA will expire on December 31, 2009 unless extended pursuant to the conditions of the agreement.

The Yuba Accord

On December 4, 2007, DWR and the Yuba County Water Agency (YCWA) entered into a water purchase agreement to provide water supplies through 2025. The agreement provides for DWR to pay for eight years of transfers for the use in a limited EWA process and for certain dry-year supplies for SWP and CVP contractors. YCWA will provide transfer water by releasing stored water in New Bullards Bar Reservoir for EWA purposes and will implement groundwater substitution in the drier years to produce the water that will go to the water contractors. In March 2008, the SWRCB approved YCWA's petitions to allow the water to be transferred at the SWP and CVP Delta facilities and to permit YCWA operations under their water right permits pursuant to specified flows for fish on the lower Yuba River. The transferred water will include water released to meet instream flow needs on the lower Yuba River pursuant to the Yuba Accord Fisheries Agreement which provides for instream flows in six different flow schedules based on different water year types. From 2008 through 2015 the release of water is estimated at 60,000 acre-feet and from 2016 to 2025 a minimum of 20,000 acre feet will be released under the Yuba Accord agreements.

Water Transfers

Water transfers relevant to this BA occur when a water user north of the Delta undertakes actions to make water available for transfer, generally for use south of the Delta. Water transfers requiring export from the Sacramento River watershed at the SWP and CVP Delta pumping facilities include transfers for dry-year transfer agreements, limited EWA, the Yuba Accord Water Purchase Agreements, the proposed Sacramento Valley Water Management Program, if implemented, and other agreements that may be developed between water users. The conveyance of water through the Delta for these transfers are done at times when pumping capacity at the Federal and State pumping plants is available to move the water. Reclamation and DWR will work together to facilitate transfers and will convey water for these transfers in accordance with all existing regulations and permit requirements.

DWR/DFG Delta Fish Agreement (Four Pumps Agreement)

The 1986 Delta Fish Agreement offsets direct losses of striped bass, steelhead, and Chinook salmon caused by the diversion of water at the Harvey O. Banks Pumping Plant. Since 1986, approximately $60 million in combined funding from the Annual Mitigation and $15 Lump Sum components have been approved for over 40 fish mitigation projects through December 2007. The Agreement has been amended to extend expenditure of the $15 million Lump Sum funding component of the original Agreement three times in 1997, 2002 and 2004. A 2008 Amendment will extend the expenditure through December 31, 2012. Article VII of the Agreement provides a process for amendments based on new information. DWR, DFG and Reclamation executed an Interim South Delta Facilities Agreement pursuant to Article VII in 1995. The 1995 Agreement incorporated the Framework Agreement of 1990 and the CALFED Agreements of 1994. In July 2005 DWR and DFG expanded the scope of the Agreement to establish a separate fund of $2.5 million to address near-term pelagic fish issues related to the Pelagic Organism Decline (POD). Through fiscal year 2007-08, $1.5 million of annual POD funding was used to support the UC Davis Delta smelt facility's operations.

In May 2007 DWR and DFG entered into a Memorandum of Understanding to begin negotiations to amend the 1986 Delta Fish Agreement to address direct and indirect take of Delta smelt and indirect take of salmon and methods to develop mitigation credits for this take pursuant to CESA. These negotiations now include mitigation considerations for the Longfin smelt. The 2008 Amendment is intended to address impacts of the SWP Delta Pumping Facilities on native species (winter-run Chinook salmon, spring-run Chinook salmon, delta smelt and Longfin smelt). Details of the Agreement and proposed mitigation projects are provided in summary in Chapter 18 "conservation actions" and in detailed in Appendix X of the BA. CDWR and CDFG are finalizing the 2008 Amendment to the Delta Fish Agreement between CDWR and CDFG, and anticipate that the Amendment will be executed prior to the issuance of the OCAP BOs.

The Proposed Action

The CVP is composed of some 18 reservoirs with a combined storage capacity of more than 11 million af, 11 powerplants, and more than 500 miles of major canals and aqueducts (see Figure 2-1). These various facilities are generally operated as an integrated project, although they are authorized and categorized in divisions. Authorized project purposes include flood control; navigation; provision of water 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. For example, flood control is not an authorized purpose of the CVP's Trinity River Division. As initially authorized, the primary CVP purpose was to provide water for irrigation throughout California's Central Valley. The CVPIA has amended CVP authorizations to include fish and wildlife mitigation, protection, and restoration as purposes equal in priority to irrigation and domestic uses, and fish and wildlife enhancement as a purpose equal in priority to power generation.

The SWP stores and distributes water for agricultural and M&I uses in the northern Central Valley, the San Francisco Bay area, the San Joaquin Valley, the Central Coast, and Southern California. Other project functions include flood control, water quality maintenance, power generation, recreation, and fish and wildlife enhancement.

The proposed action is to continue to operate the CVP and SWP. In addition to current-day operations, several future actions are to be included in this consultation. These actions are as follows: permanent barriers operated in the South Delta, an intertie between the California

Aqueduct and the Delta-Mendota Canal, Freeport Regional Water Project (FRWP), changes in the operation of the Red Bluff Diversion Dam (RBDD), the Sacramento River Water Reliability Project, the Alternative Intake Project for CCWD, the operational elements of the American River Flow Management Standard, and various operational changes that are identified in this project description.

Although the actions listed in the previous paragraph are not being implemented at present, they are part of the future proposed action on which Reclamation is consulting. Therefore, proposed activities only address the operations of the action; that is, the activities do not include construction of any facilities to implement the actions. All site-specific/localized activities of the actions such as construction/screening and any other site-specific effects will be addressed in a separate Section 7 consultation. Table 1-1 summarizes the proposed operational actions of the CVP covered by this consultation and Table 1-2 describes SWP proposed operational actions.

Table 1-1 Proposed CVP operational actions for consultation.

Action	Requirement for Action
I. Trinity River Division	SWRCB Permit Order 124
Trinity Lake operations	Safety of Dams Criteria
Lewiston Dam releases and Trinity River flows	SWRCB permits for diversions from Trinity 2000 Trinity ROD Westlands Water District (Westlands) et al., vs. Interior (Trinity litigation)
Whiskeytown Dam releases to Clear Creek	SWRCB permits for diversions from Trinity, Clear Creek (permits specify minimum downstream releases) 1960 Memorandum of Agreement (MOA) with DFG (establishes minimum flows released to Clear Creek) 1963 release schedule Consistent with AFRP objectives (Appendix A to the October 5, 1999, Decision on (b)(2) implementation) and (b)(2) availability Stability Criteria Thresholds of Trinity Storage
Townsend requirement	2000 Agreement with FWS (b)(2)
Spring Creek Debris Dam operations	1980 MOA with DFG, SWRCB
Diversions to Sacramento River	SWRCB WR 90-5 (temperature control objectives), SWRCB WR 91-1
Temperature Objectives	SWRCB WR 90-5, SWRCB WR 91-1
II. Shasta Division	SWRCB WR 90-5
Shasta Dam operations	Regulating Criteria-Flood Control Act 1944 CVPIA-Temperature Control Device (TCD) Operations

Action	Requirement for Action
Keswick Dam releases to Sacramento River Minimum flows of 3,250 cubic feet per second (cfs) October through March	1960 MOA with DFG: established flow objectives, minimum releases in dry, critical years 1981 Agreement with DFG: established normal-year minimum releases September-February SWRCB WR 90-5: established year-round minimum flows AFRP (Appendix A to the October 5, 1999 Decision on (b)(2) implementation) and (b)(2) availability Navigation flow requirement to Wilkins Slough CVPIA: ramping criteria consistent with 3406(b)(2) and 3406(b)(9)
III. Sacramento River Division	SWRCB WR 90-5
Red Bluff Diversion Dam operations • Gates raised from September 15 to May 14 with flexibility to temporarily lower gates in excess of pumping capacity • Future installation of additional pump	1986 Agreement with NOAA Fisheries et al., gates raised in winter months for fish passage
Tehama-Colusa Canal operations	Temporary diversion from Black Butte Reservoir (SWRCB permit)
Sacramento River temperature objectives	SWRCB WR 90-5: temperature objectives added to permits, modified 1960 MOU with DFG regarding minimum flows SWRCB WR 91-1 (temperature objectives)
Sacramento-Trinity Water Quality Monitoring Network	SWRCB WR 90-5, 91-1
Sacramento River Temperature Task Group	SWRCB WR 90-5, 91-1
ACID Diversion Dam ops	Reclamation contract (water service and diversion)
IV. American River Division	
Folsom Dam and Power Plant operations	U.S. Army Corps of Engineers (Corps) Flood Control Manual, Flood Control Diagram (regulating criteria) 1996 Agreement with Sacramento Area Flood Control Agency (SAFCA) (modified flood control criteria) AFRP (Appendix A to the October 5, 1999 Decision on (b)(2) implementation) and (b)(2) availability Draft DFG criteria pursuant to CVPIA 3406(b)(9) (addressing flow fluctuations) CVP local municipal diversions
Nimbus Dam operations and Lower American River flows • Includes year-round temperature control	AFRP and (b)(2) availability: minimum flows October-September, stability objectives Draft DFG criteria pursuant to CVPIA 3406(b)(9) (addressing flow fluctuations)
Folsom South Canal operations	Contractual commitments

Action	Requirement for Action
Freeport Regional Water Project	Contract with East Bay Municipal Utility District (EBMUD) Sacramento County contract and water rights
V. Eastside Division	
New Melones Dam and Reservoir operations and Lower Stanislaus River flows below Goodwin Dam	Corps Flood Control Manual, Flood Control Diagram (New Melones and Tulloch) Oakdale Irrigation District (OID), South San Joaquin Irrigation District (SSJID) contract (Tri-dams Agreement for afterbay storage) New Melones Interim Plan of Operation (NMIPO) (includes AFRP flows with (b)(2) water) 1988 OID, SSJID Agreement and Stipulation (release of annual inflows for diversion) SWRCB D-1422 (release of 98,000 af for fish and wildlife purposes, dissolved oxygen [DO] standards at Ripon) 1987 DFG Agreement (increased flows over SWRCB D-1422) 1995 WQCP (minimum DO concentration) 1999 SJRA flows and water supplies CVP Water Service contracts
Support of San Joaquin River requirements and objectives at Vernalis	SWRCB D-1641 (Vernalis flow requirements February-June, Vernalis water quality objectives, SJRA implementation) CALFED ROD Regulatory Baseline (2:1 flow/export ratio met with (b)(2), EWA)
VI. Delta Division	SWRCB D-1641
Tracy Pumping Plant • Pumping curtailments supported with (b)(2) or EWA assets	Salmon Tree Decision CVPIA CALFED ROD and EWA Operating Principles
Delta Cross Channel (DCC) operation	SWRCB D-1641(DCC closure: February-May, 14 days between May 21-June 15, 45 days between November-January) Salmon Decision Tree
Contra Costa Canal (CCC) operations	CVPIA (Fish Screen Program) 1993 Winter–run Chinook Salmon BO for Los Vaqueros 1993 Delta Smelt BO for Los Vaqueros (requires Old River diversions January-August to extent possible, diversion reduced during dry conditions, reservoir refilling criteria, reservoir releases in spring)
Export/Inflow (EI) ratio	SWRCB D-1641
X2	SWRCB D-1641
31-day export limit (Mid-April-Mid-May)	SJRA-VAMP SWRCB D-1641
Delta outflow	SWRCB D-1641 (minimum outflow July-January: 3,000-8,000 cfs, habitat protection outflow February-June: 7,100-29,200 cfs, February Salinity Starting Condition Determination)

Action	Requirement for Action
Water quality	SWRCB D-1641 (M&I standards, agricultural standards for Western/Interior Delta and southern Delta, fish and wildlife standards for San Joaquin River and Suisun Marsh)
Joint Point of Diversion (JPOD)	SWRCB D-1641
Intertie	CALFED ROD
VII. Friant Division	
Millerton Lake and Friant Dam operations, Friant-Kern Canal operations, and Madera Canal operations	Corps Flood Control Diagram, Mammoth Pool Operating Contract (with Southern California Edison [SCE], Water Deliveries [Class I, Class II, and Section 215 supply], SJRWR [flow at Gravelly Ford], Miller and Lux Water Rights exchange)
VIII. West San Joaquin Division	
San Luis Reservoir, Gianelli Pumping and Generating Plant, San Luis Canal, O'Neill Forebay operations, and Dos Amigos Pumping Plant	1961 DWR/Reclamation Agreement (as amended) CVP Water Service Contracts and Deliveries
IX. San Felipe Division	
Pacheco Pumping Plant, Santa Clara Pipeline, Hollister Conduit, and Coyote Pumping Plant	CVP Water Service Contracts and Deliveries for Santa Clara Valley Water District and San Benito County
X. Other	
Actions using (b)(1), (b)(2)	CVPIA AFRP 2003 Final Decision on (b)(2) Implementation
EWA	CALFED ROD and Programmatic BOs EWA Operating Principles CVPIA

Table 1-2 Proposed SWP Operational Actions for Consultation.

Action	Requirement for Action
I. Delta Field Division	
Clifton Court Forebay gate operations	1986 Settlement Agreement with SDWA
Clifton Court inflow criteria	USACE Public Notice #5820A (October 13, 1981)
Clifton Court storage	DWR's Division of Safety of Dams Criteria
500 cfs	USACE permit # 199900715
Skinner Fish Facility	DWR/DFG Agreement
Banks Pumping Plant	SWRCB D-1641
North Bay Aqueduct	SWRCB D-1641
Suisun Marsh Salinity Control Gates	SWRCB D-1641
Temporary Barriers	1986 Settlement Agreement with SDWA; USACE permit, Numbers SPK-200100121, SPK-20000696
Export/Inflow (EI) ratio	SWRCB D-1641
X2	SWRCB D-1641
31-day export limit (Mid-April to Mid-May)	SJRA-VAMP SWRCB D-1641
Delta outflow	SWRCB D-1641 (minimum outflow July-January: 3,000-8,000 cfs, habitat protection outflow February-June: 7,100-29,200 cfs, February Salinity Starting Condition Determination)
Water quality	SWRCB D-1641 (M&I standards, agricultural standards for Western/Interior Delta and southern Delta, fish and wildlife standards for San Joaquin River and Suisun Marsh)
Joint Point of Diversion (JPOD)	SWRCB D-1641
South Delta Improvements Program, Stage 1*	CALFED ROD
II. San Joaquin Field Division	
San Luis Reservoir, Gianelli Pumping and Generating Plant, San Luis Canal, O'Neill Forebay operations, and Dos Amigos Pumping Plant	1961 DWR/Reclamation Agreement (as amended) CVP Water Service Contracts and Deliveries
III. Oroville Field Division	
Oroville Facilities**	DWR's Division of Safety of Dams Criteria, FERC License #P-2100 Requirements
IV. Other	
EWA	CALFED ROD and Programmatic BOs EWA Operating Principles and annual interim protocols CVPIA

*Operations, not construction, of the SDIP permanent gates are included in this consultation.

**The Oroville Facilities are included in this summary for reference only and are not submitted for consultation because DWR is obtaining separate biological opinions for these operations pursuant to the relicensing process with FERC.

Action Area

The Action Area is defined as those areas directly or indirectly affected by the Proposed Action. Therefore, the Action Area for this BA is as follows including the waters of the lake or reservoir (if included) for each watercourse:

- Sacramento River from Shasta Lake downstream to and including the Sacramento-San Joaquin Delta;
- Feather River from Lake Oroville to its confluence with the Sacramento River;
- Trinity River from Trinity Lake to its confluence with the Klamath River;
- Klamath River from the confluence with the Trinity River down to and including the Klamath River estuary and plume;
- Clear Creek from Whiskeytown Reservoir to its confluence with the Sacramento River;
- American River from Folsom Lake downstream to its confluence with the Sacramento River
- Stanislaus River from New Melones Reservoir to its confluence with the San Joaquin River;
- San Joaquin River from the confluence with the Stanislaus River downstream to and including the Sacramento-San Joaquin Delta; and
- San Francisco Bay

Chapter 2 Project Description for the Central Valley Project and State Water Project

Introduction

Reclamation and DWR propose to continue to operate the CVP and SWP to divert, store, and convey Project water consistent with applicable law. See map in Figure 2-1. The CVP's major storage facilities are Shasta, Trinity, Folsom and New Melones. The upstream reservoirs release water to provide water for the Delta of which can be exported a portion through Jones pumping plant to store in the joint reservoir San Luis or deliver down the Delta Mendota Canal. The SWP owns Lake Oroville upstream and releases water for the Delta that can be exported at Harvey O. Banks Pumping Plant (Banks) for delivery through the California Aqueduct. These operations are summarized in this BA with more detail.

The Proposed Action

The proposed action is the continued operation of the CVP and SWP. The proposed action includes the operation of the temporary barriers project in the south Delta and the 500 cfs increase in SWP Delta export limit July through September. In addition to current day operations, several other actions are included in this consultation. These actions are: (1) an intertie between the California Aqueduct (CA) and the Delta-Mendota Canal (DMC), (2) Freeport Regional Water Project (FRWP), (3) the operation of permanent gates, which will replace the temporary barriers in the South Delta, (4) changes in the operation of the Red Bluff Diversion Dam (RBDD), (5) Sacramento River Water Reliability Project, (6) Alternative Intake Project for CCWD, (7) operational elements of the American River Flow Management Standard, and (8) minor operational changes that are identified in this chapter. The other actions will come online at various times in the future. As stated in Chapter 1, inclusion of future actions in the project description of this BA does not constitute a decision to take that action.

All site-specific/localized activities of the actions such as construction/screening and any other site-specific effects will be addressed in separate action-specific section 7 consultations. In addition, DWR will need to consult with the California Department of Fish and Game (DFG), as may be appropriate, to address applicable requirements of the State Endangered Species Act. This BA may assist DWR and DFG in their consultation to ensure that DWR is in compliance with the State ESA.

Table 2-1 summarizes the differences between current operational actions and future operational actions to be covered by this consultation. A detailed summary of all operational components and associated modeling assumptions are included in Table 9-5.

Table 2-1 Major Proposed Future Operational Actions for Consultation.

Area of Project	2004 Conditions	Today 2008	Future 2030
Trinity & Whiskeytown	Trinity Restoration Flows 368,600-815,000 af	Same	Same
Shasta/Sacramento River	Red Bluff Diversion Dam (RBDD) 8 months gates out	Same	New RBDD Operation 10 months gates out with pumping plant
Oroville and Feather River	Old FERC License and NMFS 2004 BO	Same	Expect New FERC License
Folsom and American River	Current Demands	Updated CurrentDemands, operate to Minimum Instream Flow Management	Build out of demands, New American River Flow Management, and Freeport Regional Water Project
New Melones and Stanislaus River	Interim Plan of Operations Guidance	Interim Plan of Operations Guidance	New Transitional Plan
Friant Division	Historic Operations	Same	Same
Sacramento-San Joaquin Delta	2001 Demands	2005 Demands	2030 Demands
Suisun Marsh	Same	Same	Expect to Implement New Charter
WQCP	D-1641	Same	Same
COA	1986 Guidance	Same	Same
CVPIA	May 9, 2003 Decision	Same	Same
CALFED	Full EWA	Full EWA	Limited EWA
Banks Pumping Plant	6680* cfs & Temp Barriers	6680* cfs & Temp Barriers	6680* cfs and Permanent operable gates
Jones Pumping Plant	Max of 4600 cfs	Same	Max 4600 cfs with Flexiblity of Intertie

- This diversion rate is normally restricted to 6,680 cfs as a three-day average inflow to Clifton Court Forebay, although between December 15 and March 15, when the San Joaquin River is above 1,000 cfs, one-third of the San Joaquin River flow at Vernalis may be pumped in addition. Furthermore, the SWP is permitted to pump an additional 500 cfs between July 1 and September 30 to offset water costs associated with fisheries actions making the summer limit effectively 7,180 cfs.

Figure 2-1 Map of California CVP and SWP Service Areas

Coordinated Operations of the CVP and SWP

Coordinated Operations Agreement

The CVP and SWP use a common water supply in the Central Valley of California. The DWR and Reclamation (collectively referred to as Project Agencies) have built water conservation and water delivery facilities in the Central Valley in order to deliver water supplies to affected water rights holders as well as project contractors. The Project Agencies' water rights are conditioned by the SWRCB to protect the beneficial uses of water within each respective project and jointly for the protection of beneficial uses in the Sacramento Valley and the Sacramento-San Joaquin Delta Estuary. The Project Agencies coordinate and operate the CVP and SWP to meet the joint water right requirements in the Delta.

The Coordinated Operations Agreement (COA), signed in 1986, defines the project facilities and their water supplies, sets forth procedures for coordination of operations, identifies formulas for sharing joint responsibilities for meeting Delta standards, as the standards existed in SWRCB Decision 1485 (D-1485), and other legal uses of water, identifies how unstored flow will be shared, sets up a framework for exchange of water and services between the Projects, and provides for periodic review of the agreement.

Implementing the COA

Obligations for In-Basin Uses

In-basin uses are defined in the COA as legal uses of water in the Sacramento Basin, including the water required under the SWRCB D-1485 Delta standards (D-1485 ordered the CVP and SWP to guarantee certain conditions for water quality protection for agricultural, municipal and industrial [M&I], and fish and wildlife use). Each project is obligated to ensure water is available for these uses, but the degree of obligation is dependent on several factors and changes throughout the year, as described below.

Balanced water conditions are defined in the COA as periods when it is mutually agreed that releases from upstream reservoirs plus unregulated flows approximately equals the water supply needed to meet Sacramento Valley in-basin uses plus exports. Excess water conditions are periods when it is mutually agreed that releases from upstream reservoirs plus unregulated flow exceed Sacramento Valley in-basin uses plus exports. Reclamation's Central Valley Operations Office (CVOO) and DWR's SWP Operations Control Office jointly decide when balanced or excess water conditions exist.

During excess water conditions, sufficient water is available to meet all beneficial needs, and the CVP and SWP are not required to supplement the supply with water from reservoir storage. Under Article 6(g) of the COA, Reclamation and DWR have the responsibility (during excess water conditions) to store and export as much water as possible, within physical, legal and contractual limits. In excess water conditions, water accounting is not required. However, during balanced water conditions, the Projects share the responsibility in meeting in-basin uses.

When water must be withdrawn from reservoir storage to meet in-basin uses, 75 percent of the responsibility is borne by the CVP and 25 percent is borne by the SWP[1]. When unstored water is available for export (i.e., Delta exports exceed storage withdrawals while balanced water conditions exist), the sum of CVP stored water, SWP stored water, and the unstored water for export is allocated 55/45 to the CVP and SWP, respectively.

Accounting and Coordination of Operations

Reclamation and DWR coordinate on a daily basis to determine target Delta outflow for water quality, reservoir release levels necessary to meet in-basin demands, schedules for joint use of the San Luis Unit facilities, and for the use of each other's facilities for pumping and wheeling.

During balanced water conditions, daily water accounting is maintained of the CVP and SWP obligations. This accounting allows for flexibility in operations and avoids the necessity of daily changes in reservoir releases that originate several days travel time from the Delta. It also means adjustments can be made "after the fact" using actual data rather than by prediction for the variables of reservoir inflow, storage withdrawals, and in-basin uses.

The accounting language of the COA provides the mechanism for determining the responsibility of each project for Delta outflow influnced standards; however, real time operations dictate actions. For example, conditions in the Delta can change rapidly. Weather conditions combined with tidal action can quickly affect Delta salinity conditions, and therefore, the Delta outflow required to manitain joint standards. If, in this circumstance, it is decided the reasonable course of action is to increase upstream reservoir releases, then the response will likely be to increase Folsom releases first. Lake Oroville water releases require about three days to reach the Delta, while water released from Lake Shasta requires five days to travel from Keswick to the Delta. As water from the other reservoirs arrives in the Delta, Folsom releases can be adjusted downward. Any imbalance in meeting each project's designed shared obligation would be captured by the COA accounting.

Reservoir release changes are one means of adjusting to changing in-basin conditions. Increasing or decreasing project exports can also immediately achieve changes to Delta outflow. As with changes in reservoir releases, imbalances in meeting each project's designed shared obligations are captured by the COA accounting.

During periods of balanced water conditions, when real-time operations dictate project actions, an accounting procedure tracks the designed sharing water obligations of the CVP and SWP. The Projects produce daily and accumulated accounting balances. The account represents the imbalance resulting from actual coordinated operations compared to the COA-designed sharing of obligations and supply. The project that is "owed" water (i.e., the project that provided more or exported less than its COA-defined share) may request the other project adjust its operations to reduce or eliminate the accumulated account within a reasonable time.

The duration of balanced water conditions varies from year to year. Some very wet years have had no periods of balanced conditions, while very dry years may have had long continuous

[1] These percentages were derived from negotiations between Reclamation and DWR for SWRCB D-1485 standards

periods of balanced conditions, and still other years may have had several periods of balanced conditions interspersed with excess water conditions. Account balances continue from one balanced water condition through the excess water condition and into the next balanced water condition. When the project that is owed water enters into flood control operations, at Shasta or Oroville, the accounting is zeroed out for that respective project.

Changes in Coordinated Operations Since 1986

Implementation of the COA principles has continuously evolved since 1986 as changes have occurred to CVP and SWP facilities, to project operations criteria, and to the overall physical and regulatory environment in which the coordination of CVP and SWP operations takes place. Since 1986, new facilities have been incorporated into the operations that were not part of the original COA. New water quality and flow standards (D-1641) have been imposed by the SWRCB; the CVPIA has changed how the CVP is operated; and finally, the Federal Endangered Species Act (ESA) responsibilities have affected both the CVP and SWP operations. The following is a list of significant changes that have occurred since 1986. Included after each item is an explanation of how it relates to the COA and its general effect on the accomplishments of the Projects.

Sacramento River Temperature Control Operations

Water temperature control operations have changed the pattern of storage and withdrawal of storage at Shasta, Trinity, and Whiskeytown, for the purpose of improving temperature control and managing coldwater pool resources in the facilities. Water temperature operations have also constrained rates of flow, and changes in rates of flow below Keswick Dam in keeping with water temperature requirements. Such constraints have reduced the CVP's capability to respond efficiently to changes in Delta export or outflow requirements. Periodically, temperature requirements have caused the timing of the CVP releases to be significantly mismatched with Delta export capability, resulting in loss of water supply. On occasion, and in accordance with Articles 6(h) and 6(i) of the COA, the SWP has been able to export water released by the CVP for temperature control in the Sacramento River. The installation of the Shasta temperature control device has significantly improved Reclamation's ability to match reservoir releases and Delta needs.

Bay-Delta Accord, and Subsequent SWRCB Implementation of D-1641

The 1994 Bay-Delta Accord committed the CVP and SWP to a set of Delta habitat protective objectives that were eventually incorporated into the 1995 Water Quality Control Plan (WQCP), and later, along with the Vernalis Adaptive Management Program (VAMP), were included by the SWRCB in D-1641 amending the water rights of the Projects. The actions taken by the CVP and SWP in implementing D-1641 significantly reduced the export water supply of both Projects. Article 11 of the COA describes the options available to the United States for responding to the establishment of new Delta standards.

Project operators must coordinate the day-to-day operations of the CVP and SWP to perform to the Projects water rights. The 1986 COA sharing formula has been used by Project operators for D-1641 Delta outflow and salinity based standards. SWRCB D-1641 contains significant new "export limitation" criteria such as the export to inflow (E/I) ratios and San Joaquin River pulse period "export limits". The 1986 COA framework never contemplated nor addressed the application of such criteria to CVP and SWP permits. When the E/I or pulse period export restrictions control Project operations, project operators attempt to utilize “equity principles” to determine how to comply with D-1641 standards. In most cases, the rate of export is attempted to be evened out over the restricted period. In some cases, a seasonal time shift of the SWP exports can occur to help facilitate an equitable sharing of responsibilities. Until the COA is updated to reflect SWRCB D-1641 conditions, project operators must continually work on a case-by-case basis in order to meet the Projects’ combined water right requirements.

North Bay Aqueduct

North Bay Aqueduct, as described above, is a SWP feature that can convey up to about 175 cfs diverted from the SWP’s Barker Slough Pumping Plant. North Bay Aqueduct Diversions are conveyed to Napa and Solano Counties. Pursuant to an agreement between Reclamation, DWR, and the CVP and SWP contractors in 2003, a portion of the SWP diversions will be treated as an export in COA accounting.

Freeport Regional Water Project

The FRWP will be a new facility that will divert up to a maximum of 286 cubic feet per second (cfs) from the Sacramento River near Freeport for Sacramento County and East Bay Municipal Utility District (EBMUD). EBMUD will divert water pursuant to its amended contract with Reclamation. The County will divert using its water rights and its CVP contract supply. This facility was not in the 1986 COA, and the diversions will result in some reduction in Delta export supply for both the CVP and SWP contractors. Pursuant to an agreement between Reclamation, DWR, and the CVP and SWP contractors in 2003, diversions to EBMUD will be treated as an export in the COA accounting, and diversions to Sacramento County will be treated as an in-basin use.

Loss of 195,000 af of D-1485 Condition 3 Replacement Pumping

The 1986 COA affirmed the SWP’s commitment to provide replacement capacity to the CVP to make up for May and June pumping reductions imposed by SWRCB D-1485 in 1978. In the evolution of COA operations since 1986, SWRCB D-1485 was superseded by SWRCB D-1641 and SWP water demand growth and other pumping constraints have reduced the available surplus capacity at Banks Pumping Plant. The CVP has not received replacement pumping since 1993. Since then there have been (and in the current operations environment there will continue to be) many years in which the CVP will be limited by insufficient Delta export capacity to convey its water supply. The loss of the up to 195,000 af of replacement pumping capacity has diminished the water delivery anticipated by the CVP under the 1986 COA framework. The dimished water delivery accomplishments results in a charge to CVPIA (b)(2) water.

State Water Resources Control Board Water Rights

1995 Water Quality Control Plan

The SWRCB adopted the 1995 Bay-Delta Water Quality Control Plan (WQCP) on May 22, 1995, which became the basis of SWRCB Decision-1641. The SWRCB continues to hold workshop and receive information regarding processes on specific areas of the 1995 WQCP. The

SWRCB amended the WQCP in 2006, but to date, the SWRCB has made no significant change to the 1995 WQCP framework.

Decision 1641

The SWRCB imposes a myriad of constraints upon the operations of the CVP and SWP in the Delta. With Water Rights Decision 1641, the SWRCB implements the objectives set forth in the SWRCB 1995 Bay-Delta WQCP and imposes flow and water quality objectives upon the Projects to assure protection of beneficial uses in the Delta. The SWRCB also grants conditional changes to points of diversion for each project with D-1641.

The various flow objectives and export restraints are designed to protect fisheries. These objectives include specific outflow requirements throughout the year, specific export restraints in the spring, and export limits based on a percentage of estuary inflow throughout the year. The water quality objectives are designed to protect agricultural, municipal and industrial, and fishery uses, and they vary throughout the year and by the wetness of the year.

Figure 2-2 and Figure 2-3 summarize the flow and quality objectives in the Delta and Suisun Marsh for the Projects from D-1641. These objectives will remain in place until such time that the SWRCB revisits them per petition or as a consequence to revisions to the SWRCB Water Quality Plan for the Bay-Delta (which is to be revisited periodically).

On December 29, 1999, SWRCB adopted and then revised (on March 15, 2000) Decision 1641, amending certain terms and conditions of the water rights of the SWP and CVP. Decision 1641 substituted certain objectives adopted in the 1995 Bay-Delta Plan for water quality objectives that had to be met under the water rights of the SWP and CVP. In effect, D-1641 obligates the SWP and CVP to comply with the objectives in the 1995 Bay-Delta Plan. The requirements in D-1641 address the standards for fish and wildlife protection, M&I water quality, agricultural water quality, and Suisun Marsh salinity. SWRCB D-1641 also authorizes SWP and CVP to jointly use each other’s points of diversion in the southern Delta, with conditional limitations and required response coordination plans. SWRCB D-1641 modified the Vernalis salinity standard under SWRCB Decision 1422 to the corresponding Vernalis salinity objective in the 1995 Bay-Delta Plan. The criteria imposed upon the CVP and SWP are summarized in Figure 2-2 (Summary Bay-Delta Standards), Figure 2-3 (Footnotes for Summary Bay-Delta Standards), and Figure 2-4 (CVP/SWP Map).

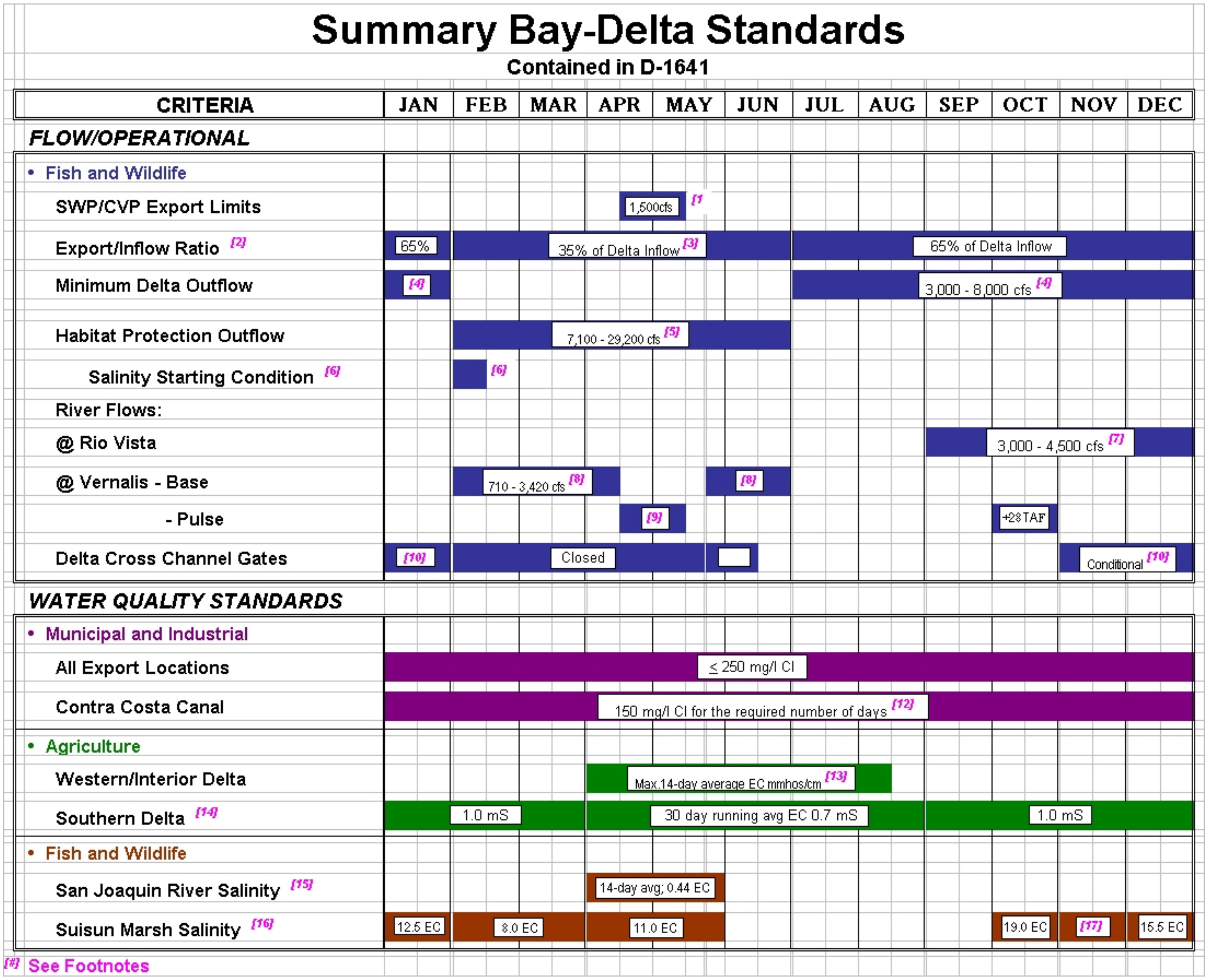

Figure 2-2 Summary Bay Delta Standards (See Footnotes below)

Footnotes

[1] Maximum 3-day running average of combined export rate (cfs) which includes Tracy Pumping Plant and Clifton Court Forebay Inflow less Byron-Bethany pumping.

Year Type	All
Apr15 - May15*	The greater of 1,500 or 100% of 3-day avg. Vernalis flow

* This time period may need to be adjusted to coincide with fish migration. Maximum export rate may be varied by CalFed Op's group.

[2] The maximum percentage of average Delta inflow (use 3-day average for balanced conditions with storage withdrawal, otherwise use 14-day average) diverted at Clifton Court Forebay (excluding Byron-Bethany pumping) and Tracy Pumping Plant using a 3-day average. (These percentages may be adjusted upward or downward depending on biological conditions, providing there is no net water cost.)

[3] The maximum percent Delta inflow diverted for Feb may vary depending on the January 8RI.

Jan 8RI	Feb exp. limit
≤ 1.0 MAF	45%
between 1.0 & 1.5 MAF	35%-45%
> 1.5 MAF	35%

[4] Minimum monthly average Delta outflow (cfs). If monthly standard ≤ 5,000 cfs, then the 7-day average must be within 1,000 cfs of standard; if monthly standard > 5,000 cfs, then the 7-day average must be ≥ 80% of standard.

Year Type	All	W	AN	BN	D	C
Jan	4,500*					
Jul		8,000	8,000	6,500	5,000	4,000
Aug		4,000	4,000	4,000	3,500	3,000
Sep	3,000					
Oct		4,000	4,000	4,000	4,000	3,000
Nov-Dec		4,500	4,500	4,500	4,500	3,500

* Increase to 6,000 if the Dec 8RI is greater than 800 TAF

[5] Minimum 3-day running average of daily Delta outflow of 7,100 cfs OR: either the daily average or 14-day running average EC at Collinsville is less than 2.64 mmhos/cm (This standard for March may be relaxed if the Feb 8RI is less than 500 TAF. The standard does not apply in May and June if the May estimate of the SRI IS < 8.1 MAF at the 90% exceedence level in which case a minimum 14-day running average flow of 4,000 cfs is required.) For additional Delta outflow objectives, see **TABLE A**.

[6] February starting salinity: If Jan 8RI > 900 TAF, then the daily or 14-day running average EC @ Collinsville must be ≤ 2.64 mmhos/cm for at least one day between Feb 1-14. If Jan 8RI is between 650 TAF and 900 TAF, then the CalFed Op's group will determine if this requirement must be met.

[7] Rio Vista minimum monthly average flow rate in cfs (the 7-day running average shall not be less than 1,000 below the monthly objective).

Year Type	All	W	AN	BN	D	C
Sep	3,000					
Oct		4,000	4,000	4,000	4,000	3,000
Nov-Dec		4,500	4,500	4,500	4,500	3,500

[8] BASE Vernalis minimum monthly average flow rate in cfs (the 7-day running average shall not be less than 20% below the objective). Take the higher objective if X2 is required to be west of Chipps Island.

Year Type	All	W	AN	BN	D	C
Feb-Apr14 and May16-Jun		2,130 or 3,420	2,130 or 3,420	1,420 or 2,280	1,420 or 2,280	710 or 1,140

[9] PULSE Vernalis minimum monthly average flow rate in cfs. Take the higher objective if X2 is required to be west of Chipps Island.

Year Type	All	W	AN	BN	D	C
Apr15 - May15		7,330 or 8,620	5,730 or 7,020	4,620 or 5,480	4,020 or 4,880	3,110 or 3,540
Oct	1,000*					

* Up to an additional 28 TAF pulse/attraction flow to bring flows up to a monthly average of 2,000 cfs except for a critical year following a critical year. Time period based on real-time monitoring and determined by CalFed Op's group.

[10] For the Nov-Jan period, Delta Cross Channel gates may be closed for up to a total of 45 days.

[11] For the May 21-June 15 period, close Delta Cross Channel gates for a total of 14 days per CALFED Op's group. During the period the Delta cross channel gates may close 4 consecutive days each week, excluding weekends.

[12] Minimum # of days that the mean daily chlorides ≤ 150 mg/l must be provided in intervals of not less than 2 weeks duration. Standard applies at Contra Costa Canal Intake or Antioch Water Works Intake.

Year Type	W	AN	BN	D	C
# Days	240	190	175	165	155

(Footnotes continued on next page)

[13] The maximum14-day running average of mean daily EC (mmhos/cm) depends on water year type.

	WESTERN DELTA				INTERIOR DELTA			
	Sac River @ Emmaton		SJR @ Jersey Point		Mokelumne R @ Terminous		SJR @ San Andreas	
Year Type	0.45 EC from April 1 to date shown	EC value from date shown to Aug15 *	0.45 EC from April 1 to date shown	EC value from date shown to Aug15 *	0.45 EC from April 1 to date shown	EC value from date shown to Aug15 *	0.45 EC from April 1 to date shown	EC value from date shown to Aug15 *
W	Aug 15		Aug 15		Aug 15		Aug 15	
AN	Jul 1	0.63	Aug 15		Aug 15		Aug 15	
BN	Jun 20	1.14	Jun 20	0.74	Aug 15		Aug 15	
D	Jun 15	1.67	Jun 15	1.35	Aug 15		Jun 25	0.58
C		2.78		2.20		0.54		0.87

* When no date is shown, EC limit continues from April 1.

[14] As per D-1641, for San Joaquin River at Vernalis: however, the April through August maximum 30- day running average EC for San Joaquin River at Brandt Bridge,Old River near Middle River, and Old River at Tracy Road Bridge shall be 1.0 EC until April 1, 2005 when the value will be 0.7 EC.

[15] Compliance will be determined between Jersey Point & Prisoners Point.
Does not apply in critical years or in May when the May 90% forecast of SRI ≤ 8.1 MAF.

[16] During deficiency period, the maximum monthly average mhtEC at Western Suisun Marsh stations as per SMPA is:

Month	mhtEC
Oct	19.0
Nov	16.5
Dec-Mar	15.6
Apr	14.0
May	12.5

[17] In November, maximum monthly average mhtEC = 16.5 for Western Marsh stations and maximum monthly average mhtEC = 15.5 for Eastern Marsh stations in all periods types.

TABLE A

Number of Days When Max. Daily Average Electrical Conductivity of 2.64 mmhos/cm Must Be Maintained. (This can also be met with a maximum 14-day running average EC of 2.64 mmhos/cm, or 3-day running average Delta outflows of 11,400 cfs and 29,200 cfs, respectively.) Port Chicago Standard is triggered only when the 14-day average EC for the last day of the previous month is 2.64 mmhos/cm or less. PMI is previous month's 8RI. If salinity/flow objectives are met for a greater number of days than required for any month, the excess days shall be applied towards the following month's requirement. The number of day's for values of the PMI between those specified below shall be determined by linear interpolation.

PMI	Chipps Island (Chipps Island Station D10)				
(TAF)	FEB	MAR	APR	MAY	JUN
≤ 500	0	0	0	0	0
750	0	0	0	0	0
1000	28*	12	2	0	0
1250	28	31	6	0	0
1500	28	31	13	0	0
1750	28	31	20	0	0
2000	28	31	25	1	0
2250	28	31	27	3	0
2500	28	31	29	11	1
2750	28	31	29	20	2
3000	28	31	30	27	4
3250	28	31	30	29	8
3500	28	31	30	30	13
3750	28	31	30	31	18
4000	28	31	30	31	23
4250	28	31	30	31	25
4500	28	31	30	31	27
4750	28	31	30	31	28
5000	28	31	30	31	29
5250	28	31	30	31	29
≥ 5500	28	31	30	31	30

*When 800 TAF < PMI < 1000 TAF, the number of days is determined by linear interpolation between 0 and 28 days.

PMI	Port Chicago (continuous recorder at Port Chicago)				
(TAF)	FEB	MAR	APR	MAY	JUN
0	0	0	0	0	0
250	1	0	0	0	0
500	4	1	0	0	0
750	8	2	0	0	0
1000	12	4	0	0	0
1250	15	6	1	0	0
1500	18	9	1	0	0
1750	20	12	2	0	0
2000	21	15	4	0	0
2250	22	17	5	1	0
2500	23	19	8	1	0
2750	24	21	10	2	0
3000	25	23	12	4	0
3250	25	24	14	6	0
3500	25	25	16	9	0
3750	26	26	18	12	0
4000	26	27	20	15	0
4250	26	27	21	18	1
4500	26	28	23	21	2
4750	27	28	24	23	3
5000	27	28	25	25	4
5250	27	29	25	26	6
5500	27	29	26	28	9
5750	27	29	27	28	13
6000	27	29	27	29	16
6250	27	30	27	29	19
6500	27	30	28	30	22
6750	27	30	28	30	24
7000	27	30	28	30	26
7250	27	30	28	30	27
7500	27	30	29	30	28
7750	27	30	29	31	28
8000	27	30	29	31	29
8250	28	30	29	31	29
8500	28	30	29	31	29
8750	28	30	29	31	30
9000	28	30	29	31	30
9250	28	30	29	31	30
9500	28	31	29	31	30
9750	28	31	29	31	30
10000	28	31	30	31	30
> 10000	28	31	30	31	30

Figure 2-3 Footnotes for Summary Bay Delta Standards

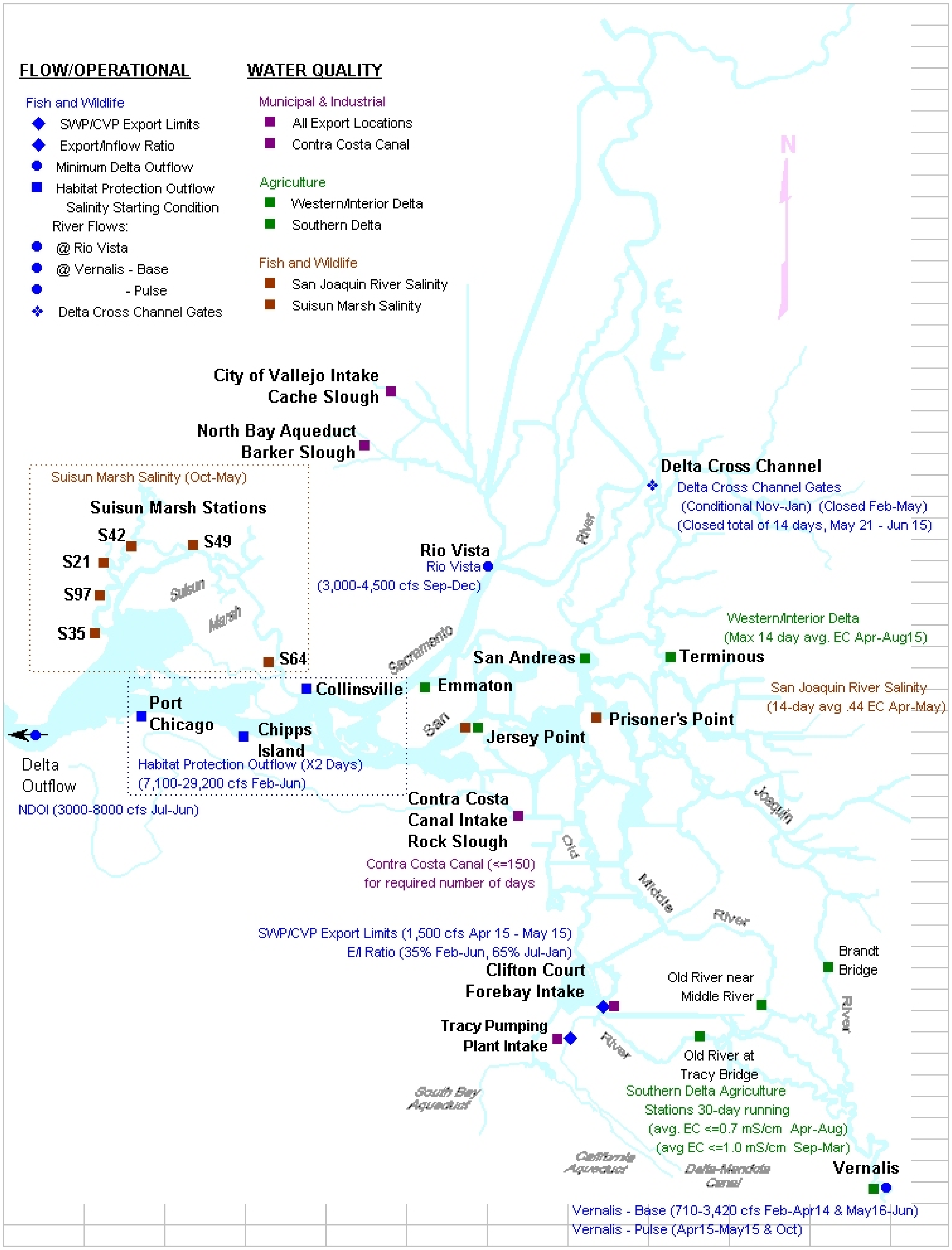

Figure 2-4 CVP/SWP Delta Map

Joint Points of Diversion

SWRCB D-1641 granted Reclamation and DWR the ability to use/exchange each Project's diversion capacity capabilities to enhance the beneficial uses of both Projects. The SWRCB conditioned the use of Joint Point of Diversion (JPOD) capabilities based on a staged implementation and conditional requirements for each stage of implementation. The stages of JPOD in SWRCB D-1641 are:

- Stage 1 – for water service to Cross Valley Canal contractors, Tracy Veterans Cemetery and Musco Olive, and to recover export reductions taken to benefit fish.
- Stage 2 – for any purpose authorized under the current project water right permits.
- Stage 3 – for any purpose authorized up to the physical capacity of the diversion facilities.

Each stage of JPOD has regulatory terms and conditions which must be satisfied in order to implement JPOD.

All stages require a response plan to ensure water levels in the southern Delta will not be lowered to the injury of local riparian water users (Water Level Response Plan). All stages require a response plan to ensure the water quality in the southern and central Delta will not be significantly degraded through operations of the JPOD to the injury of water users in the southern and central Delta.

All JPOD diversion under excess conditions in the Delta is junior to Contra Costa Water District (CCWD) water right permits for the Los Vaqueros Project, and must have an X2 location west of certain compliance locations consistent with the 1993 Los Vaqueros Biological Opinion (BO) for delta smelt.

Stage 2 has an additional requirement to complete an operations plan that will protect fish and wildlife and other legal users of water. This is commonly known as the Fisheries Response Plan. A Fisheries Response Plan was approved by the SWRCB in February 2007, but as it relied on the 2004 and 2005 Biological Opinions, the Fisheries Response Plan will need to be revised and re-submitted to the SWRCB as a future date.

Stage 3 has an additional requirement to protect water levels in the southern Delta under the operational conditions of Phase II of the South Delta Improvements Program, along with an updated companion Fisheries Response Plan.

Reclamation and DWR intend to apply all response plan criteria consistently for JPOD uses as well as water transfer uses.

In general, JPOD capabilities will be used to accomplish four basic CVP-SWP objectives:

- When wintertime excess pumping capacity becomes available during Delta excess conditions and total CVP-SWP San Luis storage is not projected to fill before the spring pulse flow period, the project with the deficit in San Luis storage may elect to use JPOD capabilities. Concurrently, under the CALFED ROD, JPOD may be used to create additional water supplies for the EWA or reduce debt for previous EWA actions.

- When summertime pumping capacity is available at Banks Pumping Plant and CVP reservoir conditions can support additional releases, the CVP may elect to use JPOD capabilities to enhance annual CVP south of Delta water supplies.
- When summertime pumping capacity is available at Banks or Jones Pumping Plant to facilitate water transfers, JPOD may be used to further facilitate the water transfer.
- During certain coordinated CVP-SWP operation scenarios for fishery entrainment management, JPOD may be used to shift CVP-SWP exports to the facility with the least fishery entrainment impact while minimizing export at the facility with the most fishery entrainment impact.

Revised WQCP (2006)

The SWRCB undertook a proceeding under its water quality authority to amend the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan) adopted in 1978 and amended in 1991 and in 1995. Prior to commencing this proceeding, the SWRCB conducted a series of workshops in 2004 and 2005 to receive information on specific topics addressed in the Bay-Delta Plan.

The SWRCB adopted a revised Bay-Delta Plan on December 13, 2006. There were no changes to the Beneficial Uses from the 1995 Plan to the 2006 Plan, nor were any new water quality objectives adopted in the 2006 Plan. A number of changes were made simply for readability. Consistency changes were also made to assure that sections of the Plan reflected the current physical condition or current regulation. The SWRCB continues to hold workshops and receive information regarding Pelagic Organism Decline (POD), Climate Change, and San Joaquin salinity and flows, and will coordinate updates of the Bay-Delta Plan with on-going development of the comprehensive Salinity Management Plan.

Real Time Decision-Making to Assist Fishery Management

Introduction

Real time decision-making to assist fishery management is a process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. For the proposed action high uncertainty exists for how to best manage our water operations while protecting listed species. Applying real time decision-making to assist fishery management to the proposed action requires the definition of management goals and a mechanism for new information and scientific understanding to be used in changing our operations to better meet the goals.

Sources of uncertainty relative to the proposed action include:

- Hydrologic conditions
- Ocean conditions

- Listed species biology

Under the proposed action the goals for real time decision-making to assist fishery management are:

- Meet contractual obligations for water delivery
- Minimize adverse effects for listed species

Framework for Actions

Reclamation and DWR work closely with FWS, NMFS, and DFG to coordinate the operation of the CVP and SWP with fishery needs. This coordination is facilitated through several forums in a cooperative management process that allows for modifying operations based on real-time data that includes current fish surveys, flow and temperature information, and salvage or loss at the project facilities, (hereinafter "triggering event").

Water Operations Management Team

The Water Operations Management Team (WOMT) is comprised of representatives from Reclamation, DWR, FWS, NMFS, and DFG. This management-level team was established to facilitate timely decision-support and decision-making at the appropriate level. The WOMT first met in 1999, and will continue to meet to make management decisions as part of the proposed project. Routinely, it also uses the CALFED Ops Group to communicate with stakeholders about its decisions. Although the goal of WOMT is to achieve consensus on decisions, the participating agencies retain their authorized roles and responsibilities.

Process for Real Time Decision- Making to Assist Fishery Management

Decisions regarding CVP and SWP operations to avoid and minimize adverse effects on listed species must consider factors that include public health, safety, and water supply reliability. To facilitate such decisions, the Project Agencies and the fishery agencies (consisting of FWS, NMFS, and DFG) have developed and refined a set of processes for various fish species to collect data, disseminate information, develop recommendations, make decisions, and provide transparency. This process consists of three types of groups that meet on a recurring basis. Management teams are made up of management staff from Reclamation, DWR, and the fishery agencies. Information teams are teams whose role is to disseminate and coordinate information among agencies and stakeholders. Fisheries and Operations technical teams are made up of technical staff from state and Federal agencies. These teams review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that fishery agencies' management can use in identifying actions to protect listed species.

The process to identify actions for protection of listed species varies to some degree among species but follows this general outline: A Fisheries or Operations Technical Team compiles and assesses current information regarding species, such as stages of reproductive development, geographic distribution, relative abundance, physical habitat conditions, then provides a recommendation to the agency with statutory obligation to enforce protection of the species in question. The agency's staff and management will review the recommendation and use it as a basis for developing, in cooperation with Reclamation and DWR, a modification of water operations that will minimize adverse effects to listed species by the Projects. If the Project Agencies do not agree with the action, then the fishery agency with the statutory authority will make a final decision on an action that they deem necessary to protect the species. In the event it is not possible to refine the proposed action in order that it does not violate section 7(a)(2) of the ESA, the Project and fisheries agencies will reinitiate consultation.

The outcomes of protective actions that are implemented will be monitored and documented, and this information will inform future recommended actions.

Groups Involved in Real Time Decision-Making to Assist Fishery Management and Information Sharing

Information Teams

CALFED Ops and Subgroups

The CALFED Ops Group consists of the Project agencies, the fishery agencies, SWRCB staff, and the U.S. Environmental Protection Agency (EPA). The CALFED Ops Group generally meets eleven times a year in a public setting so that the agencies can inform each other and stakeholders about current the operations of the CVP and SWP, implementation of the CVPIA and State and Federal endangered species acts, and additional actions to contribute to the conservation and protection of State- and Federally-listed species. The CALFED Ops Group held its first public meeting in January 1995, and during the next six years the group developed and refined its process. The CALFED Ops Group has been recognized within SWRCB D-1641, and elsewhere, as one forum for coordination on decisions to exercise certain flexibility that has been incorporated into the Delta standards for protection of beneficial uses (e.g., E/I ratios, and some DCC Closures). Several teams were established through the Ops Group process. These teams are described below:

Data Assessment Team (DAT)

The DAT consists of technical staff members from the Project and fishery agencies as well as stakeholders. The DAT meets frequently[2] during the fall, winter, and spring. The purpose of the meetings is to coordinate and disseminate information and data among agencies and stakeholders that is related to water project operations, hydrology, and fish surveys in the Delta.

Integrated Water Operations and Fisheries Forum

The Integrated Water Operations and Fisheries Forum (IWOFF) provides the forum for executives and managers of Reclamation, DWR, DFG, FWS, NMFS, USEPA and the SWRCB to meet and discuss current and proposed project planning, permitting, funding, and Endangered Species Act compliance, which affect the workloads and activities of these organizations. IWOFF provides a forum for elevation of these matters if staff is unable to reach resolution on

[2] The DAT holds weekly conference calls and may have additional discussions during other times as needed.

process/procedures requiring interagency coordination. IWOFF may also elevate such decisions up to the Director level at their discretion.

Operations and Fishery Forum

The Operations and Fishery Forum (OFF) was established as an ad-hoc stakeholder-driven process to disseminate information regarding recommendations and decisions about the operations of the CVP and SWP. OFF members are considered the contact person for their respective agency or interest group when information regarding take of listed species, or other factors and urgent issues need to be addressed by the CALFED Ops Group. Alternatively, the OFF may be directed by the CALFED Ops Group to develop recommendations on operational responses for issues of concern raised by member agencies.

B2 Interagency Team (B2IT)

The B2IT was established in 1999 and consists of technical staff members from the Project agencies. The B2IT meets weekly to discuss implementation of section 3406 (b)(2) of the CVPIA, which defines the dedication of CVP water supply for environmental purposes. It communicates with WOMT to ensure coordination with the other operational programs or resource-related aspects of project operations, including flow and temperature issues.

Technical Teams

Fisheries Technical Teams

Several fisheries specific teams have been established to provide guidance and recommendations on resource management issues. These teams include:

The Sacramento River Temperature Task Group (SRTTG): The SRTTG is a multiagency group formed pursuant to SWRCB Water Rights Orders 90-5 and 91-1, to assist with improving and stabilizing Chinook population in the Sacramento River. Annually, Reclamation develops temperature operation plans for the Shasta and Trinity divisions of the CVP. These plans consider impacts on winter-run and other races of Chinook salmon, and associated project operations. The SRTTG meets initially in the spring to discuss biological, hydrologic, and operational information, objectives, and alternative operations plans for temperature control. Once the SRTTG has recommended an operation plan for temperature control, Reclamation then submits a report to the SWRCB, generally on or before June 1st each year.

After implementation of the operation plan, the SRTTG may perform additional studies and commonly holds meetings as needed typically monthly through the summer and into fall. To develop revisions based on updated biological data, reservoir temperature profiles and operations data. Updated plans may be needed for summer operations protecting winter-run, or in fall for fall-run spawning season. If there are any changes in the plan, Reclamation submits a supplemental report to SWRCB.

Smelt Working Group (Working Group): The Working Group evaluates biological and technical issues regarding delta smelt and develops recommendations for consideration by the FWS. Since the longfin smelt became a state candidate species in 2008, the Working Group has also developed for DFG recommendations to minimize adverse effects to longfin smelt. The

Working Group consists of representatives from FWS, DFG, DWR, EPA, and Reclamation. FWS chairs the group, and a member is assigned by each agency.

The Smelt Working Group will compile and interpret the latest near real-time information regarding state- and federally-listed smelt, such as stages of development, distribution, and salvage. After evaluating available information and if they agree that a protection action is warranted, the working group will submit their recommendations in writing to FWS and DFG.

The working group may meet at any time at the request of FWS, but generally meets weekly during the months of January through June, when smelt salvage at CVP and SWP has occurred historically. However, the Delta Smelt Risk Assessment Matrix (see below) outlines the conditions when the Working Group will convene to evaluate the necessity of protective actions and provide FWS with a recommendation. Further, with the State listing of longfin smelt, the group will also convene based on longfin salvage history at the request of DFG.

Delta Smelt Risk Assessment Matrix (DSRAM): The Working Group will employ a delta smelt risk assessment matrix to assist in evaluating the need for operational modifications of SWP and CVP to protect delta smelt. This document will be a product and tool of the Working Group and will be modified by the Working Group with the approval of FWS and DFG, in consultation with Reclamation and DWR, as new knowledge becomes available. The currently approved DSRAM is provided for information in Appendix A.

If an action is taken, the Working Group will follow up on the action to attempt to ascertain its effectiveness. The ultimate decision-making authority rests with FWS. An assessment of effectiveness will be attached to the notes from the Working Group's discussion concerning the action.

The Salmon Decision Process: The Salmon Decision Process is used by the fishery agencies and project operators to facilitate the often complex coordination issues surrounding DCC gate operations and the purposes of fishery protection closures, Delta water quality, and/or export reductions. Inputs such as fish lifestage and size development, current hydrologic events, fish indicators (such as the Knight's Landing Catch Index and Sacramento Catch Index), and salvage at the export facilities, as well as current and projected Delta water quality conditions, are used to determine potential DCC closures and/or export reductions. The coordination process has worked well during the recent fall and winter DCC operations in recent years and is expected to be used in the present or modified form in the future.

American River Group: In 1996, Reclamation established a working group for the Lower American River, known as ARG. Although open to the public, the ARG meetings generally include representatives from several agencies and organizations with on-going concerns and interests regarding management of the Lower American River. The formal members of the group are Reclamation, FWS, NMFS, and DFG.

The ARG convenes monthly or more frequently if needed, with the purpose of providing fishery updates and reports for Reclamation to help manage Folsom Reservoir for fish resources in the Lower American River.

San Joaquin River Technical Committee (SJRTC): The SJRTC meets for the purposes of planning and implementing the VAMP each year and oversees two subgroups: the Biology subgroup, and the Hydrology subgroup. These two groups are charged with certain responsibilities, and must also coordinate their activities within the San Joaquin River Agreement (SJRA) Technical Committee.

Operations Technical Teams

An operations specific team is established to provide guidance and recommendations on operational issues and one is proposed for the SDIP operable gates. These teams are:

DCC Project Work Team: The DCC Project Work Team is a multiagency group under CALFED. Its purpose is to determine and evaluate the affects of DCC gate operations on Delta hydrodynamics, water quality, and fish migration. The work team coordinates with the DAT and OFF groups to conduct gate experiments and members may be used as a resource to estimate impacts from real time gate operations.

Gate Operations Review Team: When the gates proposed under SDIP Stage 1 are in place and operational, a federal and state interagency team will be convened to discuss constraints and provide input to the existing WOMT. The Gate Operations Review Team (GORT) will make recommendations for the operations of the fish control and flow control gates to minimize impacts on resident threatened and endangered species and to meet water level and water quality requirements for south Delta water users. The interagency team will include representatives of DWR, Reclamation, FWS, NMFS, and the DFG, and possibly others as needs change. The interagency team will meet through a conference call, approximately once a week. DWR will be responsible for providing predictive modeling, and SWP Operations Control Office will provide operations forecasts and the conference call line. Reclamation will be responsible for providing CVP operations forecasts, including San Joaquin River flow, and data on current water quality conditions. Other members will provide the team with the latest information related to south Delta fish species and conditions for crop irrigation. Operations plans would be developed using the Delta Simulation Model 2 (DSM2), forecasted tides, and proposed diversion rates of the projects to prepare operating schedules for the existing CCF gates and the four proposed operable gates.

Uses of Environmental Water Accounts

CVPIA Section 3406 (b)(2)

On May 9, 2003, the Interior issued its Decision on Implementation of Section 3406 (b)(2) of the CVPIA. Dedication of (b)(2) water occurs when Reclamation takes a fish, wildlife habitat restoration action based on recommendations of the FWS (and in consultation with NMFS and DFG), pursuant to Section 3406 (b)(2). Dedication and management of (b)(2) water may also assist in meeting WQCP fishery objectives and helps meet the needs of fish listed under the ESA as threatened or endangered since the enactment of the CVPIA.

The May 9, 2003, Decision describes the means by which the amount of dedicated (b)(2) water is determined. Planning and accounting for (b)(2) actions are done cooperatively and occur primarily through weekly meetings of the B2IT. Actions usually take one of two forms — instream flow augmentation below CVP reservoirs or CVP Jones pumping reductions in the Delta. Chapter 9 of this BA contains a more detailed description of (b)(2) operations, as characterized in the CalSim-II modeling assumptions and results of the modeling are summarized.

CVPIA 3406 (b)(2) Operations on Clear Creek

Dedication of (b)(2) water on Clear Creek provides actual in-stream flows below Whiskeytown Dam greater than those that would have occurred under pre-CVPIA regulations, e.g., the fish and wildlife minimum flows specified in the 1963 proposed release schedule (Table 2-4). In-stream flow objectives are usually taken from the AFRP’s plan, in consideration of spawning and incubation of fall-run Chinook salmon. Augmentation in the summer months is usually in consideration of water temperature objectives for steelhead and in late summer for spring-run Chinook salmon.

Reclamation will provide (under the new agreement) Townsend with up to 6,000 af of water annually. If the full 6,000 af is delivered, then 900 af will be dedicated to (b)(2) according to the August 2000 agreement.

CVPIA 3406 (b)(2) Operations on the Upper Sacramento River

Dedication of (b)(2) water on the Sacramento River provides actual in-stream flows below Keswick Dam greater than those that would have occurred under pre-CVPIA regulations, e.g., the fish and wildlife requirements specified in WR 90-5 and the criteria formalized in the 1993 NMFS Winter-run BO as the base. In-stream flow objectives from October 1 to April 15 (typically April 15 is when water temperature objectives for winter-run Chinook salmon become the determining factor) are usually selected to minimize dewatering of redds and provide suitable habitat for salmonid spawning, incubation, rearing, and migration.

CVPIA 3406 (b)(2) Operations on the Lower American River

Dedication of (b)(2) water on the American River provides actual in-stream flows below Nimbus Dam greater than those that would have occurred under pre-CVPIA regulations, e.g the fish and wildlife requirements previously mentioned in the American River Division. In-stream flow objectives from October through May generally aim to provide suitable habitat for salmon and steelhead spawning, incubation, and rearing, while considering impacts. In-stream flow objectives for June to September endeavor to provide suitable flows and water temperatures for juvenile steelhead rearing while balancing the effects on temperature operations into October and November.

- Flow Fluctuation and Stability Concerns:

  Through CVPIA, Reclamation has funded studies by DFG to better define the relationships of Nimbus release rates and rates of change criteria in the Lower American River to minimize the negative effects of necessary Nimbus release changes on sensitive fishery objectives. Reclamation is presently using draft criteria developed by DFG. The draft criteria have helped reduce the incidence of anadromous fish stranding relative to past historic operations.

The primary operational coordination for potentially sensitive Nimbus Dam release changes is conducted through the B2IT process. The ARG is another forum to discuss criteria for flow fluctuations. Since 1996 the group has provided input on a number of operational issues and has served as an aid towards adaptively managing releases, including flow fluctuation and stability, and managing water temperatures in the Lower American River to meet the needs of salmon and steelhead.

CVPIA 3406 (b)(2) Operations on the Stanislaus River

Dedication of (b)(2) water on the Stanislaus River provides actual in-stream flows below Goodwin Dam greater than the fish and wildlife requirements previously mentioned in the East Side Division, and in the past has been generally consistent with the IPO for New Melones. In-stream fishery management flow volumes on the Stanislaus River, as part of the IPO, are based on the New Melones end-of-February storage plus forecasted March to September inflow as shown in the IPO. The volume determined by the IPO is a combination of fishery flows pursuant to the 1987 DFG Agreement and the FWS AFRP in-stream flow goals. The fishery volume is then initially distributed based on modeled fish distributions and patterns used in the IPO.

Actual in-stream fishery management flows below Goodwin Dam will be determined in accordance with the Decision on Implementation of Section 3406 (b)(2) of the CVPIA. Reclamation has begun a process to develop a long-term operations plan for New Melones. The ultimate long-term plan will be coordinated with B2IT members, along with the stakeholders and the public before it is finalized.

CVPIA 3406 (b)(2) Operations in the Delta

Export curtailments at the CVP Jones Pumping Plant and increased CVP reservoir releases required to meet SWRCB D-1641, as well as direct export reductions for fishery management using dedicated (b)(2) water at the CVP Jones Pumping Plant, will be determined in accordance with the Interior Decision on Implementation of Section 3406 (b)(2) of the CVPIA. Direct Jones Pumping Plant export curtailments for fishery management protection will be based on coordination with the weekly B2IT meetings and vetted through WOMT, as necessary. See the Adaptive Management section for the other coordination groups, i.e., SWG, DAT, OFF and EWAT.

Environmental Water Account

The orginal Environmental Water Account was established in 2000 by the CALFED ROD, and operating criteria area described in detail in the EWA Operating Principles Agreement attachment to the ROD. In 2004, the EWA was extended to operate through the end of 2007. Reclamation, FWS, and NMFS have received congressional authorization to participate in the EWA at least through September 30, 2010, per the CALFED Bay-Delta Authorization Act (PL-108-361). However, for these Federal agencies to continue participation in the EWA beyond 2010, additional authorization will be required.

The EWA agencies acquire assets and determine how the assets should be used to benefit the at-risk native fish species of the Bay-Delta estuary. Operation of the EWA Program is guided by the EWA Team (EWAT), which is comprised of technical and policy representatives from each of the five EWA Agencies. The EWAT coordinates its activities with the WOMT.

The original purpose of the EWA was to enable diversion of water by the SWP and CVP from the Delta to be reduced at times when at risk fish species may be harmed while preventing the uncompensated loss of water to SWP and CVP contractors. Typically the EWA replaced water loss due to curtailment of pumping by purchase of surface or groundwater supplies from willing sellers and by taking advantage of regulatory flexibility and certain operational assets.

Under past operations, from 2001 through 2007, when there were pumping curtailments at Banks Pumping Plant to protect Delta fish the EWA often owed a debt of water to the SWP, usually reflected in San Luis Reservoir.

The EWA agencies are currentlyundertaking environmental review to determine the future of EWA. Because no decision has yet been made regarding EWA, for the purposes of this project description, EWA is analyzed with limited assets, focusing on providing assets to support VAMP and in some years, the “post – VAMP shoulder”. The EWA assets include the following:

- Implementation of the Yuba Accord, Component 1 Water, which is an average 60,000 af of water released annually from the Yuba River to the Delta, is an EWA asset through 2015, with a possible extension through 2025. The 60,000 af is expected to be reduced by carriage water costs in most years, estimated at 20%, leaving an EWA asset of 48,000 af per year. The SWP will provide the 48,000 af per year asset from Project supplies beyond 2015 in the event that Yuba Accord Component 1 Water is not extended.
- Purchases of assets to the extent funds are available.
- Operational assets granted the EWA in the CALFED ROD:
    - A 50 percent share of SWP export pumping of (b)(2) water and ERP water from upstream releases;
    - A share of the use of SWP pumping capacity in excess of the SWP’s needs to meet contractor requirements with the CVP on an equal basis, as needed (such use may be under Joint Point of Diversion;
    - Any water acquired through export/inflow ratio flexibility; and
    - Use of 500 cubic-feet per second (cfs) increase in authorized Banks Pumping Plant capacity in July through September (from 6,680 to 7,180 cfs).
    - Storage in project reservoirs upstream of the Delta as well as in San Luis Reservoir, with a lower priority than project water. Such stored water will share storage priority with water acquired for Level 4 refuge needs.

Operational assets averaged 82,000 af from 2001-2006, with a range from 0 to 150,000 af.

Chapter 9 of this assessment includes an analysis of modeling results that illustrates the frequency with which assets available under the limited EWA are sufficient to meet the SWP portion of the VAMP and “post – VAMP shoulder” export curtailment.

500 cfs Diversion Increase During July, August, and September

Under this operation, the maximum allowable daily diversion rate into CCF during the months of July, August, and September increases from 13,870 AF to 14,860 AF and three-day average diversions from 13,250 AF to 14,240 AF (500 cfs per day equals 990 AF). The increase in diversions has been permitted and in place since 2000. The current permit expires on September 30, 2008. An application will be made to the U.S. Army Corps of Engineers for permitting the implementation of this operation. The description of the 500 cfs increased diversion in the permit application to the Corps will be consistent with the following description.

The purpose of this diversion increase into CCF for use by the SWP is to recover export reductions made due to the ESA or other actions taken to benefit fisheries resources. The increased diversion rate will not result in any increase in water supply deliveries than would occur in the absence of the increased diversion rate. This increased diversion over the three-month period would result in an amount not to exceed 90,000 AF each year. Increased diversions above the 48 taf discussed in the previous section (Environmental Water Account) could occur for a number of reasons including:

1) Actual carriage water loss on the 60 taf of current year’s Yuba Accord Component 1 Water is less than the assumed 20%.

2) Diversion of Yuba Accord Component 1 Water exceeds the current year’s 60 taf allotment to make up for a Yuba Accord Component 1 deficit from a previous year.

3) In very wet years, the diversion of excess Delta outflow goes above and beyond the Yuba Accord Component 1 Water allotment.

Variations to hydrologic conditions coupled with regulatory requirements may limit the ability of the SWP to fully utilize the proposed increased diversion rate. Also, facility capabilities may limit the ability of the SWP to fully utilize the increased diversion rate.

In years where the accumulated export under the 500 cfs increased diversion exceeds 48 taf, the additional assets will either be applied as an export reduction specified by the fish agencies for later in the year or be held in San Luis Reservoir to be carried over to the following year and, if not “spilled”, applied to fishery protection actions (VAMP and “post VAMP” shoulder) in that year. If the SWP share of San Luis Reservoir fills prior to the following year’s VAMP and there is not unused space available in the reservoir to store this asset, then the asset will convert to SWP supply (commonly referred to as “spilling”). During the period in which the asset is spilling, SWP exports will be reduced by the same volume as the accumulated asset. Any reductions in exports resulting from “spilling” are expected to occur in the December – March period.

Implementation of the proposed action is contingent on meeting the following conditions:

1. The increased diversion rate will not result in an increase in annual SWP water supply allocations than would occur in the absence of the increased diversion rate. Water pumped due to the increased capacity will only be used to offset reduced diversions that occurred or will occur because of ESA or other actions taken to benefit fisheries.

2. Use of the increased diversion rate will be in accordance with all terms and conditions of existing biological opinions governing SWP operations.
3. All three temporary agricultural barriers (Middle River, Old River near Tracy and Grant Line Canal) must be in place and operating when SWP diversions are increased. When the temporary barriers are replaced by the permanent operable flow-control gates, proposed as Stage 1 of the South Delta Improvements Program, the gates must be operating to their specified criteria. (See SDIP gate operation description, Chapter 2.)
4. Prior to the start of, or during any time which the SWP has increased its diversion rate between July 1 and September 30 in accordance with the approved operations plan, if the combined salvage of listed fish species reaches a level of concern, the Data Assessment Team (DAT) will convene to assess the need to modify the planned increase in SWP diversion rates. If DAT does not concur with the continued use of the increased SWP diversion rate, then the issue will be elevated to the WOMT. The WOMT consider the DAT assessment as to whether the use of the SWP increased diversion rate should continue or be suspended. If WOMT is unable to reach agreement on the operation, the relevant fish regulatory agency will determine whether the 500 cfs increased diversion is or continues to be implemented.

Central Valley Project

Project Management Objectives

Facilities are operated and maintained by local Reclamation area offices, with operations overseen by the Central Valley Operations Office (CVOO) at the Joint Operations Center in Sacramento, California. The CVOO is responsible for recommending CVP operating policy, developing annual operating plans, coordinating CVP operations with the SWP and other entities, establishing CVP-wide standards and procedures, and making day-to-day operating decisions.

Central Valley Project Improvement Act

On October 30, 1992, Public Law 102-575, (Reclamation Projects Authorization and Adjustment Act of 1992) was passed. Included in the law was Title 34, the Central Valley Project Improvement Act (CVPIA). The CVPIA amended previous authorizations of the CVP to include fish and wildlife protection, restoration, and mitigation as project purposes having equal priority with irrigation and domestic water supply uses, and fish and wildlife enhancement having an equal priority with power generation. Among the changes mandated by the CVPIA are:

- Dedicating 800,000 af annually to fish, wildlife, and habitat restoration
- Authorizing water transfers outside the CVP service area
- Implementing an anadromous fish restoration program
- Creating a restoration fund financed by water and power users
- Providing for the Shasta Temperature Control Device

- Implementing fish passage measures at Red Bluff Diversion Dam (RBDD)
- Calling for planning to increase the CVP yield
- Mandating firm water supplies for Central Valley wildlife refuges
- Improving the Tracy Fish Collection Facility (TFCF)
- Meeting Federal trust responsibility to protect fishery resources(Trinity River)

The CVPIA is being implemented as authorized. The Final Programmatic Environmental Impact Statement (PEIS) for the CVPIA analyzed projected conditions in 2022, 30 years from the CVPIA's adoption in 1992. The Final PEIS was released in October 1999 and the CVPIA Record of Decision (ROD) was signed on January 9, 2001. The Biological Opinions (BOs) were issued on November 21, 2000.

Operations of the CVP reflect provisions of the CVPIA, particularly sections 3406(b)(1), (b)(2), and (b)(3). On May 9, 2003, Interior issued its decision on Implementation of Section 3406 (b)(2) of the CVPIA. The CVPIA Section 3406 (b)(2) Implementation Team (B2IT) formulates recommendations for implementing upstream and Delta actions with CVP delivery capability.

Water Service Contracts, Allocations and Deliveries

Water Needs Assessment

Water needs assessments have been performed for each CVP water contractor eligible to participate in the CVP long-term contract renewal process. Water needs assessments confirm a contractor's past beneficial use and determine future CVP water supplies needed to meet the contractor's anticipated future demands. The assessments are based on a common methodology used to determine the amount of CVP water needed to balance a contractor's water demands with available surface and groundwater supplies. All of the contractor assessments have been finalized.

Future American River Operations - Water Service Contracts and Deliveries

Surface water deliveries from the American River are made to various water rights entities and CVP contractors. Total American River Division annual demands on the American and Sacramento Rivers are estimated to increase from about 324,000 acre-feet in 2005 and 605,000 acre-feet in 2030 without the Freeport Regional Water project maximum of 133,000 acre-feet during drier years. Reclamation is negotiating the renewal of 13 long-term water service contracts, four Warren Act contracts, and has a role in six infrastructure or Folsom Reservoir operations actions influencing the management of American River Division facilities and water use.

Water Allocation – CVP

In most years, the combination of carryover storage and runoff into CVP reservoirs is sufficient to provide the water to meet CVP contractors' demands. Since 1992, increasing constraints placed on operations by legislative and ESA requirements have removed significant operational flexibility to deliver water to all CVP contractors. This reduction in flexibility has its greatest allocation effect on CVP water service contractors south of the Delta.

The water allocation process for CVP begins in the fall when preliminary assessments are made of the next year's water supply possibilities, given current storage conditions combined with a range of hydrologic conditions. These preliminary assessments may be refined as the water year progresses. Beginning February 1, forecasts of water year runoff are prepared using precipitation to date, snow water content accumulation, and runoff to date. All of CVP's Sacramento River Settlement water rights contracts and San Joaquin River Exchange contracts require that contractors be informed no later than February 15 of any possible deficiency in their supplies. In recent years, February 20th has been the target date for the first announcement of all CVP contractors' forecasted water allocations for the upcoming contract year. Forecasts of runoff and operations plans are updated at least monthly between February and May.

Reclamation uses the 90 percent probability of exceedance forecast as the basis of water allocations. Furthermore, NMFS reviews the operations plans devised to support the initial water allocation, and any subsequent updates to them, for sufficiency with respect to the criteria for Sacramento River temperature control.

CVP M&I Water Shortage Operational Assumptions-

The CVP has 253 water service contracts (including Sacramento River Settlement Contracts). These water service contracts have had varying water shortage provisions (e.g., in some contracts, municipal and industrial (M&I) and agricultural uses have shared shortages equally; in most of the larger M&I contracts, agricultural water has been shorted 25 percent of its contract entitlement before M&I water was shorted, after which both shared shortages equally).

The M&I minimum shortage allocation does not apply to contracts for the (1) Friant Division, (2) New Melones interim supply, (3) Hidden and Buchanan Units, (4) Cross Valley contractors, (5) San Joaquin River Exchange settlement contractors, and (6) Sacramento River settlement contractors. Any separate shortage- related contractual provisions will prevail.

There will be a minimum shortage allocation for M&I water supplies of 75 percent of a contractor's historical use (i.e., the last 3 years of water deliveries unconstrained by the availability of CVP water). Historical use can be adjusted for growth, extraordinary water conservation measures, and use of non-CVP water as those terms are defined in the proposed policy. Before the M&I water allocation is reduced, the irrigation water allocation would be reduced below 75 percent of contract entitlement.

When the allocation of irrigation water is reduced below 25 percent of contract entitlement, Reclamation will reassess the availability of CVP water and CVP water demand; however, due to limited water supplies during these times, M&I water allocation may be reduced below 75 percent of adjusted historical use during extraordinary and rare times such as prolonged and severe drought. Under these extrodinary conditions allocation percentages for both South of Delta and North of Delta irrigation and M&I contractors are the same.

Reclamation will deliver CVP water to all M&I contractors at not less than a public health and safety level if CVP water is available, if an emergency situation exists, but not exceeding 75 percent on contract total (and taking into consideration water supplies available to the M&I contractors from other sources). This is in recognition, however, that the M&I allocation may, nevertheless, fall to 50 percent as the irrigation allocation drops below 25 percent and approaches zero due to limited CVP supplies.

Allocation Modeling Assumptions:

Ag 100% to 75% then M&I is at 100%

Ag 70%	M&I 95%
Ag 65%	M&I 90%
Ag 60%	M&I 85%
Ag 55%	M&I 80%
Ag 50% to 25%	M&I 75%

Dry and Critical Years:

Ag 20%	M&I 70%
Ag 15%	M&I 65%
Ag 10%	M&I 60%
Ag 5%	M&I 55%
Ag 0%	M&I 50%

Project Facilities

Trinity River Division Operations

The Trinity River Division, completed in 1964, includes facilities to store and regulate water in the Trinity River, as well as facilities to divert water to the Sacramento River Basin. Trinity Dam is located on the Trinity River and regulates the flow from a drainage area of approximately 720 square miles. The dam was completed in 1962, forming Trinity Lake, which has a maximum storage capacity of approximately 2.4 million acre-feet (maf). See map in Figure 2-5.

The mean annual inflow to Trinity Lake from the Trinity River is about 1.2 maf per year. Historically, an average of about two-thirds of the annual inflow has been diverted to the Sacramento River Basin (1991-2003). Trinity Lake stores water for release to the Trinity River and for diversion to the Sacramento River via Lewiston Reservoir, Carr Tunnel, Whiskeytown Reservoir, and Spring Creek Tunnel where it commingles in Keswick Reservoir with Sacramento River water released from both the Shasta Dam and Spring Creek Debris Dam.

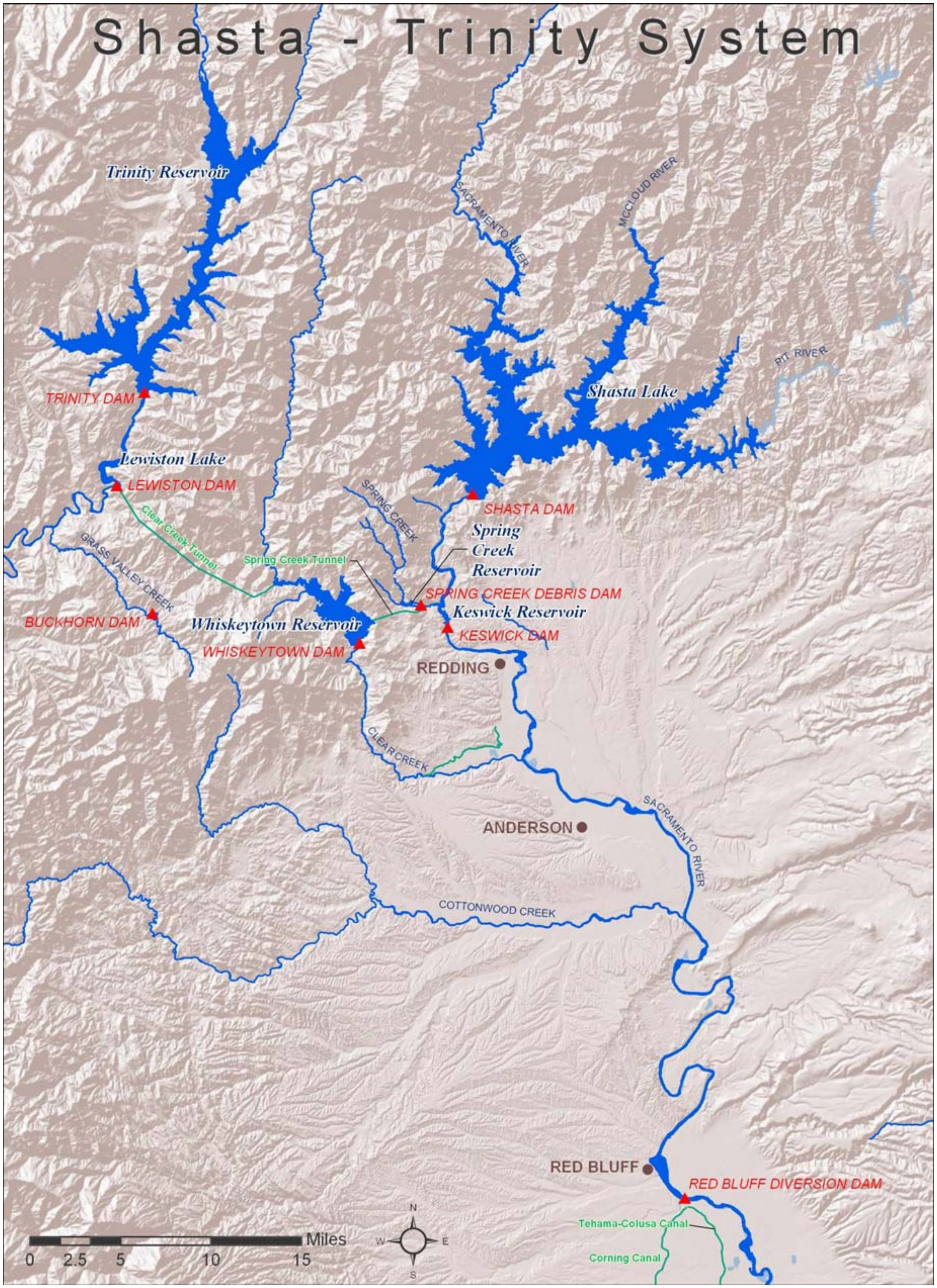

Figure 2-5 Shasta-Trinity System

Safety of Dams at Trinity Reservoir

Periodically, increased water releases are made from Trinity Dam consistent with Reclamation Safety of Dams criteria intended to prevent overtopping of Trinity Dam. Although flood control is not an authorized purpose of the Trinity River Division, flood control benefits are provided through normal operations.

The Safety of Dams release criteria specifies that Carr Powerplant capacity should be used as a first preference destination for Safety of Dams releases made at Trinity Dam. Trinity River releases are made as a second preference destination. During significant Northern California high water flood events, the Sacramento River water stages are also at concern levels. Under such high water conditions, the water that would otherwise move through Carr Powerplant is routed to the Trinity River. Total river release can reach up to 11,000 cfs below Lewiston Dam (under Safety of Dams criteria) due to local high water concerns in the flood plain and local bridge flow capacities. The Safety of Dam criteria provides seasonal storage targets and recommended releases November 1 to March 31. During the May 2006 the river flows were over 10,000 cfs for several days.

Fish and Wildlife Requirements on Trinity River

Based on the Trinity River Main-stem Fishery Restoration ROD, dated December 19, 2000, 368,600 to 815,000 af is allocated annually for Trinity River flows. This amount is scheduled in coordination with the U.S. Fish and Wildlife Service (FWS) to best meet habitat, temperature, and sediment transport objectives in the Trinity Basin.

Temperature objectives for the Trinity River are set forth in SWRCB order WR 90-5. See also Table 2-2 below. These objectives vary by reach and by season. Between Lewiston Dam and Douglas City Bridge, the daily average temperature should not exceed 60 degrees Fahrenheit (°F) from July 1 to September 14, and 56°F from September 15 to October 1. From October 1 to December 31, the daily average temperature should not exceed 56°F between Lewiston Dam and the confluence of the North Fork Trinity River. Reclamation consults with FWS in establishing a schedule of releases from Lewiston Dam that can best achieve these objectives.

For the purpose of determining the Trinity Basin water year type, forecasts using the 50 percent exceedance as of April 1st are used. There are no make-up/or increases for flows forgone if the water year type changes up or down from an earlier 50 percent forecast. In the modeling, actual historic Trinity inflows were used rather than a forecast. There is a temperature curtain in Lewiston Reservoir that provides for lower temperature water releases into the Trinity River.

Table 2-2 Water temperature objectives for the Trinity River during the summer, fall, and winter as established by the CRWQCB-NCR (California Regional Water Quality Control Board North Coast Region).

Date	Temperature Objective (°F)	
	Douglas City (RM 93.8)	North Fork Trinity River (RM 72.4)
July 1 through Sept 14	60	-
Sept 15 through Sept 30	56	-
Oct 1 through Dec 31	-	56

Transbasin Diversions

Diversion of Trinity water to the Sacramento Basin provides limited water supply and hydroelectric power generation for the CVP and assists in water temperature control in the Trinity River and upper Sacramento River. The amounts and timing of the Trinity exports are determined by subtracting Trinity River scheduled flow and targeted carryover storage from the forecasted Trinity water supply.

The seasonal timing of Trinity exports is a result of determining how to make best use of a limited volume of Trinity export (in concert with releases from Shasta) to help conserve cold water pools and meet temperature objectives on the upper Sacramento and Trinity rivers, as well as power production economics. A key consideration in the export timing determination is the thermal degradation that occurs in Whiskeytown Lake due to the long residence time of transbasin exports in the lake.

To minimize the thermal degradation effects, transbasin export patterns are typically scheduled by an operator to provide an approximate 120,000 af volume to occur in late spring to create a thermal connection to the Spring Creek Powerhouse before larger transbasin volumes are scheduled to occur during the hot summer months (Figure 2-6). Typically, the water flowing from the Trinity Basin through Whiskeytown Lake must be sustained at fairly high rates to avoid warming and to function most efficiently for temperature control. The time period for which effective temperature control releases can be made from Whiskeytown Lake may be compressed when the total volume of Trinity water available for export is limited.

Export volumes from Trinity are made in coordination with the operation of Shasta Reservoir. Other important considerations affecting the timing of Trinity exports are based on the utility of power generation and allowances for normal maintenance of the diversion works and generation facilities.

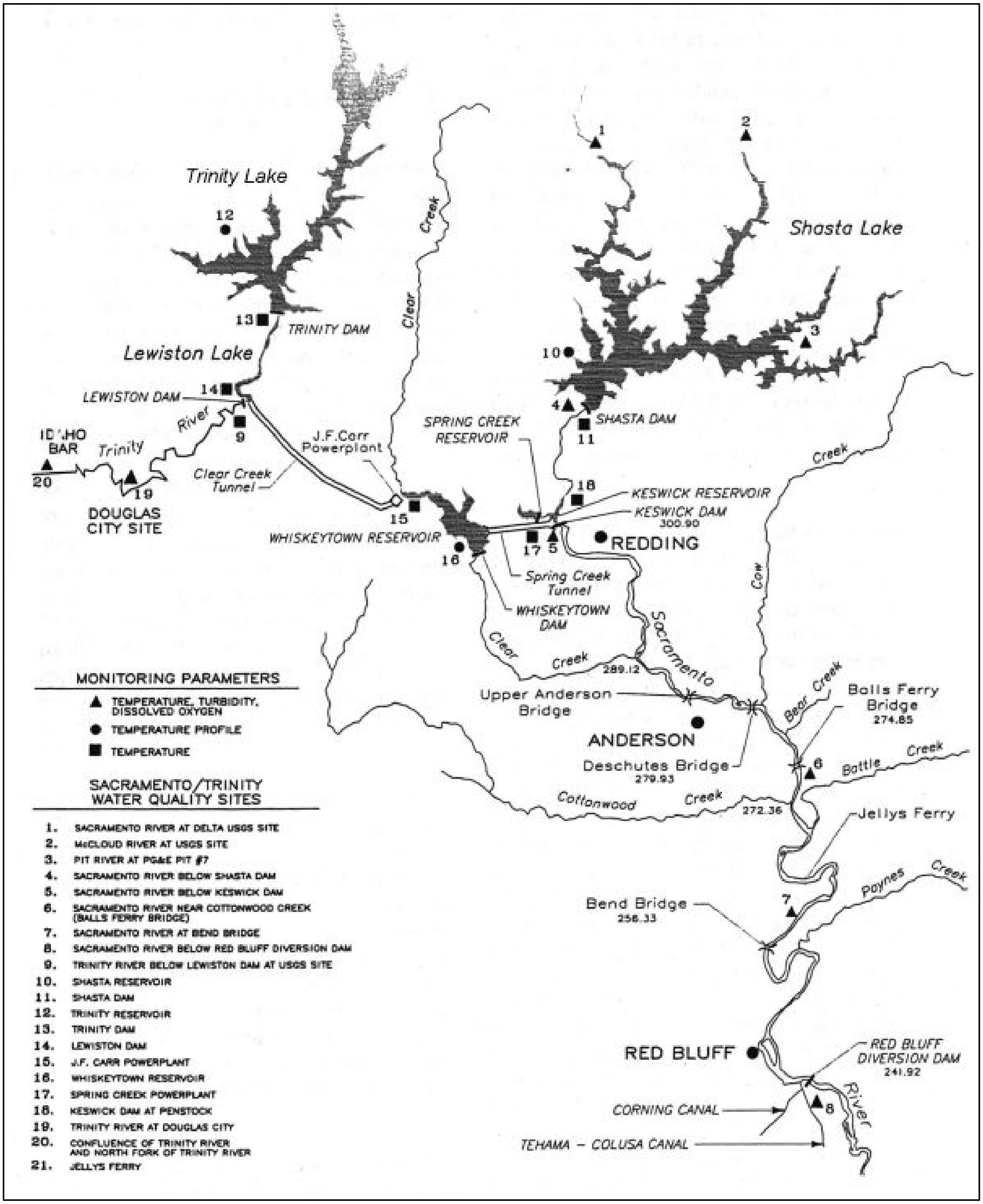

Figure 2-6 Sacramento-Trinity Water Quality Network (with river miles [RM]).

Trinity Lake historically reached its greatest storage level at the end of May. With the present pattern of prescribed Trinity releases, maximum storage may occur by the end of April or in early May.

Reclamation maintains at least 600,000 af in Trinity Reservoir, except during the 10 to 15 percent of the years when Shasta Reservoir is also drawn down. Reclamation will address end of water year carryover on a case-by-case basis in dry and critically dry water year types with FWS and NMFS through the WOMT and B2IT processes.

Whiskeytown Reservoir Operations

Since 1964, a portion of the flow from the Trinity River Basin has been exported to the Sacramento River Basin through the CVP facilities. Water is diverted from the Trinity River at Lewiston Dam via the Clear Creek Tunnel and passes through the Judge Francis Carr Powerhouse as it is discharged into Whiskeytown Lake on Clear Creek. From Whiskeytown Lake, water is released through the Spring Creek Power Conduit to the Spring Creek Powerplant and into Keswick Reservoir. All of the water diverted from the Trinity River, plus a portion of Clear Creek flows, is diverted through the Spring Creek Power Conduit into Keswick Reservoir.

Spring Creek also flows into the Sacramento River and enters at Keswick Reservoir. Flows on Spring Creek are partially regulated by the Spring Creek Debris Dam. Historically (1964-1992), an average annual quantity of 1,269,000 af of water has been diverted from Whiskeytown Lake to Keswick Reservoir. This annual quantity is approximately 17 percent of the flow measured in the Sacramento River at Keswick.

Whiskeytown is normally operated to (1) regulate inflows for power generation and recreation; (2) support upper Sacramento River temperature objectives; and (3) provide for releases to Clear Creek consistent with the CVPIA Anadromous Fish Restoration Program (AFRP) objectives. Although it stores up to 241,000 af, this storage is not normally used as a source of water supply. There is a temperature curtain in Whiskeytown Reservoir.

Spillway Flows below Whiskeytown Lake

Whiskeytown Lake is drawn down approximately 35,000 af per year of storage space during November through April to regulate flows for power generation. Heavy rainfall events occasionally result in spillway discharges to Clear Creek, as shown in Table 2-3 below.

Table 2-3 Days of Spilling below Whiskeytown and 40-30-30 Index from Water Year 1978 to 2005

Water Year	Days of Spilling	40-30-30 Index
1978	5	AN
1979	0	BN
1980	0	AN
1981	0	D
1982	63	W
1983	81	W
1984	0	W
1985	0	D

Water Year	Days of Spilling	40-30-30 Index
1986	17	W
1987	0	D
1988	0	C
1989	0	D
1990	8	C
1991	0	C
1992	0	C
1993	10	AN
1994	0	C
1995	14	W
1996	0	W
1997	5	W
1998	8	W
1999	0	W
2000	0	AN
2001	0	D
2002	0	D
2003	8	AN
2004	0	BN
2005	0	AN
2006	4	W
2007	0	D

Operations at Whiskeytown Lake during flood conditions are complicated by its operational relationship with the Trinity River, Sacramento River, and Clear Creek. On occasion, imports of Trinity River water to Whiskeytown Reservoir may be suspended to avoid aggravating high flow conditions in the Sacramento Basin.

Fish and Wildlife Requirements on Clear Creek

Water rights permits issued by the SWRCB for diversions from Trinity River and Clear Creek specify minimum downstream releases from Lewiston and Whiskeytown Dams, respectively. Two agreements govern releases from Whiskeytown Lake:

- A 1960 Memorandum of Agreement (MOA) with the DFG established minimum flows to be released to Clear Creek at Whiskeytown Dam, Table 2-4 .
- A 1963 release schedule for Whiskeytown Dam was developed with FWS and implemented, but never finalized. Although this release schedule was never formalized, Reclamation has operated according to this proposed schedule since May 1963.

Table 2-4 Minimum flows at Whiskeytown Dam from 1960 MOA with the DFG

Period	Minimum flow (cfs)
1960 MOA with the DFG	
January 1 - February 28(29)	50
March 1 - May 31	30
June 1 - September 30	0
October 1 - October 15	10
October 16 - October 31	30
November 1 - December 31	100
1963 FWS Proposed Normal year flow (cfs)	
January 1 - October 31	50
November 1 - December 31	100
1963 FWS Proposed Critical year flow (cfs)	
January 1 - October 31	30
November 1 - December 31	70

Spring Creek Debris Dam Operations

The Spring Creek Debris Dam (SCDD) is a feature of the Trinity Division of the CVP. It was constructed to regulate runoff containing debris and acid mine drainage from Spring Creek, a tributary to the Sacramento River that enters Keswick Reservoir. The SCDD can store approximately 5,800 af of water. Operation of SCDD and Shasta Dam has allowed some control of the toxic wastes with dilution criteria. In January 1980, Reclamation, the DFG, and the SWRCB executed a Memorandum of Understanding (MOU) to implement actions that protect the Sacramento River system from heavy metal pollution from Spring Creek and adjacent watersheds.

The MOU identifies agency actions and responsibilities, and establishes release criteria based on allowable concentrations of total copper and zinc in the Sacramento River below Keswick Dam.

The MOU states that Reclamation agrees to operate to dilute releases from SCDD (according to these criteria and schedules provided) and that such operation will not cause flood control parameters on the Sacramento River to be exceeded and will not unreasonably interfere with other project requirements as determined by Reclamation. The MOU also specifies a minimum schedule for monitoring copper and zinc concentrations at SCDD and in the Sacramento River below Keswick Dam. Reclamation has primary responsibility for the monitoring; however, the DFG and the RWQCB also collect and analyze samples on an as-needed basis. Due to more extensive monitoring, improved sampling and analyses techniques, and continuing cleanup efforts in the Spring Creek drainage basin, Reclamation now operates SCDD targeting the more stringent Central Valley Region Water Quality Control Plan (Basin Plan) criteria in addition to the MOU goals. Instead of the total copper and total zinc criteria contained in the MOU, Reclamation operates SCDD releases and Keswick dilution flows to not exceed the Basin Plan standards of 0.0056 mg/L dissolved copper and 0.016 mg/L dissolved zinc. Release rates are estimated from a mass balance calculation of the copper and zinc in the debris dam release and in the river.

In order to minimize the build-up of metal concentrations in the Spring Creek arm of Keswick Reservoir, releases from the debris dam are coordinated with releases from the Spring Creek Powerplant to keep the Spring Creek arm of Keswick Reservoir in circulation with the main water body of Keswick Lake.

The operation of SCDD is complicated during major heavy rainfall events. SCDD reservoir can fill to uncontrolled spill elevations in a relatively short time period, anywhere from days to weeks. Uncontrolled spills at SCDD can occur during major flood events on the upper Sacramento River and also during localized rainfall events in the Spring Creek watershed. During flood control events, Keswick releases may be reduced to meet flood control objectives at Bend Bridge when storage and inflow at Spring Creek Reservoir are high.

Because SCDD releases are maintained as a dilution ratio of Keswick releases to maintain the required dilution of copper and zinc, uncontrolled spills can and have occurred from SCDD. In this operational situation, high metal concentration loads during heavy rainfall are usually limited to areas immediately downstream of Keswick Dam because of the high runoff entering the Sacramento River adding dilution flow. In the operational situation when Keswick releases are increased for flood control purposes, SCDD releases are also increased in an effort to reduce spill potential.

In the operational situation when heavy rainfall events will fill SCDD and Shasta Reservoir will not reach flood control conditions, increased releases from CVP storage may be required to maintain desired dilution ratios for metal concentrations. Reclamation has voluntarily released additional water from CVP storage to maintain release ratios for toxic metals below Keswick Dam. Reclamation has typically attempted to meet the Basin Plan standards but these releases have no established criteria and are dealt with on a case-by-case basis. Since water released for dilution of toxic spills is likely to be in excess of other CVP requirements, such releases increase the risk of a loss of water for other beneficial purposes.

Shasta Division and Sacramento River Division

The CVP's Shasta Division includes facilities that conserve water in the Sacramento River for (1) flood control, (2) navigation maintenance, (3) agricultural water supplies, (4) M&I water supplies (5) hydroelectric power generation, (6) conservation of fish in the Sacramento River, and (7) protection of the Sacramento-San Joaquin Delta from intrusion of saline ocean water. The Shasta Division includes Shasta Dam, Lake, and Powerplant; Keswick Dam, Reservoir, and Powerplant, and the Shasta Temperature Control Device.

The Sacramento River Division was authorized after completion of the Shasta Division. Total authorized diversions for the Sacramento River Division are approximately 2.8 maf. Historically the total diversion has varied from 1.8 maf in a critically dry year to the full 2.8 maf in wet year.

It includes facilities for the diversion and conveyance of water to CVP contractors on the west side of the Sacramento River. The division includes the Sacramento Canals Unit, which was authorized in 1950 and consists of the RBDD, the Corning Pumping Plant, and the Corning and Tehama-Colusa Canals.

The unit was authorized to supply irrigation water to over 200,000 acres of land in the Sacramento Valley, principally in Tehama, Glenn, Colusa, and Yolo counties. Black Butte Dam, which is operated by the U.S. Army Corps of Engineers (Corps), also provides supplemental water to the Tehama-Colusa Canals as it crosses Stony Creek. The operations of the Shasta and Sacramento River divisions are presented together because of their operational inter-relationships.

Shasta Dam is located on the Sacramento River just below the confluence of the Sacramento, McCloud, and Pit Rivers. The dam regulates the flow from a drainage area of approximately 6,649 square miles. Shasta Dam was completed in 1945, forming Shasta Lake, which has a maximum storage capacity of 4,552,000 af. Water in Shasta Lake is released through or around the Shasta Powerplant to the Sacramento River where it is re-regulated downstream by Keswick Dam. A small amount of water is diverted directly from Shasta Lake for M&I uses by local communities.

Keswick Reservoir was formed by the completion of Keswick Dam in 1950. It has a capacity of approximately 23,800 af and serves as an afterbay for releases from Shasta Dam and for discharges from the Spring Creek Powerplant. All releases from Keswick Reservoir are made to the Sacramento River at Keswick Dam. The dam has a fish trapping facility that operates in conjunction with the Coleman National Fish Hatchery on Battle Creek.

Flood Control

Flood control objectives for Shasta Lake require that releases be restricted to quantities that will not cause downstream flows or stages to exceed specified levels. These include a flow of 79,000 cfs at the tailwater of Keswick Dam, and a stage of 39.2 feet in the Sacramento River at Bend Bridge gauging station, which corresponds to a flow of approximately 100,000 cfs. Flood control operations are based on regulating criteria developed by the Corps pursuant to the provisions of the Flood Control Act of 1944. Maximum flood space reservation is 1.3 maf, with variable storage space requirements based on an inflow parameter.

Flood control operation at Shasta Lake requires the forecasting of runoff conditions into Shasta Lake, as well as runoff conditions of unregulated creek systems downstream from Keswick Dam, as far in advance as possible. A critical element of upper Sacramento River flood operations is the local runoff entering the Sacramento River between Keswick Dam and Bend Bridge.

The unregulated creeks (major creek systems are Cottonwood Creek, Cow Creek, and Battle Creek) in this reach of the Sacramento River can be very sensitive to a large rainfall event and produce large rates of runoff into the Sacramento River in short time periods. During large rainfall and flooding events, the local runoff between Keswick Dam and Bend Bridge can exceed 100,000 cfs.

The travel time required for release changes at Keswick Dam to affect Bend Bridge flows is approximately 8 to 10 hours. If the total flow at Bend Bridge is projected to exceed 100,000 cfs, the release from Keswick Dam is decreased to maintain Bend Bridge flow below 100,000 cfs. As the flow at Bend Bridge is projected to recede, the Keswick Dam release is increased to evacuate water stored in the flood control space at Shasta Lake. Changes to Keswick Dam releases are scheduled to minimize rapid fluctuations in the flow at Bend Bridge.

The flood control criteria for Keswick releases specify releases should not be increased more than 15,000 cfs or decreased more than 4,000 cfs in any 2-hour period. The restriction on the rate of decrease is intended to prevent sloughing of saturated downstream channel embankments caused by rapid reductions in river stage. In rare instances, the rate of decrease may have to be accelerated to avoid exceeding critical flood stages downstream.

Fish and Wildlife Requirements in the Sacramento River

Reclamation operates the Shasta, Sacramento River, and Trinity River divisions of the CVP to meet (to the extent possible) the provisions of SWRCB Order 90-05. An April 5, 1960, MOA between Reclamation and the DFG originally established flow objectives in the Sacramento River for the protection and preservation of fish and wildlife resources. The agreement provided for minimum releases into the natural channel of the Sacramento River at Keswick Dam for normal and critically dry years (Table 2-5). Since October 1981, Keswick Dam has operated based on a minimum release of 3,250 cfs for normal years from September 1 through the end of February, in accordance with an agreement between Reclamation and DFG. This release schedule was included in Order 90-05, which maintains a minimum release of 3,250 cfs at Keswick Dam and RBDD from September through the end of February in all water years, except critically dry years.

Table 2-5 Current minimum flow requirements and objectives (cfs) on the Sacramento River below Keswick Dam

Water year type	MOA	WR 90-5	MOA and WR 90-5	Proposed Flow Objectives below Keswick
Period	**Normal**	**Normal**	**Critically dry**	**All**
January 1 - February 28(29)	2600	3250	2000	3250
March 1 - March 31	2300	2300	2300	3250
April 1 - April 30	2300	2300	2300	---*
May 1 - August 31	2300	2300	2300	---*
September 1 - September 30	3900	3250	2800	---*
October 1 - November 30	3900	3250	2800	3250
December 1 - December 31	2600	3250	2000	3250

Note: * No regulation.

The 1960 MOA between Reclamation and the DFG provides that releases from Keswick Dam (from September 1 through December 31) are made with minimum water level fluctuation or change to protect salmon to the extent compatible with other operations requirements. Releases from Shasta and Keswick Dams are gradually reduced in September and early October during the transition from meeting Delta export and water quality demands to operating the system for flood control and fishery concerns from October through December.

Reclamation proposes a minimum flow of 3,250 cfs from October 1 through March 31 and ramping constraints for Keswick release reductions from July 1 through March 31 as follows:

- Releases must be reduced between sunset and sunrise.
- When Keswick releases are 6,000 cfs or greater, decreases may not exceed 15 percent per night. Decreases also may not exceed 2.5 percent in one hour.
- For Keswick releases between 4,000 and 5,999 cfs, decreases may not exceed 200 cfs per night. Decreases also may not exceed 100 cfs per hour.
- For Keswick releases between 3,250 and 3,999 cfs, decreases may not exceed 100 cfs per night.
- Variances to these release requirements are allowed under flood control operations.

Reclamation usually attempts to reduce releases from Keswick Dam to the minimum fishery requirement by October 15 each year and to minimize changes in Keswick releases between October 15 and December 31. Releases may be increased during this period to meet unexpected downstream needs such as higher outflows in the Delta to meet water quality requirements, or to meet flood control requirements. Releases from Keswick Dam may be reduced when downstream tributary inflows increase to a level that will meet flow needs. Reclamation attempts to establish a base flow that minimizes release fluctuations to reduce impacts to fisheries and bank erosion from October through December.

A recent change in agricultural water diversion practices has affected Keswick Dam release rates in the fall. This program is generally known as the Rice Straw Decomposition and Waterfowl Habitat Program. Historically, the preferred method of clearing fields of rice stubble was to systematically burn it. Today, rice field burning has been phased out due to air quality concerns and has been replaced by a program of rice field flooding that decomposes rice stubble and provides additional waterfowl habitat. The result has been an increase in water demand to flood rice fields in October and November, which has increased the need for higher Keswick releases in all but the wettest of fall months.

The changes in agricultural practice over the last decade related to the Rice Straw Decomposition and Waterfowl Habitat Program have been incorporated into the systematic modeling of agricultural use and hydrology effects, and the CalSim-II model used here incorporates these effects. The increased water demand for fall rice field flooding and decomposition on the Sacramento River during this timeframe affects Reclamation’s ability to maintain a stable base flow.

Minimum Flow for Navigation – Wilkins Slough

Historical commerce on the Sacramento River resulted in a CVP authorization to maintain minimum flows of 5,000 cfs at Chico Landing to support navigation. Currently, there is no commercial traffic between Sacramento and Chico Landing, and the Corps has not dredged this reach to preserve channel depths since 1972. However, long-time water users diverting from the river have set their pump intakes just below this level. Therefore, the CVP is operated to meet the navigation flow requirement of 5,000 cfs to Wilkins Slough, (gauging station on the Sacramento River), under all but the most critical water supply conditions, to facilitate pumping and use of screened diversions.

At flows below 5,000 cfs at Wilkins Slough, diverters have reported increased pump cavitation as well as greater pumping head requirements. Diverters are able to operate for extended periods at flows as low as 4,000 cfs at Wilkins Slough, but pumping operations become severely affected and some pumps become inoperable at flows lower than this. Flows may drop as low as 3,500 cfs for short periods while changes are made in Keswick releases to reach target levels at Wilkins Slough, but using the 3,500 cfs rate as a target level for an extended period would have major impacts on diverters.

No criteria have been established specifying when the navigation minimum flow should be relaxed. However, the basis for Reclamation's decision to operate at less than 5,000 cfs is the increased importance of conserving water in storage when water supplies are not sufficient to meet full contractual deliveries and other operational requirements.

Water Temperature Operations in the Upper Sacramento River

Water temperature in the upper Sacramento River is governed by current water right permit requirements and is consistent with past biological opinion requirements. Water temperature on the Sacramento River system is influenced by several factors, including the relative water temperatures and ratios of releases from Shasta Dam and from the Spring Creek Powerplant. The temperature of water released from Shasta Dam and the Spring Creek Powerplant is a function of the reservoir temperature profiles at the discharge points at Shasta and Whiskeytown, the depths from which releases are made, the seasonal management of the deep cold water reserves, ambient seasonal air temperatures and other climatic conditions, tributary accretions and water temperatures, and residence time in Keswick, Whiskeytown and Lewiston Reservoirs, and in the Sacramento River.

SWRCB Water Rights Order 90-05 and Water Rights Order 91-01

In 1990 and 1991, the SWRCB issued Water Rights Orders 90-05 and 91-01 modifying Reclamation's water rights for the Sacramento River. The orders stated Reclamation shall operate Keswick and Shasta Dams and the Spring Creek Powerplant to meet a daily average water temperature of 56°F as far downstream in the Sacramento River as practicable during periods when higher temperature would be harmful to fisheries. The optimal control point is the RBDD.

Under the orders, the water temperature compliance point may be modified when the objective cannot be met at RBDD. In addition, Order 90-05 modified the minimum flow requirements initially established in the 1960 MOA for the Sacramento River below Keswick Dam. The water right orders also recommended the construction of a Shasta Temperature Control Device (TCD) to improve the management of the limited cold water resources.

Pursuant to SWRCB Orders 90-05 and 91-01, Reclamation configured and implemented the Sacramento-Trinity Water Quality Monitoring Network to monitor temperature and other parameters at key locations in the Sacramento and Trinity Rivers. The SWRCB orders also required Reclamation to establish the Sacramento River Temperature Task Group (SRTTG) to formulate, monitor, and coordinate temperature control plans for the upper Sacramento and Trinity Rivers. This group consists of representatives from Reclamation, SWRCB, NMFS, FWS, DFG, Western, DWR, and the Hoopa Valley Indian Tribe.

Each year, with finite cold water resources and competing demands usually an issue, the SRTTG will devise operation plans with the flexibility to provide the best protection consistent with the CVP’s temperature control capabilities and considering the annual needs and seasonal spawning distribution monitoring information for winter-run and fall-run Chinook salmon. In every year since the SWRCB issued the orders, those plans have included modifying the RBDD compliance point to make best use of the cold water resources based on the location of spawning Chinook salmon. Reports are submitted periodically to the SWRCB over the temperature control season defining our temperature operation plans. The SWRCB has overall authority to determine if the plan is sufficient to meet water right permit requirements.

Shasta Temperature Control Device

Construction of the Temperature Control Device (TCD) at Shasta Dam was completed in 1997. This device is designed for greater flexibility in managing the cold water reserves in Shasta Lake while enabling hydroelectric power generation to occur and to improve salmon habitat conditions in the upper Sacramento River. The TCD is also designed to enable selective release of water from varying lake levels through the power plant in order to manage and maintain adequate water temperatures in the Sacramento River downstream of Keswick Dam.

Prior to construction of the Shasta TCD, Reclamation released water from Shasta Dam’s low-level river outlets to alleviate high water temperatures during critical periods of the spawning and incubation life stages of the winter-run Chinook stock. Releases through the low-level outlets bypass the power plant and result in a loss of hydroelectric generation at the Shasta Powerplant. The release of water through the low-level river outlets was a major facet of Reclamation’s efforts to control upper Sacramento River temperatures from 1987 through 1996.

The seasonal operation of the TCD is generally as follows: during mid-winter and early spring the highest elevation gates possible are utilized to draw from the upper portions of the lake to conserve deeper colder resources (see Table 2-6). During late spring and summer, the operators begin the seasonal progression of opening deeper gates as Shasta Lake elevation decreases and cold water resources are utilized. In late summer and fall, the TCD side gates are opened to utilize the remaining cold water resource below the Shasta Powerplant elevation in Shasta Lake.

Table 2-6 Shasta Temperature Control Device Gates with Elevation and Storage

TCD Gates	Shasta Elevation with 35 feet of submergence	Shasta Storage
Upper Gates	1035	~3.65 MAF
Middle Gates	935	~2.50 MAF
Pressure Relief Gates	840	~0.67 MAF
Side Gates	720*	~0.01 MAF

* Low Level intake bottom.

The seasonal progression of the Shasta TCD operation is designed to maximize the conservation of cold water resources deep in Shasta Lake, until the time the resource is of greatest management value to fishery management purposes. Recent operational experience with the Shasta TCD has demonstrated significant operational flexibility improvement for cold water conservation and upper Sacramento River water temperature and fishery habitat management purposes. Recent operational experience has also demonstrated the Shasta TCD has significant leaks that are inherent to TCD design.

Reclamation's Proposed Upper Sacramento River Temperature Objectives

Reclamation will continue a policy of developing annual operations plans and water allocations based on a conservative 90 percent exceedance forecast. Reclamation is not proposing a minimum end-of-water-year (September 30) carryover storage in Shasta Reservoir.

In continuing compliance with Water Rights Orders 90-05 and 91-01 requirements, Reclamation will implement operations to provide year round temperature protection in the upper Sacramento River, consistent with the intent of Order 90-05 that protection be provided to the extent controllable. Among factors that affect the extent to which river temperatures will be controllable will include Shasta TCD performance, the availability of cold water, the balancing of habitat needs for different species in spring, summer, and fall, and the constraints on operations created by the combined effect of the projects and demands assumed to be in place in the future.

Under all but the most adverse drought and low Shasta Reservoir storage conditions, Reclamation proposes to continue operating CVP facilities to provide water temperature control at Ball's Ferry or at locations further downstream (as far as Bend Bridge) based on annual plans developed in coordination with the Sacramento River Temperature Task Group (SRTTG). Reclamation and the SRTTG will take into account projections of cold water resources, numbers of expected spawning salmon, and spawning distribution (as monitoring information becomes available) to make the decisions on allocation of the cold water resources.

Locating the target temperature compliance at Ball's Ferry (1) reduces the need to compensate for the warming effects of Cottonwood Creek and Battle Creek during the spring runoff months with deeper cold water releases and (2) improves the reliability of cold water resources through the fall months. Reclamation proposes Sacramento River temperature control point to be consistent with the capability of the CVP to manage cold water resources and to use the process of annual planning in coordination with the SRTTG to arrive at the best use of that capability.

Anderson-Cottonwood Irrigation District (ACID) Diversion Dam

ACID holds senior water rights and has diverted into the ACID Canal for irrigation along the west side of the Sacramento River between Redding and Cottonwood since 1916. The United States and ACID signed a contract providing for the project water service and agreement on diversion of water. ACID diverts to its main canal (on the right bank of the river) from a diversion dam located in Redding about five miles downstream from Keswick Dam.

Close coordination is required between Reclamation and ACID for regulation of river flows to ensure safe operation of ACIDs diversion dam during the irrigation season. The irrigation season for ACID runs from April through October.

Keswick release rate decreases required for the ACID operations are limited to 15 percent in a 24-hour period and 2.5 percent in any one hour. Therefore, advance notification is important when scheduling decreases to allow for the installation or removal of the ACID diversion dam.

Red Bluff Diversion Dam Operations

The Red Bluff Diversion Dam (RBDD), located on the Sacramento River approximately two miles southeast of Red Bluff, is a gated structure with fish ladders at each abutment. When the gates are lowered, the impounded water rises about 13 feet, creating Lake Red Bluff and allowing gravity diversions through a set of drum fish screens into the stilling basin servicing the Tehama-Colusa and Corning canals. Construction of RBDD was completed in 1964.

The Tehama-Colusa Canal is a lined canal extending 111 miles south from the RBDD and provides irrigation service on the west side of the Sacramento Valley in Tehama, Glenn, Colusa, and northern Yolo counties. Construction of the Tehama-Colusa Canal began in 1965, and it was completed in 1980.

The Corning Pumping Plant lifts water approximately 56 feet from the screened portion of the settling basin into the unlined, 21 mile-long Corning Canal. The Corning Canal was completed in 1959, to provide water to the CVP contractors in Tehama County that could not be served by gravity from the Tehama-Colusa Canal. The Tehama-Colusa Canal Authority (TCCA) operates both the Tehama-Colusa and Corning canals.

Since 1986, the RBDD gates have been raised during winter months to allow passage of winter-run Chinook salmon. As documented in the 2004 NMFS biological opinion addressing the long-term CVP and SWP operations, the gates are raised from approximately September 15 through May 14, each year. In the near term, Reclamation proposes the continued operation of the RBDD using the eight-month gate-open procedures of the past ten years, and to use the research pumping plant to provide water to the canals during times when the gates-out configuration precludes gravity diversions during the irrigation season. Additionally, although covered under a separate NMFS biological opinion, Reclamation proposes the continued use of rediversions of CVP water stored in Black Butte Reservoir to supplement the water pumped at RBDD during the gates-out period. This water is rediverted with the aid of temporary gravel berms through an unscreened, constant head orifice (CHO) into the Tehama-Colusa Canal.

In addition to proposing to operate the RBDD with the gates in for 8 months annually to enable gravity diversion of water into the Tehama-Colusa Canal, Reclamation proposes retention of the provision for a 10-day emergency pre-irrigation gate closure, as necessary, contingent upon a case-by-case consultation with NMFS. Reclamation most recently coordinated such a gate closure with NMFS in the spring of 2007. Around that time, dead green sturgeon were discovered in the vicinity of the dam, and Reclamation worked with the other resource agencies to review the gate operation protocol to try and reduce future potential adverse affects to adult green sturgeon that pass the dam. The resulting, new protocol for all gates in operation is to open individual gates to a minimum height of 12 inches to substantially reduce the possibility of injury should adult green sturgeon pass beneath the gates.

American River Division

Reclamation's Folsom Lake, the largest reservoir in the watershed, has a capacity of 977,000 af. Folsom Dam, located approximately 30 miles upstream from the confluence with the Sacramento River, is operated as a major component of the CVP. The American River Division includes facilities that provide conservation of water on the American River for flood control, fish and wildlife protection, recreation, protection of the Delta from intrusion of saline ocean water, irrigation and M&I water supplies, and hydroelectric power generation. Initially authorized features of the American River Division included Folsom Dam, Lake, and Powerplant; Nimbus Dam and Powerplant, and Lake Natoma. See map in Figure 2-7.

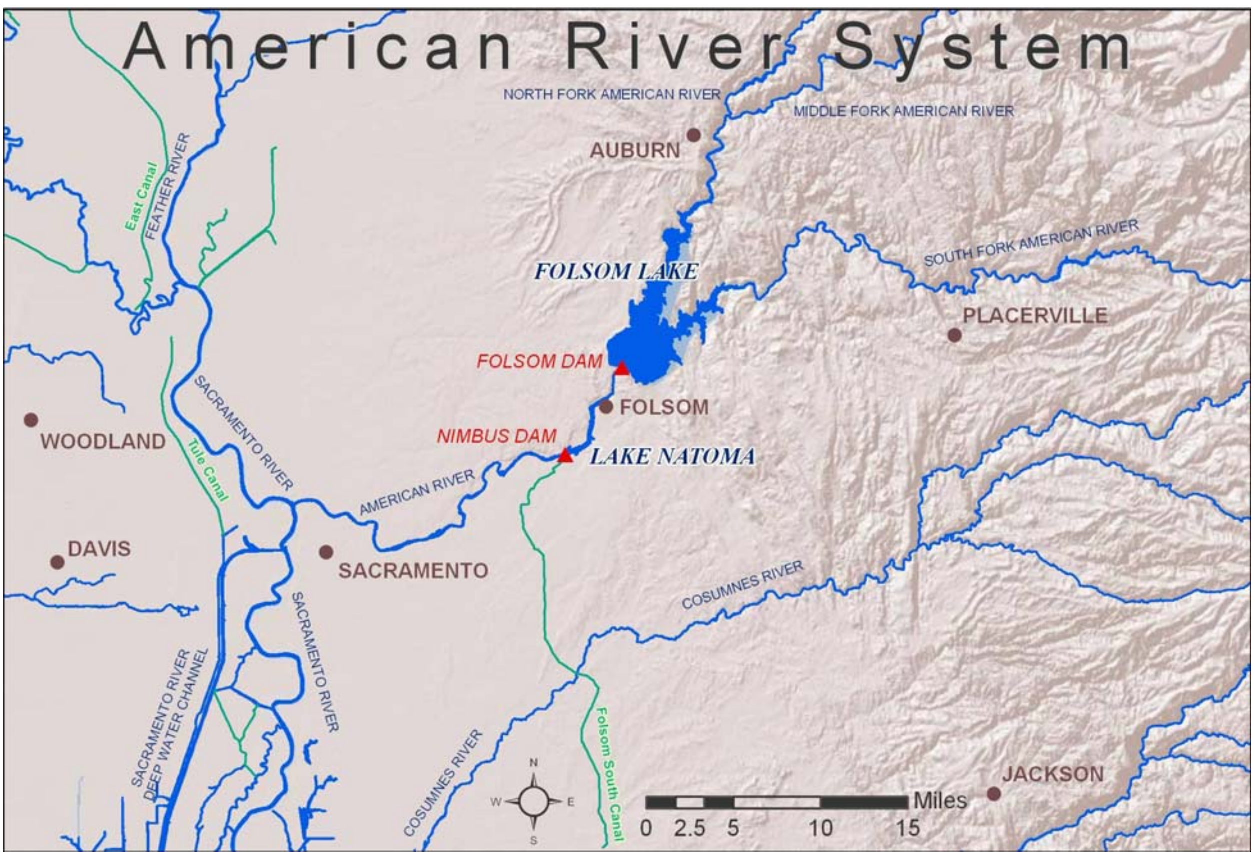

Figure 2-7 American River System

Table 2-7 provides Reclamation's annual water deliveries for the period 2000 through 2006 in the American River Division. The totals reveal an increasing trend in water deliveries over that period. For this Biological Assessment, present level of American River Division water demands are modeled at about 325 taf per year. Future level (2030) water demands are modeled at near 800 taf per year. The modeled deliveries vary depending on modeled annual water allocations.

Table 2-7 Annual Water Delivery - American River Division

Year	Water Delivery (taf)
2000	196
2001	206
2002	238
2003	271
2004	266
2005	297
2006	282

Releases from Folsom Dam are re-regulated approximately seven miles downstream by Nimbus Dam. This facility is also operated by Reclamation as part of the CVP. Nimbus Dam creates Lake Natoma, which serves as a forebay for diversions to the Folsom South Canal. This CVP facility serves water to M&I users in Sacramento County. Releases from Nimbus Dam to the American River pass through the Nimbus Powerplant, or, at flows in excess of 5,000 cfs, the spillway gates.

Although Folsom Lake is the main storage and flood control reservoir on the American River, numerous other small reservoirs in the upper basin provide hydroelectric generation and water supply. None of the upstream reservoirs have any specific flood control responsibilities. The total upstream reservoir storage above Folsom Lake is approximately 820,000 af. Ninety percent of this upstream storage is contained by five reservoirs: French Meadows (136,000 af); Hell Hole (208,000 af); Loon Lake (76,000 af); Union Valley (271,000 af); and Ice House (46,000 af). Reclamation has agreements with the operators of some of these reservoirs to coordinate operations for releases.

French Meadows and Hell Hole reservoirs, located on the Middle Fork of the American River, are owned and operated by the Placer County Water Agency (PCWA). The PCWA provides wholesale water to agricultural and urban areas within Placer County. For urban areas, the PCWA operates water treatment plants and sells wholesale treated water to municipalities that provide retail delivery to their customers. The cities of Rocklin and Lincoln receive water from the PCWA. Loon Lake (also on the Middle Fork), and Union Valley and Ice House reservoirs on the South Fork, are all operated by the Sacramento Municipal Utilities District (SMUD) for hydropower purposes.

Flood Control

Flood control requirements and regulating criteria are specified by the Corps and described in the Folsom Dam and Lake, American River, California Water Control Manual (Corps 1987). Flood control objectives for Folsom require the dam and lake are operated to:

- Protect the City of Sacramento and other areas within the Lower American River floodplain against reasonable probable rain floods.
- Control flows in the American River downstream from Folsom Dam to existing channel capacities, insofar as practicable, and to reduce flooding along the lower Sacramento River and in the Delta in conjunction with other CVP projects.
- Provide the maximum amount of water conservation storage without impairing the flood control functions of the reservoir.
- Provide the maximum amount of power practicable and be consistent with required flood control operations and the conservation functions of the reservoir.

From June 1 through September 30, no flood control storage restrictions exist. From October 1 through November 16 and from April 20 through May 31, reserving storage space for flood control is a function of the date only, with full flood reservation space required from November 17 through February 7. Beginning February 8 and continuing through April 20, flood reservation space is a function of both date and current hydrologic conditions in the basin.

If the inflow into Folsom Reservoir causes the storage to encroach into the space reserved for flood control, releases from Nimbus Dam are increased. Flood control regulations prescribe the following releases when water is stored within the flood control reservation space:

- Maximum inflow (after the storage entered into the flood control reservation space) of as much as 115,000 cfs, but not less than 20,000 cfs, when inflows are increasing.
- Releases will not be increased more than 15,000 cfs or decreased more than 10,000 cfs during any two-hour period.
- Flood control requirements override other operational considerations in the fall and winter period. Consequently, changes in river releases of short duration may occur.

In February 1986, the American River Basin experienced a significant flood event. Folsom Dam and Reservoir moderated the flood event and performed the flood control objectives, but with serious operational strains and concerns in the Lower American River and the overall protection of the communities in the floodplain areas. A similar flood event occurred in January 1997. Since then, significant review and enhancement of Lower American River flooding issues has occurred and continues to occur. A major element of those efforts has been the Sacramento Area Flood Control Agency (SAFCA) sponsored flood control plan diagram for Folsom Reservoir.

Since 1996, Reclamation has operated according to modified flood control criteria, which reserve 400 to 670 thousand af of flood control space in Folsom and in a combination of three upstream reservoirs. This flood control plan, which provides additional protection for the Lower American River, is implemented through an agreement between Reclamation and the SAFCA. The terms of the agreement allow some of the empty reservoir space in Hell Hole, Union Valley, and French Meadows to be treated as if it were available in Folsom.

The SAFCA release criteria are generally equivalent to the Corps plan, except the SAFCA diagram may prescribe flood releases earlier than the Corps plan. The SAFCA diagram also relies on Folsom Dam outlet capacity to make the earlier flood releases. The outlet capacity at Folsom Dam is currently limited to 32,000 cfs based on lake elevation. However, in general the SAFCA plan diagram provides greater flood protection than the existing Corps plan for communities in the American River floodplain.

Required flood control space under the SAFCA diagram will begin to decrease on March 1. Between March 1 and April 20, the rate of filling is a function of the date and available upstream space. As of April 21, the required flood reservation is about 225,000 af. From April 21 to June 1, the required flood reservation is a function of the date only, with Folsom storage permitted to fill completely on June 1.

Fish and Wildlife Requirements in the Lower American River

The minimum allowable flows in the Lower American River are defined by SWRCB Decision 893 (D-893) which states that, in the interest of fish conservation, releases should not ordinarily fall below 250 cfs between January 1 and September 15 or below 500 cfs at other times. D-893 minimum flows are rarely the controlling objective of CVP operations at Nimbus Dam. Nimbus Dam releases are nearly always controlled during significant portions of a water year by either flood control requirements or are coordinated with other CVP and SWP releases to meet downstream Sacramento-San Joaquin Delta WQCP requirements and CVP water supply objectives. Power regulation and management needs occasionally control Nimbus Dam releases. Nimbus Dam releases are expected to exceed the D-893 minimum flows in all but the driest of conditions.

Reclamation continues to work with the Sacramento Water Forum, FWS, NMFS, DFG, and other interested parties to intergrate a revised flow management standard for the Lower American River into CVP operations and water rights. This project description and modeling assumptions include the operational components of the recommended Lower American River flows and is consistent with the proposed flow management standard. Until this action is adopted by the SWRCB, the minimum legally required flows will be defined by D-893. However, Reclamation intends to operate to the proposed flow management standard using releases of additional water pursuant to Section 3406 (b)(2) of the CVPIA. Use of additional (b)(2) flows above the proposed flow standard is envisioned only on a case-by-case basis. Such additional use of (b)(2) flows would be subject to available resources and such use would be coupled with plans to not intentionally cause significantly lower river flows later in a water year. This case-by-case use of additional (b)(2) for minimum flows is not included in the modeling results.

Water temperature control operations in the Lower American River are affected by many factors and operational tradeoffs. These include available cold water resources, Nimbus release schedules, annual hydrology, Folsom power penstock shutter management flexibility, Folsom Dam Urban Water Supply TCD management, and Nimbus Hatchery considerations. Shutter and

TCD management provide the majority of operational flexibility used to control downstream temperatures.

During the late 1960s, Reclamation designed a modification to the trashrack structures to provide selective withdrawal capability at Folsom Dam. Folsom Powerplant is located at the foot of Folsom Dam on the right abutment. Three 15-foot-diameter steel penstocks for delivering water to the turbines are embedded in the concrete section of the dam. The centerline of each penstock intake is at elevation 307.0 feet and the minimum power pool elevation is 328.5 feet. A reinforced concrete trashrack structure with steel trashracks protects each penstock intake.

The steel trashracks, located in five bays around each intake, extend the full height of the trashrack structure (between 281 and 428 feet). Steel guides were attached to the upstream side of the trashrack panels between elevation 281 and 401 feet. Forty-five 13-foot steel shutter panels (nine per bay) and operated by the gantry crane, were installed in these guides to select the level of withdrawal from the reservoir. The shutter panels are attached to one another, in a configuration starting with the top shutter, in groups of three, two, and four.

Selective withdrawal capability on the Folsom Dam Urban Water Supply Pipeline became operational in 2003. The centerline to the 84-inch-diameter Urban Water Supply intake is at elevation 317 feet. An enclosure structure extending from just below the water supply intake to an elevation of 442 feet was attached to the upstream face of Folsom Dam. A telescoping control gate allows for selective withdrawal of water anywhere between 331 and 401 feet elevation under normal operations.

The current objectives for water temperatures in the Lower American River address the needs for steelhead incubation and rearing during the late spring and summer, and for fall–run Chinook spawning and incubation starting in late October or early November.

A major challenge is determining the starting date at which time the objective is met. Establishing the start date requires a balancing between forecasted release rates, the volume of available cold water, and the estimated date at which time Folsom Reservoir turns over and becomes isothermic. Reclamation will work to provide suitable spawning temperatures as early as possible (after November 1) to help avoid temperature related pre-spawning mortality of adults and reduced egg viability. Operations will be balanced against the possibility of running out of cold water and increasing downstream temperatures after spawning is initiated and creating temperature related effects to eggs already in the gravel.

The cold water resources available in any given year at Folsom Lake needed to meet the stated water temperature goals are often insufficient. Only in wetter hydrologic conditions is the volume of cold water resources available sufficient to meet all the water temperature objectives. Therefore, significant operations tradeoffs and flexibilities are considered part of an annual planning process for coordinating an operation strategy that realistically manages the limited cold water resources available. Reclamation's coordination on the planning and management of cold water resources is done through the B2IT and ARG groups as discussed earlier in this Chapter.

The management process begins in the spring as Folsom Reservoir fills. All penstock shutters are put in the down position to isolate the colder water in the reservoir below an elevation of 401 feet. The reservoir water surface elevation must be at least 25 feet higher than the sill of the upper shutter (426 feet) to avoid cavitation of the power turbines. The earliest this can occur is in the month of March, due to the need to maintain flood control space in the reservoir during the winter. The pattern of spring run-off is then a significant factor in determining the availability of cold water for later use. Folsom inflow temperatures begin to increase and the lake starts to stratify as early as April. By the time the reservoir is filled or reaches peak storage (sometime in the May through June period), the reservoir is highly stratified with surface waters too warm to meet downstream temperature objectives. There are, however, times during the filling process when use of the spillway gates can be used to conserve cold water.

In the spring of 2003, high inflows and encroachment into the allowable storage space for flood control required releases that exceeded the available capacity of the power plant. Under these conditions, standard operations of Folsom calls for the use of the river outlets that would draw upon the cold water pool. Instead, Reclamation reviewed the release requirements, Safety of Dams issues, reservoir temperature conditions, and the benefits to the cold water pool and determined that it could use the spillway gates to make the incremental releases above powerplant capacity, thereby conserving cold water for later use. The ability to take similar actions (as needed in the future) will be evaluated on a case-by-case basis.

The annual temperature management strategy and challenge is to balance conservation of cold water for later use in the fall, with the more immediate needs of steelhead during the summer. The planning and forecasting process for the use of the cold water pool begins in the spring as Folsom Reservoir fills. Actual Folsom Reservoir cold water resource availability becomes significantly more defined through the assessment of reservoir water temperature profiles and more definite projections of inflows and storage. Technical modeling analysis begins in the spring for the projected Lower American River water temperature management plan. The significant variables and key assumptions in the analysis include:

- Starting reservoir temperature conditions
- Forecasted inflow and outflow quantities
- Assumed meteorological conditions
- Assumed inflow temperatures
- Assumed Urban Water Supply TCD operations

A series of shutter management scenarios are then incorporated into the model to gain a better understanding of the potential for meeting both summer steelhead and fall salmon temperature needs. Most annual strategies contain significant tradeoffs and risks for water temperature management for steelhead and fall–run salmon goals and needs due to the frequently limited cold water resource. The planning process continues throughout the summer. New temperature forecasts and operational strategies are updated as more information on actual operations and ambient conditions is gained. This process is shared with the American River Group (ARG).

Meeting both the summer steelhead and fall salmon temperature objectives without negatively impacting other CVP project purposes requires the final shutter pull be reserved for use in the fall to provide suitable fall-run Chinook salmon spawning temperatures. In most years, the volume of cold water is not sufficient to support strict compliance with the summer temperature target at the downstream end of the compliance reach (Watt Avenue Bridge) while at the same time reserving the final shutter pull for salmon, or in some cases, continue to meet steelhead objectives later in the summer. A strategy that is used under these conditions is to allow the annual compliance location water temperatures to warm towards the upper end of the annual water temperature design value before making a shutter pull. This management flexibility is essential to the annual management strategy to extend the effectiveness of cold water management through the summer and fall months.

The Urban Water Supply TCD has provided additional flexibility to conserve cold water for later use. Initial studies are being conducted evaluating the impact of warmer water deliveries to the water treatment plants receiving the water. As water supply temperatures increase into the upper-60°F range, treatment costs, the potential for taste and odor and disinfection byproducts, and customer complaints increase. It is expected that the TCD will be operated during the summer months and deliver water that is slightly warmer than that which could be used to meet downstream temperatures (60°F to 62°F), but not so warm as to cause significant treatment issues.

Water temperatures feeding the Nimbus Fish Hatchery were historically too high for hatchery operations during some dry or critical years. Temperatures in the Nimbus Hatchery are generally in the desirable range of 42°F to 55°F, except for the months of June, July, August, and September. When temperatures get above 60°F during these months, the hatchery must begin to treat the fish with chemicals to prevent disease. When temperatures reach the 60°F to 70°F range, treatment becomes difficult and conditions become increasingly dangerous for the fish. When temperatures climb into the 60°F to 70°F range, hatchery personnel may confer with Reclamation to determine a compromise operation of the temperature shutter at Folsom Dam for the release of cooler water.

Reclamation operates Nimbus to maintain the health of the hatchery fish while minimizing the loss of the cold water pool for fish spawning in the river during fall. This is done on a case-by-case basis and is different in various months and year types. Temperatures above 70°F in the hatchery usually mean the fish need to be moved to another hatchery. The real time implementation of CVPIA AFRP objective flows and meeting SWRCB D-1641 Delta standards with the limited water resources of the Lower American River requires a significant coordination effort to manage the cold water resources at Folsom Lake. Reclamation consults with the FWS, NMFS, and DFG through B2IT when these types of difficult decisions are needed. In addition, Reclamation communicates with the American River Group (ARG) on real time data and operational trade offs.

The Nimbus Fish Hatchery and the American River Trout Hatchery were constructed to mitigate the loss of riverine habitat caused by the construction of Nimbus and Folsom Dam. The hatcheries are located approximately one-quarter mile downstream from Nimbus Dam on the south side of the American River. To meet the mitigation requirement, annual production goals are approximately 4.2 million salmon smolts and 430,000 steelhead yearlings.

A fish diversion weir at the hatcheries blocks Chinook salmon from continuing upstream and guides them to the hatchery fish ladder entrance. The fish diversion weir consists of eight piers on 30-foot spacing, including two riverbank abutments. Fish rack support frames and walkways are installed each fall via an overhead cable system. A pipe rack is then put in place to support the pipe pickets (¾-inch steel rods spaced on 2½-inch centers). The pipe rack rests on a submerged steel I-beam support frame that extends between the piers and forms the upper support structure for a rock filled crib foundation. The rock foundation has deteriorated with age and is subject to annual scour which can leave holes in the foundation that allow fish to pass if left unattended.

Fish rack supports and pickets are installed around September 15, of each year and correspond with the beginning of the fall-run Chinook salmon spawning season. A release equal to or less than 1,500 cfs from Nimbus Dam is required for safety and to provide full access to the fish rack supports. It takes six people approximately three days to install the fish rack supports and pickets. In years after high winter flows have caused active scour of the rock foundation, a short period (less than eight hours) of lower flow (approximately 500 cfs) is needed to remove debris from the I-beam support frames, seat the pipe racks, and fill holes in the rock foundation. Compete installation can take up to seven days, but is generally completed in less time. The fish rack supports and pickets are usually removed at the end of fall-run Chinook salmon spawning season (mid-January) when flows are less than 2,000 cfs. If Nimbus Dam releases are expected to exceed 5,000 cfs during the operational period, the pipe pickets are removed until flows decrease.

Delta Division and West San Joaquin Division

CVP Facilities

The CVP’s Delta Division includes the Delta Cross Channel (DCC), the Contra Costa Canal and Pumping Plants, Contra Loma Dam, Martinez Dam, the Jones Pumping Plant (formerly Tracy Pumping Plant), the Tracy Fish Collection Facility (TFCF), and the Delta Mendota Canal (DMC). The DCC is a controlled diversion channel between the Sacramento River and Snodgrass Slough. The Contra Costa Water District (CCWD) diversion facilities use CVP water resources to serve district customers directly and to operate CCWD’s Los Vaqueros Project. The Jones Pumping Plant diverts water from the Delta to the head of the DMC. See map in Figure 2-8.

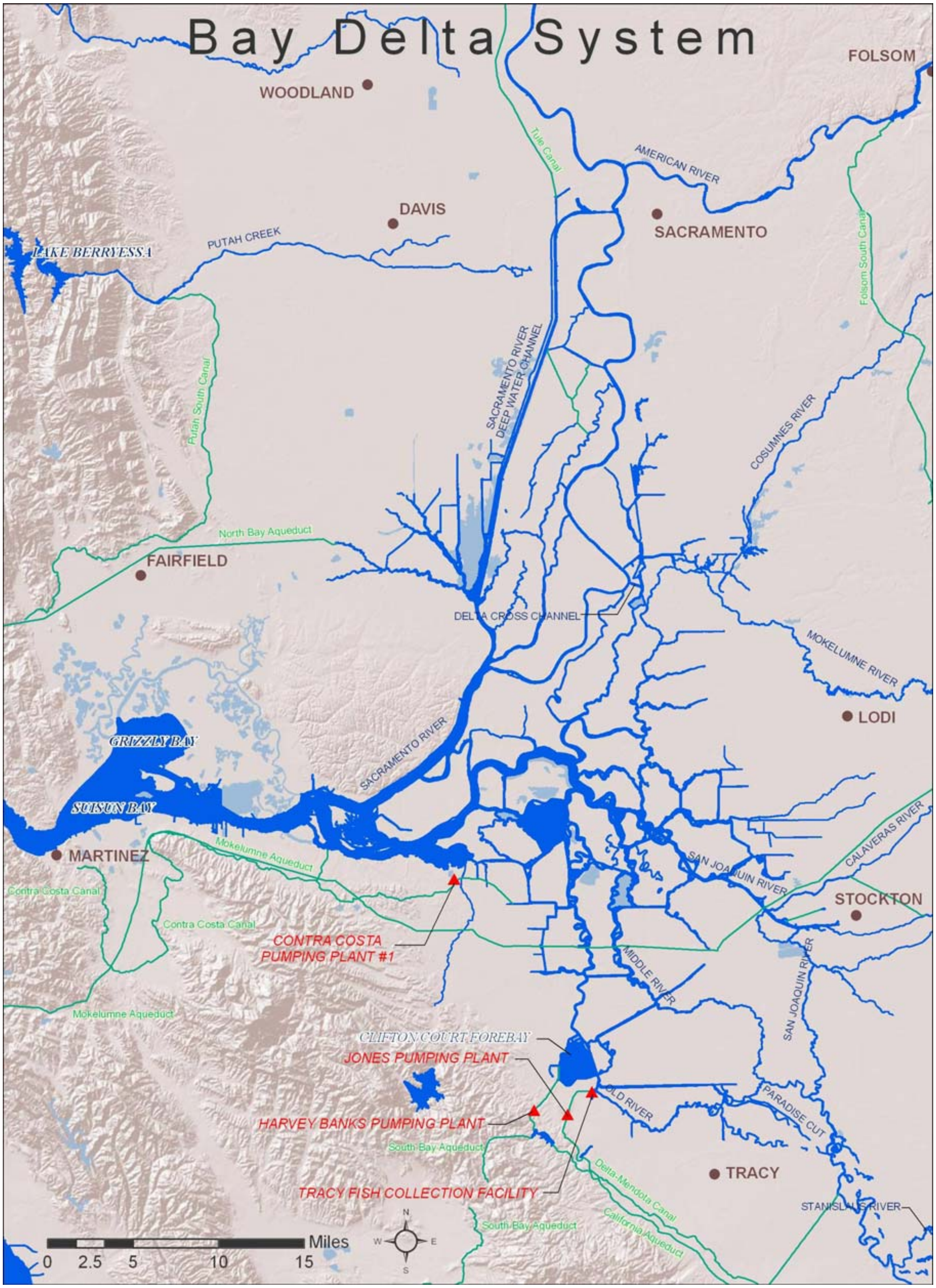

Figure 2-8. Bay Delta System.

Delta Cross Channel Operations

The DCC is a gated diversion channel in the Sacramento River near Walnut Grove and Snodgrass Slough. Flows into the DCC from the Sacramento River are controlled by two 60-foot by 30-foot radial gates. When the gates are open, water flows from the Sacramento River through the cross channel to channels of the lower Mokelumne and San Joaquin Rivers toward the interior Delta. The DCC operation improves water quality in the interior Delta by improving circulation patterns of good quality water from the Sacramento River towards Delta diversion facilities.

Reclamation operates the DCC in the open position to (1) improve the transfer of water from the Sacramento River to the export facilities at the Banks and Jones Pumping Plants, (2) improve water quality in the southern Delta, and (3) reduce salt water intrusion rates in the western Delta. During the late fall, winter, and spring, the gates are often periodically closed to protect out-migrating salmonids from entering the interior Delta. In addition, whenever flows in the Sacramento River at Sacramento reach 20,000 to 25,000 cfs (on a sustained basis) the gates are closed to reduce potential scouring and flooding that might occur in the channels on the downstream side of the gates.

Flow rates through the gates are determined by Sacramento River stage and are not affected by export rates in the south Delta. The DCC also serves as a link between the Mokelumne River and the Sacramento River for small craft, and is used extensively by recreational boaters and fishermen whenever it is open. Because alternative routes around the DCC are quite long, Reclamation tries to provide adequate notice of DCC closures so boaters may plan for the longer excursion.

SWRCB D-1641 DCC standards provide for closure of the DCC gates for fisheries protection at certain times of the year. From November through January, the DCC may be closed for up to 45 days for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days for fishery protection purposes during the May 21 through June 15 time period. Reclamation determines the timing and duration of the closures after discussion with FWS, DFG, and NMFS. These discussions will occur through WOMT as part of the weekly review of CVP/SWP operations.

WOMT typically relies on monitoring for fish presence and movement in the Sacramento River and Delta, the salvage of salmon at the Tracy and Skinner facilities, and hydrologic cues when considering the timing of DCC closures. However, the overriding factors are current water quality conditions in the interior and western Delta. From mid-June to November, Reclamation usually keeps the gates open on a continuous basis. The DCC is also usually opened for the busy recreational Memorial Day weekend, if this is possible from a fishery, water quality, and flow standpoint.

The Salmon Decision Process (see Appendix B) includes “Indicators of Sensitive Periods for Salmon” such as hydrologic changes, detection of spring-run salmon or spring-run salmon surrogates at monitoring sites or the salvage facilities, and turbidity increases at monitoring sites to trigger the Salmon Decision Process.

The Salmon Decision Process is used by the fishery agencies and project operators to facilitate the often complex coordination issues surrounding DCC gate operations and the purposes of fishery protection closures, Delta water quality, and/or export reductions. Inputs such as fish lifestage and size development, current hydrologic events, fish indicators (such as the Knight's Landing Catch Index and Sacramento Catch Index), and salvage at the export facilities, as well as current and projected Delta water quality conditions, are used to determine potential DCC closures and/or export reductions. The coordination process has worked well during the recent fall and winter DCC operations and is expected to be used in the present or modified form in the future.

Jones Pumping Plant

The CVP and SWP use the Sacramento River, San Joaquin River, and Delta channels to transport water to export pumping plants located in the south Delta. The CVP's Jones Pumping Plant, about five miles north of Tracy, consists of six available pumps. The Jones Pumping Plant is located at the end of an earth-lined intake channel about 2.5 miles in length. At the head of the intake channel, louver screens (that are part of the TFCF) intercept fish, which are then collected, held, and transported by tanker truck to release sites far away from the pumping plants.

Jones Pumping Plant has a permitted diversion capacity of 4,600 cfs with maximum pumping rates typically ranging from 4,500 to 4,300 cfs during the peak of the irrigation season and approximately 4,200 cfs during the winter non-irrigation season until construction and full operation of the proposed DMC/California Aquaduct Intertie, described on page 2-124. The winter-time constraints at the Jones Pumping Plant are the result of a DMC freeboard constriction near O'Neill Forebay, O'Neill Pumping Plant capacity, and the current water demand in the upper sections of the DMC.

Tracy Fish Collection Facility

The TFCF is located in the south-west portion of the Sacramento-San Joaquin Delta and uses behavioral barriers consisting of primary and secondary louvers as illustrated in Figure 2-9, to guide entrained fish into holding tanks before transport by truck to release sites within the Delta. The original design of the TFCF focused on smaller fish (<200 mm) that would have difficulty fighting the strong pumping plant induced flows since the intake is essentially open to the Delta and also impacted by tidal action.

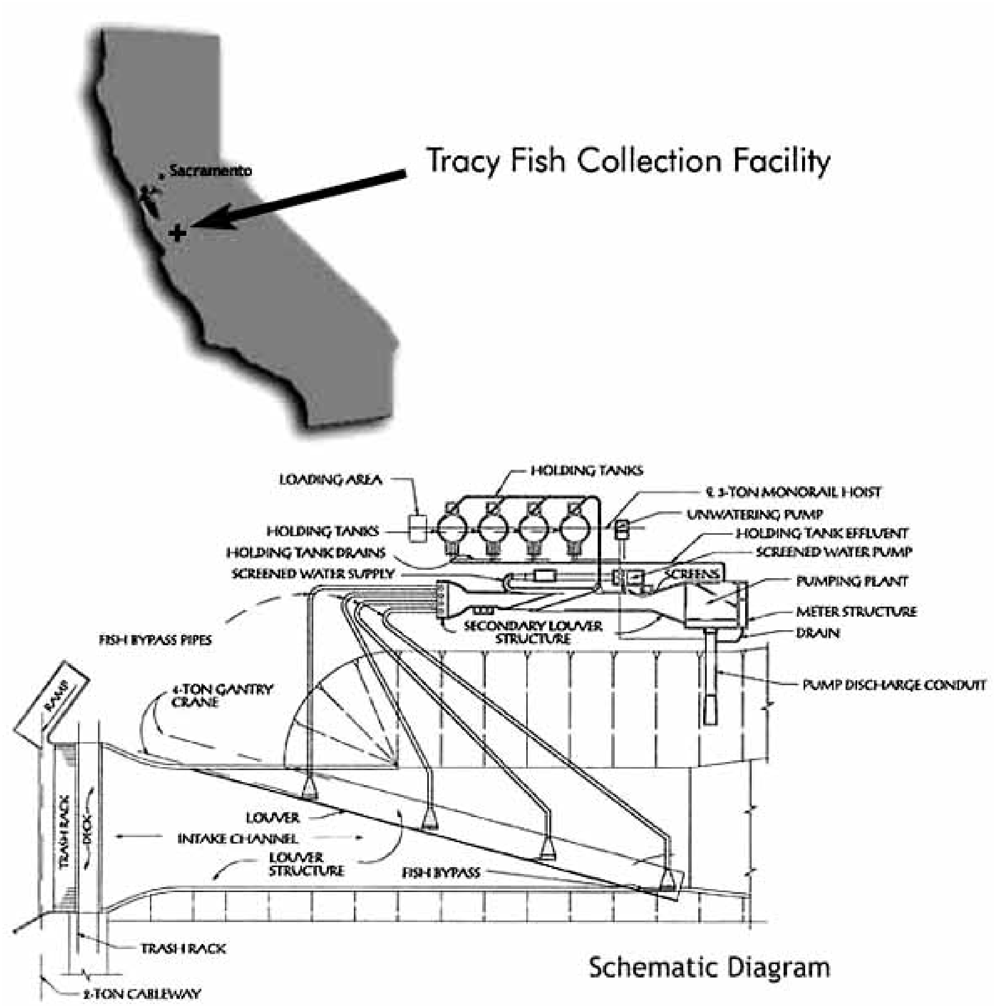

Figure 2-9 Tracy Fish Collection Facility Diagram

The primary louvers are located in the primary channel just downstream of the trashrack structure. The secondary louvers are located in the secondary channel just downstream of the traveling water screen. The louvers allow water to pass through onto the pumping plant but the openings between the slats are tight enough and angled against the flow of water such a way as to prevent most fish from passing between them and instead enter one of four bypass entrances along the louver arrays.

There are approximately 52 different species of fish entrained into the TFCF per year; however, the total numbers are significantly different for the various species salvaged. Also, it is difficult if not impossible to determine exactly how many safely make it all the way to the collection tanks awaiting transport back to the Delta. Hauling trucks used to transport salvaged fish to release sites inject oxygen and contain an eight parts per thousand salt solution to reduce stress. The CVP uses two release sites, one on the Sacramento River near Horseshoe Bend and the other on the San Joaquin River immediately upstream of the Antioch Bridge. During a facility inspection a few years ago, TFCF personnel noticed significant decay of the transition boxes and conduits between the primary and secondary louvers. The temporary rehabilitation of these transition boxes and conduits was performed during the fall and winter of 2002. Extensive rehabilitation of the transition boxes and conduits was completed during the San Joaquin pulse period of 2004.

When south Delta hydraulic conditions allow, and within the original design criteria for the TFCF, the louvers are operated with the D-1485 and federal ESA BO objectives of achieving water approach velocities: for striped bass of approximately 1 foot per second (ft/s) from May 15 through October 31, and for salmon of approximately 3 ft/s from November 1 through May 14. Channel velocity criteria are a function of bypass ratios through the facility. Due to changes in south Delta hydrology over the past fifty years, the present-day TFCF is able to meet these conditions approximately 55 percent of the time.

Fish passing through the facility will be sampled at intervals of no less than 20 minutes every 2 hours when listed fish are present, generally December through June. When fish are not present, sampling intervals will be 10 minutes every 2 hours. Fish observed during sampling intervals are identified by species, measured to fork length, examined for marks or tags, and placed in the collection facilities for transport by tanker truck to the release sites in the North Delta away from the pumps. In addition, TFCF personnel are presently required, per the court order, to monitor for the presence of spent female delta smelt in anticipation of expanding the salvage operations to include sub 20 mm larval delta smelt detection.

DFG is leading studies to look at fish survival during the Collection, Handling, Transportation and Release (CHTR) process examining delta smelt injury, stress, survival, and predation. Thus far they have presented initial findings at various interagency meetings (IEP, CVFFRT, and AFS) showing relatively high survival and low injury. Final reports are forthcoming and should be finished within the next year. DWR has concurrently been conducting focused studies examining the release phase of the salvage process including a study examining predation at the point of release and a study examining injury and survival of delta smelt and chinook salmon through the release pipe. Data analyses for these studies are ongoing and reports should be available in early 2009. Based on these studies, improvements to release operations and/or facilities studies are being implemented.

There does not appear to be any previously generated information on present day efficiencies other than some very limited Tracy Research work for salmon that needs to be redone. The last efficiency and survival studies were the original studies when they were designing and testing the louver concept back in the 1950s/1960s. DFG and USFWS (Jerry Morinaka and Gonzalo Castillo, PI's) have recently begun a 3 year study examining pre-screen loss and facility/louver efficiency for juvenile and adult delta smelt at the skinner fish facility. DWR has also conducted pre-screen loss and facility efficiency studies for steelhead with a final report due for publication in the early fall 2008.

Contra Costa Water District Diversion Facilities

Contra Costa Water District (CCWD) diverts water from the Delta for irrigation and M&I uses under CVP contract; under its own permit and license at Mallard Slough; and under its own Los Vaqueros water right permit at Old River near State Route 4. CCWD's system includes intake facilities at Mallard Slough, Rock Slough, and Old River near State Route 4; the Contra Costa Canal and shortcut pipeline; and the Los Vaqueros Reservoir. CCWD will be adding a fourth diversion point on Victoria Canal (the Alternative Intake Project, described below) to help meet its water quality goals. The Rock Slough intake facilities, the Contra Costa Canal, and the shortcut pipeline are owned by Reclamation, and operated and maintained by CCWD under contract with Reclamation. Mallard Slough Intake, Old River Intake and Los Vaqueros Reservoir are owned and operated by CCWD.

The Mallard Slough Intake is located at the southern end of a 3,000-foot-long channel running due south from Suisun Bay, near Mallard Slough (across from Chipps Island). The Mallard Slough Pump Station was refurbished in 2002, which included constructing a positive barrier fish screen at this intake. The Mallard Slough Intake can pump up to 39.3 cfs. CCWD's d permit issued by the SWRCB authorizes diversions of up to 26,780 acre-feet per year at Mallard Slough. However, this intake is rarely used due to the generally high salinity at this location. Pumping at the Mallard Slough Intake since 1993 has on average accounted for about 3% of CCWD's total diversions. When CCWD diverts water at the Mallard Slough Intake, CCWD reduces pumping of CVP water at its other intakes, primarily at the Rock Slough Intake.

The Rock Slough Intake is located about four miles southeast of Oakley, where water flows through a trash rack into the earth-lined portion of the Contra Costa Canal. This section of the canal is open to tidal influence and continues for four miles to Pumping Plant 1, which has capacity to pump up to 350 cfs into the concrete-lined portion of the canal. Prior to completion of the Los Vaqueros Project in 1997, this was CCWD's primary diversion point. Pumping Plant 1 is not screened; Reclamation, in collaboration with CCWD, is responsible for constructing a fish screen as authorized by CVPIA and required by the 1993 FWS BO for the Los Vaqueros Project. Reclamation has received an extension on fish screen construction until December 2008, and is preparing to request a further extension until 2013 because the requirements for screen design will change when CCWD completes the Contra Costa Canal Replacement Project, which will replace the earth-lined section of canal from Rock Slough to Pumping Plant #1 with a pipeline. When completed, the Canal Replacement project will eliminate tidal flows into the Canal intake section and should significantly reduce entrainment impacts and improve the feasibility of screening Rock Slough. Typically, CCWD diverts about 17% of its total supply through the Rock Slough intake.

Construction of the Old River Intake was completed in 1997 as a part of the Los Vaqueros Project. The Old River Intake is located on Old River near State Route 4. It has a positive-barrier fish screen and a pumping capacity of 250 cfs, and can pump water via pipeline either to the Contra Costa Canal or to Los Vaqueros Reservoir. Pumping to storage in Los Vaqueros Reservoir is limited to 200 cfs by the terms of the Los Vaqueros Project biological opinions and by D-1629, the State Board water right decision for the Project. Typically, CCWD diverts about 80% of its total supply through the Old River Intake.

As described above, the first four miles of the Contra Costa Canal is earth-lined; after Pumping Plant 1, the Contra Costa Canal is concrete-lined and continues for 44 miles to its termination point in Martinez Reservoir. Pumping Plants 1 - 4 lift the water to an elevation of 127 feet. A blending facility just downstream of Pumping Plant 4 allows water from the Los Vaqueros Project pipeline and water from the Contra Costa Canal to mix to maintain CCWD's delivered water quality goals for salinity. Canal capacity is 350 cfs at this blending facility and decreases to 22 cfs at the terminus at Martinez Reservoir, which provides flow regulation. The Contra Loma Reservoir is connected to the Canal and provides flow regulation and emergency storage. Two short canals, Clayton Canal and Ygnacio Canal, are integrated into the distribution system. The Clayton Canal is no longer in service.

Los Vaqueros Reservoir is an off-stream reservoir with a capacity of 100 thousand acre-feet (taf). Construction was completed and filling started in 1998 as part of the Los Vaqueros Project to improve delivered water quality and emergency storage reliability for CCWD's customers. Releases from Los Vaqueros Reservoir are conveyed to the Contra Costa Canal via a pipeline.

CCWD diverts approximately 127 taf per year in total, of which approximately 110 taf is CVP contract supply. In winter and spring months when the Delta is relatively fresh (generally January through July), demand is supplied by direct diversion from the Delta. In addition, when salinity is low enough, Los Vaqueros Reservoir is filled at a rate of up to 200 cfs from the Old River Intake. However, the biological opinions for the Los Vaqueros Project and the Alternative Intake Project, CCWD's memorandum of understanding with the DFG, and SWRCB D-1629 of the State Water Resources Control Board include fisheries protection measures consisting of a 75-day period during which CCWD does not fill Los Vaqueros Reservoir and a concurrent 30-day period during which CCWD halts all diversions from the Delta, provided that Los Vaqueros Reservoir storage is above emergency levels. The default dates for the no-fill and no-diversion periods are March 15 through May 31 and April 1 through April 30, respectively; FWS, NMFS and DFG can change these dates to best protect the subject species. During the no-diversion period, CCWD customer demand is met by releases from Los Vaqueros Reservoir.

In the late summer and fall months, CCWD releases water from Los Vaqueros Reservoir to blend with higher-salinity direct diversions from the Delta to meet CCWD water quality goals.

Water Demands—Delta Mendota Canal (DMC) and San Luis Unit

Water demands for the DMC and San Luis Unit are primarily composed of three separate types: CVP water service contractors, exchange contractors, and wildlife refuge contractors. A significantly different relationship exists between Reclamation and each of these three groups. Exchange contractors "exchanged" their senior rights to water in the San Joaquin River for a CVP water supply from the Delta. Reclamation thus guaranteed the exchange contractors a firm water supply of 840,000 af per annum, with a maximum reduction under the Shasta critical year criteria to an annual water supply of 650,000 af.

Conversely, water service contractors did not have water rights. Agricultural water service contractors also receive their supply from the Delta, but their supplies are subject to the availability of CVP water supplies that can be developed and reductions in contractual supply can exceed 25 percent. Wildlife refuge contractors provide water supplies to specific managed lands for wildlife purposes and the CVP contract water supply can be reduced under critically dry conditions up to 25 percent.

To achieve the best operation of the CVP, it is necessary to combine the contractual demands of these three types of contractors to achieve an overall pattern of requests for water. In most years sufficient supplies are not available to meet all water demands because of reductions in CVP water supplies which are due to restricted Delta pumping capability. In some dry or critically dry years, water deliveries are limited because there is insufficient storage in northern CVP reservoirs to meet all in-stream fishery objectives including water temperatures, and to make additional water deliveries via the Jones Pumping Plant. The scheduling of water demands, together with the scheduling of the releases of water supplies from the northern CVP to meet those demands, is a CVP operational objective that is intertwined with the Trinity, Sacramento, and American River operations.

More information on San Luis Operations is found under Coordinated Operations on page 2-115.

East Side Division

New Melones Operations

The Stanislaus River originates in the western slopes of the Sierra Nevada and drains a watershed of approximately 900 square miles. The average unimpaired runoff in the basin is approximately 1.2 maf per year; the median historical unimpaired runoff is 1.1 maf per year. Snowmelt contributes the largest portion of the flows in the Stanislaus River, with the highest runoff occurring in the months of April, May, and June. Agricultural water supply development in the Stanislaus River watershed began in the 1850s and has significantly altered the basin's hydrologic conditions. See map in Figure 2-10.

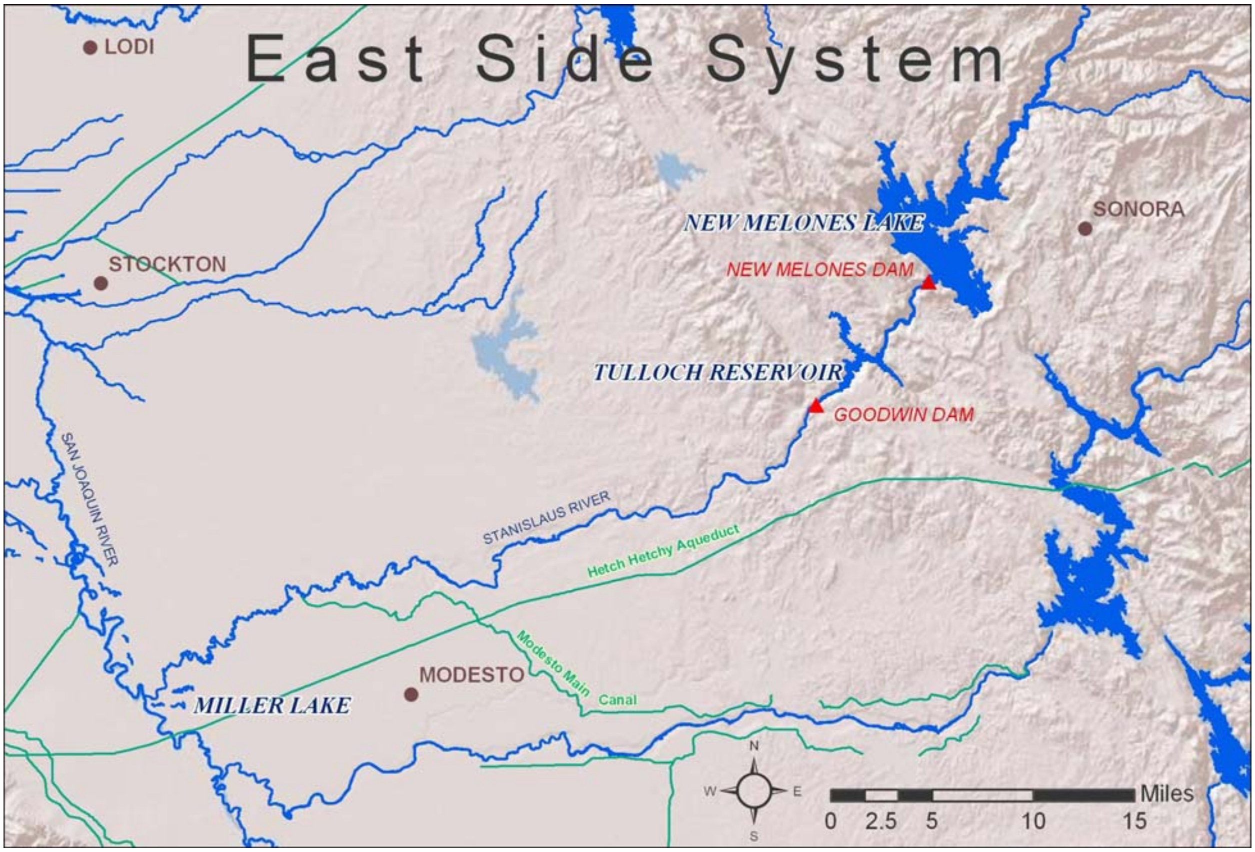

Figure 2-10 East Side System

Currently, the flow in the lower Stanislaus River is primarily controlled by New Melones Reservoir, which has a storage capacity of about 2.4 maf. The reservoir was completed by the Corps in 1978 and approved for filling in 1983. New Melones Reservoir is located approximately 60 miles upstream from the confluence of the Stanislaus River and the San Joaquin River and is operated by Reclamation. Congressional authorization for New Melones integrates New Melones Reservoir as a financial component of the CVP, but it is authorized to provide water supply benefits within the defined Stanislaus Basin per the 1980 ROD before additional water supplies can be used out of the defined Stanislaus Basin.

New Melones Reservoir is operated primarily for purposes of water supply, flood control, power generation, fishery enhancement, and water quality improvement in the lower San Joaquin River. The reservoir and river also provide recreation benefits. Flood control operations are conducted in conformance with the Corps's operational guidelines.

Another major water storage project in the Stanislaus River watershed is the Tri-Dam Project, a power generation project that consists of Donnells and Beardsley Dams, located upstream of New Melones Reservoir on the middle fork Stanislaus River, and Tulloch Dam and Powerplant, located approximately 6 miles downstream of New Melones Dam on the main stem Stanislaus River. New Spicer Reservoir on the north fork of the Stanislaus River has a storage capacity of 189,000 af and is used for power generation.

Releases from Donnells and Beardsley Dams affect inflows to New Melones Reservoir. Under contractual agreements between Reclamation, the Oakdale Irrigation District (OID), and South San Joaquin Irrigation District (SSJID), Tulloch Reservoir provides afterbay storage to re-regulate power releases from New Melones Powerplant. The main water diversion point on the Stanislaus River is Goodwin Dam, located approximately 1.9 miles downstream of Tulloch Dam.

Goodwin Dam, constructed by OID and SSJID in 1912, creates a re-regulating reservoir for releases from Tulloch Powerplant and provides for diversions to canals north and south of the Stanislaus River for delivery to OID and SSJID. Water impounded behind Goodwin Dam may be pumped into the Goodwin Tunnel for deliveries to the Central San Joaquin Water Conservation District and the Stockton East Water District.

Twenty ungaged tributaries contribute flow to the lower portion of the Stanislaus River, below Goodwin Dam. These streams provide intermittent flows, occurring primarily during the months of November through April. Agricultural return flows, as well as operational spills from irrigation canals receiving water from both the Stanislaus and Tuolumne Rivers, enter the lower portion of the Stanislaus River. In addition, a portion of the flow in the lower reach of the Stanislaus River originates from groundwater accretions.

Flood Control

The New Melones Reservoir flood control operation is coordinated with the operation of Tulloch Reservoir. The flood control objective is to maintain flood flows at the Orange Blossom Bridge at less than 8,000 cfs. When possible, however, releases from Tulloch Dam are maintained at levels that would not result in downstream flows in excess of 1,250 cfs to 1,500 cfs because of seepage problems in agricultural lands adjoining the river associated with flows above this level. Up to 450,000 af of the 2.4 maf storage volume in New Melones Reservoir is dedicated for flood control and 10,000 af of Tulloch Reservoir storage is set aside for flood control. Based upon the flood control diagrams prepared by the Corps, part or all of the dedicated flood control storage may be used for conservation storage, depending on the time of year and the current flood hazard.

Requirements for New Melones Operations

The operating criteria for New Melones Reservoir are affected by (1) water rights, (2) in-stream fish and wildlife flow requirements (3) SWRCB D-1641 Vernalis water quality requirements, (4) dissolved oxygen (DO) requirements on the Stanislaus River, (5) SWRCB D-1641 Vernalis flow requirements, (6) CVP contracts, and (7) flood control considerations. Water released from New Melones Dam and Powerplant is re-regulated at Tulloch Reservoir and is either diverted at Goodwin Dam or released from Goodwin Dam to the lower Stanislaus River.

Flows in the lower Stanislaus River serve multiple purposes concurrently. The purposes include water supply for riparian water right holders, fishery management objectives, and DO requirements per SWRCB D-1422. In addition, water from the Stanislaus River enters the San Joaquin River where it contributes to flow and helps improve water quality conditions at Vernalis. D-1422, issued in 1973, provided the primary operational criteria for New Melones Reservoir and permitted Reclamation to appropriate water from the Stanislaus River for irrigation and M&I uses. D-1422 requires the operation of New Melones Reservoir include releases for existing water rights, fish and wildlife enhancement, and the maintenance of water quality conditions on the Stanislaus and San Joaquin Rivers.

Water Rights Obligations

When Reclamation began operations of New Melones Reservoir in 1980, the obligations for releases (to meet downstream water rights) were defined in a 1972 Agreement and Stipulation among Reclamation, OID, and SSJID. The 1972 Agreement and Stipulation required Reclamation release annual inflows to New Melones Reservoir of up to 654,000 af per year for diversion at Goodwin Dam by OID and SSJID, in recognition of their prior water rights. Actual historical diversions prior to 1972 varied considerably, depending upon hydrologic conditions. In addition to releases for diversion by OID and SSJID, water is released from New Melones Reservoir to satisfy riparian water rights totaling approximately 48,000 af annually downstream of Goodwin Dam.

In 1988, following a year of low inflow to New Melones Reservoir, the Agreement and Stipulation among Reclamation, OID, and SSJID was superseded by an agreement that provided for conservation storage by OID and SSJID. The new agreement required Reclamation to release New Melones Reservoir inflows of up to 600,000 af each year for diversion at Goodwin Dam by OID and SSJID.

In years when annual inflows to New Melones Reservoir are less than 600,000 af, Reclamation provides all inflows plus one-third the difference between the inflow for that year and 600,000 af per year. The 1988 Agreement and Stipulation created a conservation account in which the difference between the entitled quantity and the actual quantity diverted by OID and SSJID in a year may be stored in New Melones Reservoir for use in subsequent years. This conservation account has a maximum storage limit of 200,000 af, and withdrawals are constrained by criteria in the agreement.

In-stream Flow Requirements

Under D-1422, Reclamation is required to release 98,000 af of water per year, with a reduction to 69,000 af in critical years, from New Melones Reservoir to the Stanislaus River on a distribution pattern to be specified each year by DFG for fish and wildlife purposes. In 1987, an agreement between Reclamation and DFG provided for increased releases from New Melones to enhance fishery resources for an interim period, during which habitat requirements were to be better defined and a study of Chinook salmon fisheries on the Stanislaus River would be completed.

During the study period, releases for in-stream flows would range from 98,300 to 302,100 af per year. The exact quantity to be released each year was to be determined based on a formulation involving storage, projected inflows, projected water supply, water quality demands, projected CVP contractor demands, and target carryover storage. Because of dry hydrologic conditions during the 1987 to 1992 drought period, the ability to provide increased releases was limited. FWS published the results of a 1993 study, which recommended a minimum in-stream flow on the Stanislaus River of 155,700 af per year for spawning and rearing (Aceituno 1993).

Dissolved Oxygen Requirements

SWRCB D-1422 requires that water be released from New Melones Reservoir to maintain DO standards in the Stanislaus River. The 1995 revision to the WQCP established a minimum DO concentration of 7 milligrams per liter (mg/L), as measured on the Stanislaus River near Ripon. Although not part of the proposed action, Reclamation is evaluating studies to support moving the DO compliance point upstream to Orange Blossom Bridge. The location would better correspond to steelhead rearing in the spring and summer months. If movement of the DO compliance point appears adequately protective, Reclamation will petition the SWRCB to modify the standard.

Vernalis Water Quality Requirement

SWRCB D-1422 also specifies that New Melones Reservoir must operate to maintain average monthly level total dissolved solids (TDS), commonly measured as a conversion from electrical conductivity, in the San Joaquin River at Vernalis as it enters the Delta. SWRCB D-1422 specifies an average monthly concentration of 500 parts per million (ppm) TDS for all months. Historically, releases were made from New Melones Reservoir for this standard, but due to shortages in water supply and high concentrations of TDS upstream of the confluence of the Stanislaus River, the D-1422 standard was not always met during the 1987-1992 drought. Reclamation has always met the D-1641 standard since 1995.

In the past, when sufficient supplies were not available to meet the water quality standards for the entire year, the emphasis for use of the available water was during the irrigation season, generally from April through September. SWRCB D-1641 modified the water quality objectives at Vernalis to include the irrigation and non-irrigation season objectives contained in the 1995 Bay-Delta WQCP. The revised standard is an average monthly electric conductivity 0.7 milliSiemens per centimeter (mS/cm) (approximately 455 ppm TDS) during the months of April through August, and 1.0 mS/cm (approximately 650 ppm TDS) during the months of September through March.

Bay-Delta Vernalis Flow Requirements

SWRCB D-1641 sets flow requirements on the San Joaquin River at Vernalis from February to June. These flows are commonly known as San Joaquin River base flows.

Table 2-8 San Joaquin base flows-Vernalis

Water Year Class	February-June Flow (cfs)*
Critical	710-1140
Dry	1420-2280
Below Normal	1420-2280
Above Normal	2130-3420
Wet	2130-3420
*the higher flow required when X2 is required to be at or west of Chipps Island	

Since D-1641 has been in place, the San Joaquin base flow requirements have at times, been an additional demand on the New Melones water supply beyond that provided for in the Interim Plan of Operation (IPO).

CVP Contracts

Reclamation entered into water service contracts for the delivery of water from New Melones Reservoir, based on a 1980 hydrologic evaluation of the long-term availability of water in the Stanislaus River Basin. Based on this study, Reclamation entered into a long-term water service contract for up to 49,000 af per year of water annually (based on a firm water supply), and two long-term water service contracts totaling 106,000 af per year (based on an interim water supply). Water deliveries under these contracts were not immediately available prior to 1992 for two reasons: 1) new diversion facilities were required to be constructed and prior to 1992 were not yet fully operational; and 2) water supplies were severely limited during the 1987 to 1992 drought.

New Melones Operations

Since 1997, the New Melones IPO has guided CVP operations on the Stanislaus River. The IPO was developed as a joint effort between Reclamation and FWS, in conjunction with the Stanislaus River Basin Stakeholders (SRBS). The process of developing the plan began in 1995 with a goal to develop a long-term management plan with clear operating criteria, given a fundamental recognition by all parties that New Melones Reservoir water supplies are over-committed on a long-term basis, and consequently, unable to meet all the potential beneficial uses designated as purposes.

In 1996, the focus shifted to the development of an interim operations plan for 1997 and 1998. At an SRBS meeting on January 29, 1997, a final interim plan of operation was agreed to in concept. The IPO was transmitted to the SRBS on May 1, 1997. Although meant to be a short-term plan, it continued to be the guiding operations criteria in effect for the annual planning to meet beneficial uses from New Melones storage.

In summary, the IPO defines categories of water supply based on storage and projected inflow. It then allocates annual water quantities for in-stream fishery enhancement (1987 DFG Agreement and CVPIA Section 3406(b)(2) management), SWRCB D-1641 San Joaquin River water quality requirements (Water Quality), SWRCB D-1641 Vernalis flow requirements (Bay-Delta), and use by CVP contractors.

Table 2-9 Inflow characterization for the New Melones IPO

Annual water supply category	March-September forecasted inflow plus end of February storage (thousand af)
Low	0 – 1400
Medium-low	1400 – 2000
Medium	2000 – 2500
Medium-high	2500 – 3000
High	3000 – 6000

Table 2-10 New Melones IPO flow objectives (in thousand af)

Storage plus inflow		Fishery		Vernalis water quality		Bay-Delta		CVP contractors	
From	To	From	To	From	To	From	To	From	To
1400	2000	98	125	70	80	0	0	0	0
2000	2500	125	345	80	175	0	0	0	59
2500	3000	345	467	175	250	75	75	90	90
3000	6000	467	467	250	250	75	75	90	90

It should be noted that when the water supply condition is determined to be in the “Low” IPO designation, the IPO proposes no operations guidance. In this case, Reclamation would meet with the SRBS group to coordinate a practical strategy to guide annual New Melones Reservoir operations under this very limited water supply condition.

In addition, the IPO is limited in its ability to fully provide for the D-1641 Vernalis salinity and base flow objectives using Stanislaus River flows in all year types. If the Vernalis salinity standard cannot be met using the IPO designated Goodwin release pattern, then an additional volume of water is dedicated to meet the salinity standard. This permit obligation is met before an allocation is made to CVPIA (b)(2) uses or CVP Eastside contracts.

In water years 2002, 2003 and 2004, Reclamation deviated from the IPO to provide additional releases for Vernalis salinity and Vernalis base flow standards and additional deliveries to CVP contractors. Several consecutive years of dry hydrology in the San Joaquin River Basin have demonstrated the limited ability of New Melones to fully satisfy the demands placed on its yield. Despite the need to consider annual deviations, the IPO remains the initial guidance for New Melones Reservoir operations.

CVPIA Section 3406 (b)(2) releases from New Melones Reservoir consist of the portion of the fishery flow management volume utilized that is greater than the 1987 DFG Agreement and the volume used in meeting the Vernalis water quality requirements and/or Ripon dissolved oxygen requirements.

New Melones Reservoir – Future Operations

To better understand improved agricultural practices in the San Joaquin valley, Reclamation, as well as other stakeholders, began to gather and analyze new data about basin hydrology and salinity water quality characteristics. To provide a basis to develop a long-term operating plan, Reclamation sponsored updates to the San Joaquin River Basin component of CalSim-II to better represent and model how river flows and water quality in the San Joaquin River are likely to affect operations at New Melones Reservoir.

This new information and the resulting CalSim-II model improvements were peer reviewed in 2004 and additional refinements were made to the model based on that review. The resulting model is considered by Reclamation to be the best representation of the significant hydrologic and water quality dynamics that currently affect New Melones operations.

The relationships developed for the current model are significantly different than the assumptions used to develop the 1997 IPO. Given that the 1997 IPO was only meant to be a temporary management tool and that water quality conditions are changing in the basin, the fundamental operating assumptions of the 1997 IPO are not entirely consistent with the improved CalSim-II model.

As an important first step in evaluating the effects of a permanent operating plan for New Melones, Reclamation concludes that the following general assumptions best represents future New Melones operations for the purpose of this consultation. These operational parameters recognize existing priorities in beneficial uses, and the 1928 to 1934 drought is used as the basis to evaluate risks associated with successive dry years. The current analysis of future New Melones operations is based on two sets of project beneficial uses: a primary set of uses tied to pre-existing water rights and long-standing permit terms, and a secondary set of uses that came into effect after the primary set.

The operational parameters for allocation to Eastside Division water service contracts and CVPIA (b)(2) are based on available yield over the 1928-34 drought period. The available project quantity is allocated between water service contracts and CVPIA (b)(2) use.

Table 2-11 Fundamental considerations used to define the New Melones Reservoir operations parameters.

CVP Beneficial Uses (Pior to 1992). The pre-1992 long-term beneficial uses for Reclamation's water supply/water rights at New Melones Reservoir are as follows:

- Existing OID/SSJID Settlement Contract
- D-1641 Vernalis Salinity Objective
- Stanislaus River Dissolved Oxygen
- 1987 DFG Fishery Agreement

CVP Beneficial Uses (After 1992). The beneficial uses for Reclamation's water supply/water rights at New Melones Reservoir established after 1992 are as follows:

- D-1641 Vernalis Feb-June Base Flow objective
- CVPIA (b)(2) water to increase Goodwin Dam releases for AFRP instream flow objectives
- CVP Eastside Division water services contracts

Basic Allocation Bands. Similar to the 1997 IPO, the representation of future New Melones operations defines categories of water supply based on projected storage and inflows.

1) High Allocation Years (Projected New Melones Melones Carryover Storage greater than 1.7 MAF End of September)

- DFG allocation is 302 taf
- Vernalis flow objectives are met
- CVPIA (b)(2) water allocation is 155 taf
- CVP Eastside contract allocation is 155 taf
- Vernalis Salinity and Stanislaus River DO objectives are met

2) Mid-Allocation Years

- DFG allocation is 98.3 taf
- Vernalis flow objectives are met
- CVPIA B2 water allocation to meet instream fishery needs is to be determined in coordination with USFWS, DFG and NOAA fisheries in a collaborative planning process
- Vernalis Salinity and Stanislaus River DO objectives are met
- CVP Eastside contract allocation is to be determined after all the instream needs are met

3) "Conference Year" conditions - New Melones Index is less than 1.0 MAF.

- As with the IPO, if the projected end of September New Melones Index (i.e. projected inflow plus storage) is less than 1.0 MAF, Reclamation would meet with USFWS stakeholders, DFG, and NOAA Fisheries to coordinate a practical strategy to guide New Melones Reservoir operations to meet the most basic needs associated with

Stanislaus River instream flows, DO, and Vernalis salinity. Allocation for CVPIA (b)(2) flows would be determined in coordination with USFWS, DFG and NOAA Fisheries.

San Joaquin River Agreement/Vernalis Adaptive Management Plan (VAMP)

Adopted by the SWRCB in D-1641, the San Joaquin River Agreement (SJRA) includes a 12-year program providing for flows and exports in the lower San Joaquin River during a 31-day pulse flow period during April and May. It also provides for the collection of experimental data during that time to further the understanding of the effects of flows, exports, and the barrier at the head of Old River on salmon survival. This experimental program is commonly referred to as the VAMP (Vernalis Adaptive Management Plan). The SWRCB indicates that VAMP experimental data will be used to create permanent objectives for the pulse flow period. Reclamation and DWR intend to continue a VAMP-like action for the foreseeable future or until the SWRCB adopts new permanent objectives that replace the current program. It is anticipated that new SWRCB objectives will be as protective as the current program and that such protections will remain in place through 2030.

Continuation of the VAMP operations for a period of time after the expiration of SJRA may be considered reasonably foreseeable because it could be accomplished using well established capabilities and authorities already available to Reclamation and DWR. Specifically, flow increases to achieve VAMP targets could be provided using CVPIA section 3406 (b)(1), (b)(2), and (b)(3). Export reductions would be provided by Reclamation using CVPIA section 3406 (b)(1) or (b)(2), and by DWR using the substitution of the water supply acquired from the Yuba Accord flows. The combination of those operations elements would enable Reclamation and DWR to meet VAMP objectives in most years. Chapter 9 contains an analysis of the capability of DWR to provide for export reduction during the VAMP pulse flow period, using the 48,000 acre feet of substitute supply assumed to be available from the Yuba Accord.

Within the SJRA, the 1997 IPO has been assumed as the baseline operation for New Melones Reservoir, which forms part of the existing flow condition. The existing flow condition is used to compute the supplemental flows which will be provided on the San Joaquin River to meet the target flows for the 31-day pulse during April and May. These supplemental flows that will be provided from other sources in the San Joaquin River Basin under the control of the parties to the SJRA.

The parties to the SJRA include several agencies that contribute flow to the San Joaquin, divert from or store water on the tributaries to the San Joaquin, or have an element of control over the flows in the lower San Joaquin River. These include Reclamation; OID; SSJID; Modesto ID; Turlock ID; Merced ID; and the San Joaquin River Exchange Contractors. The VAMP is based on coordination among these participating agencies in carrying out their operations to meet a steady target flow objective at Vernalis.

The target flow at Vernalis for the spring pulse flow period is determined each year according to the specifications contained in the SJRA. The target flow is determined prior to the spring pulse flows as an increase above the existing flows, and so “adapts” to the prevailing hydrologic conditions. Possible target flows specified in the agreement are (1) 2000 cfs, (2) 3200 cfs, (3) 4450 cfs, (4) 5700 cfs, and (5) 7000 cfs.

The Hydrology Group develops forecasts of flow at Vernalis, determines the appropriate target flow, devises an operations plan including flow schedules for each contributing agency, coordinates implementation of the VAMP flows, monitors conditions that may affect the objective of meeting the target flow, updates and adjusts the planned flow contributions as needed, and accounts for the flow contributions. The Hydrology Group includes designees with technical expertise from each agency that contributes water to the VAMP. During VAMP, the Hydrology group communicates via regular conference calls, shares current information and forecasts via e-mail and an internet website. The Hydrology group has two lead coordinators, one from Reclamation’s CVO and one designated by the SJRG. Subsequent to the end of the VAMP, a group similar to the Hydrology Group, with the same or similar role, will be maintained as part of the ongoing coordination of operations in the San Joaquin River basin.

CVP-SWP operations forecasts include Vernalis flows that meet the appropriate pulse flow targets for the predicted hydrologic conditions. The flows in the San Joaquin River upstream of the Stanislaus River are forecasted for the assumed hydrologic conditions. The upstream of the Stanislaus River flows are then adjusted so when combined with the forecasted Stanislaus River flow based on the 1997 IPO, the combined flow would provide the appropriate Vernalis flows consistent with the pulse flow target identified in the SJRA. An analysis of how the flows are produced upstream of the Stanislaus River is included in the SJRA Environmental Impact Statement (EIS)/Environmental Impact Report (EIR). For purposes of CVP-SWP operations forecasts, the VAMP target flows are simply assumed to exist at the confluence of the Stanislaus and San Joaquin Rivers. The assessment of the effects of CVP-SWP operations in the Delta begins downstream of that point.

The VAMP program has two distinct components, a flow objective and an export restriction. The flow objectives were designed to provide similar protection to those defined in the WQCP. Fishery releases on the Stanislaus above that called for in the 1987 DFG Agreement are typically considered WQCP (b)(2) releases. The export reduction involves a combined State and Federal pumping limitation on the Delta pumps. The combined export targets for the 31 days of VAMP are specified in the SJRA: 1500 cfs (when target flows are 2000, 3200, 4450, or 7000 cfs), and 2250 cfs (when target flow is 5700 cfs, or 3000 cfs [alternate export target when flow target is 7000 cfs]). Pumping reductions which cannot be recovered by adjustments in CVP operations are considered a WQCP (b)(2) expense. Reductions of SWP pumping are limited to the amount that can be recovered through operations adjustments and the export of up to 48 taf of transferred water made available from the Yuba Accord.

Water Temperatures

Water temperatures in the lower Stanislaus River are affected by many factors and operational tradeoffs. These include available cold water resources in New Melones reservoir, Goodwin release rates for fishery flow management and water quality objectives, as well as residence time in Tulloch Reservoir, as affected by local irrigation demand.

Reclamation intends to plan and manage flows to meet a 65 degrees F water temperature objective at Orange Blossom Bridge for steelhead incubation and rearing during the late spring and summer. However, during critically dry years and low reservoir storages this objective cannot be met. FWS, in coordination with NMFS and DFG, identifies the schedule for Reclamation to provide fall pulse attraction flows for salmon. The pulse flows are a combination of water purchased under the San Joaquin River Agreement and CVPIA (b)(2) and (3) water. This movement of water also helps to transport cold water from New Melones Reservoir into Tulloch Reservoir before the spawning season begins.

San Felipe Division

Construction of the San Felipe Division of the CVP was authorized in 1967 (Figure 2-11). The San Felipe Division provides a supplemental water supply (for irrigation, M&I uses) in the Santa Clara Valley in Santa Clara County, and the north portion of San Benito County.

The San Felipe Division delivers both irrigation and M&I water supplies. Water is delivered within the service areas not only by direct diversion from distribution systems, but also through in-stream and offstream groundwater recharge operations being carried out by local interests. A primary purpose of the San Felipe Division in Santa Clara County is to provide supplemental water to help prevent land surface subsidence in the Santa Clara Valley. The majority of the water supplied to Santa Clara County is used for M&I purposes, either pumped from the groundwater basin or delivered from treatment plants. In San Benito County, a distribution system was constructed to provide supplemental water to about 19,700 arable acres.

The facilities required to serve Santa Clara and San Benito Counties include 54 miles of tunnels and conduits, two large pumping plants, and one reservoir. Water is conveyed from the Delta of the San Joaquin and Sacramento Rivers through the DMC. It is then pumped into the San Luis Reservoir and diverted through the 1.8-mile long of Pacheco Tunnel inlet to the Pacheco Pumping Plant. Twelve 2,000-horse-power pumps lift a maximum of 490 cfs a height varying from 85 feet to 300 feet to the 5.3-mile-long Pacheco Tunnel. The water then flows through the tunnel and without additional pumping, through 29 miles of concrete, high-pressure pipeline, varying in diameter from 10 feet to 8 feet, and the mile-long Santa Clara Tunnel. In Santa Clara County, the pipeline terminates at the Coyote Pumping Plant, which is capable of pumping water to into Anderson Reservoir or Calero Reservoir for further distribution at treatment plants or groundwater recharge.

Santa Clara Valley Water District is the non-Federal operating entity for all the San Felipe Division facilities except for the Hollister Conduit and San Justo Reservoir. The San Benito County Water District operates San Justo Reservoir and the Hollister Conduit.

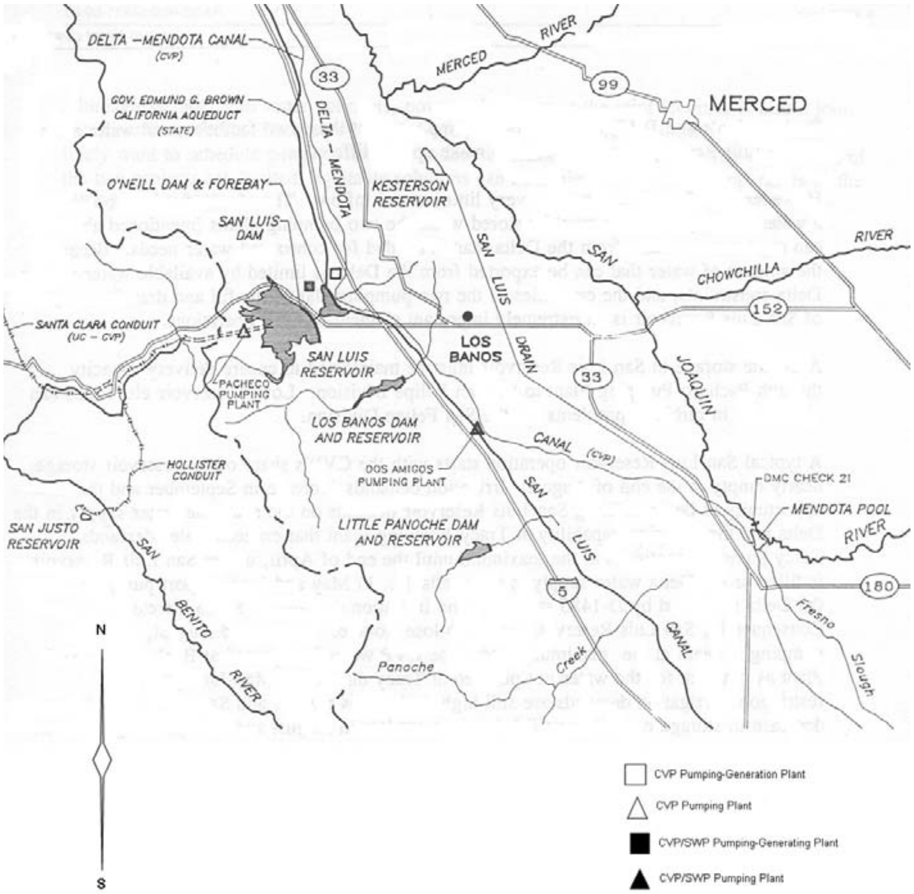

Figure 2-11 West San Joaquin Division and San Felipe Division

The Hollister Conduit branches off the Pacheco Conduit 8 miles from the outlet of the Pacheco Tunnel. This 19.1-mile-long high-pressure pipeline, with a maximum capacity of 83 cfs, terminates at the San Justo Reservoir.

The 9,906 af capacity San Justo Reservoir is located about three miles southwest of the City of Hollister. The San Justo Dam is an earthfill structure 141 feet high with a crest length of 722 feet. This project includes a dike structure 66 feet high with a crest length of 918 feet. This reservoir regulates San Benito County's import water supplies, allows pressure deliveries to some of the agricultural lands in the service area, and provides storage for peaking of agricultural water.

The San Benito County Water District operates San Justo Reservoir and the Hollister Conduit.

Friant Division

This division operates separately from the rest of the CVP and is not integrated into the CVP OCAP. This description of Friant operations is provided for informational purposes. Friant Dam is located on the San Joaquin River, 25 miles northeast of Fresno where the San Joaquin River exits the Sierra foothills and enters the valley. The drainage basin is 1,676 square miles with an average annual runoff of 1,774,000 af. Completed in 1942, the dam is a concrete gravity structure, 319-feet high, with a crest length of 3,488 feet. Although the dam was completed in 1942, it was not placed into full operation until 1951.

The dam provides flood control on the San Joaquin River, provides downstream releases to meet senior water rights requirements above Mendota Pool, and provides conservation storage as well as diversion into Madera and Friant-Kern Canals. Water is delivered to a million acres of agricultural land in Fresno, Kern, Madera, and Tulare Counties in the San Joaquin Valley via the Friant-Kern Canal south into Tulare Lake Basin and via the Madera Canal northerly to Madera and Chowchilla IDs. A minimum of 5 cfs is required to pass the last water right holding located about 40 miles downstream near Gravelly Ford.

Flood control storage space in Millerton Lake is based on a complex formula, which considers upstream storage in the Southern California Edison reservoirs. The reservoir, Millerton Lake, first stored water on February 21, 1944. It has a total capacity of 520,528 af, a surface area of 4,900 acres, and is approximately 15-miles long. The lake’s 45 miles of shoreline varies from gentle slopes near the dam to steep canyon walls farther inland. The reservoir provides boating, fishing, picnicking, and swimming.

At this time, the Friant Division is generally hydrologically disconnected from the Delta as the San Joaquin River is dewatered in two reaches between Friant Dam and the confluence of the Merced River, except in extremely wet years. Under flood conditions, water is diverted into two bypass channels that carry flood flows to the confluence of the Merced River.

In 2006, parties to NRDC v. Rodgers executed a stipulation of settlement that calls for, among other things, restoration of flows from Friant Dam to the confluence of the Merced River. Implementation of the settlement is not included in this consultation as it is a large project which has not been sufficiently developed to allow for analysis of the effects of implementation of settlement action on listed aquatic species at this time. At some point in the future, consultation may need to be reinitiated to evaluate the effects of the Restoration Program on continued CVP and SWP operations.

State Water Project

The DWR holds contracts with 29 public agencies in Northern, Central and Southern California for water supplies from the SWP. Water stored in the Oroville facilities, along with excess water available in the Sacramento-San Joaquin Delta is captured in the Delta and conveyed through several facilities to SWP contractors.

The SWP is operated to provide flood control and water for agricultural, municipal, industrial, recreational, and environmental purposes. Water is conserved in Oroville Reservoir and released to serve three Feather River area contractors and two contractors served from the North Bay Aqueduct, and to be pumped at the Harvey O. Banks Pumping Plant (Banks) in the Delta and delivered to the remaining 24 contractors in the SWP service areas south of the Delta. In addition to pumping water released from Oroville Reservoir, the Banks pumps water from other sources entering the Delta.

Project Management Objectives

The SWP is managed to maximize the capture of water in the Delta and the usable supply released to the Delta from Oroville storage. The maximum daily pumping rate at Banks is controlled by a combination of the State Water Resources Control Board's Water Rights Decision 1641 (D-1641), the adaptive management process described in this biological assessment, and permits issued by the Corps that regulate the rate of diversion of water into Clifton Court Forebay (CCF) for pumping at Banks. This diversion rate is normally restricted to 6,680 cfs as a three-day average inflow to CCF and 6,993 cfs as a one-day average inflow to CCF. CCF diversions may be greater than these rates between December 15 and March 15, when the inflow into CCF may be augmented by one-third of the San Joaquin River flow at Vernalis when those flows are equal to or greater than 1,000 cfs. Additionally, the SWP has a permit to export an additional 500 cfs between July 1 and September 30. (Please see section on 500 cfs permit, below.) The purpose for the current permitted action is to replace pumping foregone for the benefit of Delta fish species, making the summer limit effectively 7,180 cfs. Prior to creation of the EWA, this summer capacity was available to SWP to offset pumping curtailments made to benefit fish.

The hourly operation of the CCF radial gates is governed by agreements with local agricultural interests to protect water levels in the south Delta area. The radial gates controlling inflow to the forebay may be open during any period of the tidal cycle with the exception of the two hours before and after the low-low tide and the hours leading up to the high-high tide each day. CCF gate operations are governed by agreements and response plans to protect south Delta water users, and a more detailed discussion of these operations and agreement will follow under CCF and JPOD sections.

Banks is operated to minimize the impact to power loads on the California electrical grid to the extent practical, using CCF as a holding reservoir to allow that flexibility. Generally more pump units are operated during off-peak periods and fewer during peak periods. Because the installed capacity of the pumping plant is 10,300 cfs, the plant can be operated to reduce power grid impacts, by running all available pumps at night and a reduced number during the higher energy demand hours, even when CCF is admitting the maximum permitted inflow.

There are years (primarily wetter years) when Banks operations are demand limited, and Banks is able to pump enough water from the Delta to fill San Luis Reservoir and meet all contractor demands without maximizing its pumping capability every day of the year. This has been less likely in recent years, where the contractors request all or nearly all of their contract Table A amount every year. Consequently, current Banks operations are more often supply limited. Under these current full demand conditions, Banks pumping plant is almost always operated to the maximum extent possible to maximize the water captured, subject to the limitations of water quality, Delta standards, and a host of other variables, until all needs are satisfied and all storage south of the Delta is full.

San Luis Reservoir is an offstream storage facility located along the California Aqueduct downstream of Banks. San Luis Reservoir is used by both projects to augment deliveries to their contractors during periods when Delta pumping is insufficient to meet downstream demands.

San Luis Reservoir operates like a giant regulator on the SWP system, accepting any water pumped from Banks that exceeds contractor demands, then releasing that water back to the aqueduct system when Banks pumping is insufficient to meet demands. The reservoir allows the SWP to meet peak-season demands that are seldom balanced by Banks pumping.

San Luis Reservoir is generally filled in the spring or even earlier in some years. When it and other SWP storage facilities south of the Delta are full or nearly so, when Banks pumping is meeting all current Table A demands, and when the Delta is in excess conditions, DWR will use any available excess pumping capacity at Banks to deliver Article 21 water to the SWP contractors.

Article 21 water is one of several types of SWP water supply made available to the SWP contractors under the long-term SWP water supply contracts between DWR and the SWP contractors. As its name implies, Article 21 water is provided for under Article 21 of the contracts[3]. Unlike Table A water, which is an allocated annual supply made available for scheduled delivery throughout the year, Article 21 water is an interruptible water supply made available only when certain conditions exist. However, Article 21 water is an important part of the total SWP supplies contractually provided under the SWP contracts. As with all SWP water, Article 21 water is supplied under existing SWP water rights permits, and is pumped from the Delta under the same environmental, regulatory, and operational constraints that apply to all SWP supplies.

When Article 21 water is available, DWR may only offer it for a short time, and the offer may be discontinued when the necessary conditions no longer exist. While not a dependable supply, Article 21 water is an important part of the total SWP supplies available to contractors. Since Article 21 deliveries are in addition to scheduled Table A deliveries, this supply is delivered to contractors that can, on relatively short notice, put it to beneficial use. Typically, contractors have used Article 21 water to meet needs such as additional short-term irrigation demands, replenishment of local groundwater basins, and storage in local surface reservoirs, all of which provide contractors with opportunities for better water management through more efficient coordination with their local water supplies. When Article 21 of the long-term water supply contracts was developed, both DWR and the contractors recognized that DWR was not capable of meeting the full contract demands in all years because not all of the planned SWP facilities had been constructed. The SWP's inability to capture all of the water available in the Delta meant that contractors were forced to develop their own local water management programs and projects to store excess water that the SWP could capture from the Delta.

[3]Article 21 provides, in part: "Each year from water sources available to the project, the State shall make available and allocate interruptible water to contactors. Allocations of interruptible water in any one year may not be carried over for delivery in a subsequent year, nor shall the delivery of water in any year impact a contractor's approved deliveries of annual [Table A water] or the contractor's allocation of water for the next year. Deliveries of interruptible water in excess of a contractor's annual [Table A water] may be made if the deliveries do not adversely affect the State's delivery of annual [Table A water] to other contractors or adversely affect project operations…"

Article 21 water is typically offered to contractors on a short-term (daily or weekly) basis when all of the following conditions exist: the SWP share[4] of San Luis Reservoir is physically full, or projected to be physically full within approximately one week at permitted pumping rates; other SWP reservoirs south of the Delta are at their storage targets or the conveyance capacity to fill these reservoirs is maximized; the Delta is in excess condition; current Table A demand is being fully met; and Banks has export capacity beyond that which is needed to meet current Table A and other SWP operational demands. The increment of available unused Banks capacity is offered as the Article 21 delivery capacity. Contractors then indicate their desired rate of delivery of Article 21 water. It is allocated in proportion to their Table A contractual quantities if requests exceed the amount offered. Deliveries can be discontinued at any time, when any of the above factors change. In the modeling for Article 21, deliveries are only made in months when the State share of San Luis Reservoir is full. In actual operations, Article 21 may be offered a few days in advance of actual filling. Article 21 water will not be offered until State storage in San Luis Reservoir is either physically full or projected to be physically full within approximately one week at permitted pumping rates. Also, any carried-over EWA water asset stored in the State share of San Luis Reservoir (whether it be from the use of the 500 cfs or other operational assets) will not be considered part of the SWP storage when determining the availability of Article 21. This will ensure that the carried-over EWA water asset does not result in increased Article 21 deliveries.

During parts of April and May, the Vernalis Adaptive Management Program (VAMP) takes effect as described in the CVP section above. The state and federal pumps reduce their export pumping to benefit fish in the San Joaquin River system. Around this same time, water demands from both agricultural and M&I contractors are increasing, Article 21 water is usually discontinued, and San Luis supplies are released to the SWP facilities to supplement Delta pumping at Banks, thereby meeting contractor demands. The SWP intends to continue VAMP-type export reductions through 2030 to the extent that the limited EWA assets, (as described in an earlier section) will meet the associated water costs. Chapter 9 of this assessment includes an analysis of modeling results that illustrates the frequency on which assets are available under a limited EWA to meet the SWP portion of VAMP.

Immediately following VAMP, a “post –VAMP shoulder” may occur. This action is an extension of the reduced pumping levels that occur during VAMP depending on the availability of EWA and limited EWA assets. Chapter 9 includes an analysis of modeling results that illustrates the frequency on which assets are available under a limited EWA to meet the “post –VAMP shoulder”.

After VAMP and the “post-VAMP shoulder”, Delta pumping at Banks can be increased depending on Delta inflow and Delta standards. By late May, demands usually exceed the restored pumping rate at Banks, and continued releases from San Luis Reservoir are needed to meet contractor demands for Table A water.

[4] Not including any carried-over EWA or limited EWA asset which may reside in the SWP share of San Luis Reservoir.

During this summer period, DWR is also releasing water from Oroville Reservoir to supplement Delta inflow and allow Banks to export the stored Oroville water to help meet demand. These releases are scheduled to maximize export capability and gain maximum benefit from the stored water while meeting fish flow requirements, temperature requirements, Delta water quality, and all other applicable standards in the Feather River and the Delta.

DWR must balance storage between Oroville and San Luis Reservoirs carefully to meet flood control requirements, Delta water quality and flow requirements, and optimize the supplies to its contractors consistent with all environmental constraints. Oroville Reservoir may be operated to move water through the Delta to San Luis Reservoir via Banks under different schedules depending on Delta conditions, reservoir storage volumes, and storage targets. Predicting those operational differences is difficult, as the decisions reflect operator judgment based on many real-time factors as to when to move water from Oroville Reservoir to San Luis Reservoir.

As San Luis Reservoir is drawn down to meet contractor demands, it usually reaches its low point in late August or early September. From September through early October, demand for deliveries usually drops below the ability of Banks to divert from the Delta, and the difference in Banks pumping is then added to San Luis Reservoir, reversing its spring and summer decline. From early October until the first major storms in late fall or winter unregulated flow continues to decline and releases from Lake Oroville are restricted (due to flow stability agreements with DFG) resulting in export rates at Banks that are somewhat less than demand typically causing a second seasonal decrease in the SWP's share of San Luis Reservoir. Once the fall and winter storms increase runoff into the Delta, Banks can increase its pumping rate and eventually fill (in all but the driest years) the state portion of San Luis Reservoir before April of the following year.

Water Service Contracts, Allocations, and Deliveries

The following discussion presents the practices of DWR in determining the overall amount of Table A water that can be allocated and the allocation process itself. There are many variables that control how much water the SWP can capture and provide to its contractors for beneficial use.

The allocations are developed from analysis of a broad range of variables that include:

- Volume of water stored in Oroville Reservoir
- Flood operation restrictions at Oroville Reservoir
- End-of-water-year (September 30) target for water stored in Oroville Reservoir
- Volume of water stored in San Luis Reservoir
- End-of-month targets for water stored in San Luis Reservoir
- Snow survey results
- Forecasted runoff
- Feather River flow requirements for fish habitat

- Feather River service area delivery obligations
- Feather River flow for senior water rights river diversions
- Anticipated depletions in the Sacramento River basin
- Anticipated Delta conditions
- Precipitation and streamflow conditions since the last snow surveys and forecasts
- Contractor delivery requests and delivery patterns

From these and other variables, the Operations Control Office estimates the water supply available to allocate to contractors and meet other project needs. The Operations Control Office transmits these estimates to the State Water Project Analysis Office, where staff enters the water supply, contractor requests, and Table A amounts into a spreadsheet and computes the allocation percentage that would be provided by the available water supply.

The staffs of the Operations Control Office and State Water Project Analysis Office meet with DWR senior management, usually including the Director, to make the final decision on allocating water to the contractors. The decision is made, and announced in a press release followed by Notices to Contractors.

The initial allocation announcement is made by December 1 of each year. The allocation of water is made with a conservative assumption of future precipitation, and generally in graduated steps, carefully avoiding over-allocating water before the hydrologic conditions are well defined for the year.

Both the DWR and the contractors are conservative in their estimates, leading to the potential for significant variations between projections and actual operations, especially under wet hydrologic conditions.

Other influences affect the accuracy of estimates of annual demand for Table A and the resulting allocation percentage. One factor is the contractual ability of SWP contractors to carry over allocated but undelivered Table A from one year to the next if space is available in San Luis Reservoir. Contractors will generally use their carryover supplies early in the calendar year if it appears that San Luis reservoir will fill. By using the prior year’s carryover, the contractors reduce their delivery requests for the current year’s Table A allocation and instead schedule delivery of carryover supplies.

Carryover supplies left in San Luis Reservoir by SWP contractors may result in higher storage levels in San Luis Reservoir at December 31 than would have occurred in the absence of carryover. If there were no carryover privilege, contractors would seek to store the water within their service areas or in other storage facilities outside of their service areas. As project pumping fills San Luis Reservoir, the contractors are notified to take or lose their carryover supplies. If they can take delivery of and use or store the carryover water, San Luis Reservoir storage then returns to the level that would have prevailed absent the carryover program.

If the contractors are unable to take delivery of all of their carryover water, that water then converts to project water as San Luis Reservoir fills, and Article 21 water becomes available for delivery to contractors.

Article 21 water delivered early in the calendar year may be reclassified as Table A later in the year depending on final allocations, hydrology, and contractor requests. Such reclassification does not affect the amount of water carried over in San Luis Reservoir, nor does it alter pumping volumes or schedules. The total water exported from the Delta and delivered by the SWP in any year is a function of a number of variables that is greater than the list of variables shown above that help determine Table A allocations.

If there are no carryover or Article 21 supplies available, Table A requests will be greater in the January-April period, and there would be a higher percentage allocation of Table A for the year than if carryover and Article 21 were available to meet demand. For this reason, the total amount of Article 21 water delivered does not provide a measure of the change in Delta diversions attributable to Article 21 deliveries. Instead, one must analyze the total exports from the Delta.

Monterey Agreement

In 1994, DWR and certain representatives of the SWP contractors agreed to a set of principles known as the Monterey Agreement, to settle long-term water allocation disputes, and to establish a new water management strategy for the SWP. This project description only includes the system-wide water operations consistent with the Monterey Agreement and not the specific actions by DWR and State Water Contractors needed to implement the agreement.

The Monterey Agreement resulted in 27 of the 29 SWP contractors signing amendments to their long-term water supply contracts in 1995, and the Monterey Amendment has been implemented as part of SWP operations for these 27 SWP contractors since 1996. The original Environmental Impact Report prepared for the Monterey Agreement was challenged, and the EIR was required to be decertified. DWR is currently preparing an EIR on the Monterey Amendment following that litigation and approval of a settlement agreement with the plaintiffs in May 2003. A draft of the new EIR was released in October 2007, the comment period closed in January 2008, and a final EIR is scheduled for completion in the fall of 2008.

The alternatives evaluated in the EIR include continuation of the Monterey Amendment, certain No Project alternatives that would revert some contract terms to pre-Monterey Amendment terms, and two “court ordered no-project” alternatives that would impose a reduction in Table A supplies by implementing a permanent shortage provision together with an offsetting increase in the supply of Article 21 water.

Adoption of any of the alternatives would not measurably change SWP Delta operations, although the internal classification of water provided to SWP contractors could change as to the balance between Table A and Article 21 water, as could the relative allocation of water between urban and agricultural contractors. The Monterey Amendment provides for certain transfers of water from agricultural to urban contractors; impacts from those transfers are all south of the Delta and have no effect on the Delta.

The only impact of Monterey Amendment operations on Delta exports is identified in the draft EIR as the facilitation of approval for out-of-service-area storage programs. Because DWR had previously approved water storage programs outside of individual SWP contractor's service areas and many such storage programs now exist, this water management method is unlikely to be voided by future actions of DWR. These increased exports can only occur if they are within the diversions permitted at the time. None of the alternatives being considered would result in demand for added Delta diversions above currently assumed levels and all are subject to whatever regulatory restrictions are in force at the time.

Thus the current operational assumptions, based on continued Delta export operations as described in this chapter of the BA, provides an appropriate basis for evaluation of SWP operations irrespective of subsequent decisions of DWR based upon the Monterey EIR.

Changes in DWR's Allocation of Table A Water and Article 21 Water

The Monterey Amendment revised the temporary shortage provision that specified an initial reduction of supplies for agricultural use when requests for SWP water exceeded the available supply. The Amendment specifies that whenever the supply of Table A water is less than the total of all contractors' requests, the available supply of Table A water is allocated among all contractors in proportion to each contractor's annual Table A amount.

The Monterey Amendment amended Article 21 by eliminating the category of scheduled "surplus water," which was available for scheduled delivery and by renaming "unscheduled water" to "interruptible water." Surplus water was scheduled water made available to the contractors when DWR had supplies beyond what was needed to meet Table A deliveries, reservoir storage targets, and Delta regulatory requirements. Surplus water and unscheduled water were made available first to contractors requesting it for agricultural use or for groundwater replenishment. Because of the contractors' increasing demands for Table A water and the increasing regulatory requirements imposed on SWP operations, DWR is now able to supply water that is not Table A water only on an unscheduled, i.e., interruptible basis.

Pursuant to the revised Article 21, DWR allocates the available interruptible supply to requesting contractors in proportion to their annual Table A amounts.

The result of these contractual changes are that DWR now allocates Table A and interruptible water among contractors in proportion to annual Table A amounts without consideration of whether the water would be used for M&I or agricultural purposes. Agricultural and M&I contractors share any reductions in deliveries or opportunities for surplus water in proportion to their annual Table A amounts.

Historical Water Deliveries to Southern California

The pumping from the Delta to serve southern California has been influenced by changes in available water supply sources to serve the region. The Colorado River and the SWP have been the major supply sources for southern California.

The Quantification Settlement Agreement (QSA) signed in 2003 resulted in a decrease in the amount of Colorado River water available to California. To illustrate the impact of that decrease on demand from the Sacramento-San Joaquin Delta, it is instructive to look at the magnitude of the two imported supply sources available to MWDSC.

During part of this period, MWDSC was also filling Diamond Valley Lake (810,000 acre-feet, late 1998-early 2002) and adding some water to groundwater storage programs. In wetter years, demand for imported water may often decrease because local sources are augmented and local rainfall reduces irrigation demand. Table 2-12 below illustrates the effects of the wet years from 1995-1998 on demand for imported water and the effect of reduced Colorado River diversions under the QSA on MWDSC deliveries from the Delta.

Table 2-12 Wet Year effects

Calendar Year	Sacramento Valley Water Year Type	Delta Supplies	Colorado Supplies	Total
1994	Critically Dry	807,866	1,303,212	2,111,078
1995	Wet	436,042	997,414	1,433,456
1996	Wet	593,380	1,230,353	1,823,733
1997	Wet	721,810	1,241,821	1,963,631
1998	Wet	410,065	1,073,125	1,483,190
1999	Wet	852,617	1,215,224	2,067,841
2000	Above Normal	1,541,816	1,303,148	2,844,964
2001	Dry	1,023,169	1,253,579	2,276,748
2002	Dry	1,408,919	1,241,088	2,650,007
2003	Above Normal	1,686,973	688,043	2,375,016
2004	Below Normal	1,724,380	733,095	2,457,475
2005	Above Normal	1,616,710	839,704	2,456,414
2006	Wet	1,521,681*	594,544	2,116,225
2007	Dry	1,395,827*	713,456*	2,109,283

* - These figures are preliminary.

Project Facilities

Oroville Field Division

Oroville Dam and related facilities comprise a multipurpose project. The reservoir stores winter and spring runoff, which is released into the Feather River to meet the Project's needs. It also provides pumpback capability to allow for on-peak electrical generation, 750,000 acre-feet of flood control storage, recreation, and freshwater releases to control salinity intrusion in the Sacramento-San Joaquin Delta and for fish and wildlife protection.

The Oroville facilities are shown in Figure 2-12. Two small embankments, Bidwell Canyon and Parish Camp Saddle Dams, complement Oroville Dam in containing Lake Oroville. The lake has a surface area of 15,858 acres, a storage capacity of 3,538,000 af, and is fed by the North, Middle, and South forks of the Feather River. Average annual unimpaired runoff into the lake is about 4.5 million af.

A maximum of 17,000 cfs can be released through the Edward Hyatt Powerplant, located underground near the left abutment of Oroville Dam. Three of the six units are conventional generators driven by vertical-shaft, Francis-type turbines. The other three are motor-generators coupled to Francis-type, reversible pump turbines. The latter units allow pumped storage operations. The intake structure has an overflow type shutter system that determines the level from which water is drawn.

Approximately four miles downstream of Oroville Dam and Edward Hyatt Powerplant is the Thermalito Diversion Dam. Thermalito Diversion Dam consists of a 625-foot-long, concrete gravity section with a regulated ogee spillway that releases water to the low flow channel of the Feather River. On the right abutment is the Thermalito Power Canal regulating headwork structure.

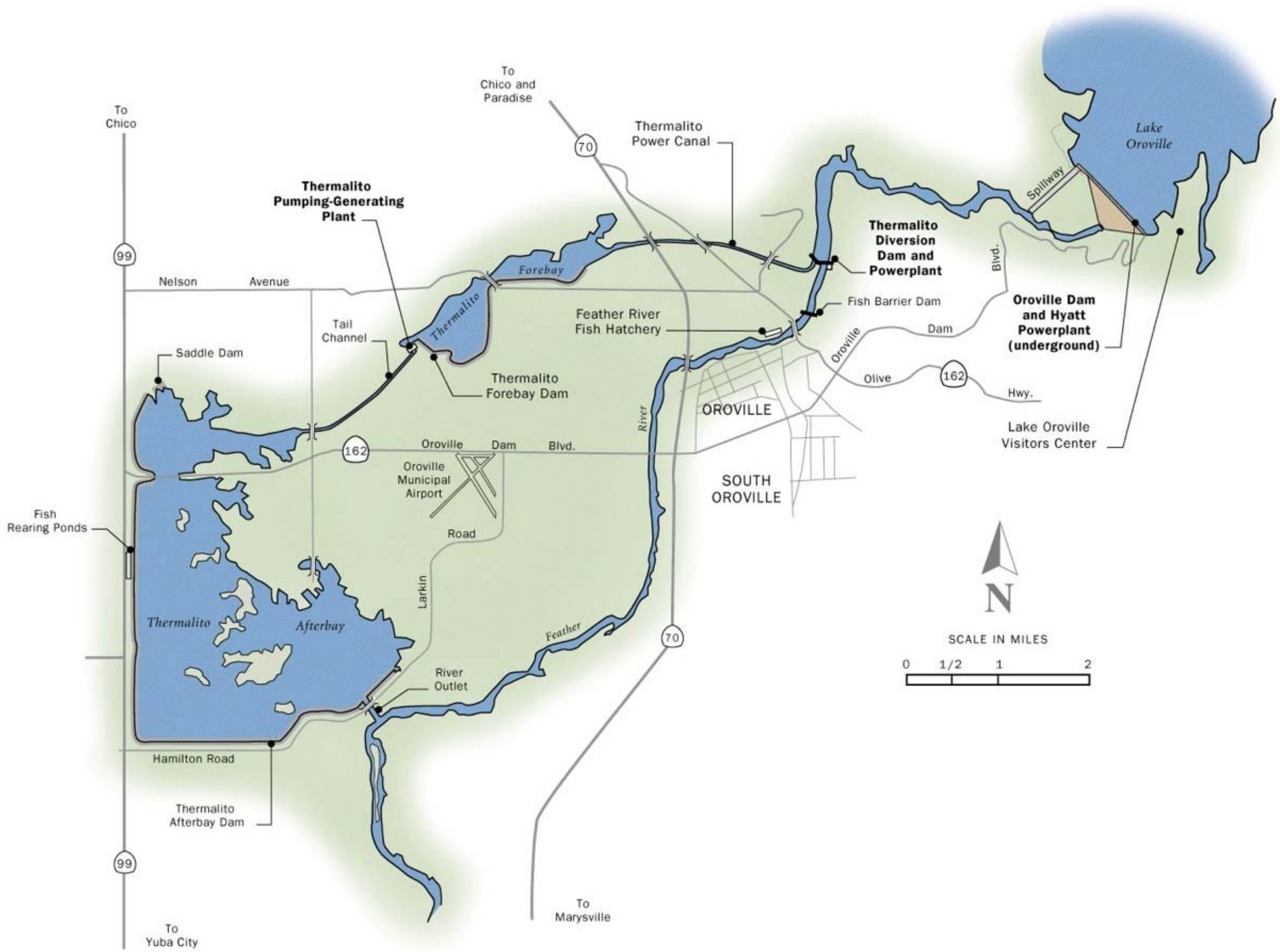

Figure 2-12 Oroville Facilities on the Feather River

The purpose of the diversion dam is to divert water into the 2-mile long Thermalito Power Canal that conveys water in either direction and creates a tailwater pool (called Thermalito Diversion Pool) for Edward Hyatt Powerplant. The Thermalito Diversion Pool acts as a forebay when Hyatt is pumping water back into Lake Oroville. On the left abutment is the Thermalito Diversion Dam Powerplant, with a capacity of 600 cfs that releases water to the low-flow section of the Feather River.

Thermalito Power Canal hydraulically links the Thermalito Diversion Pool to the Thermalito Forebay (11,768 af), which is the off-stream regulating reservoir for Thermalito Powerplant. Thermalito Powerplant is a generating-pumping plant operated in tandem with the Edward Hyatt Powerplant. Water released to generate power in excess of local and downstream requirements is conserved in storage and, at times, pumped back through both powerplants into Lake Oroville during off-peak hours. Energy price and availability are the two main factors that determine if a pumpback operation is economical. A pumpback operation most commonly occurs when energy prices are high during the weekday on-peak hours and low during the weekday off-peak hours or on the weekend. The Oroville Thermalito Complex has a capacity of approximately 17,000 cfs through the powerplants, which can be returned to the Feather River via the Afterbay's river outlet.

Local agricultural districts divert water directly from the afterbay. These diversion points are in lieu of the traditional river diversion exercised by the local districts whose water rights are senior to the SWP. The total capacity of afterbay diversions during peak demands is 4,050 cfs.

The Feather River Fish Hatchery (FRFH), mitigation for the construction of Oroville Dam, produces Chinook salmon and steelhead and is operated by DFG. The FRFH program, operations and production, is detailed in the FERC Biological Assessment for the Oroville Project and will be detailed in the NMFS FERC Biological Opinion, expected in June 2008. Both indirect and direct take resulting from FRFH operations will be authorized through section 4(d) of the Endangered Species Act, in the form of NMFS-approved Hatchery and Genetic Management Plans (HGMPs). DWR is preparing HGMPs for the spring and fall-run Chinook and steelhead production programs at the Feather River Fish Hatchery.

Current Operations - Minimum Flows and Temperature Requirements

Operation of Oroville will continue under existing criteria, consistent with past project descriptions, until a final decision is made in the FERC relicensing process. The release temperatures from Oroville Dam are designed to meet Feather River Fish Hatchery and Robinson Riffle temperature schedules included in the 1983 DFG Agreement, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish and Wildlife", concerning the operations of the Oroville Division of the State Water Project for Management of Fish and Wildlife and OCAP while also conserving the coldwater pool in Lake Oroville. Current operation indicates that water temperatures at Robinson Riffle are almost always met when the hatchery objectives are met. Due to temperature requirements of endangered fish species and the hatchery and overriding meteorologic conditions, the temperature requests for agriculture can be difficult to satisfy.

Water is withdrawn from Lake Oroville at depths that will provide sufficiently cold water to meet the Feather River Fish Hatchery and Robinson Riffle temperature targets. The reservoir depth from which water is released initially determines the river temperatures, but atmospheric conditions, which fluctuate from day to day, modify downstream river temperatures. Altering the reservoir release depth requires installation or removal of shutters at the intake structures. Shutters are held at the minimum depth necessary to release water that meets the Feather River Fish Hatchery and Robinson Riffle criteria. In order to conserve the coldwater pool during dry years, DWR has strived to meet the Robinson Riffle temperatures by increasing releases to the LFC rather than releasing colder water.

Additionally, DWR maintains a minimum flow of 600 cfs within the Feather River Low Flow Channel (LFC) (except during flood events when flows are governed by the Flood Operations Manual and under certain other conditions as described in the 1984 FERC order). Downstream of the Thermalito Afterbay Outlet, in the High Flow Channel (HFC), a minimum release for flows in the Feather River is to be 1,000 cfs from April through September and 1,700 cfs from October through March, when the April-to-July unimpaired runoff in the Feather River is greater than 55 percent of normal. When the April-to-July unimpaired runoff is less than 55 percent of normal, the License requires minimum flows of 1,000 cfs from March to September and 1,200 cfs from October to February (Table 2-13). In practice, flows are maintained below 2,500 cfs from October 15 to November 30 to prevent spawning in the overbank areas.

According to the 1983 Agreement, if during the period of October 15 to November 30, the average highest 1-hour flow of combined releases exceeds 2,500 cfs; with the exception of flood management, accidents, or maintenance; then the minimum flow must be no lower than 500 cfs less than that flow through the following March 31. The 1983 Agreement also states that if the April 1 runoff forecast in a given year indicates that the reservoir level will be drawn down to 733 feet, water releases for fish may be reduced, but not by more than 25 percent.

Table 2-13 Combined Minimum Instream Flow Requirements in the Feather River Below Thermalito Afterbay Outlet When Lake Oroville Elevation is Projected to be Greater vs. Less Than 733' in the Current Water Year

Conditions	Period	Minimum Flows
When Lake Oroville Elevation is Projected to be Greater Than 733' & the **Preceding** Water Year's April – July Water Conditions are ≥ 55% of Normal (1)	October - February	1,700 cfs
	March	1,700 cfs
	April - September	1,000 cfs
When Lake Oroville Elevation is Projected to be Greater Than 733' & the Preceding Water Year's April – July Water Conditions are < 55% of Normal (1)	October - February	1,200 cfs
	March	1,000 cfs
	April - September	1,000 cfs
When Lake Oroville Elevation is Projected to be Less Than 733' in the **Current** Water Year (2)	October - February	900 cfs < Q < 1,200 cfs
	March	750 cfs < Q < 1,000 cfs
	April - September	750 cfs < Q < 1,000 cfs

Notes:

1) Normal is defined as the Mean April – July Unimpaired Runoff of the Feather River near Oroville of 1,942,000 AF (1911 – 1960).
2) In accordance with FERC's Order Amending License dated September 18, 1984, Article 53 was amended to provide a third tier of minimum flow requirements defined as follows: If the April 1 runoff forecast in a given water year indicates that, under normal operation of Project 2100, the reservoir level will be drawn to elevation 733 feet (approximately 1,500,000 AF), releases for fish life in the above schedule may suffer monthly deficiencies in the same proportion as the respective monthly deficiencies imposed upon deliveries of water for agricultural use from the Project. However, in no case shall the fish water releases in the above schedule be reduced by more than 25 percent.

Current operations of the Oroville Facilities are governed by water temperature requirements at two locations: the FRFH and in the LFC at Robinson Riffle. DWR has taken various temperature management actions to achieve the water temperature requirements, including curtailing pumpback operations, removing shutters at intakes of the Hyatt Pumping-Generating Plant, releasing flow through the river valves (for FRFH only), and redirecting flows at the Thermalito Diversion Dam to the LFC (for Robinson Riffle only).

To date, the river valves have been used infrequently. Prior to 1992, they were used twice: first in 1967 during the initial construction of the dam, and second in 1977 during the drought of record. Since 1992, the river valves have only been used twice for temperature control: in 2001 and 2002. To ensure that the river valves will operate reliably, DWR exercises them annually. When operated to meet temperature criteria, DWR can and does operate the river valves at a flow rate up to the 1,500 cfs needed for FRFH temperature management purposes.

Other than local diversions, outflow from the Oroville Complex is to the Feather River, combining flows from the LFC and Thermalito Afterbay. Outflow typically varies from spring seasonal highs averaging 8,000 cfs to about 3,500 cfs in November. The average annual outflow from the Project is in excess of 3 maf to support downstream water supply, environmental, and water quality needs.

Table 2-14 shows an example of releases from Oroville for various downstream uses during dry hydrologic conditions (Water Years 2001 and 2002). As a practical matter, water supply exports are met with water available after Delta requirements are met. Some of the water released for instream and Delta requirements may be available for export by the SWP after Delta standards have been met.

Table 2-14 Historical Records of Releases from the Oroville Facilities in 2001 and 2002, by Downstream Use

Downstream Use	Water Year 2001 Release		Water Year 2002 Release	
	Volume (taf)	Percentage	Volume (taf)	Percentage
Feather River Service Area	1,024	46	925	34
Instream and Delta Requirements	1,099	50	1,043	38
Flood Management	0	0	0	0
Support of Exports	93	4	773	28
Total	2,216	100	2,741	100

Source: DWR SWP Operations Control Office
Key:
taf – thousand acre-feet

Feather River Flow Requirements

The existing Feather River flow requirements below Oroville Dam are based on an August 1983 Agreement between the DWR and DFG. The 1983 Agreement established criteria and objectives for flow and temperatures in the LFC, FRFH, and HFC. This agreement includes the following:

- Established minimum flows between the Thermalito Afterbay Outlet and Verona that vary by water year type.
- Required flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except flood management operations.
- Required flow stability during the peak of the fall-run Chinook spawning season.

- Set an objective of suitable water temperature conditions during the fall months for salmon and during the later spring/summer months for shad and striped bass.
- Established a process whereby DFG would recommend each year, by June 1, a spawning gravel maintenance program to be implemented during that calendar year.

Low Flow Channel

The 1983 Agreement specifies that DWR release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fishery purposes. This is the total volume of flows from the Diversion Dam Outlet, Diversion Dam Powerplant, and FRFH Pipeline.

High Flow Channel

Based on the 1983 Agreement, Table 2-15 summarizes the minimum flow requirement for the HFC when releases would not draw Oroville Reservoir below elevation 733 feet above mean sea level (ft msl).

Table 2-15 High Flow Channel minimum flow requirements as measured downstream from the Thermalito Afterbay Outlet.

Forecasted April-through-July unimpaired runoff (percent of normal[1])	Minimum Flow in HFC (cfs)		
	October through February	March	April through September
55 percent or greater	1,700	1,700	1,000
Less than 55 percent	1,200	1,000	1,000

Source: 1983 Agreement

[1] The preceding water year's unimpaired runoff shall be reported in Licensee's Bulletin 120, "*Water Conditions in California-Fall Report*." The term "normal" is defined as the April-through-July mean unimpaired runoff near Oroville of 1,942,000 af in the period of 1911 through 1960.

Key:

cfs – cubic feet per second

HFC – High Flow Channel

If the April 1 forecast in a given water year indicates that Oroville Reservoir would be drawn down to elevation 733 ft msl, minimum flows in the HFC may be diminished on a monthly average basis, in the same proportion as the respective monthly deficiencies imposed on deliveries for agricultural use of the Project. However, in no case shall the minimum flow releases be reduced by more than 25 percent. If between October 15 and November 30, the highest total 1-hour flow exceeds 2,500 cfs, DWR shall maintain a minimum flow within 500 cfs of that peak flow, unless such flows are caused by flood flows, or an inadvertent equipment failure or malfunction.

Temperature Requirements

Low Flow Channel

NMFS has established a water temperature requirement for steelhead trout and spring-run Chinook salmon at Feather River RM 61.6 (Robinson Riffle in the LFC) from June 1 through

September 30. The water temperature should be maintained at less than or equal to 65°F on a daily average basis.

High Flow Channel

While no numeric temperature requirement currently exists for the HFC, the 1983 Agreement requires DWR to provide suitable Feather River water temperatures for fall-run salmon not later than September 15, and to provide for suitable water temperatures below the Thermalito Afterbay Outlet for shad, striped bass, and other warm water fish between May 1 and September 15.

Current FRFH intake water temperature, as required by the 1983 DFG and DWR Agreement are in Table 2-16.

Table 2-16 Feather River Fish Hatchery Temperature Requirements

Period		Degrees F (± 4 ºF allowed)
April 1 – November 30		
	April 1 – May 15	51
	May 16 – May 31	55
	June 1 – June 15	56
	June 16 – August 15	60
	August 16 – August 31	58
	September 1 – September 30	52
	October 1 – November 30	51
December 1 – March 31		No greater than 55

Table 2-17 summarizes current flow and temperature management in the Feather River Fish Hatchery and the Lower Feather River below Oroville Dam. These operational measures are in place in compliance with FERC license terms, agency agreements or ESA Biological Opinions and are provided to fully describe the baseline conditions.

Table 2-17 Lower Feather River Flows and Temperature Management under Existing Conditions

Type of Measure	Title	Description
Minimum Flows	Minimum Release to Low Flow Channel (this includes water that returns from hatchery)	Maintain minimum flow of 600 cubic feet per second (cfs) within the Feather River downstream of the Thermalito Diversion Dam and the Feather River Fish Hatchery. FERC 1984. [Low Flow Channel Flow Standard]
	Minimum Release to High Flow Channel	Release water necessary to maintain flows in the Feather River below the Thermalito Afterbay Outlet in accordance with the minimum flow schedule presented in the Federal Energy Regulatory Commission (FERC) order, provided that releases will not cause Lake Oroville to be drawn below elevation 733 feet (ft) (approximately 1.5 million acre-feet [maf] of storage). If the April 1 runoff forecast in a given year indicates that the reservoir level will be drawn to 733 ft, water releases for fish may be reduced, but not by more than 25 percent.
Maximum Flows (non-flood control)	Maximum Flow into Feather River Fish Hatchery	Maximum flow into Feather River Fish Hatchery from the Diversion Pool is 115 cfs year round.
	Maximum Flow in the High Flow Channel	Maximum flow at Feather River below Thermalito Afterbay Outlet is **10,000 cfs** when Lake Oroville inflow is less than 10,000 cfs. [High Flow Channel Flow Standard] When Lake Oroville inflow is greater than 10,000 cfs, the maximum flow in the river below Thermalito Afterbay Outlet will be limited to inflow. If higher flow releases coincide with Chinook spawning activity, the ramping rate used to return to the minimum flow requirement will be chosen to avoid redd dewatering.
Ramping Rates	Ramping Rate Criteria	Flows less than 2,500 cfs cannot be reduced more than **300 cfs** during any 24-hour period, except for flood releases, failures, etc. (as per the 2004 Operating Criteria and Plan [OCAP] Biological Opinion [BO]).
Water Supply	Releases from Lake Oroville	Releases for water supply, flood control, Sacramento–San Joaquin Delta (Delta) water quality requirements, and instream flow requirements of an average of 3 million acre-feet per year (maf/year) and approximately 1 maf/year to the Feather River Service Area (FRSA) for agricultural, municipal, and industrial uses in accordance with State Water Project (SWP) contracts, California Department of Water Resources (DWR) agreements, and water rights.

Type of Measure	Title	Description
	Diversions from Feather River	Diversion of an estimated 60–70 thousand acre-feet per year (taf/year) from the Feather River by senior water right holders per State Water Resources Control Board (SWRCB) licenses or permits for appropriative users.
Flood Protection/Management	Flood Protection	The Oroville Facilities are operated for flood control purposes in conformance with the flood management regulations prescribed by the Secretary of the Army under the provisions of an Act of Congress (58 Stat. 890; 33 United States Code [USC] 709). - During floods, water releases from Oroville Dam and Thermalito Afterbay Dam will not increase floodflows above those prior to project existence. Operation of the project in the interest of flood control shall be in accordance with Section 204 of the Flood Control Act of 1958. - At high flows, fluctuate releases at least every couple of days to avoid riverbank/levee damage at one level. - Avoid extended periods of flow over the quantities listed above as much as possible to minimize the risk of seepage damage to orchards adjacent to the Feather River. - Maximum allowable flow is 180,000 cfs year round at the Feather River above the Yuba River. Maximum allowable flow is 300,000 cfs year round at the Feather River below the Yuba River. - Maximum allowable flow is 320,000 cfs year round at the Feather River below the Bear River.

Type of Measure	Title	Description
Temperature Criteria/Targets	At the Feather River Fish Hatchery and Robinson Riffle	Water temperature at Robinson Riffle must be less than 65 degrees between June and September. Water temperature during the fall months, after September 15, should be suitable for fall-run Chinook salmon. Water temperature from May through August should be suitable for American shad, striped bass, etc. At the Feather River Fish Hatchery Temperature (+/- 4°F) April 1–May 15 51° May 16–May 31 55° June 1–June 15 56° June 16–August 15 60° August 16–August 31 58° September 1–September 30 52° October 1–November 30 51° December 1–March 31 no greater than 55°
	Thermalito Afterbay Temperature Control	Operate facilities pursuant to the May 1968 Joint Water Agreement.
Natural Salmonid Spawning and Rearing Habitat	Salmonid Habitat Improvement – Endangered Species Act (ESA) Species Recovery Measures	Maintain conditions in the Low Flow Channel pursuant to 1983 Operating Agreement between DFG and DWR which is to prevent damage to fish and wildlife resources from operations and construction of the project.

Excerpt from Appendix B of the FERC Preliminary Draft Environmental Assessment, Oroville Facilities—FERC Project No. 2100

Flood Control

Flood control operations at Oroville Dam are conducted in coordination with DWR's Flood Operations Center and in accordance with the requirements set forth by the Corps. The Federal Government shared the expense of Oroville Dam, which provides up to 750,000 af of flood control space. The spillway is located on the right abutment of the dam and has two separate elements: a controlled gated outlet and an emergency uncontrolled spillway. The gated control structure releases water to a concrete-lined chute that extends to the river. The uncontrolled emergency spill flows over natural terrain.

Table 2-18 Water Year/Days in Flood Control/40-30-30 Index

Water Year	Days in Flood Control	40-30-30 Index
1981	0	D
1982	35	W
1983	51	W
1984	16	W
1985	0	D
1986	25	W
1987	0	D
1988	0	C
1989	0	D
1990	0	C
1991	0	C
1992	0	C
1993	8	AN
1994	0	C
1995	35	W
1996	22	W
1997	57	W
1998	0	W
1999	58	W
2000	0	AN
2001	0	D
2002	0	D

Feather River Ramping Rate Requirements

Maximum allowable ramp-down release requirements are intended to prevent rapid reductions in water levels that could potentially cause redd dewatering and stranding of juvenile salmonids and other aquatic organisms. Ramp-down release requirements to the LFC during periods outside of flood management operations, and to the extent controllable during flood management operations, are shown in Table 2-19.

Table 2-19 Lower Feather River Ramping Rates

Releases to the Feather River Low Flow Channel (cfs)	Rate of Decrease (cfs)
5,000 to 3,501	1,000 per 24 hours
3,500 to 2,501	500 per 24 hours
2,500 to 600	300 per 24 hours

Key:
cfs = cubic feet per second
Source: NMFS 2004a

Proposed Operational Changes with the Federal Energy Regulatory Commission (FERC) Relicensing of the Oroville Project– Near Term and Future Operations

Until FERC issues the new license for the Oroville Project, DWR will not significantly change the operations of the facilities and when the FERC license is issued, it is assumed that downstream of Thermalito Afterbay Outlet, the future flows will remain the same.

There is a great deal of uncertainty as to when the license will be issued and what conditions will be imposed by FERC and the State Water Resources Control Board (SWRCB). The process that DWR has to go through to get the new license is as follows: DWR will finalize the Final Environment Impact Report in May 2008, the SWRCB will prepare the Clean Water Act Section 401 Certification (401 Cert) for the project which may take up to a year and the 401 Cert may have additional requirements for DWR operations of Oroville. Once the 401 Cert is issued, FERC can issue the new license; however, in the interim, the documents or process may be challenged in court. When the new FERC license is issued, additional flow or temperature requirements may be required. At this time, DWR can only assume that the flow and temperature conditions required will be those in the FERC Settlement Agreement (SA); therefore, those are what DWR proposes for the near-term and future Oroville operations.

The proposed future operations in the SA described in the Project Description include 100-200 cfs increase in flows in the Low Flow Channel (LFC) of the Lower Feather River and reduced water temperatures at the Feather River Hatchery and in the Low Flow and High Flow channels, after further analysis of alternatives and construction of one or more temperature control facilities. These are described in more detail in the SA. The flows in the HFC downstream of the TAO will not change. It is unlikely that either the proposed minor flow changes in the LFC or the reduced water temperatures will affect conditions in the Sacramento River downstream of the confluence but if they were detectable, they would be beneficial to anadromous fish in the Sacramento River.

Given the uncertainty of what will be in the FERC license or 401 Certification, it is not possible to establish the DWR proposed SA conditions as the baseline for the OCAP Biological Asessment.

The original FERC license to operate the Oroville Project expired in January 2007 and until a new license is issued, DWR will operate to the existing FERC license. FERC has and will continue to issue an annual license until it is prepared to issue the new 50-year license. In preparation for the expiration of the FERC license, DWR began working on the relicensing process in 2001. As part of the process, DWR entered into a Settlement Agreement with State, federal and local agencies, State Water Contractors, Non-Governmental Organizations, and Tribal governments to implement improvements within the FERC Boundary. The FERC boundary includes all of the Oroville Project facilities, extends upstream into the tributaries of Lake Oroville, includes portions of the LFC on the lower Feather River and downstream of the Thermalito Afterbay Outlet into the HFC. In addition to the Settlement Agreement signed in 2006, a Habitat Expansion Agreement was negotiated to address the fish passage issue over Oroville Dam and NMFS and FWS' Section 18 Authority under the Federal Power Act. FERC prepared an EIS for the proposed license and DWR prepared and EIR and Biological Asesessements for FERC based on the terms and conditions in the Settlement Agreement. The SWRCB is working on the Section 401 Certification process and when all the environmental documents and permits are complete, the new 50-year FERC license will be issued for the Oroville Project, possibly in 2009.

FERC requested consultation with NMFS on the Oroville Project Settlement Agreement and DWR prepared and submitted the FERC Biological Assessment in June 2007 to NMFS and FERC. The Settlement Agreement does not change the flows in the HFC although there will be a proposed increase in minimum flows in the LFC. The Settlement Agreement includes habitat restoration actions such as side-channel construction, structural habitat improvement such as boulders and large woody debris, spawning gravel augmentation, a fish counting weir, riparian vegetation and floodplain restoration, and facility modifications to improve coldwater temperatures in the low and high flow channels. The Settlement Agreement and the FERC BA provide substantial detail on the Settlement Agreement restoration actions in the Lower Feather River. It is anticipated that NMFS will issue a Biological Opinion on the Settlement Agreement in summer of 2008. The NMFS Biological Opinion will provide take coverage for the Settlement Agreement actions that will be implemented once the new FERC license is issued.

Below is a summary of articles in the Settlement Agreement referred to by number and is by no means a complete description of the terms and conditions therein. The numbering of the tables in this section is consistent with the numbering in the SA for direct comparison. The reader is encouraged to read the source document for a full understanding of the terms and related details.

Minimum Flows in the Low Flow and High Flow Channels

When the FERC license is issued, DWR will release a minimum flow of 700 cfs into the Low Flow Channel (LFC). The minimum flow shall be 800 cfs from September 9 to March 31 of each year to accommodate spawning of anadromous fish, unless the NMFS, FWS, DFG, and California SWRCB provide a written notice that a lower flow (between 700 cfs and 800 cfs) substantially meets the needs of anadromous fish. If the DWR receives such a notice, it may operate consistent with the revised minimum flow. HFC flows will remain the same as the existing license, consistent with the 1983 DWR and DFG Operating Agreement to continue to protect Chinook salmon from redd dewatering (A108.2).

Water Temperatures for the Feather River Fish Hatchery

When the FERC license is issued, DWR will use the temperatures in Table 2-20 as targets, and will seek to achieve them through the use of operational measures described below.

Table 2-20 Maximum Mean Daily Temperatures,

September 1-September 30	56 °F
October 1 – May 31	55 °F
June 1 – August 31	60°F

The temperatures in Table 2-20 are Maximum Mean Daily Temperatures, calculated by adding the hourly temperatures achieved each day and dividing by 24. DWR will strive to meet Maximum Mean Daily Temperatures through operational changes including but not limited to (i) curtailing pump-back operation and (ii) removing shutters on Hyatt intake and (iii) after river valve refurbishment. DWR will consider the use of the river valve up to a maximum of 1500 cfs; however these flows need not exceed the actual flows in the HFC, and should not be less than those specified in HFC minimum flows described above, which will not change with the new FERC license. During this interim period, DWR shall not be in violation if the Maximum Mean Daily Temperatures are not achieved through operational changes.

Prior to FERC license implementation, DWR agreed to begin the necessary studies for the refurbishment or replacement of the river valve. On October 31, 2006, DWR submitted to specific agencies a Reconnaissance Study of Facilities Modification to address temperature habitat needs for anadromous fisheries in the Low Flow Channel and the HFC. Under the provisions of Settlement Agreement Appendix B Section B108(a), DWR has begun a study to evaluate whether to refurbish or replace the river valve that may at times be used to provide cold water for the Feather River Fish Hatchery.

Upon completion of Facilities Modification(s) as provided in A108, and no later than the end of year ten following license issuance, Table 2-20 temperatures shall become requirements, and DWR shall not exceed the Maximum Mean Daily Temperatures in Table 2-20 for the remainder of the License term, except in Conference Years as referenced in A107.2(d).

During the term of the FERC license, DWR will not exceed the hatchery water temperatures in Table 2-21. There will be no minimum temperature requirement except for the period of April 1 through May 31, during which the temperatures shall not fall below 51 ºF.

Table 2-21 Hatchery Water Temperatures

September 1-September 30	56 °F
October 1 – November 30	55 °F
December 1 – March 31	55 °F
April 1 – May 15	55 °F
May 16-May 31	59°F
June 1-June 15	60°F

June 16- August 15	64°F
August 16 – August 31	62°F

Upon completion of Facilities Modification(s) as provided in A108 (discussed below), DWR may develop a new table for hatchery temperature requirements that is at least as protective as Table 2-21. If a new table is developed, it shall be developed in consultation with the Ecological Committee, including specifically FWS, NMFS, DFG, California SWRCB, and RWQCB. The new table shall be submitted to FERC for approval, and upon approval shall become the temperature requirements for the hatchery for the remainder of the license term.

During Conference Years, as defined in A108.6, DWR shall confer with the FWS, NMFS, DFG, and California SWRCB to determine proper temperature and hatchery disease management goals.

Water Temperatures in the Lower Feather River

Under the Settlement Agreement, DWR is committing to a Feasibility Study and Implementation Plan to improve temperature conditions (Facilities Modification(s)) for spawning, egg incubation, rearing and holding habitat for anadromous fish in the Low Flow Channel and HFC (A108.4). The Plan will recommend a specific alternative for implementation and will be prepared in consultation with the resource agencies.

Prior to the Facilities Modification(s) described in Article A108.4, if DWR does not achieve the applicable Table 2-22 Robinson Riffle temperature upon release of the specified minimum flow, DWR shall singularly, or in combination perform the following actions:

(1) Curtail pump-back operation,

(2) Remove shutters on Hyatt Intake, and

(3) Increase flow releases in the LFC up to a maximum of 1500 cfs, consistent with the minimum flow standards in the HFC. Table 2-22 temperatures are targets and if they are not met there is no license violation.

If in any given year DWR anticipates that these measures will not achieve the temperatures in Table 2-22. DWR shall consult with the NMFS, FWS, DFG, and California SWRCB to discuss potential approaches to best managing the remaining coldwater pool in Lake Oroville, which may result in changes in the way Licensee performs actions (1), (2), and (3) listed above.

Table 2-22 LFC as Measured at Robinson Riffle.

(all temperatures are in daily mean value (degrees F))

Month	Temperature (° F)
January	56
February	56
March	56
April	56
May 1-15	56-63*
May 16-31	63
June 1 – 15	63
June 16 – 30	63
July	63
August	63
September 1-8	63-58*
September 9 – 30	58
October	56
November	56
December	56
* Indicates a period of transition from the first temperature to the second temperature.	

After completion of the Facilities Modification(s), DWR shall no longer be required to perform the measures listed in (1), (2), and (3), unless Table 2-22 temperatures are exceeded. DWR shall operate the project to meet temperature requirements in Table 2-22 in the LFC, unless it is a Conference Year as described in Article 108.6. The proposed water temperature objectives in Table 2-23 (in Article 108), measured at the southern FERC project boundary, will be evaluated for potential water temperature improvements in the HFC. DWR will study options for Facilities Modification(s) to achieve those temperature benefits.

There would be a testing period of at least five years in length to determine whether the HFC temperature benefits are being realized (A108.5). At the end of the testing period, DWR will prepare a testing report that may recommend changes in the facilities, compliance requirements for the HFC and the definition of Conference Years (those years where DWR may have difficulties in achieving the temperature requirements due to hydrologic conditions.) The challenges of implementing Table 2-23 temperatures will require the phased development of the Table 2-23 water temperature objective and likely, a revision to Table 2-23 prior to Table 2-23 becoming a compliance obligation.

Table 2-23 HFC as measured at Downstream Project Boundary

(all temperatures are in daily mean value (degrees F))

Month	Temperature
January	56
February	56
March	56
April	61
May	64
June	64
July	64
August	64
September	61
October	60
November	56
December	56

Habitat Expansion Agreement

The Habitat Expansion Agreement is a component of the 2006 Settlement Agreement to address DWR obligations in regard to blockage and fish passage issues in regard to the construction of Oroville Dam. Because it deals with offsite mitigation it will not included in the new FERC license.

Construction of the Oroville Facilities and Pacific Gas and Electric Company's construction of other hydroelectric facilities on the upper Feather River tributaries blocked passage and reduced available habitat for ESA listed anadromous salmonids Central Valley spring-run Chinook salmon (Oncorhynchus tshawytscha) (spring-run) and Central Valley steelhead *(*O. mykiss*)* (steelhead). The reduction in spring-run habitat resulted in spatial overlap with fall-run Chinook salmon and has led to increased redd superimposition, competition for limited habitat, and genetic introgression. FERC relicensing of hydroelectric projects in the Feather River basin has focused attention on the desirability of expanding spawning, rearing and adult holding habitat available for Central Valley spring-run and steelhead. The Settlement Agreement Appendix F includes a provision to establish a habitat enhancement program with an approach for identifying, evaluating, selecting and implementing the most promising action(s) to expand such spawning, rearing and adult holding habitat in the Sacramento River Basin as a contribution to the conservation and recovery of these species. The specific goal of the Habitat Expansion Agreement is to expand habitat sufficiently to accommodate an estimated net increase of 2,000 to 3,000 spring-run or steelhead for spawning (Habitat Expansion Threshold). The population size target of 2,000 to 3,000 spawning individuals was selected because it is approximately the number of spring-run and steelhead that historically migrated to the upper Feather River. Endangered species issues will be addressed and documented on a specific project-related basis for any restoration actions chosen and implemented under this Agreement.

Anadromous Fish Monitoring on the Lower Feather River

Until the new FERC license is issued and until a new monitoring program is adopted, DWR will continue to monitor anadromous fish in the Lower Feather River in compliance with the project description set out in Reclamation's 2004 BA.

As required in the FERC Settlement Agreement (Article A101), within three years following the FERC license issuance, DWR will develop a comprehensive Lower Feather River Habitat Improvement Plan that will provide an overall strategy for managing the various environmental measures developed for implementation, including the implementation schedules, monitoring, and reporting. Each of the programs and components of the Lower Feather River Habitat Improvement Plan shall be individually evaluated to assess the overall effectiveness of each action within the Lower Feather River Habitat Improvement Plan.

Delta Field Division

SWP facilities in the southern Delta include Clifton Court Forebay, John E. Skinner Fish Facility, and the Banks Pumping Plant. CCF is a 31,000 af reservoir located in the southwestern edge of the Delta, about ten miles northwest of Tracy. CCF provides storage for off-peak pumping, moderates the effect of the pumps on the fluctuation of flow and stage in adjacent Delta channels, and collects sediment before it enters the California Aqueduct. Diversions from Old River into CCF are regulated by five radial gates.

The John E. Skinner Delta Fish Protective Facility is located west of the CCF, two miles upstream of the Banks Pumping Plant. The Skinner Fish Facility screens fish away from the pumps that lift water into the California Aqueduct (CA). Large fish and debris are directed away from the facility by a 388-foot long trash boom. Smaller fish are diverted from the intake channel into bypasses by a series of metal louvers, while the main flow of water continues through the louvers and towards the pumps. These fish pass through a secondary system of screens and pipes into seven holding tanks, where a subsample is counted and recorded. The salvaged fish are then returned to the Delta in oxygenated tank trucks.

The Banks Pumping Plant is in the south Delta, about eight miles northwest of Tracy and marks the beginning of the CA. By means of 11 pumps, including two rated at 375 cfs capacity, five at 1,130 cfs capacity, and four at 1,067 cfs capacity, the plant provides the initial lift of water 244 feet into the CA. The nominal capacity of the Banks Pumping Plant is 10,300 cfs.

Other SWP operated facilities in and near the Delta include the North Bay Aqueduct (NBA), the Suisun Marsh Salinity Control Gates (SMSCG), Roaring River Distribution System (RRDS), and up to four temporary barriers in the south Delta. Each of these facilities is discussed further in later sections.

Clifton Court Forebay

CCF is a regulated reservoir at the head of the CA in the south Delta. Inflows to the CCF are controlled by radial gates, whose real-time operations are constrained by a scouring limit (i.e. 12,000 cfs) at the gates and by water level concerns in the south Delta for local agricultural diverters. An interim agreement between DWR and South Delta Water Agency specifies three modes, or “priorities,” for CCF gate operation. These priorities are depicted in Figure 2-13 below. Of the three priorities, Priority 1 is the most protective of south Delta water levels. Under Priority 1, CCF gates are only opened during the ebb tides, allowing the flood tides to replenish south Delta channels. Priority 2 is slightly less protective because the CCF gates may be open as in Priority 1, but also during the last hour of the higher flood tide and through most of the lower flood tide. Finally, Priority 3 requires that the CCF gates be closed during the rising limb of the higher flood tide and also during the lowest part of the lower ebb tide, but permits the CCF gates to be open at all other times.

When a large head differential exists between the outside and the inside of the gates, theoretical inflow can be as high as 15,000 cfs for a very short time. However, existing operating procedures identify a maximum design flow rate of 12,000 cfs, to minimize water velocities in surrounding south Delta channels, to control erosion, and to prevent damage to the facility.

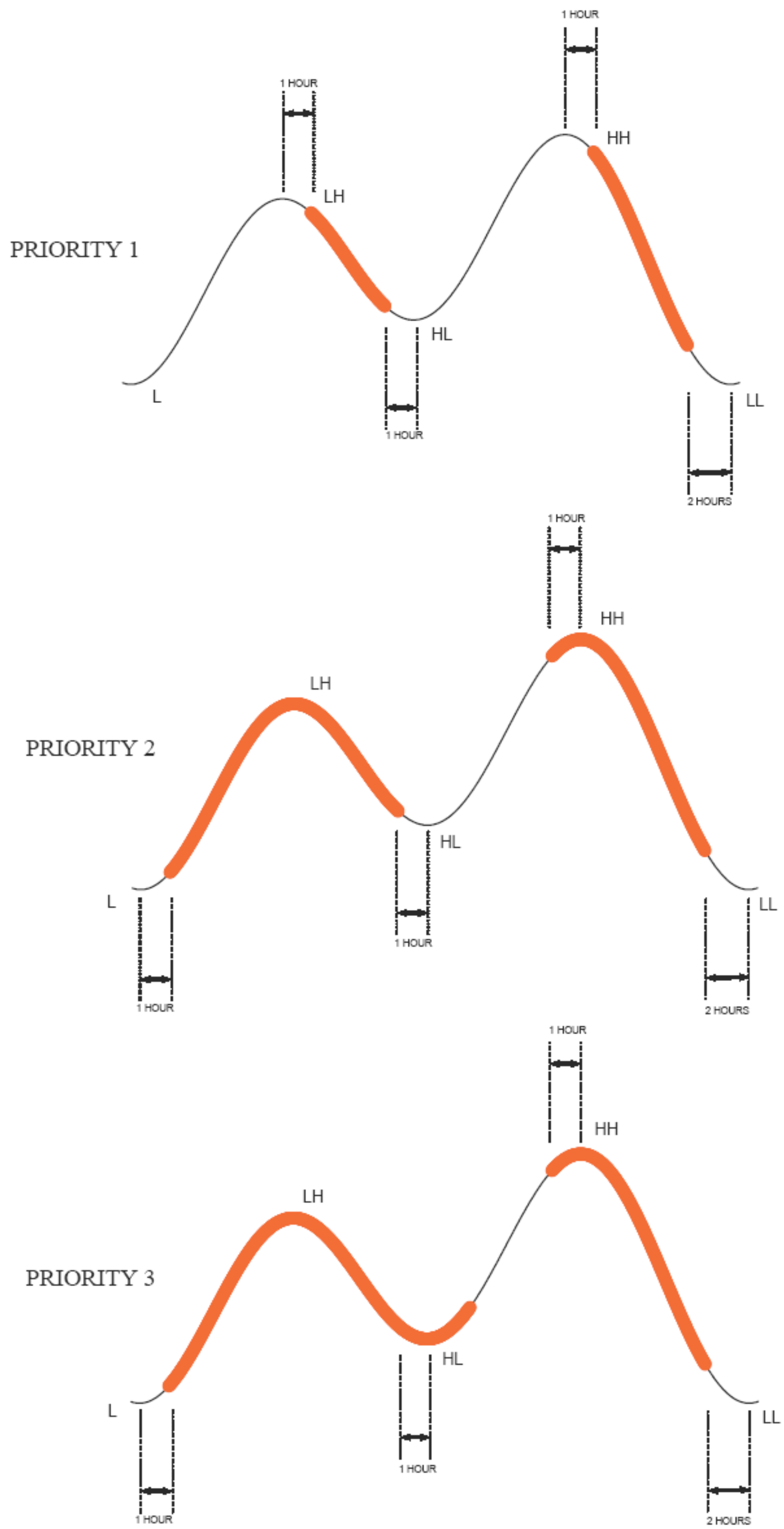

Figure 2-13 Clifton Court Gate Operations

Clifton Court Forebay Aquatic Weed Control Program

DWR will apply copper based herbicide complexes including copper sulfate pentahydrate, Komeen,® and Nautique® on an as-needed basis to control aquatic weeds and algal blooms in Clifton Court Forebay (Forebay). Komeen® is a chelated copper herbicide (copper-ethylenediamine complex and copper sulfate pentahydrate) and Nautique® is a copper carbonate compound (see Sepro product labels). These products are used to control algal blooms so that such algae blooms do not degrade drinking water quality through tastes and odors and production of algal toxins. Dense growth of submerged aquatic weeds, predominantly *Egeria densa*, can cause severe head loss and pump cavitation at Banks Pumping Plant when the stems of the rooted plant break free and drift into the trashracks. This mass of uprooted and broken vegetation essentially forms a watertight plug at the trashracks and vertical louver array. The resulting blockage necessitates a reduction in the pumping rate of water to prevent potential equipment damage through cavitation at the pumps. Cavitation creates excessive wear and deterioration of the pump impeller blades. Excessive floating weed mats also reduce the efficiency of fish salvage at the Skinner Fish Facility. Ultimately, this all results in a reduction in the volume of water diverted by the State Water Project.

Herbicide treatments will occur only in July and August on an as needed basis in the Forebay dependent upon the level of vegetation biomass in the enclosure. It is not possible to predict future Forebay conditions with climate change. However, the frequency of herbicide applications is not expected to occur more than twice per year. Herbicides are typically applied early in the growing season when plants are susceptible to the herbicides due to rapid growth and formation of plant tissues, or later in the season, when plants are mobilizing energy stores from their leaves towards their roots for over wintering senescence. Past use of aquatic herbicides is presented inTable 2-24.

Table 2-24 Aquatic herbicide applications in Clifton Court Forebay, 1995- Present.

Note: The past applications are provided to give the reader an indication of the frequency of herbicide applications in the past (baseline).

Year	Date	Aquatic Herbicide
1995	5/15/1995	Komeen®
1995	8/21/1995	Komeen®
1996	6/11/1996	Komeen®
1996	9/10/1996	Komeen®
1997	5/23/1997	Komeen®
1997	7/14/1997	Komeen®
1998	7/13/1998	Komeen®
1999	6/11/1999	Komeen®
2000	7/31/2000	Komeen®

Year	Date	Aquatic Herbicide
2001	6/29/2001	Nautique
2002	6/24/2002	Komeen®
2003	5/12/2003	Nautique
2003	8/13/2003	Copper Sulfate
2004	6/3/2004	Komeen®
2004	7/22/2004	Copper Sulfate
2005	5/3/2005	Komeen®
2005	6/21/2005	Komeen®
2006	6/1/2006	Komeen®
2006	6/29/2006	Komeen®

Additionally, copper sulfate pentahydrate was applied once in 2003 and 2004 by helicopter to control taste and odor producing benthic cyanobacteria.

Aquatic weed management problems in the Forebay have to date been limited to about 700 acres of the 2,180 total water surface acres. Application of the herbicide is limited to only those areas in the Forebay that require treatment. The copper based herbicides, Komeen® or Nautique, are applied by helicopter or boat to only those portions where aquatic weeds present a management problem to the State.

To date, algal problems in the Forebay have been caused by attached benthic cyanobacteria which produce unpleasant tastes and odors in the domestic drinking water derived from the SWP operations. Copper sulfate is applied to the nearshore areas of the Forebay when results of Solid phase microextraction (SPME) (APHA, 2005) analysis exceed the control tolerances (MIB < 5 ng/L and geosmin < 10 ng/L are not detected by consumers in drinking water supplies). (Aquatic Pesticide Application Plan, 2004). Highest biomass of taste and odor producing cyanobacteria was present in the nearshore areas but not limited to shallow benthic zone. Annually, application areas may vary considerably based on the extent of the algal infestation in the Forebay.

The DWR receives Clean Water Act pollutant discharge coverage under the National Pollutant Discharge Elimination System (NPDES) Permit No. CAG990005 (General Permit) issued by the State Water Resources Control Board (State Board) for application of aquatic pesticides to the State Water Project's (SWP) aqueducts, forebays, and reservoirs when necessary to achieve management goals. The State Board functions as the Environmental Protection Agency's (EPA) non-federal representative for implementation of the Clean Water Act in California.

A Mitigated Negative Declaration was prepared by DWR to comply with California Environmental Quality Act (CEQA) requirements associated with regulatory requirements established by the SWRCB. DWR, a public entity, was granted a Section 5.3 Exception by the

SWRCB (Water Quality Order 2004-0009-DWQ) and is not required to meet the copper limitation in receiving waters during the exception period from March 1 to November 30 as described in the DWR's Aquatic Pesticide Application Plan. DWR's Mitigated Negative Declaration was reviewed by DFG and no comments were submitted. However, to date, neither DWR nor the State Board has engaged the Services in section 7 consultations regarding the adverse impacts of the aquatic weed control program on listed fish species within the Forebay as a result of actions undertaken under the authority of DWR's NPDES permit.

Proposed Measures to Reduce Fish Mortality

Komeen® will be applied according to the product label directions as required by state and federal law. The Forebay elevation will be raised to +2 feet above mean sea level for an average depth of about 6 feet within the 700-water surface acre treatment zone. The herbicide will be applied at a rate of 13 gallons per surface acre to achieve a final operational concentration in the water body of 0.64 mg/L Cu^{2+}. (640 ppb). Application rate of 13 gallons per surface area is calculated based on mean depth. The product label allows applications up to 1 mg/L (1000 ppb or 1 ppm). DWR applies Komeen in accordance with the specimen label that states, "If treated water is a source of potable water, the residue of copper must not exceed 1 ppm (mg/L)".

In 2005, 770 surface acres were treated with Komeen®. Clifton Court Forebay has a mean depth of 6 feet at 2 feet above mean sea level; thus the volume treated is 4620 acre-feet.

The concentration of the active ingredient (Cu^{2+}) is calculated from the following equation:

Cu^{2+} (ppm) = Komeen (gallon)/ (Mean Depth (feet) * 3.34)) Source: Komeen® Specimen Label EPA reg No. 67690-25

The calculated concentration of Cu^{2+} for the 2005 application was 0.65 mg/L Cu^{2+}. The copper level required to control *Egeria densa* (the main component of the Clifton Court Forebay aquatic plant community) is 0.5 - 0.75 mg/L Cu^{2+}. Source: Komeen® Specimen Label.

Prior to application of copper based herbicides, toxicity testing and literature review of LC-50 levels for salmon, steelhead, delta smelt, and green sturgeon may be conducted upon consultation with fisheries agency staff.Once applied, the initial stock copper concentration is reduced rapidly (hours) by dilution (Komeen® applied according to the Specimen Label (SePro Corporation) of the product in the receiving water to achieve final concentration levels. Based on the treatment elevation of +2 feet, only about 20 percent (4,630 AF) of the 22,665 AF Forebay will be treated (AF = Acre-feet= volume). The copper will be applied beginning on one side of the Forebay allowing fish to move out of the treatment area. In addition, Komeen® will be applied by boats at a slower rate than in previous years when a helicopter was used.

In 2006 DWR proposed the following actions to reduce fish mortality in coordination with DFG and NOAA/NMFS. Also, the hydroacoustical aquatic plant survey was continued in 2007 when no Komeen application was done. A survey in 2008 is also planned. These actions will continue to be followed in the future.

1. Komeen® or copper sulfate will not be applied prior to July 1.
2. The salvage of listed fish species at Skinner Fish Facility will be monitored prior to the Komeen® application.

3. The intake (radial) gates at Clifton Court Forebay will be closed 24 hours prior to the scheduled application to improve fish passage out of the designated treatment areas.

4. The radial gates will not be re-opened to allow inflow into the Forebay for 24 hours following the end of the aquatic herbicide application. The Clifton Court intake gates will therefore be closed for 48 hours. The Komeen® Specimen Label recommends a 12-24 hours contact with target weeds to provide effective control. Twenty-four hours is at the high end for recommended contact time according to the Komeen® Specimen Label.

5. Komeen® will be applied by boat, first to the nearshore areas and then outwards in transects away from the shore. The application will be conducted by a private contractor and supervised by a California Certified Pest Control Advisor.

6. The herbicide treatment will be scheduled and planned for minimizing the treatment area by using hydroacoustical plant mapping technology to locate and estimate the area of submerged vegetation beds. The smallest possible area will be treated to minimize both the volume of aquatic herbicide applied and lessen the impacts to fish in the Forebay. Examples of figures from the 2005 hydroacoustical survey are enclosed.

7. Copper monitoring and analysis will follow the procedures described in the DWR Quality Assurance Project Plan submitted to the State Water Resources Control Board in February 2002. There are no plans to measure sediment and detrial copper concentrations. The Quality Assurance Plan was submitted to the SWRCB on February 26, 2002 and no comments were received.

Alternative Weed Control Options

DWR has evaluated both mechanical and non-copper based chemicals in Clifton Court Forebay. In 2007, no aquatic herbicides were applied to the Forebay and a mechanical harvester was operated for 27 days in July and August. Harvesting reduced the standing crop of floating pondweed (*Potamogeton nodosus*) but has the potential to cause stem fragmentations in *Egeria densa* and disperse the plant. In 2006, the harvester was operated for six days.

In 1999, DWR and SePro tested the non-copper based aquatic pesticide, Sonar™ (SRP) in four 10-acre test plots. Fluridone is the active ingredient in Sonar. The efficacy was evaluated one month after application by comparing weed density in the treated plots to untreated controls. We found no significant reduction in aquatic plants within the Sonar™ treated plots. Although Sonar™ has been effective in a number of lakes, the short residence time in Clifton Court and high water movements combined to reduce its efficacy in the Forebay. In 2000, DWR and SePro treated one 50-acre test plot again using the granular Sonar™. Due to the high movement of the water and high wind conditions, the results were similar to 1999. Repeated applications of Sonar (e.g. weekly) would be required to maintain the target concentration of Fluridone.

Sonar is now available in a new formulation (Q) that might prove effective with the short residence time in Clifton Court. DWR is evaluating this new formulation which could provide multi-year control of aquatic weeds in the Forebay. Department of Boating and Waterways used Sonar in their *Egeria densa* Control Program (EDCP) and reported (1) no degradation of Delta water quality following treatments; (2) minimal persistent concentrations of chemicals following treatments (most far below labeled rates, application concentrations, and guiding standards); and

(3) less than significant adverse toxicity effects on test organisms used by EDCP contract laboratories.

There are no alternative treatments to copper sulfate for algae that are effective at controlling taste and odor producing cyanobacteria.

Notification of Other Agencies

Fish and Game has been notified of the application and outage (period of interruption in pumping at H.O. Banks Delta Pumping Plant) dates and times.

North Bay Aqueduct Intake at Barker Slough

The Barker Slough Pumping Plant diverts water from Barker Slough into the North Bay Aqueduct (NBA) for delivery in Napa and Solano Counties. Maximum pumping capacity is 175 cfs (pipeline capacity). During the past few years, daily pumping rates have ranged between 0 and 140 cfs. The current maximum pumping rate is 140 cfs because an additional pump is required to be installed to reach 175 cfs. In addition, growth of biofilm in a portion of the pipeline is also limiting the NBA ability to reach its full capacity.

The NBA intake is located approximately 10 miles from the main stem Sacramento River at the end of Barker Slough. Per salmon screening criteria, each of the ten NBA pump bays is individually screened with a positive barrier fish screen consisting of a series of flat, stainless steel, wedge-wire panels with a slot width of 3/32 inch. This configuration is designed to exclude fish approximately one inch or larger from being entrained. The bays tied to the two smaller units have an approach velocity of about 0.2 ft/s. The larger units were designed for a 0.5 ft/s approach velocity, but actual approach velocity is about 0.44 ft/s. The screens are routinely cleaned to prevent excessive head loss, thereby minimizing increased localized approach velocities.

Delta smelt monitoring was required at Barker Slough under the March 6, 1995 OCAP BO. Starting in 1995, monitoring was required every other day at three sites from mid-February through mid-July, when delta smelt may be present and continued monitoring was stopped in 2005. As part of the Interagency Ecological Program (IEP), DWR has contracted with the DFG to conduct the required monitoring each year since the BO was issued. Details about the survey and data are available on DFG’s website (http://www.delta.dfg.ca.gov/data/NBA).

A recent review by the IEP indicates that the present NBA monitoring program is not very effective for the management of delta smelt. Data from the first nine years of monitoring show that catch of delta smelt in Barker Slough has been consistently very low, an average of just five percent of the values for nearby north Delta stations (Cache, Miner and Lindsey sloughs)(10-45); thus the monitoring was stopped in 2005. These results are discussed in further detail in Chapter 13 which is titled Delta Effects.

Based on these findings, the Delta Smelt Working Group recommended a broader regional survey during the primary period when delta smelt are most vulnerable to water project diversions. Beginning in 2008, the NBA larval sampling will be replaced by an expanded 20 mm survey (described at http://www.delta.dfg.ca.gov/data/20mm) that has proven to be fairly effecting and tracking delta smelt distribution and reducing entrainment. The expanded survey covers all existing 20-mm stations, in addition to a new suite of stations near NBA. The expanded survey also has an earlier seasonal start and stop date to focus on the presence of larvae in the Delta. The gear type was a surface boom tow, as opposed to oblique sled tows that have traditionally been used to sample larval fishes in the San Francisco Estuary.

Coordinated Facilities of the CVP and SWP

Joint Project Facilities

Suisun Marsh

Since the early 1970's, the California Legislature, SWRCB, Reclamation, DFG, Suisun Resource Conservation District (SRCD), DWR, and other agencies have worked to preserve beneficial uses of Suisun Marsh in mitigation for perceived impacts of reduced Delta Outflow on the salinity regime. Early on, salinity standards set by the State Water Resources Control Board (SWRCB) to protect alkali bulrush production, a primary waterfowl plant food. The most recent standard under Water Right Decision 1641 acknowledges that multiple beneficial uses deserve protection.

A contractual agreement between DWR, Reclamation, DFG and SRCD contains provisions for DWR and Reclamation to mitigate the effects on Suisun Marsh channel water salinity from the SWP and CVP operations and other upstream diversions. The Suisun Marsh Preservation Agreement (SMPA) requires DWR and Reclamation to meet salinity standards (Figure 2-14), sets a timeline for implementing the Plan of Protection, and delineates monitoring and mitigation requirements. In addition to the contractual agreement, SWRCB Water Rights Decision 1485 codified salinity standards in 1978, which have been carried forward to SWRCB Water Rights Decision 1641.

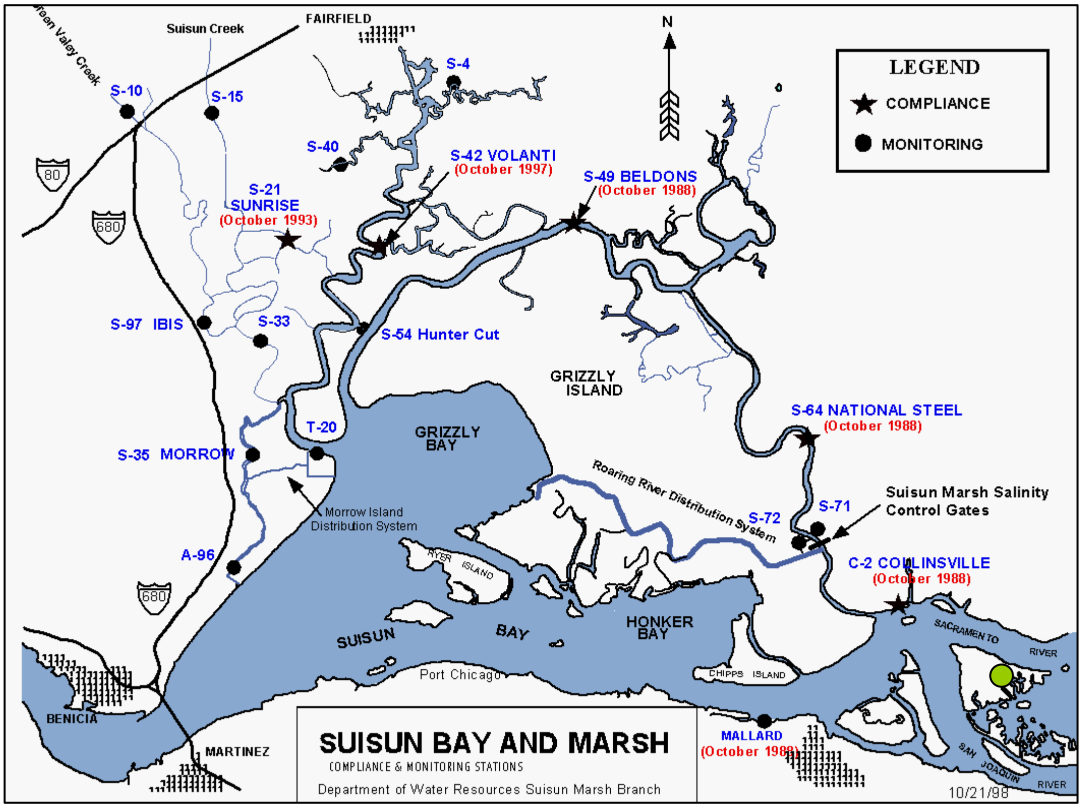

Figure 2-14 Compliance and monitoring stations and salinity control facilities in Suisun Marsh.

There are two primary physical mechanisms for meeting salinity standards set forth in D-1641 and the SMPA: (1) the implementation and operation of physical facilities in the Marsh; and (2) management of Delta outflow (i.e. facility operations are driven largely by salinity levels upstream of Montezuma Slough and salinity levels are highly sensitive to Delta outflow). Physical facilities (described below) have been operating since the early 1980s and have proven to be a highly reliable method for meeting standards. However, since Delta outflow cannot be actively managed by the Suisun Marsh Program, Marsh facility operations must be adaptive in response to changing salinity levels in the Delta.

CALFED Charter for Development of an Implementation Plan for Suisun Marsh Wildlife Habitat Management and Preservation

The goal of the CALFED Charter is to develop a regional plan that balances implementation of the CALFED Program, Suisun Marsh Preservation Agreement, and other management and restoration programs within Suisun Marsh. This is to be conducted in a manner that is responsive to the concerns of stakeholders and based upon voluntary participation by private land owners. The Habitat Management, Preservation, and Restoration Plan for the Suisun Marsh (Suisun Marsh Plan) and its accompanying Programmatic Environmental Impact Statement/Report (PEIS/EIR) will develop, analyze, and evaluate potential effects of various actions in the Suisun Marsh. The actions are intended to preserve and enhance managed seasonal wetlands, implement a comprehensive levee protection/improvement program, and protect ecosystem and drinking water quality, while restoring habitat for tidal marsh-dependent sensitive species, consistent with the CALFED Bay-Delta Program's strategic goals and objectives. The FWS and Reclamation are NEPA co-leads while DFG is the lead state CEQA agency.

A complete list of participating agencies is provided below:

- Bureau of Reclamation (Reclamation)
- U.S. Fish & Wildlife Service (FWS)
- California Department of Fish and Game (DFG)
- Suisun Resource Conservation District (SRCD)
- California Department of Water Resources (DWR)
- U.S. Army Corps of Engineers (Corps)
- NOAA National Marine Fisheries Service (NMFS)
- San Francisco Bay-Delta Science Consortium (Bay-Delta Consortium)
- California Bay-Delta Authority (CBDA)
- CALFED Ecosystem Restoration, Levees, Drinking Water, and Science Programs
- Bay Conservation and Development Commission (BCDC)
- US Geological Survey (USGS) Suisun Resource Conservation District

Suisun Marsh Salinity Control Gates

The SMSCG are located on Montezuma Slough about 2 miles downstream from the confluence of the Sacramento and San Joaquin Rivers, near Collinsville. Operation of the SMSCG began in October 1988 as Phase II of the Plan of Protection for the Suisun Marsh. The objective of Suisun Marsh Salinity Control Gate operation is to decrease the salinity of the water in Montezuma Slough The facility, spanning the 465 foot width of Montezuma Slough, consists of a boat lock, a series of three radial gates, and removable flashboards. The gates control salinity by restricting the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retaining lower salinity Sacramento River water from the previous ebb tide. Operation of the gates in this fashion lowers salinity in Suisun Marsh channels and results in a net movement of water from east to west.

When Delta outflow is low to moderate and the gates are not operating, tidal flow past the gate is approximately +/- 5,000-6,000 cfs while the net flow is near zero. When operated, flood tide flows are arrested while ebb tide flows remain in the range of 5,000-6,000 cfs. The net flow in Montezuma Slough becomes approximately 2,500-2,800 cfs. The Corps of Engineers permit for operating the SMSCG requires that it be operated between October and May only when needed to meet Suisun Marsh salinity standards. Historically, the gate has been operated as early as October 1, while in some years (e.g. 1996) the gate was not operated at all. When the channel water salinity decreases sufficiently below the salinity standards, or at the end of the control season, the flashboards are removed and the gates raised to allow unrestricted movement through Montezuma Slough. Details of annual gate operations can be found in “Summary of Salinity Conditions in Suisun Marsh During Water Years 1984-1992" (DWR, 1994b), or the “Suisun Marsh Monitoring Program Data Summary” produced annually by DWR, Division of Environmental Services.

The approximately 2,800 cfs net flow induced by SMSCG operation is effective at moving the salinity downstream in Montezuma Slough. Salinity is reduced by roughly one-hundred percent at Beldons Landing, and lesser amounts further west along Montezuma Slough. At the same time, the salinity field in Suisun Bay moves upstream as net Delta outflow (measured nominally at Chipps Island) is reduced by gate operation (Figure 2-15). Net outflow through Carquinez Strait is not affected. Figure 2-15 indicates the approximate position of X2 and how is transported upstream when the gate is operated.

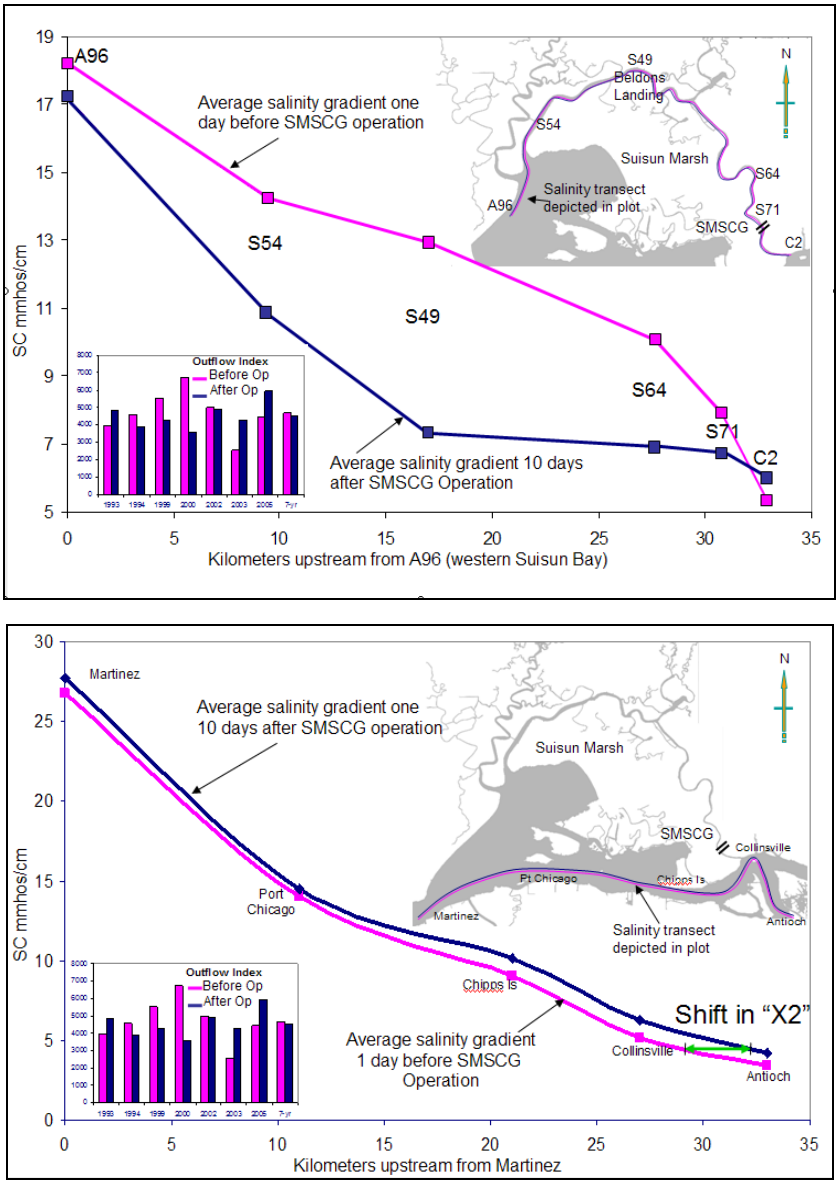

Figure 2-15 Average of seven years salinity response to SMSCG gate operation in Montezuma Slough and Suisun Bay.

Note: Magenta line is salinity profile 1 day before gate operation, blue line is salinity 10 days after gate operation.

It is important to note that historical gate operations (1988 – 2002) were much more frequent than recent and current operations (2006 – May 2008). Operational frequency is affected by many drivers (hydrologic conditions, weather, Delta outflow, tide, fishery considerations, etc). The gates have also been operated for scientific studies. Figure 2-16 shows that the gates were operated between 60 and 120 days between October and December during the early years (1988-

2004). Salmon passage studies between 1998 and 2003 increased the number of operating days by up to 14 to meet study requirements. After discussions with NMFS based on study findings, the boat lock portion of the gate is now held open at all times during SMSCG operation to allow for continuous salmon passage opportunity. With increased understanding of the effectiveness of the gates in lowering salinity in Montezuma Slough, salinity standards have been met with less frequent gate operation since 2006. Figure 3 shows that despite very low outflow in the fall of the two most recent water years, gate operation was not required at all in fall 2007 and was limited to 17 days in winter 2008. Assuming no significant, long-term changes in the drivers mentioned above, this level of operational frequency (10 – 20 days per year) can generally be expected to continue to meet standards in the future except perhaps during the most critical hydrologic conditions and/or other conditions that affect Delta outflow.

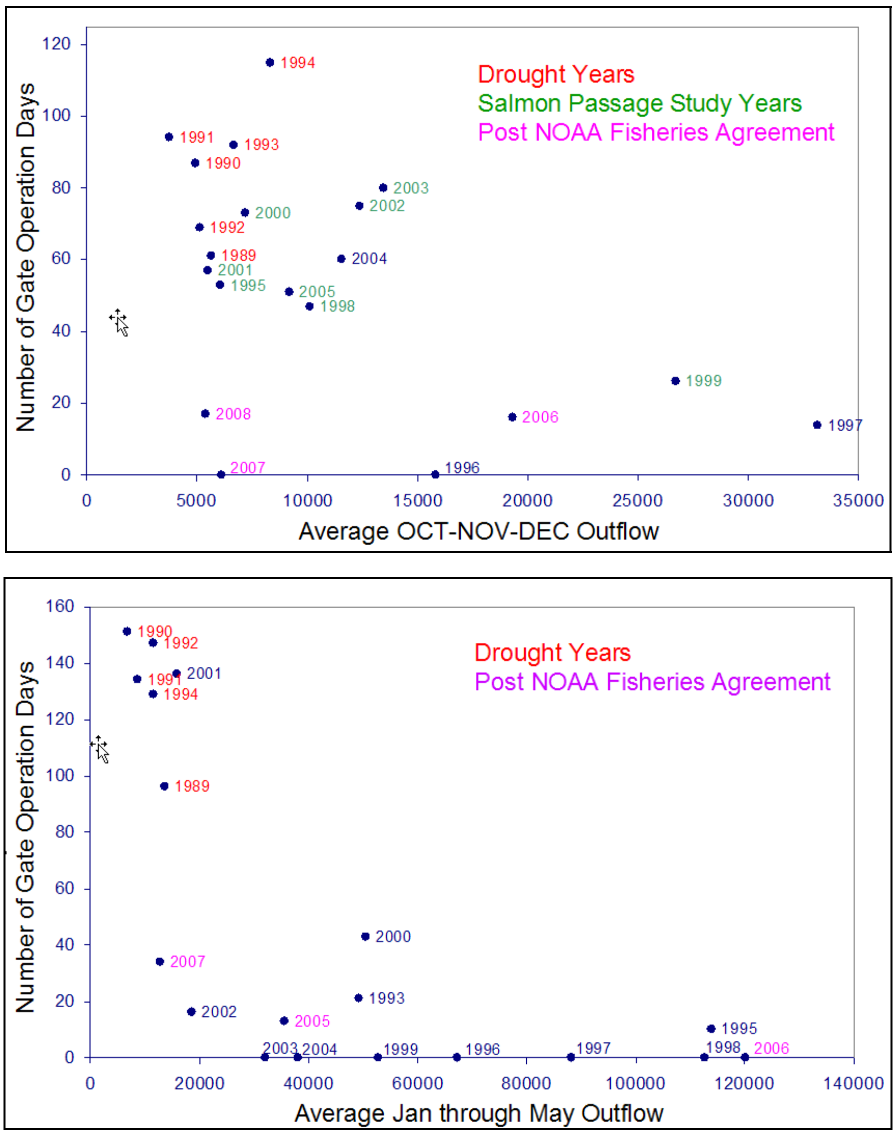

Figure 2-16 SMSCG operation frequency versus outflow since 1988.

SMSCG Fish Passage Study

The SMSCG were constructed and operate under Permit 16223E58 issued by the Corps, which includes a special condition to evaluate the nature of delays to migrating fish. Ultrasonic telemetry studies in 1993 and 1994 showed that the physical configuration and operation of the gates during the Control Season have a negative effect on adult salmonid passage (Tillman et al 1996: Edwards et al 1996).

The Department coordinated additional fish passage studies in 1998, 1999, 2001, 2002, 2003, and 2004. Migrating adult fall-run Chinook salmon were tagged and tracked by telemetry in the vicinity of the SMSCG to assess potential measures to increase the salmon passage rate and decrease salmon passage time through the gates.

Results in 2001, 2003, and 2004 indicate that leaving the boat-lock open during the Control Season when the flashboards are in place at the SMSCG and the radial gates are tidally operated provides a nearly equivalent fish passage to the Non-Control Season configuration when the flashboards are out and the radial gates are open. This approach minimizes delay and blockage of adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead migrating upstream during the Control Season while the SMSCG is operating. However, the boat-lock gates may be closed temporarily to stabilize flows to facilitate safe passage of watercraft through the facility.

Reclamation and DWR are continuing to coordinate with the SMSCG Steering Committee in identifying water quality criteria, operational rules, and potential measures to facilitate removal of the flashboards during the Control Season that would provide the most benefit to migrating fish. However, the flashboards would not be removed during the Control Season unless it was certain that standards would be met for the remainder of the Control Season without the flashboards installed.

Roaring River Distribution System

The Roaring River Distribution System (RRDS) was constructed during 1979 and 1980 as part of the Initial Facilities in the Plan of Protection for the Suisun Marsh. The system was constructed to provide lower salinity water to 5,000 acres of private and 3,000 acres of DFG managed wetlands on Simmons, Hammond, Van Sickle, Wheeler, and Grizzly Islands.

The RRDS includes a 40-acre intake pond that supplies water to Roaring River Slough. Motorized slide gates in Montezuma Slough and flap gates in the pond control flows through the culverts into the pond. A manually operated flap gate and flashboard riser are located at the confluence of Roaring River and Montezuma Slough to allow drainage back into Montezuma Slough for controlling water levels in the distribution system and for flood protection. DWR owns and operates this drain gate to ensure the Roaring River levees are not compromised during extremely high tides.

Water is diverted through a bank of eight 60-inch-diameter culverts equipped with fish screens into the Roaring River intake pond on high tides to raise the water surface elevation in RRDS above the adjacent managed wetlands. Managed wetlands north and south of the RRDS receive water, as needed, through publicly and privately owned turnouts on the system.

The intake to the RRDS is screened to prevent entrainment of fish larger than approximately 25 mm. DWR designed and installed the screens based on DFG criteria. The screen is a stationary vertical screen constructed of continuous-slot stainless steel wedge wire. All screens have 3/32-inch slot openings. After the listing of delta smelt, RRDS diversion rates have been controlled to maintain an average approach velocity below 0.2 ft/s at the intake fish screen. Initially, the intake culverts were held at about 20 percent capacity to meet the velocity criterion at high tide. Since 1996, the motorized slide gates have been operated remotely to allow hourly adjustment of gate openings to maximize diversion throughout the tide.

Routine maintenance of the system is conducted by DWR and primarily consists of maintaining the levee roads and fish screens. RRDS, like other levees in the marsh, have experienced subsidence since the levees were constructed in 1980. In 1999, DWR restored all 16 miles of levees to design elevation as part of damage repairs following the 1998 flooding in Suisun Marsh. In 2006, portions of the north levee were repaired to address damage following the January 2006 flooding.

Morrow Island Distribution System

The Morrow Island Distribution System (MIDS) was constructed in 1979 and 1980 in the south-western Suisun Marsh as part of the Initial Facilities in the Plan of Protection for the Suisun Marsh. The contractual requirement for the Reclamation and DWR is to provide water to the ownerships so that lands may be managed according to approved local management plans.The system was constructed primarily to channel drainage water from the adjacent managed wetlands for discharge into Suisun Slough and Grizzly Bay. This approach increases circulation and reduces salinity in Goodyear Slough (GYS).

The MIDS is used year-round, but most intensively from September through June. When managed wetlands are filling and circulating, water is tidally diverted from Goodyear Slough just south of Pierce Harbor through three 48-inch culverts. Drainage water from Morrow Island is discharged into Grizzly Bay by way of the C-Line Outfall (two 36-inch culverts) and into the mouth of Suisun Slough by way of the M-Line Outfall (three 48-inch culverts), rather than back into Goodyear Slough. This helps prevent increases in salinity due to drainage water discharges into Goodyear Slough. The M-Line ditch is approximately 1.6 miles in length and the C-Line ditch is approximately 0.8 miles in length.

The 1997 FWS BO issued for dredging of the facility included a requirement for screening the diversion to protect delta smelt. Due to the high cost of fish screens and the lack of certainty surrounding their effectiveness at MIDS, DWR and Reclamation proposed to investigate fish entrainment at the MIDS intake with regard to fishery populations in Goodyear Slough and to evaluate whether screening the diversion would provide substantial benefits to local populations of listed fish species. DWR staff monitored fish entrainment from September 2004 to June 2006 at the MIDS in Suisun Marsh (Figure 1) to evaluate entrainment losses at the facility. Monitoring took place over several months under various operational configurations to provide data on the site-specific impact of the MIDS diversion with a focus on delta smelt and salmonids. Over 20 different species were identified during the sampling, yet only two fall-run sized Chinook salmon (south intake, 2006) and no delta smelt from entrained water were caught. Two species that associate with instream structures, threespine stickleback and prickly sculpin, comprised most of the entrained fish. DWR and Reclamation staff will continue coordination with the fishery agencies to address the screening requirement.

Reclamation and DWR continue to coordinate with FWS, NMFS, and DFG regarding fish entrainment at this facility. The objective remains to provide the greatest benefit for aquatic species in Suisun Marsh. Studies suggest that GYS is a marginal, rarely used habitat for special-status fishes. Therefore, implementation and/or monitoring of a tidal restoration project elsewhere is emerging as the most beneficial and practical approach (in lieu of installing and maintaining fish screens). Restoration of tidal wetland ecosystems is expected to aid in the recovery of several listed and special status species within the marsh and improve food availability for delta smelt and other pelagic organisms.

To meet contractual commitments, the typical MIDS annual operation includes the actions described below. There are currently no plans to modify operations.

Preseason Fill

Approximately three weeks prior to waterfowl hunting season (mid to late October through mid to late January), the intake structure is open 35% to 60% to initially fill the MIDS. As the system of ditches fills, individual owners fill their ponds to desired water levels with water from the system and GYS, as needed.

Circulation Drain/Fill

During waterfowl hunting season, the intake structure is partially to fully open in order for individual landowners to circulate water through waterfowl ponds and to maintain appropriate water levels during the hunting season. In the event of high tides and/or significant storm events, the intakes may be closed as needed to reduce the risk of levee failure.

End-of-Season Drain

Following waterfowl hunting season, the intake structure is closed in order to deeply drain the waterfowl ponds through the MIDS outfall structures to Grizzly Bay.

End-of-Season Leaching

Following the end-of-season drain, the intake structure is partially open in order to provide water for individual landowners to circulate through waterfowl ponds to remove salt accumulated during the waterfowl hunting season.

Brood Pond Circulation

Except for leaching cycles, the MIDS intake structure is partially to fully open in order for individual landowners to circulate water through waterfowl ponds and to maintain appropriate salinity levels to create duck breeding areas.

Maintenance Drain

During late spring to September 15, the MIDS intake structure is closed to allow landowners to drain their waterfowl ponds in preparation for summer maintenance activities.

Goodyear Slough Outfall

The Goodyear Slough Outfall was constructed in 1979 and 1980 as part of the Initial Facilities. A channel approximately 69 feet wide was dredged from the south end of Goodyear Slough to Suisun Bay (about 2,800 feet). The excavated material was used for levee construction. The control structure consists of four 48-inch culverts with flap gates on the bay side. On ebb tides, Goodyear

Slough receives watershed runoff from Green Valley Creek and, to a lesser extent, Suisun Creek. The system was designed to draw creek flow south into Goodyear Slough, and thereby reduce salinity, by draining water one-way from the lower end of Goodyear Slough into Suisun Bay on the ebb tide. The one-way flap gates at the Outfall close on flood tide keeping saltier bay water from mixing into the slough. The system creates a small net flow in the southerly direction overlaid on a larger, bi-directional tidal flow. The system provides lower salinity water to the wetland managers who flood their ponds with Goodyear Slough water. Another initial facility, the Morrow Island Distribution System, diverts from Goodyear slough and receives lower salinity water. Since the gates are passively operated (in response to water surface elevation differentials) there are no operations schedules or records. The system is open for free fish movement except very near the Outfall when flap gates are closed during flood tides.

South Delta Temporary Barriers Project

The South Delta Temporary Barrier Project (TBP) was initiated by DWR in 1991. Permit extensions were granted in 1996 and again in 2001, when DWR obtained permits to extend the Temporary Barriers Project through 2007. The FWS has approved the extension of the permits through 2008. Continued coverage by FWS for the TBP will be assessed under this OCAP BA for the operational effects and under a separate Section 7 consultation for the construction and demolition effects. The NMFS recently submitted a biological opinion to the Corps which provides incidental take coverage for the continuation of the TBP through 2010.

The project consists of four rock barriers across south Delta channels. In various combinations, these barriers improve water levels and San Joaquin River salmon migration in the south Delta. The existing TBP consists of installation and removal of temporary rock barriers at the following locations:

- Middle River near Victoria Canal, about 0.5 miles south of the confluence of Middle River, Trapper Slough, and North Canal
- Old River near Tracy, about 0.5 miles east of the DMC intake
- Grant Line Canal near Tracy Boulevard Bridge, about 400 feet east of Tracy Boulevard Bridge
- The head of Old River at the confluence of Old River and San Joaquin River

The barriers on Middle River, Old River near Tracy, and Grant Line Canal are flow control facilities designed to improve water levels for agricultural diversions and are in place during the growing season. Under the FWS BO for the Temporary Barriers, operation of the barriers at Middle River and Old River near Tracy can begin May 15, or as early as April 15 if the spring barrier at the head of Old River is in place. From May 16 to May 31 (if the barrier at the head of Old River is removed) the tide gates are tied open in the barriers in Middle River and Old River near Tracy. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

During the spring, the barrier at the head of Old River is designed to reduce the number of out-migrating salmon smolts entering Old River. During the fall, this barrier is designed to improve flow and DO conditions in the San Joaquin River for the immigration of adult fall-run Chinook salmon. The barrier at the head of Old River barrier is typically in place between April 15 to

May 15 for the spring, and between early September to late November for the fall. Installation and operation of the barrier also depends on San Joaquin flow conditions.

Proposed Installation and Operations of the Temporary Barriers

The installation and operation of the TBP will continue until the permanent gates are constructed. The proposed installation schedule through 2010 will be identical to the current schedule. However, because of recent court rulings to protect Delta smelt, the installation of the spring HOR barrier is prohibited for 2008. As a result, the agricultural barriers installations are delayed according to the current permits until mid-May.

To improve water circulation and quality, DWR in coordination with the South Delta Water Agency and Reclamation, began in 2007 to manually tie open the culvert flap gates at the Old River near Tracy barrier to improve water circulation and untie them when water levels fell unacceptably. This operation is expected to continue in subsequent years as needed to improve quality. Adjusting the barrier weir heights is being considered to improve water quality and circulation. DWR will consult with FWS and NMFS if changes in the height of any or all of the weirs are sought.

As the permanent gates are being constructed, temporary barrier operations will continue as planned and permitted. Because the permanent gates will not be constructed in the exact location of the temporary barriers, the temporary barriers can continue to be operated normally until the permanent gate structure that replaces it becomes operational. Computer model forecasts, real time monitoring, and coordination with local, State, and federal agencies and stakeholders will help determine if the temporary rock barriers operations need to be modified during the transition period.

Conservation Strategies and Mitigation Measures

Various measures and conditions required by regulatory agencies under past and current permits to avoid, minimize, and compensate for the TBP impacts have been complied with by DWR. An ongoing monitoring plan is implemented each year the barriers are installed and an annual monitoring report is prepared to summarize the activities. The monitoring elements include fisheries monitoring and water quality analysis, Head of Old River fish entrainment and Kodiak trawling study, salmon smolt survival investigations, barrier effects on SWP and CVP entrainment, Swainson's Hawk monitoring, water elevation, water quality sampling, and hydrologic modeling.

Past mitigation accomplished by DWR includes:

- installing and operating fish screens at Sherman Island,
- acquiring riparian scrub, shaded mudflat, shallow water habitat, and intertidal vegetation (*Mason's lilaeopsis*) at Kimball Island, and
- granting conservation easement to DFG at the Grizzly Slough for Swainson's hawk mitigation.

DWR will continue to meet the mitigation requirements of the TBP permits.

San Luis Complex

Water in the mainstem of the California Aqueduct flows south by gravity into the San Luis Joint-Use Complex (Figure 2-17), which was designed and constructed by the federal government and is operated and maintained by the DWR. This section of the California Aqueduct serves both the SWP and the federal CVP.

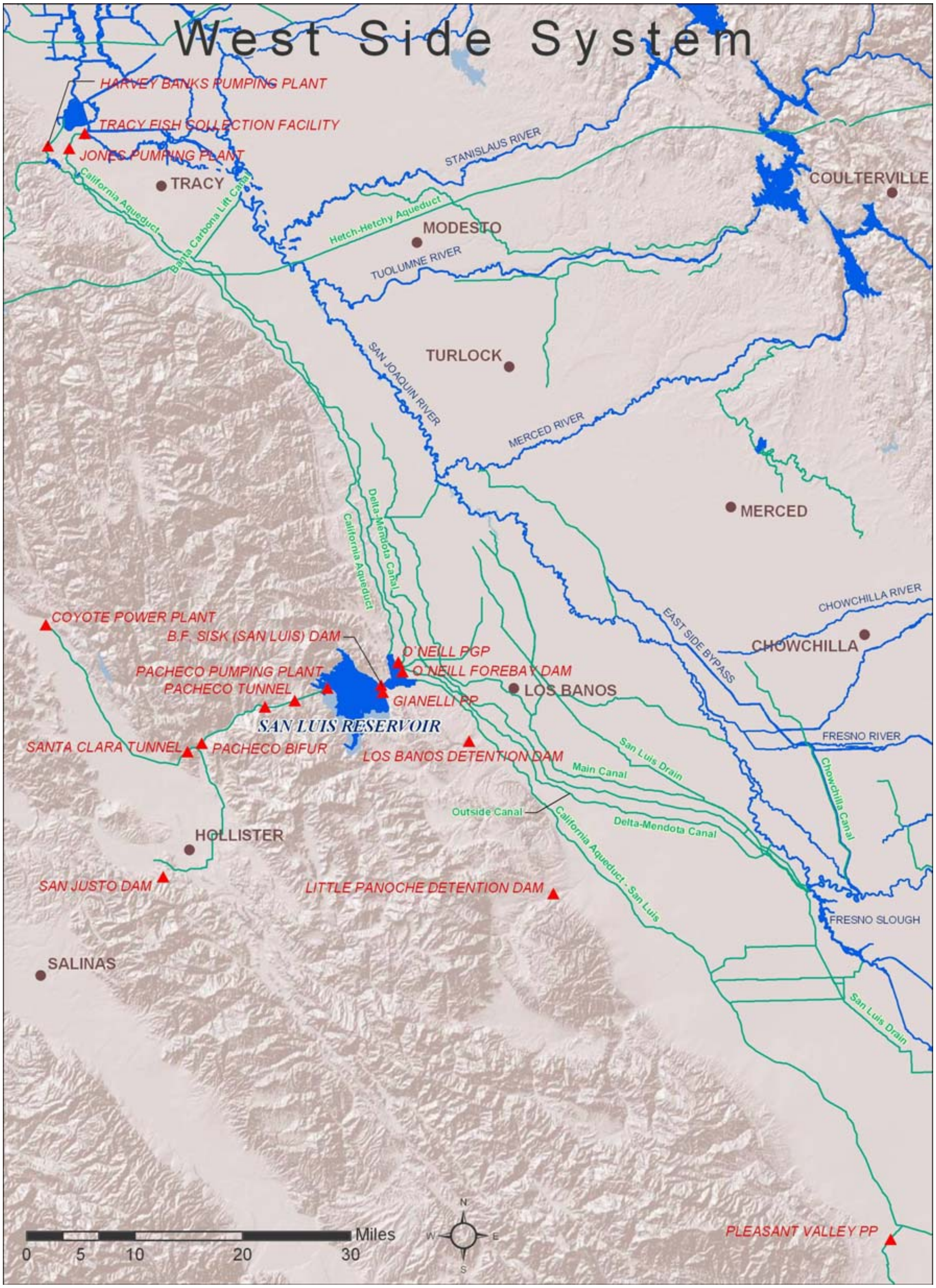

Figure 2-17 San Luis Complex

San Luis Reservoir, the nation’s largest offstream reservoir (it has no natural watershed), is impounded by Sisk Dam, lies at the base of the foothills on the west side of the San Joaquin

Valley in Merced County, about two miles west of O'Neill Forebay. The reservoir provides offstream storage for excess winter and spring flows diverted from the Delta. It is sized to provide seasonal carryover storage. The reservoir can hold 2,027,840 af, of which 1,062,180 af is the state's share, and 965,660 af is the federal share. Construction began in 1963 and was completed in 1967. Filled in 1969, the reservoir also provides a variety of recreational activities as well as fish and wildlife benefits.

In addition to the Sisk Dam, San Luis Reservoir and O'Neill Dam and Forebay, the San Luis Complex consists of the following: (1) O'Neill Pumping-Generating Plant (Federal facility); (2) William R. Gianelli Pumping-Generating Plant (joint Federal-State facilities); (3) San Luis Canal (joint Federal-State facilities); (4) Dos Amigos Pumping Plant (joint Federal-State facilities); (5) Coalinga Canal (Federal facility); (6) Pleasant Valley Pumping Plant (Federal facility); and (7) the Los Banos and Little Panoche Detention Dams and Reservoirs (joint Federal-State facilities).

The O'Neill Pumping-Generating Plant pumps water from the Delta-Mendota Canal to the O'Neill Forebay where it mixes with water from the California Aqueduct. From O'Neill Forebay, the water can either be pumped up into San Luis Reservoir via Gianelli Pumping-Generating Plant or leave via the San Luis Canal. The Dos Amigos Pumping Plant is located on the San Luis Canal and 18 miles southeast of Sisk Dam. It lifts water 113 feet from the Aqueduct as it flows south from O'Neill Forebay.

Los Banos Detention Dam and Reservoir provide flood protection for San Luis Canal, Delta Mendota Canal, the City of Los Banos, and other downstream developments. Between September and March, 14,000 af of space is maintained for flood control under specified conditions. Little Panoche Detention Dam and Reservoir provide flood protection for San Luis Canal, Delta Mendota Canal and other downstream developments. Water is stored behind the dam above dead storage of 315 af only during the period that inflow from Little Panoche Creek exceeds the capacity of the outlet works.

To provide water to CVP and SWP contractors: (1) water demands and anticipated water schedules for water service contractors and exchange contractors must be determined; (2) a plan to fill and draw down San Luis Reservoir must be made; and (3) Delta pumping and San Luis Reservoir use must be coordinated.

The San Luis Reservoir has very little natural inflow. Water is redirected during the fall, winter and spring months when the two pumping plants can divert more water from the Delta than is needed for scheduled demands. Because the amount of water that can be diverted from the Delta is limited by available water supply, Delta constraints, and the capacities of the two pumping plants, the fill and drawdown cycle of San Luis Reservoir is an extremely important element of Project operations.

Reclamation attempts to maintain adequate storage in San Luis Reservoir to ensure delivery capacity through Pacheco Pumping Plant to the San Felipe Division. Delivery capacity is significantly diminished as reservoir levels drop to the 326 ft elevation (79,000 acre-feet), the bottom of the lowest Pacheco Tunnel Inlet pipe. Lower reservoir elevations can also result in turbidity and algal treatment problems for the San Felipe Division water users. These conditions of reduced or impending interruption in San Felipe Division deliveries require operational responses by Santa Clara Valley Water District to reduce or eliminate water deliveries for in-stream and offstream groundwater recharge, and to manage for treatment plant impacts.

Depending on availability of local supplies, prolonged reduction or interruption in San Felipe Division deliveries may also result in localized groundwater overdraft.

A typical San Luis Reservoir annual operation cycle starts with the CVP's share of the reservoir storage nearly empty at the end of August. Irrigation demands decrease in September and the opportunity to begin refilling San Luis Reservoir depends on the available water supply in the northern CVP reservoirs and the pumping capability at Jones Pumping Plant that exceeds water demands. Jones Pumping Plant operations generally continue at the maximum diversion rates until early spring, unless San Luis Reservoir is filled or the Delta water supply is not available. As outlined in the Interior's Decision on Implementation of Section 3406 (b)(2) of the CVPIA, Jones Pumping Plant diversion rates may be reduced during the fill cycle of the San Luis Reservoir for fishery management.

In April and May, export pumping from the Delta is limited during the SWRCB D-1641 San Joaquin River pulse period standards as well as by the Vernalis Adaptive Management Program. During this same time, CVP-SWP irrigation demands are increasing. Consequently, by April and May the San Luis Reservoir has begun the annual drawdown cycle. In some exceptionally wet conditions, when excess flood water supplies from the San Joaquin River or Tulare Lake Basin occur in the spring, the San Luis Reservoir may not begin its drawdown cycle until late in the spring.

In July and August, the Jones Pumping Plant diversion is at the maximum capability and some CVP water may be exported using excess Banks Pumping Plant capacity as part of a Joint Point of Diversion operation. Irrigation demands are greatest during this period and San Luis continues to decrease in storage capability until it reaches a low point late in August and the cycle begins anew.

San Luis Unit Operation

The CVP operation of the San Luis Unit requires coordination with the SWP since some of its facilities are entirely owned by the State and others are joint State and Federal facilities. Similar to the CVP, the SWP also has water demands and schedules it must meet with limited water supplies and facilities. Coordinating the operations of the two projects avoids inefficient situations (for example, one entity pumping water at the San Luis Reservoir while the other is releasing water).

Total CVP San Luis Unit annual water supply is contingent on coordination with the SWP needs and capabilities. When the SWP excess capacity is used to support additional pumping for the CVP under the Joint Point of Diversion (JPOD) allowance (see section on JPOD, below), it may be of little consequence to SWP operations, but extremely critical to CVP operations. The availability of excess SWP capacity for the CVP is contingent on the ability of the SWP to meet its SWP contractors' water supply commitments. Generally, the CVP will utilize excess SWP capacity; however, there are times when the SWP may need to utilize excess CVP capacity. Additionally, close coordination by CVP and SWP is required during this type of operation to ensure that water pumped into O'Neill Forebay does not exceed the CVP's capability to pump into San Luis Reservoir or into the San Luis Canal at the Dos Amigos Pumping Plant.

Although secondary to water management concerns, power scheduling at the joint facilities also requires close coordination. Because of time-of-use power cost differences, both entities will likely want to schedule pumping and generation simultaneously. When facility capabilities of the two projects are limited, equitable solutions are achieved between the operators of the SWP and the CVP.

From time to time, coordination between the Projects is also necessary to avoid sustained rapid drawdown limit at San Luis Reservoir which can cause sloughing of the bank material into the reservoir, resulting in water quality degradation and requiring additional maintenance on the dam.

With the existing facility configuration, the operation of the San Luis Reservoir could impact the water quality and reliability of water deliveries to the San Felipe Division, if San Luis Reservoir is drawn down too low. Reclamation has an obligation to address this condition and may solicit cooperation from DWR, as long as changes in SWP operations to assist with providing additional water in San Luis Reservoir (beyond what is needed for SWP deliveries and the SWP share of San Luis Reservoir minimum storage) does not impact SWP allocations and/or deliveries. If the CVP is not able to maintain sufficient storage in San Luis Reservoir, there could be potential impacts to resources in Santa Clara and San Benito Counties. Solving the San Luis low point problem or developing an alternative method to deliver CVP water to the San Felipe Division would allow Reclamation to utilize the CVP share of San Luis Reservoir fully without impacting the San Felipe Division water supply. If Reclamation pursues changes to the operation of the CVP (and SWP), such changes would have to be consistent with the operating criteria of the specific facility. If alternate delivery methods for the San Felipe Division are implemented, it may allow the CVP to utilize more of it available storage in San Luis Reservoir, but may not change the total diversions from the Delta. For example, any changes in Delta pumping that would be the result of additional effective storage capacity in San Luis Reservoir would be consistent with the operating conditions for the Banks and Jones Pumping Plants.

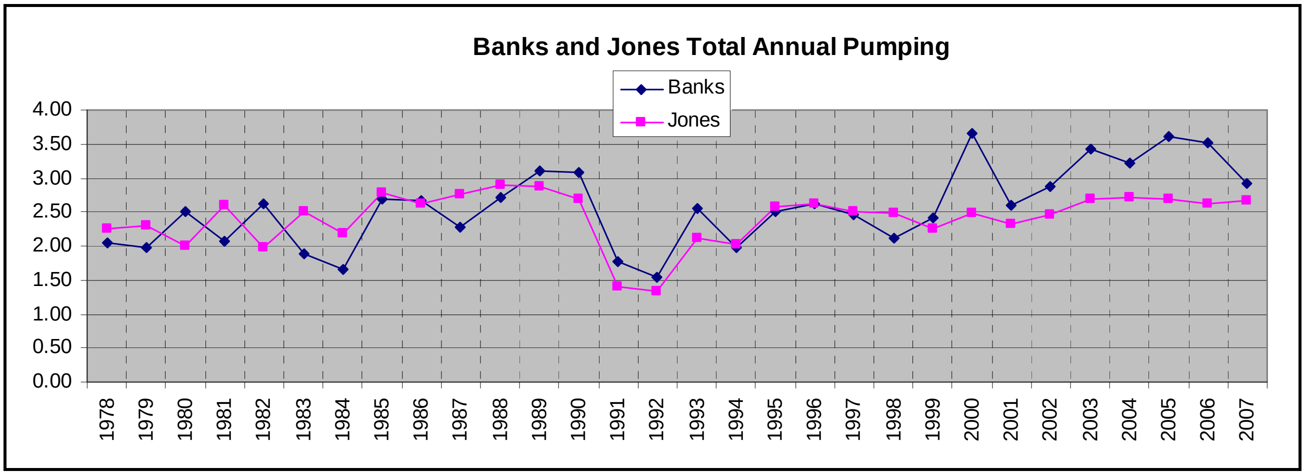

Figure 2-18 Total Annual Pumping at Banks and Jones Pumping Plant 1978-2007 (MAF)

Table 2-25 Total Annual Pumping at Banks and Jones Pumping Plant 1978-2007 (MAF)

WY	Hydrologic Index 40-30-30	Banks SWP	Banks CVP	Banks Total	Jones SWP	Jones CVP	Jones Total	Contra Costa	CVP Total Delta Pumping	SWP Total Delta Pumping	CVP SOD-Ag Allocation	Shasta Index Critical
1978	AN	2.01	0.04	2.05	0.00	2.26	2.26	0.08	2.38	2.01	100%	
1979	BN	1.76	0.23	1.98	0.00	2.30	2.30	0.09	2.61	1.76	100%	
1980	AN	2.17	0.34	2.52	0.00	2.00	2.00	0.09	2.43	2.17	100%	
1981	D	1.97	0.10	2.07	0.00	2.60	2.60	0.11	2.80	1.97	100%	
1982	W	2.43	0.20	2.63	0.00	1.97	1.97	0.08	2.25	2.43	100%	
1983	W	1.76	0.13	1.89	0.00	2.51	2.51	0.08	2.72	1.76	100%	
1984	W	1.40	0.25	1.65	0.00	2.19	2.19	0.10	2.54	1.40	100%	
1985	D	2.16	0.53	2.68	0.00	2.79	2.79	0.11	3.43	2.16	100%	
1986	W	2.46	0.21	2.67	0.00	2.62	2.62	0.11	2.94	2.46	100%	
1987	D	2.01	0.27	2.28	0.00	2.76	2.76	0.13	3.16	2.01	100%	
1988	C	2.32	0.38	2.71	0.00	2.90	2.90	0.14	3.42	2.32	100%	
1989	D	2.70	0.39	3.10	0.00	2.87	2.87	0.13	3.40	2.70	100%	
1990	C	2.85	0.24	3.09	0.00	2.70	2.70	0.14	3.07	2.85	50%	
1991	C	1.64	0.14	1.78	0.00	1.41	1.41	0.11	1.65	1.64	25%	C
1992	C	1.51	0.04	1.55	0.00	1.34	1.34	0.10	1.49	1.51	25%	C
1993	AN	2.53	0.02	2.56	0.00	2.11	2.11	0.10	2.22	2.53	50%	
1994	C	1.73	0.24	1.97	0.00	2.02	2.02	0.11	2.37	1.73	35%	C
1995	W	2.48	0.03	2.50	0.00	2.58	2.58	0.09	2.70	2.48	100%	
1996	W	2.60	0.01	2.61	0.06	2.57	2.63	0.10	2.68	2.66	95%	
1997	W	2.12	0.34	2.46	0.00	2.51	2.51	0.11	2.96	2.12	90%	
1998	W	2.07	0.04	2.11	0.01	2.46	2.47	0.16	2.66	2.09	100%	
1999	W	2.37	0.04	2.41	0.00	2.26	2.26	0.13	2.44	2.37	70%	
2000	AN	3.45	0.22	3.66	0.00	2.49	2.49	0.13	2.83	3.45	65%	
2001	D	2.37	0.23	2.60	0.01	2.31	2.32	0.10	2.65	2.38	49%	
2002	D	2.70	0.17	2.87	0.00	2.46	2.46	0.12	2.75	2.70	70%	
2003	AN	3.39	0.04	3.43	0.00	2.68	2.68	0.14	2.86	3.39	75%	
2004	BN	3.14	0.09	3.23	0.00	2.72	2.72	0.12	2.93	3.14	70%	
2005	AN	3.58	0.03	3.61	0.00	2.68	2.68	0.12	2.83	3.58	85%	
2006	W	3.50	0.01	3.51	0.00	2.62	2.62	0.12	2.74	3.50	100%	
2007	D	2.82	0.11	2.93	0.00	2.67	2.67	0.11	2.90	2.82	50%	

Source: CVO Operations Data Base

Transfers

California Water Law and the CVPIA promote water transfers as important water resource management measures to address water shortages provided certain protections to source areas and users are incorporated into the water transfer. Parties seeking water transfers generally acquire water from sellers who have surplus reservoir storage water, sellers who can pump groundwater instead of using surface water, or sellers who will fallow crops or substitute a crop that uses less water in order to reduce normal consumptive use of surface diversions.

Water transfers (relevant to this document) occur when a water right holder within the Delta or Sacramento-San Joaquin watershed undertakes actions to make water available for transfer by export from the Delta. With the exception of the flows pursuant to the Yuba River Accord, this BA does not address the upstream operations that may be necessary to make water available for transfer. Also, this document does not address the impacts of water transfers to terrestrial species. The flows for the Yuba River Accord may provide up to 60,000 acre feet annually for EWA, in the lower Yuba River (estimated to provide up to 48,000 acre feet of additional Delta export), and may provide additional water to the CVP and SWP and their contractors in drier years. The upstream effects of other transfers and effects to terrestrial species would require a separate ESA consultation with FWS and/or NMFS.

Transfers requiring export from the Delta are done at times when pumping and conveyance capacity at the CVP or SWP export facilities is available to move the water. Additionally, operations to accomplish these transfers must be carried out in coordination with CVP and SWP operations, such that the capabilities of the Projects to exercise their own water rights or to meet their legal and regulatory requirements are not diminished or limited in any way. Exports for transfers would have to be consistent with the terms of the OCAP biological opinions and could not infringe upon the capability of the Projects to comply with the terms of the opinions.

In particular, parties to the transfer are responsible for providing for any incremental changes in flows required to protect Delta water quality standards. All transfers will be in accordance with all existing regulations and requirements.

Purchasers of water for water transfers may include Reclamation, DWR, SWP contractors, CVP contractors, other State and Federal agencies, or other parties. DWR and Reclamation have operated water acquisition programs in the past to provide water for environmental programs and additional supplies to SWP contractors, CVP contractors, and other parties. The DWR programs include the 1991, 1992, and 1994 Drought Water Banks and Dry Year Programs in 2001 and 2002. Reclamation operated a forbearance program in 2001 by purchasing CVP contractors' water in the Sacramento Valley for CVPIA in-stream flows, and to augment water supplies for CVP contractors south of the Delta and wildlife refuges. Reclamation administers the CVPIA Water Acquisition Program for Refuge Level 4 supplies and fishery in-stream flows. The CALFED Ecosystem Restoration Program (ERP) will, in the future, acquire water for fishery and ecosystem restoration. DWR, and potentially Reclamation in the future, has agreed to participate in a Yuba River Accord that will provide fish flows on the Yuba River and also water supply that may be transferred at DWR and Reclamation Delta Facilities. It is anticipated that Reclamation will join in the Accord and fully participate in the Yuba Accord upon completion of this consultation. The Yuba River Accord water would be transferred to offset VAMP water costs.

Also in the past, CVP and SWP contractors have also independently acquired water and arranged for pumping and conveyance through SWP facilities. State Water Code provisions grant other parties access to unused conveyance capacity, although SWP contractors have priority access to capacity not being used by the DWR to meet SWP contract amounts.

The Yuba River Accord includes three separate but interrelated agreements that would protect and enhance fisheries resources in the lower Yuba River, increase local water supply reliability, and provide DWR with increased operational flexibility for protection of Delta fisheries resources through Project re-operation, and provision of added dry-year water supplies to state and federal water contractors. These proposed agreements are the:

- Principles of Agreement for Proposed Lower Yuba River Fisheries Agreement (Fisheries Agreement)
- Principles of Agreement for Proposed Conjunctive Use Agreements (Conjunctive Use Agreements)
- Principles of Agreement for Proposed Long-term Transfer Agreement (Water Purchase Agreement)

The Fisheries Agreement was developed by state, federal, and consulting fisheries biologists, fisheries advocates, and policy representatives. Compared to the interim flow requirements of the SWRCB Revised Water Right Decision 1644 (RD-1644), the Fisheries Agreement would establish higher minimum instream flows during most months of most water years.

To assure that Yuba County Water Agency's (YCWA) water supply reliability would not be reduced by the higher minimum instream flows, YCWA and its participating Member Units would implement the Conjunctive Use Agreements. These agreements would establish a comprehensive conjunctive use program that would integrate the surface water and groundwater supplies of the local irrigation districts and mutual water companies that YCWA serves in Yuba County. Integration of surface water and groundwater would allow YCWA to increase the efficiency of its water management.

Under the Water Purchase Agreement, DWR would enter into an agreement with YCWA to purchase water from YCWA to off-set water costs resulting from VAMP as long as operational and hydrological conditions allow. Additional water purchased by DWR would be available for south-of-Delta CVP and SWP contractors in drier years. The limited EWA would take delivery of 60,000 af (48,000 af export) of water in every year; the CVP/SWP would receive additional water in the drier years. In the future Reclamation may become a party to the Water Purchase Agreement.

The Fisheries Agreement is the cornerstone of the Yuba Accord Alternative. To become effective, however, all three agreements (Fisheries, Conjunctive Use, and Water Purchase) must undergo CEQA and NEPA review and be fully approved and executed by the individual parties to each agreement. Also, implementation of the Yuba Accord Alternative would require appropriate SWRCB amendments of YCWA's water-right permits and RD-1644. CEQA review is complete, the agreements are being executed, and the SWRCB approved the Yuba River Accord.

Transfer Capacity

The assumption in this BA is that under both existing conditions and in the future, water transfer programs for environmental and water supply augmentation will continue in some form, and that in most years (all but the driest), the scope of annual water transfers will be limited by available Delta pumping capacity, and exports for transfers will be limited to the months July-September. As such, looking at an indicator of available transfer capacity in those months is one way of estimating an upper boundary to the effects of transfers on an annual basis.

The CVP and SWP may provide Delta export pumping for transfers using pumping capacity at Banks and Jones beyond that which is being used to deliver project water supply, up to the physical maximums of the pumps, consistent with prevailing operations constraints such as E/I ratio, conveyance or storage capacity, and any protective criteria in effect that may apply as conditions on such transfers. For example, pumping for transfers may have conditions for protection of Delta water levels, water quality, fisheries, or other beneficial uses.

The surplus capacity available for transfers will vary a great deal with hydrologic conditions. In general, as hydrologic conditions get wetter, surplus capacity diminishes because the CVP and SWP are more fully using export pumping capacity for Project supplies. CVP's Jones Pumping Plant, with no forebay for pumped diversions and with limited capability to fine tune rates of pumping, has little surplus capacity, except in the driest hydrologic conditions. SWP has the most surplus capacity in critical and some dry years, less or sometimes none in a broad middle range of hydrologic conditions, and some surplus again in some above normal and wet years when demands may be lower because contractors have alternative supplies.

The availability of water for transfer and the demand for transfer water may also vary with hydrologic conditions. Accordingly, since many transfers are negotiated between willing buyers and sellers under prevailing market conditions, price of water also may be a factor determining how much is transferred in any year. This document does not attempt to identify how much of the available and useable surplus export capacity of the CVP and SWP will actually be used for transfers in a particular year, but recent history, the expectations for EWA, and the needs of other transfer programs suggest a growing reliance on transfers.

Under both the present and future conditions, capability to export transfers will often be capacity-limited, except in Critical and some Dry years. In these Critical and some Dry years, both Banks and Jones have more available capacity for transfers, so export capacity is less likely to limit transfers. Rather, either supply or demand for transfers may be a limiting factor. During such years, low project exports and high demand for water supply could make it possible to transfer larger amounts of water.

Proposed Exports for Transfers

Although transfers may occur at any time of year, proposed exports for transfers apply only to the months July through September. For transfers outside those months, or in excess of the proposed amounts, Reclamation and DWR would request separate consultation. In consideration of the estimates of available capacity for export of transfers during July-September, and in recognition of the many other possible operations contingencies and constraints that may limit actual use of that capacity for transfers, the proposed use of SWP/CVP export capacity for transfers is as follows:

Water Year Class	Maximum Transfer Amount
Critical	up to 600 kaf
Dry (following Critical)	up to 600 kaf
Dry (following Dry)	up to 600 kaf
All other Years	up to 360 kaf

Near-Term Future Projects Identified in the 2004 BA

The actions listed below were included in the 2004 BA. The projects do not yet have final approval. However, Reclamation believes they may be implemented in the near term. Reclamation is including these actions in the project description so that the effects of these actions on aquatic species may be analyzed. The analysis does not include any effects to terrestrial species. These will be addressed in separate construction consultation.

DMC/CA Intertie Proposed Action

The proposed action, known as the DMC and CA Intertie (DMC/CA Intertie), consists of construction and operation of a pumping plant and pipeline connections between the DMC and the CA. The DMC/CA Intertie alignment is proposed for DMC milepost 7.2 where the DMC and the CA are about 500 feet apart.

The DMC/CA Intertie would be used in a number of ways to achieve multiple benefits, including meeting current water supply demands, allowing for the maintenance and repair of the CVP Delta export and conveyance facilities, and providing operational flexibility to respond to emergencies. The Intertie would allow flow in both directions, which would provide additional flexibility to both CVP and SWP operations. The Intertie includes a 467 cfs pumping plant at the DMC that would allow up to 467 cfs to be pumped from the DMC to the CA. Up to 900 cfs flow could be conveyed from the CA to the DMC using gravity flow. The intertie will not be used to increase total CVP exports until certain criteria are in place.

The DMC/CA Intertie will be operated by the San Luis and Delta-Mendota Water Authority (Authority). A three-way agreement among Reclamation, DWR, and the Authority would identify the responsibilities and procedures for operating the Intertie. The Intertie would be owned by Reclamation. A permanent easement would be obtained by Reclamation where the Intertie alignment crossed State property.

Location

The site of the proposed action is an unincorporated area of Alameda County, west of the City of Tracy. The site is situated in a rural area zoned for general agriculture and is under Federal and State ownership. The DMC/CA Intertie would be located at milepost 7.2 of the DMC, connecting with milepost 9.0 of the CA.

Operations

The Intertie would be used under three different scenarios:

1. Up to 467 cfs would be pumped from the DMC to the CA to help meet water supply demands of CVP contractors. This would allow Jones Pumping Plant to pump to its authorized capacity of up to 4,600 cfs, subject to all applicable export pumping restrictions for water quality and fishery protections.
2. Up to 467 cfs would be pumped from the DMC to the CA to minimize impacts to water deliveries due to temporary restrictions in flow or water levels on the lower DMC (south of the Intertie) or the upper CA (north of the Intertie) for system maintenance or due to an emergency shutdown.
3. Up to 900 cfs would be conveyed from the CA to the DMC using gravity flow to minimize impacts to water deliveries due to temporary restrictions in flow or water levels on the lower CA (south of the Intertie) or the upper DMC (north of the Intertie) for system maintenance or due to an emergency shutdown.

The DMC/CA Intertie provides operational flexibility between the DMC and CA. It would not result in any changes to authorized pumping capacity at Jones Pumping Plant or Banks Delta Pumping Plant.

Water conveyed at the Intertie to minimize reductions to water deliveries during system maintenance or an emergency shutdown on the DMC or CA could include pumping of CVP water at Banks Pumping Plant or SWP water at Jones Pumping Plant through use of JPOD. In accordance with COA Articles 10(c) and 10(d), JPOD may be used to replace conveyance opportunities lost because of scheduled maintenance, or unforeseen outages. Use of JPOD for this purpose could occur under Stage 2 operations defined in SWRCB D-1641, or could occur as a result of a Temporary Urgency request to the SWRCB. Use of JPOD in this case does not result in any net increase in allowed exports at CVP and SWP export facilities. When in use, water within the DMC would be transferred to the CA via the Intertie. Water diverted through the Intertie would be conveyed through the CA to O'Neill Forebay.

Freeport Regional Water Project

The Freeport Regional Water Project (FRWP) is currently under construction. Once completed FRWP will divert up to a maximum of about 286 cubic feet per second (cfs) from the Sacramento River near Freeport for Sacramento County (deliveries expected in 2011) and East Bay Municipal Utility District (EBMUD) deliveries expected in late 2009. EBMUD will divert water pursuant to its amended contract with Reclamation. The County will divert using its water rights and its CVP contract supply. This facility was not in the 1986 COA, and the diversions will result in some reduction in Delta export supply for both the CVP and SWP contractors. Pursuant to an agreement between Reclamation, DWR, and the CVP and SWP contractors in 2003, diversions to EBMUD will be treated as an export in the COA accounting and diversions to Sacramento County will be treated as an in-basin use.

Reclamation proposes to deliver CVP water pursuant to its respective water supply contracts with SCWA and EBMUD through the FRWP, to areas in central Sacramento County. SCWA is responsible for providing water supplies and facilities to areas in central Sacramento County, including the Laguna, Vineyard, Elk Grove, and Mather Field communities, through a capital funding zone known as Zone 40.

The FRWP has a design capacity of 286 cfs (185 millions of gallons per day [mgd]). Up to 132 cfs (85 mgd) would be diverted under Sacramento County's existing Reclamation water service contract and other anticipated water entitlements and up to 155 cfs (100 mgd) of water would be diverted under EBMUD's amended Reclamation water service contract. Under the terms of its amendatory contract with Reclamation, EBMUD is able to take delivery of Sacramento River water in any year in which EBMUD's March 1 forecast of its October 1 total system storage is less than 500,000 af. When this condition is met, the amendatory contract entitles EBMUD to take up to 133,000 af annually. However, deliveries to EBMUD are subject to curtailment pursuant to CVP shortage conditions and project capacity (100 mgd), and are further limited to no more than 165,000 af in any 3-consecutive-year period that EBMUD's October 1 storage forecast remains below 500,000 af. EBMUD would take delivery of its entitlement at a maximum rate of 100 mgd (112,000 af per year). Deliveries would start at the beginning of the CVP contract year (March 1) or any time afterward. Deliveries would cease when EBMUD's CVP allocation for that year is reached, when the 165,000 af limitation is reached, or when EBMUD no longer needs the water (whichever comes first). Average annual deliveries to EBMUD are approximately 23,000 af. Maximum delivery in any one water year is approximately 99,000 af.

The primary project components are (1) an intake facility on the Sacramento River near Freeport, (2) the Zone 40 Surface Water Treatment Plant (WTP) located in central Sacramento County, (3) a terminal facility at the point of delivery to the Folsom South Canal (FSC), (4) a canal pumping plant at the terminus of the FSC, (5) an Aqueduct pumping plant and pretreatment facility near Camanche Reservoir, and (6) a series of pipelines carrying water from the intake facility to the Zone 40 Surface WTP and to the Mokelumne Aqueducts. The existing FSC is part of the water conveyance system. See Chapter 9 for modeling results on annual diversions at Freeport in the American River Section, Modeling Results Section subheading.

State Water Project Oroville Facilities

Implementation of the new FERC license for the Oroville Project will occur when FERC issues the new license. Because it is not known exactly when that will occur, it is considered a near term and future project. The current, near term and future operations for the Oroville Facilities are described above.

Other Future Projects

These projects are potential future actions that have not been approved; however, the effects of these actions are analyzed in this BA.

Sacramento River Reliability Project

The Sacramento River Reliability Project (SRRP) consists of constructing an in-river intake and fish screens (Elverta Diversion) on the Sacramento River at RM 74.6 and support facilities, north of Elverta Road, in Sacramento County. The SRRP includes realignment of 0.3 miles of the Garden Highway near the new Elverta intake structure; constructing a 235 mgd (365 cfs) North

Natomas water treatment plant near the new intake facility, water pipelines from the intake structure to the North Natomas water treatment plant, a booster pump station, and 27 to 30 miles of new underground treated water pipelines from the North Natomas water treatment plant to connection points within existing water distribution systems of Placer County Water Agency (PCWA), City of Roseville (Roseville), Sacramento Suburban Water District (SSWD), and City of Sacramento (Sacramento).

Diversion from the SRRP would be made as described below:

- PCWA would divert its 35-taf CVP water from the Elverta Diversion.
- SSWD would divert up to 29 taf of PCWA's MFP water from the Elverta Diversion through exchange with the CVP during Water Forum non-wet years.
- Roseville would divert its CVP water first, and MFP water next, at Folsom Dam in accordance with its WFA limitation on American River Diversion (maximum annual amount of 54.9 taf). Roseville would also receive 4 taf transfer of MFP water from SJWD at Folsom Dam during Water Forum wet and average years. Roseville would divert from Elverta Diversion the remaining of 30 taf PCWA's MFP water not diverted at Folsom Dam through exchange with CVP due to its WFA limitation on diversion from the American River.
- For the City of Sacramento diversion priority would be the (1) Fairbairn WTP, (2) North Natomas WTP, and (3) Sacramento River WTP. The annual diversion amount at Fairbairn WTP is subject to WFA limitations (varied with hydrological conditions) while the annual diversion amount at the North Natomas WTP is up to Sacramento's Sacramento River water right (81.8 taf per year). The diversion amount at Sacramento River WTP is intended to meet the remaining demand after diversions from Fairbairn WTP and North Natomas WTP.

Alternative Intake Project

CCWD's Alternative Intake Project (AIP) consists of a new 250 cfs screened intake in Victoria Canal, and a pump station and ancillary structures, utilities, and access and security features; levee improvements; and a conveyance pipeline to CCWD's existing conveyance facilities.

CCWD will operate the intake and pipeline together with its existing facilities to better meet its delivered water quality goals and to better protect listed species. Operations with the AIP will be similar to existing operations: CCWD will deliver Delta water to its customers by direct diversion when salinity at its intakes is low enough, and will blend Delta water with releases from Los Vaqueros Reservoir when salinity at its intakes exceeds the delivered water quality goal. Los Vaqueros Reservoir will be filled from the existing Old River intake or the new Victoria Canal intake during periods of high flow in the Delta, when Delta salinity is low. The choice of which intake to use at any given time will be based in large part upon salinity, consistent with fish protection requirements in the biological opinions; salinity at the Victoria Canal intake site is at times lower than salinity at the existing intakes. The no-fill and no-diversion periods described above will continue as part of CCWD operations, as will monitoring and shifting of diversions among the four intakes to minimize impacts to listed species.

The AIP is a water quality project, and will not increase CCWD's average annual diversions from the Delta. However, it will alter the timing and pattern of CCWD's diversions in two ways: winter and spring diversions will decrease while late summer and fall diversions increase because Victoria Canal salinity tends to be lower in the late summer and fall than salinity at CCWD's existing intakes; and diversions at the unscreened Rock Slough Intake will decrease while diversions at screened intakes will increase. It is estimated that with the AIP, Rock Slough intake diversions will fall to about 10% of CCWD's total diversions, with the remaining diversions taking place at the other screened intakes. About 88% of the diversions will occur at the Old River and Victoria Canal intakes, with the split between these two intakes largely depending on water quality.

The effects of the AIP are covered by the April 27, 2007 FWS BO for delta smelt (amended on May 16, 2007).

Red Bluff Diversion Dam Pumping Plant

Reclamation signed the ROD July 16, 2008 for RBDD pumping plant and plans to change the operation of the RBDD to improve fish passage problems. The project features construction of a new pumping plant and operation of the RBDD gates in the out position for approximately 10 months of the year. Reclamation is calling for the construction of a pumping plant upstream from the dam that could augment existing capabilities for diverting water into the Tehama-Colusa Canal during times when gravity diversion is not possible due to the RBDD gates being out. Reclamation completed ESA section 7 consultations with the FWS and the NMFS to address construction of a new pumping plant at maximum capacity of 2,500 cfs.

The new pumping plant would be capable of operating throughout the year, providing both additional flexibility in dam gate operation and water diversions for the Tehama-Colusa Canal Authority (TCCA) customers. In order to improve adult green sturgeon passage during their spawning migrations (generally March through July) the gates could remain open during the early part of the irrigation season and the new pumping plant could be used alone or in concert with other means to divert water to the Tehama-Colusa and Corning canals.

Green sturgeon spawn upstream of the diversion dam and the majority of adult upstream and downstream migrations occur prior to July and after August. After the new pumping plant has been constructed and is operational, Reclamation proposes to operate the Red Bluff Diversion Dam with the gates in during the period from four days prior to the Memorial Day weekend to three days after the holiday weekend (to facilitate the Memorial Day boat races in Lake Red Bluff), and between July 1 and the end of the Labor Day weekend. This operation would provide for improved sturgeon and salmon passage.

The pumping plant project will occur in three phases. The first, completion of the NEPA/CEQA process has already been accomplished. The design and permitting phase is commencing, subject to the availability of funding, and is anticipated to take about 18-36 months. As funding permits, property acquisition will also occur during this phase, and further funding commitments would be secured during this time. The final phase, facilities construction, is anticipated to take approximately 18-36 months but this timeline will be updated during final design and permitting.

South Delta Improvements Program Stage 1

Introduction

DWR and Reclamation have agreed to jointly pursue the development of the South Delta Improvements Program (SDIP) to address regional and local water supply needs, as well as the needs of the aquatic environment. The objectives of the SDIP are to: 1) reduce the movement of outmigrating salmon from the San Joaquin River into Old River, 2) maintain adequate water levels and circulation in south Delta channels, and 3) increase water delivery and reliability to the SWP and CVP by increasing the diversion limit at Clifton Court Forebay to 8500 cfs.[5]

The decision to implement the proposed project is being done in two stages. Stage 1 will address the first two objectives and involves the construction and operation of gates at four locations in the south Delta channels. A decision to implement Stage 2 would address increasing the water delivery reliability of the SWP and CVP by increasing the diversion limit at Clifton Court Forebay. This decision has been deferred indefinitely.

The Final EIR/EIS was completed in December 2006. The Department certified the final EIR as meeting the requirements of the California Environmental Quality Act at that time. The Department plans to issue a Notice of Determination to proceed with implementing Stage 1 of the SDIP once the biological opinions on the continued long term operations of the CVP/SWP and the biological opinions for the dredging and construction of the gates are received.

Reclamation and DWR are seeking to construct and operate the gates proposed for the four locations. Key operational features of these gates are included as part of this project description. A separate consultation under the State and federal Endangered Species Acts will be conducted for the impacts of constructing the gates and the channel dredging contained in Stage 1.

The permanent operable gates, which will be constructed in the south Delta in late 2012, will be operated within an adaptive management framework, as described below under “Gate Operations Review Team,” so that the benefits from these gate operations can be maximized. The gates can be opened or closed at any time in response to the local tidal level and flow conditions within the south Delta. In this regard, they are very different from the temporary barriers that have been installed for the past several years.

Because these operable gates are designed as “lift gates” that are hinged at the bottom of the channel, “closure” of the gates can be specified at any tidal level, leaving a weir opening for some tidal flow over the gate. The ability to operate the tidal gates to a specified weir crest elevation (i.e., top of the gates) that is relatively precise provides a great deal of flexibility. The top elevation of each individual gate can be slightly different (i.e., steps) to provide less weir flow as the tidal level declines. The top elevation of the gates can also be slowly raised or lowered to adjust the tidal level and/or tidal flow in response to local south Delta conditions.

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[5] This project description does not include any aspect of the SDIP that is not explicitly identified in the text. Examples of SDIP actions that are not included are construction of the four permanent gates and dredging. Both of these activities will be covered by subsequent consultation.

South Delta Gates

The proposed management of south Delta tidal level and tidal flow conditions involves the use of five gates:

- CCF intake tidal gate (existing),
- Grant Line Canal (at western end) flow control gate,
- Old River at DMC flow control gate,
- Middle River flow control gate, and
- Head of Old River fish control gate.

The CCF intake gate already exists and has been used since SWP began Banks operations in 1972 to control flows from Old River and maintain the water level inside of CCF. Unlike the existing CCF intake gate, the four other gates are proposed by SDIP and are not in place. The operation of the CCF intake gate is directly related to SWP export operations, but the operation of the fish and flow control gates, as proposed by Stage I of SDIP, will serve the primary purpose of protecting fisheries and beneficial uses.

These five gates in the south Delta would be operated to accomplish the following purposes:

1. Maintain a relatively high water level within the CCF to allow SWP to maximize Banks pumping during the off-peak (nighttime) hours. The CCF level cannot be allowed to fall below –2 feet msl because of cavitation concerns at the SWP's Banks pumps. The CCF gates are closed when the outside tidal level in Old River drops below the CCF level (to avoid outflow from CCF). As described earlier in this chapter, the CCF gates are also operated under three “gate priorities” to reduce water level impacts to other south Delta water users.

2. Control the inflow to CCF below the design flow of about 15,000 cfs to prevent excessive erosion of the entrance channel. The CCF gates are partially closed when the difference between the CCF level and Old River tidal level is more than 1.0 foot to avoid inflow velocities of greater than 10 feet/sec.

3. Maintain the high-tide conditions in the south Delta by not diverting into CCF during the flood-tide period that precedes the higher-high tide each day. The CCF intake gates are closed for about 6 hours each day to preserve the high-tide level in Old River to supply sufficient water for Tom Paine Slough siphons. This CCF tidal gate operation is referred to as priority 3 by DWR, as described earlier in this chapter.

4. Control the minimum tidal level elevation upstream of the flow-control gates to be greater than a selected target elevation (i.e., 0.0 feet msl). The flow-control gates can be closed (raised) to maintain a specified top elevation (e.g., 0.0 feet msl) as the upstream tidal level declines during ebb tide.

5. Control the tidal flushing upstream of the flow-control gates with relatively low-salinity water from Old River and Middle River downstream of the gates (i.e., high fraction of Sacramento River water). The flow-control gates would remain fully open during periods

of flood tide (i.e., upstream flow) and then two of the gates would be fully closed (i.e., top elevation of gates above upstream water surface) during periods of ebb tide (i.e., downstream flow). The remaining gate (i.e., Grant Line) would be maintained at a lower elevation (i.e., 0.0 feet msl) to allow the ebb tide flow to exit from the south Delta channels so that the flood-tide flow over the gates can be maximized during each tidal cycle.

6. Control the San Joaquin River flow diversion into Old River. This could increase the flow past Stockton and raise the low DO concentrations in the DWSC. Reduced flow to Old River might also reduce salinity in the south Delta channels by limiting the volume of relatively high-salinity water from the San Joaquin River that enters the south Delta channels. The head of Old River temporary barrier has been installed in October and November of many years to improve flow and DO conditions in the DWSC for up-migrating Chinook salmon. In recent years, the barrier has also been installed in April and/or May during a portion of the outmigration period to reduce the percentage of Chinook salmon smolts that are diverted into Old River and toward the CVP and SWP pumping plants.

Operation of the SDIP gates to accomplish the SDIP purposes without significant environmental impacts to water quality, tidal flows, or listed fish will require an accurate understanding of the effects of these gates. The proposed SDIP gate operations will increase the tidal circulation in the south Delta channels. Gate operations to promote circulation would raise the Old River at Tracy and Middle River gates at each high tide to produce a circulation of water in the south Delta channels down Grant Line Canal. The Old River at Tracy and Middle River gates remain raised (closed) until the next flood-tide period when the downstream level is above the upstream water level. These gates are then lowered (opened) to allow flood-tide (upstream) flows across the gates. Gate operations to promote circulation use a Grant Line gate weir crest at -0.5 feet msl during most periods of ebb tide (downstream flow) to protect the minimum level elevation of 0.0 feet msl. All gates are lowered (i.e., opened) during floodtide periods as soon as the downstream tidal level is above the upstream water level.

Gate Operations Review Team

A federal and state interagency team will be convened to discuss constraints and provide input to the existing WOMT. The Gate Operations Review Team (GORT) will make recommendations for the operations of the fish control and flow control gates to minimize impacts on resident threatened and endangered species and to meet water level and water quality requirements for south Delta water users. The interagency team will include representatives of DWR, Reclamation, FWS, NMFS, and the DFG, and possibly others as needs change. The interagency team will meet through a conference call, approximately once a week. DWR will be responsible for providing predictive modeling, and SWP Operations Control Office will provide operations forecasts and the conference call line. Reclamation will be responsible for providing CVP operations forecasts, including San Joaquin River flow, and data on current water quality conditions. Other members will provide the team with the latest information related to south Delta fish species and conditions for crop irrigation. Operations plans would be developed using the Delta Simulation Model 2 (DSM2), forecasted tides, and proposed diversion rates of the projects to prepare operating schedules for the existing CCF gates and the four proposed operable gates.

The GORT will use information shared at the weekly meetings to determine gate operations for that week. Although there are numerous ways the gates could be operated to address the many issues in the south Delta, it is assumed that the GORT will make recommendations that attempt to balance these needs. A likely gate operation is described below. It is assumed that the gates operations adopted by the GORT under varying circumstances would be the same or similar to this description.

Head of Old River Fish Control Gate

Operations

The operation (or closing) of the head of Old River fish control gate is intended to reduce adverse effects to the San Joaquin River watershed Central Valley fall-/late fall–run Chinook salmon and steelhead by reducing the downstream movement of juvenile salmonids into the south Delta channels via Old River. Because the gate will be operable, operations can be more flexible in response to the detection of fish presence and/or water quality problems. The operation of the head of Old River fish control gate for fish protection and during other times of the year would lower the electrical conductivity (EC) of the western portion of these channels. This gate can have the largest effect on south Delta salinity. The salinity in the south Delta channels can be reduced to approach the EC at CCF exports if the San Joaquin River diversion flow into the head of Old River is reduced.

Spring Operations/Vernalis Adaptive Management Plan

Operation (closing) of the head of Old River fish control gate is currently proposed to begin on April 15. Spring operation is generally expected to continue through May 15, to protect outmigrating salmon and steelhead. During this time, the head of Old River gate would be fully closed, unless the San Joaquin River is flowing above 10,000 cfs or the GORT recommends a partial opening for other purposes.

If FWS, NMFS, or DFG determine that fishery resources are at risk, and that the gate needs to be operated at a different time or for a longer period to protect fish (e.g., just prior to and/or after the April 15 to May 15 period), it may be operated provided the following criteria are met:

- take of other species (i.e., delta smelt) would not increase in excess of the take authorized by the original proposed operation;
- outmigrating salmon, steelhead, or other species (e.g., splittail) are present; and
- South Delta Water Agency (SDWA) agricultural diverters are able to divert water of adequate quality and quantity.

Salmon presence is determined by NMFS and DFG through their monitoring of the river system and coordination with the hatchery releases to the San Joaquin River. The ability of SDWA to divert adequate quantities of water is dependent upon the water level in south Delta channels. If needed, the flow control gates would be operated to the criteria specified for them under Spring Operations (below). The criteria for determining adequate water quality would be the south Delta standards contained in SWRCB’s D-1641.

Summer and Fall Operations

When the Spring operation is completed and through November 30, the head of Old River fish control gate would be operated to improve flow in the San Joaquin River, thus helping to avoid historically-present low dissolved oxygen conditions in the lower San Joaquin River near Stockton. During this period, partial operation of the gate (partial closure to restrict flows from the San Joaquin River into Old River to approximately 500 cfs) may also be warranted to protect water quality in the South Delta channels. Generally, water quality in the south Delta channels is acceptable through June. Operations of the head of Old River fish control gate would be under review of the GORT and at the request of DFG, NMFS and FWS.

Operations during the months of October and November to improve flow and water quality conditions (i.e., low dissolved oxygen) in the San Joaquin River for adult migrating Chinook salmon is expected to provide a benefit similar to that achieved with the temporary barrier. Operations would not occur if the San Joaquin River flow at Vernalis is greater than 5,000 cfs because it is expected that this flow would maintain sufficient DO in the San Joaquin River.

When the gate is not operated, it is fully lowered in the channel. Operation of the gate is not proposed during the period December through March. Any operation of the gate proposed for the December-March period would require re-initiation of ESA consultation.

Flow Control Gates

The flow control gates in Middle River, Grant Line Canal, and Old River near the DMC, would be operated (closed during some portion of the tidal cycle) throughout the agricultural season of April 15 through November 30. As with the head of Old River fish control gate, when the gates are not operated, they are fully lowered in the channel. Operation of the gates is not proposed during the period December through March. Any operation of the gates proposed for the December-March period would require re-initiation of ESA consultation.

Spring Operations

During April 15 through May 15(or until the Spring operation of the head of Old River gate is completed), water quality in the south Delta is acceptable for the beneficial uses, but closure of the head of Old River fish control gate has negative impacts on water levels in the south Delta. Therefore, the flow control gates would be operated to control minimum water levels in most year types. In the less frequent year types, dry or critically dry, when water quality in the south Delta is threatened by this static use of the gates, circulation may be induced to improve water quality in the south Delta channels. Circulation using the flow control gates is described in the summer operations section which follows. During these times, Reclamation and DWR have committed to maintaining 0.0 foot msl water levels in Old River near the CVP Tracy facility and at the west end of Grant Line Canal.

Summer and Fall Operations

When the Spring operation of the head of Old River fish control gate is completed and through November 30, the gates would be operated to control minimum water levels and increase water circulation to improve water quality in the south Delta channels. Reclamation and DWR have committed to maintaining water levels during these times at 0.0 foot msl in Old River near the CVP Tracy facility, 0.0 foot msl at the west end of Grant Line Canal, and 0.5 foot msl in Middle

River at Mowry Bridge. It is anticipated that the target level in Middle River would be lowered to 0.0 foot msl following extension of some agricultural diversions.

The proposed gate operations will increase the tidal circulation in the south Delta channels. This is accomplished by tidal flushing upstream of the flow-control gates with relatively low-salinity water from Old River and Middle River downstream of the gates (i.e., high fraction of Sacramento River water). The flow-control gates would remain fully open during periods of flood tide (i.e., upstream flow) and then two of the gates would be fully closed (i.e., top elevation of gates above upstream water surface) during periods of ebb tide (i.e., downstream flow). The remaining gate (i.e., Grant Line) would be maintained at a lower elevation (i.e., 0.0 feet msl) to allow the ebb tide flow to exit from the south Delta channels so that the flood-tide flow over the gates can be maximized during each tidal cycle. This is the same operation described as Purpose 5 earlier in the description of the SDIP gates.

Actual gate operations would likely vary from this general circulation plan and would be discussed on a weekly basis by the GORT. Proposed flow control gate operations would involve forecasting of water levels and potential changes in water quality in south Delta channels and operating the gates to maintain the agreed-upon water levels and water quality objectives. Forecasting would be performed on a frequent basis using the Delta Simulation Model 2 (DSM2), forecasted tides, and proposed diversion rates of the projects to prepare operating schedules for the existing CCF gates and the four proposed operable gates.

Gate Operations and CVP/SWP Exports

Because of the hydraulic interconnectivity of the south Delta channels, the CCF, and the export facilities, the permanent operable gates would not be operated entirely independent of CVP and SWP exports. The flow control gate opening and closing frequencies and durations would be adjusted to meet the water level and circulation objectives. Furthermore, the head of Old River Fish Control Gate operation period and duration would be adjusted to address the presence of fish species and the water quality conditions in the San Joaquin River. Adjustments in the operation of the gates would be determined and then refined by the GORT based on real-time conditions. Opportunities to adjust gate operations in a manner that reduces entrainment and impingement of aquatic species or improves in-Delta water supply conditions that are associated with Delta exports could result.

As described in the Flow Control Gates operations sections, the Middle River, Grant Line Canal, and Old River near DMC flow control gates are operated to improve stage and water quality in the south Delta. The flow control gates increase the stage upstream of the barriers while the CVP and SWP Delta export facilities are all downstream of the permanent operable gates. The gates are designed to capture the flood tide upstream of the structures, and the operation of the flow control gates is not based on exports. Although currently not contemplated, through the adaptive management program and the GORT, flow control gate operations could be modified to protect beneficial uses in a manner such that the gate operations are, to a certain degree, dependent on export operations.

As described in the Head of Old River Fish Control Gate operations section, the head of Old River fish control gate is operated to prevent the movement of Central Valley Chinook Salmon into the South Delta and to improve dissolved oxygen in the Stockton Deep Water Ship Channel. The operation of the fish control gate is independent from exports and is based on the presence of species and the water quality in the San Joaquin River. Since the head of Old River fish control gate controls the quantity of San Joaquin River water that enters the south Delta, gate operation could be used to control the water quality at the CVP and, to a lesser degree, the SWP Delta export facilities.

ESA coverage for the SDIP operable gates is being accomplished through two consultation processes. The effects of the operation of the gates are included in the OCAP re-consultation and are evaluated in the Delta Effects Chapter, Chapter 13. The effects of the construction of the gates, the presence of the structures in the channels (passage and predation effects), and channel dredging are included in a separate consultation process. Table 2-26 below summarizes this approach.

Table 2-26 Consultation Processes Summary

SDIP Operable Gates	OCAP BA	Separate Consultation
Hydrologic Effects of the operation of the Permanent Gates – Chapter 13	x	
Short- and long-term Construction Effects, including channel dredging		x
Fish passage effects of the structure		x
Predation effects due to the physical presence of the structures		x

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Chapter 3 Basic Biology, Life History and Baseline for Central Valley Steelhead

This Chapter provides information on the basic biology, life history, distribution and abundance, critical habitat conditions, and status of Central Valley steelhead (*Oncorhynchus myisss*) in the action area. In general, the majority of Central Valley steelhead are confined to non-historical spawning and rearing habitat below impassable dams, but the existing spawning and rearing habitat can sustain steelhead at current population levels. In addition, monitoring data indicates that much of the anadromous form of the species is hatchery supported. There is also a strong resident component to the population (referred to as rainbow trout) that interacts with and produces both resident and anadromous offspring.

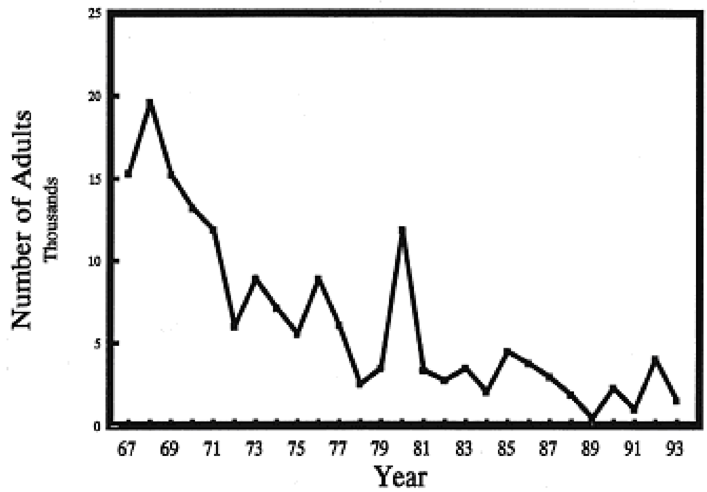
Status

Central Valley steelhead were listed as threatened under the Endangered Species Act (ESA) on January 5, 2006 (71 FR 834). This Distinct Population Segment (DPS) consists of steelhead populations in the Sacramento and San Joaquin River (inclusive of and downstream of the Merced River) basins in California's Central Valley. Critical habitat was designated for Central Valley steelhead on September 2, 2005 (70 CFR 52488).

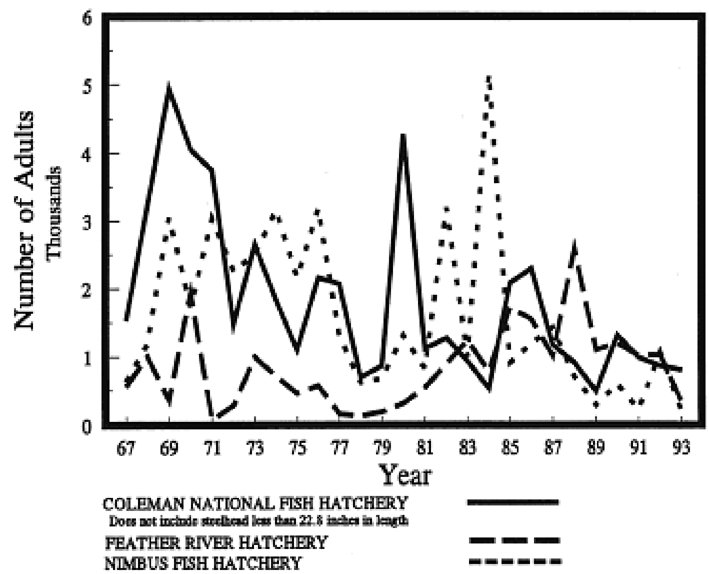
Populations of naturally spawned Central Valley steelhead are at lower levels than were found historically (Figure 3-1) and are composed predominantly of hatchery fish. Steelhead require cool water to rear through the summer, and much of this habitat is now upstream of impassable dams. The California Fish and Wildlife Plan of 1965 estimated the combined annual run size for Central Valley and San Francisco Bay tributaries to be about 40,000 during the 1950s (DFG 1965, as cited in McEwan and Jackson 1996). The spawning population during the mid-1960s for the Central Valley basin was estimated at nearly 27,000 (DFG 1965, as cited in McEwan and Jackson 1996). These numbers likely consisted of both hatchery and wild steelhead. McEwan and Jackson (1996) estimated the annual run size for the Central Valley basin to be less than 10,000 adults by the early 1990s. Much of the abundance data since the mid-1960s was obtained by visual fish counts at the Red Bluff Diversion Dam (RBDD) fish ladders when gates were closed during much of the steelhead migration season. Current abundance estimates are unavailable for naturally spawned fish since RBDD gate operations were changed, so the extent to which populations have changed following the 1987–94 drought is unknown. National Marine Fisheries Service (NMFS) (NOAA Fisheries 2003) status review estimated the Central Valley steelhead population at less than 3,000 adults. This document is primarily limited to a discussion of the status of Central Valley steelhead stocks in habitats influenced by Central Valley Project (CVP) and State Water Project (SWP) operations. According to McEwan (2001), the primary stressors affecting Central Valley steelhead are all related to water development and water management, and the greatest stressor is the loss of spawning and rearing habitat due to dam construction.

The Central California Coast (CCC) steelhead DPS was listed as a threatened species on January 5, 2006 (71 FR 834). The Central California Coast steelhead DPS extends from the Russian

River on the north to the San Lorenzo River on the south and includes Suisun Bay, San Pablo Bay, and San Francisco Bay. Critical habitat was designated for Central California Coast steelhead on September 2, 2005 (70 CFR 52488). Overall, the abundance of the CCC steehead ESU has declined from an estimated 94,000 returning adults in the 1960s to estimates of less than 10,000 in recent times (Busby *et al.* 1996; NOAA Fisheries 1997). These numbers represent over an 85 percent decline in the population. Project effects to the migratory pathway of CCC steelhead are expected to be minimal to water quality because the tidal flows through the area of CCC habitat are so much larger. The steelhead effects analysis throughout this BA does not identify any effects of the project on steelhead that occur in the Central California Coast DPS; therefore, they are not specifically referenced except in the determination of effects. Because the project area overlaps this DPS, these fish are being addressed in this Biological Assessment (BA). Central Valley Project (CVP) and State Water Project (SWP) operations are not expected to influence conditions significant to steelhead in these areas, so effects to Central California Coast Steelhead are not anticipated. Central California Coast steelhead critical habitat is shown in Figure 3-19. Suisun Creek was not included in the Critical Habitat designation (70 CFR 52488).



Adjusted adult steelhead counts at Red Bluff Diversion Dam on the Sacramento River, 1967-1993.



Adult steelhead counts at Coleman, Feather River, and Nimbus fish hatcheries, 1967-1993.

Figure 3-1 Adult steelhead counts at RBDD, 1967–93 (top) and adult steelhead counts at Coleman National Fish Hatchery, Feather River Fish Hatchery, and Nimbus Hatchery, 1967-93 (bottom). The revised Red Bluff gates open period after 1993 eliminated RBDD counting ability. *Source: McEwan and Jackson 1996.*

Taxonomy

Steelhead is a name used for anadromous rainbow trout (*Oncorhynchus mykiss*), a salmonid species native to western North America and the Pacific coast of Asia. In North America, steelhead are found in Pacific coast drainages from Southern California to Alaska. In Asia, they are found in coastal streams of the Kamchatka Peninsula, with scattered populations on the Siberian mainland (Burgner et al. 1992, as cited in McEwan and Jackson 1996). Known spawning populations are found in coastal streams along much of the California coast, as well as in the Central Valley.

Only two subspecies of North American rainbow trout contain both resident (nonmigratory) and anadromous (migratory or sea-run) forms: coastal rainbow trout (*O. m. irideus*) and Columbia River redband trout (*O. m. gairdneri*). Columbia River redband trout occur in tributaries of the upper Columbia River east of the Cascades (McEwan and Jackson 1996). Coastal rainbow trout occupy coastal streams from California to Alaska, including tributaries to the San Francisco Estuary. All California steelhead populations are *O. m. irideus,* including those in the Central Valley.

Historically, resident rainbow trout and steelhead were considered separate subspecies or different species altogether. However, researchers have found little or no morphologic or genetic differentiation between the two forms inhabiting the same stream system (Behnke 1972; Allendorf 1975; Allendorf and Utter 1979; Busby et al. 1993; Nielsen 1994, all as cited in McEwan and Jackson 1996), indicating there is substantial interbreeding. However, differences in mitochondrial DNA have been found by some researchers (Wilson et al. 1985, as cited in McEwan and Jackson 1996). Based on the cumulative genetic evidence, researchers have proposed that steelhead and related resident rainbow trout with the potential to interbreed be considered as one unit for restoration and management purposes (Busby et al. 1993, as cited in McEwan and Jackson 1996; NMFS 1996).

NMFS (1998) divided West Coast steelhead into 15 ESUs based on distinct genetic characteristics, freshwater ichthyogeography, and other parameters. Most steelhead stocks found in the Central Valley comprise the Central Valley ESU, which recent genetic data indicate is distinct from other coastal steelhead stocks (Busby et al. 1996; NMFS 1997b, 1998). DNA analysis of steelhead tissue samples collected from the Coleman National Fish Hatchery, Feather River Hatchery, Deer and Mill Creeks, and the Stanislaus River demonstrated these stocks are genetically similar to each other. Coleman National Fish Hatchery and Feather River Hatchery steelhead stocks are considered part of the Central Valley ESU because broodstock histories and genetic evidence show these two stocks are similar to naturally spawned steelhead in Deer and Mill Creeks.

NMFS (1998, 1999) does not consider Nimbus Hatchery and Mokelumne River Fish Installation stocks to be part of the Central Valley ESU. Genetic analysis indicated steelhead from the American River (collected from both the Nimbus Hatchery and the American River) are genetically more similar to Eel River steelhead (Northern California ESU) than other Central Valley steelhead stocks. Eel River steelhead were used to found the Nimbus Hatchery stock. Mokelumne River rainbow trout (hatchery produced and naturally spawned) are genetically most similar to Mount Shasta Hatchery trout, but also show genetic similarity to the Northern

California ESU (Nielsen 1997, as cited in NMFS 1997b). Nielsen et al 2005 found American River steelhead to be genetically different from other Central Valley stocks (Figure 3-2).

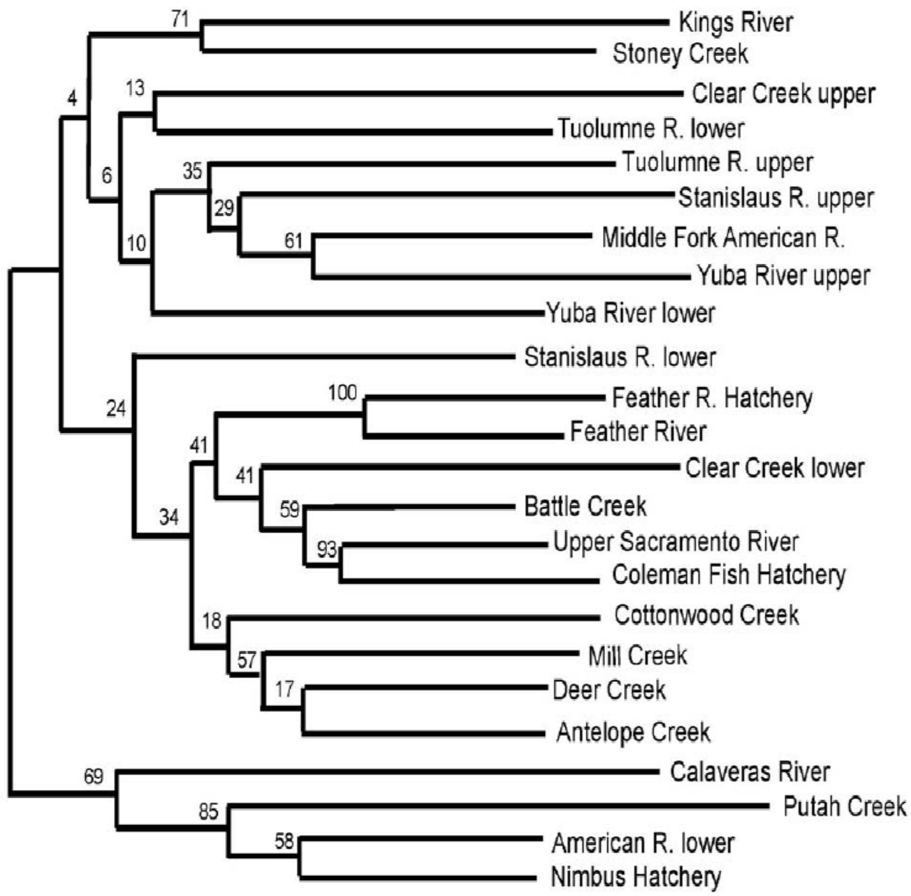


Figure 3-2 Unrooted Neighbor-Joining tree based on Cavalli-Sforza and Edwards chord distance for the Central Valley system derived from allelic variation at 11 microsatellite loci. Branches with bootstrap values (percent of 2000 replicate trees) are provided (from Nielsen et al. 2005).

Steelhead Biology and Life History

Steelhead, as currently defined, is the anadromous form of rainbow trout (McEwan and Jackson 1996). However, as stated above, steelhead life history can be quite variable, with some individuals or populations reverting to residency when flow conditions block access to the ocean. The following is an idealized life history for Central Valley stocks. McEwan and Jackson (1996) provided an extensive summary of the biology of coastal and Central Valley stocks and a list of useful references that contain more detailed information.

Adult migration from the ocean to spawning grounds occurs during much of the year, with peak migration occurring in the fall or early winter (Figure 3-4). Migration through the Sacramento River mainstem begins in July, peaks at the end of September, and continues through February or March (Bailey 1954; Hallock et al. 1961, both as cited in McEwan and Jackson 1996). Counts made at RBDD from 1969 through 1982 (Hallock 1989, as cited in McEwan and Jackson 1996) and on the Feather River (Painter et al. 1977; DWR unpublished) follow the above pattern, although some fish were counted as late as April and May. Weekly counts at Clough Dam on Mill Creek during a 10-year period from 1953 to 1963 showed a similar migration pattern as well. The migration peaked in mid-November and again in February. This second peak is not reflected in counts made in the Sacramento River mainstem (Bailey 1954; Hallock et al. 1961, both as cited in McEwan and Jackson 1996) or at RBDD (Hallock 1989, as cited in McEwan and Jackson 1996).

Central Valley steelhead are mostly ‘winter steelhead’ and may contain some ‘summer steelhead’ (the naming convention refers to the seasonal period of adult upstream migration). Winter steelhead mature in the ocean and arrive on the spawning grounds nearly ready to spawn. In contrast, summer steelhead, or stream-maturing steelhead, enter freshwater with immature gonads and typically spend several months in freshwater before spawning. The optimal temperature range during migration is unknown for Central Valley stocks. Based on northern stocks, the optimal temperature range for migrating adult steelhead is 46 to 52 degrees Fahrenheit (°F) (Bovee 1978; Reiser and Bjornn 1979; Bell 1986, all as cited in McEwan and Jackson 1996). The reported minimum depth for successful passage is about 7 inches (Reisner and Bjornn 1979, as cited in McEwan and Jackson 1996). Depth is usually not a factor preventing access to spawning areas in the rivers currently under consultation. However, excessive water velocity (>10 to 13 feet per second [ft/s]) and obstacles may prevent access to upstream spawning grounds.

Historically, Central Valley steelhead spawned primarily in upper stream reaches and smaller tributaries, although steelhead spawn in most available channel types in unimpounded stream reaches of the Pacific Northwest (Montgomery et al. 1999). Due to water development projects, most spawning is now confined to lower stream reaches below dams. In a few streams, such as Mill and Deer Creeks, steelhead still have access to historical spawning areas. Peak spawning generally occurs from December through April (McEwan and Jackson 1996) (Figure 3-4).

Males typically arrive in the spawning areas first (McMillan et al 2007). Upon arrival, the female selects a site and excavates a redd (nest) in the gravel and deposits her eggs, while an attendant male fertilizes them. Occupied redds in the American River typically have one male and one female but occasionally two and sometimes three males are present. The ratio of male to female steelhead arriving at Nimbus Hatchery is higher than one and ranged from 1.09 to 1.52 males per female between 2002 and 2007 (Hannon and Deason 2007).

Fecundity is directly related to body size (Moyle 1976). Spawning females average about 4,000 eggs, but the actual number produced varies among stocks and by the size and age of the fish (Leitritz and Lewis 1976). The eggs are covered with gravel when the female excavates another redd upstream. Spawning occurs mainly in gravel substrates (particle size range of about 0.2–4.0 inches). Sand-gravel and gravel-cobble substrates are also used, but these must be highly permeable and contain less than 5 percent sand and silt to provide sufficient oxygen to the incubating eggs. Adults tend to spawn in shallow areas (6–24 inches deep) with moderate water velocities (about 1 to 3.6 ft/s) (Bovee 1978, as cited in McEwan and Jackson 1996, Hannon and Deason 2007, Figure 3-3). The optimal temperature range for spawning is 39 to 52°F (Bovee

1978; Reiser and Bjornn 1979; Bell 1986, all as cited in McEwan and Jackson 1996). Egg mortality begins to occur at 56°F (McEwan and Jackson 1996).

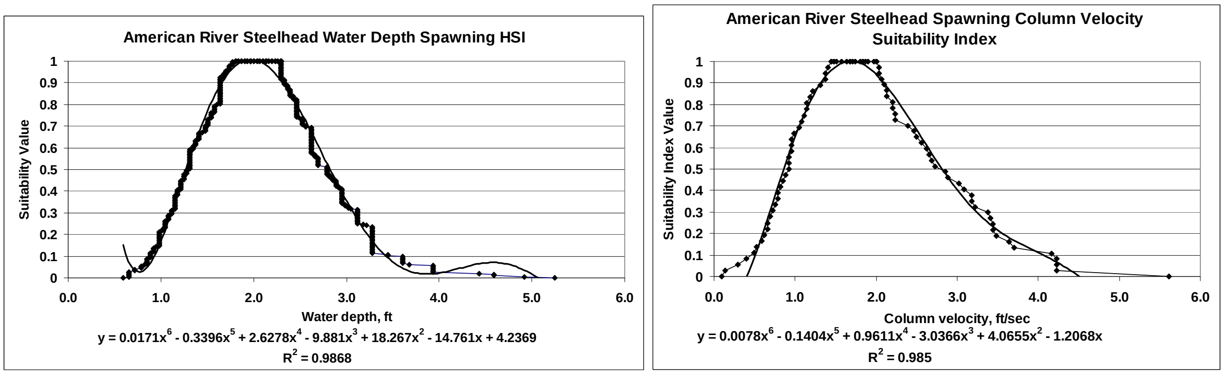


Figure 3-3 Steelhead spawning habitat depth and velocity suitability indices in the American River, Hannon and Deason 2007.

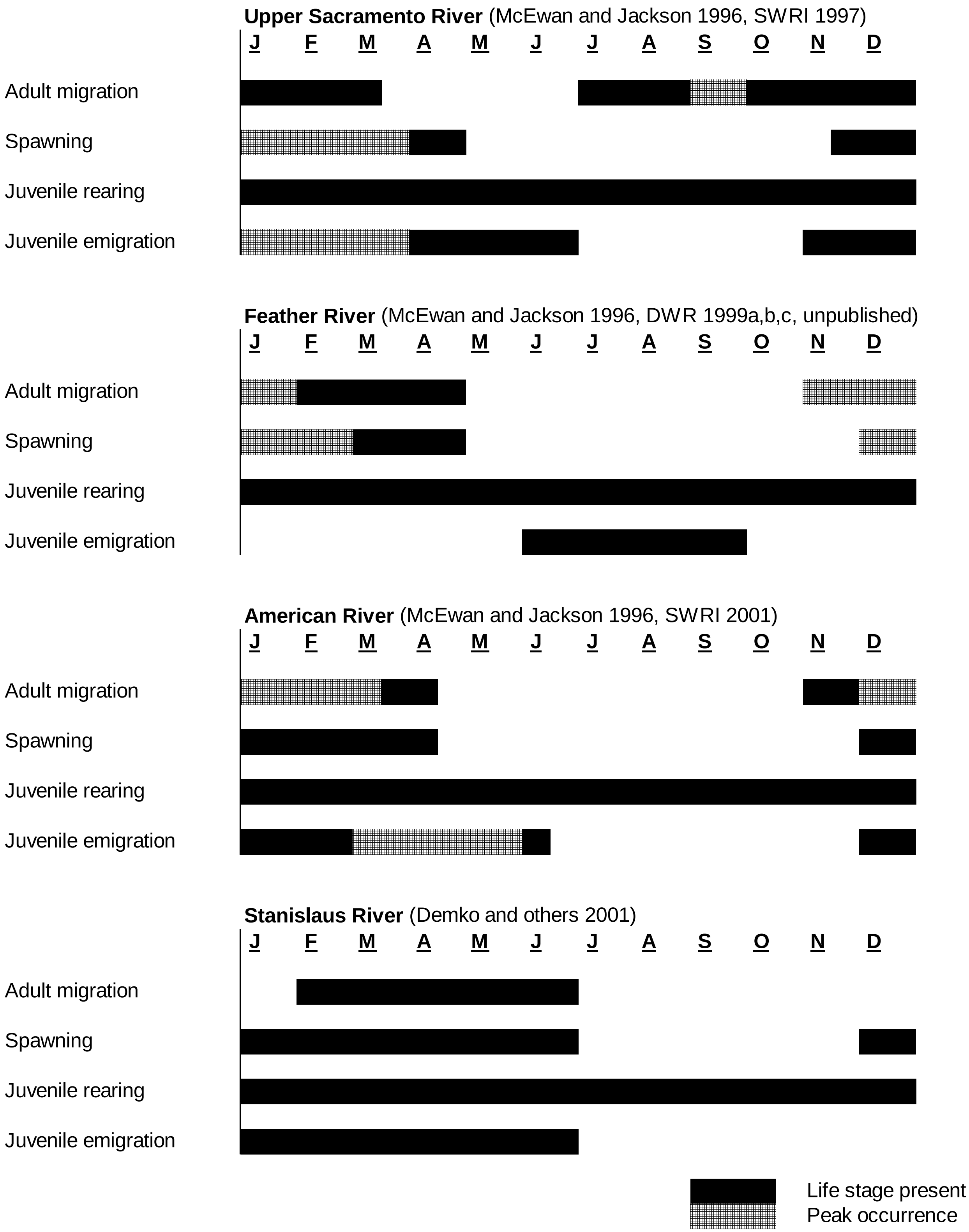


Figure 3-4 Steelhead life cycle for various Central Valley streams.

Unlike Chinook salmon, Central Valley steelhead may not die after spawning (McEwan and Jackson 1996). Some may return to the ocean and repeat the spawning cycle for two or three years. The percentage of adults surviving spawning is generally thought to be low for Central Valley steelhead, but varies annually and between stocks. Recent acoustic tagging of Central Valley steelhead kelts from Coleman Hatchery indicates survival rates can be high, especially for Central Valley steelhead reconditioned by holding and feeding at the hatchery prior to release. Some return immediately to the ocean and some remain and rear in the Sacramento River (Robert Null, personal communication).

The time required for egg development is approximately four weeks, but is temperature-dependent (McEwan and Jackson 1996). For northern steelhead populations, optimal egg development occurs at 48 to 52°F. Egg mortality may begin at temperatures above 56 °F in northern populations (Bovee 1978; Reiser and Bjornn 1979; and Bell 1986, all as cited in McEwan and Jackson 1996). After hatching, the yolk-sac fry or alevins remain in the gravel for another four to six weeks (Shapovalov and Taft 1954, as cited in McEwan and Jackson 1996). At 50°F steelhead fry emerge from the gravel about 60 days after egg fertilization (Leitritz and Lewis 1980). Merz et al (2004) showed that spawning substrate quality influenced a number of physical parameters affecting egg survival including temperature, dissolved oxygen, and substrate permeability. Changes in flow and sediment transport can have negative effects on spawning conditions (Poff et al 1997). These deleterious effects contribute to decreased substrate permeability and dissolved oxygen content.

Upon emergence from the gravel, the fry move to shallow protected areas associated with the stream margin (Royal 1972; Barnhart 1986, both as cited in McEwan and Jackson 1996). Steelhead fry tend to inhabit areas with cobble-rubble substrate, a depth less than 14 inches, and temperature ranging from 45 to 60 °F (Bovee 1978, as cited in McEwan and Jackson 1996). Myrick (1998, 2000) found steelhead from the Feather and Mokelumne preferred temperatures between 62.5°F and 68°F. Older juveniles use riffles and larger juveniles may also use pools and deeper runs (Barnhart 1986, as cited in McEwan and Jackson 1996). However, specific depths and habitats used by juvenile rainbow trout can be affected by predation risk (Brown and Brasher 1995). Central Valley steelhead can show mortality at constant temperatures of 77°F although they can tolerate 85°F for short periods. Hatchery reared steelhead in thermal gradients selected temperatures of 64–66°F while wild caught steelhead selected temperatures around 63°F (Cech and Myrick 2001).

Yearling steelhead in the Central Valley feed mostly on immature aquatic insects but when other items such as emerging mayflies and salmonid eggs are abundant these may dominate their diets (Merz 2002).

Juvenile Central Valley steelhead may migrate to the ocean after spending one to three years in freshwater (McEwan and Jackson 1996). Fork length (FL) data for steelhead emigrating past Chipps Island suggest the Central Valley stocks show little variability in size at emigration (Figure 3-5 and Figure 3-6).

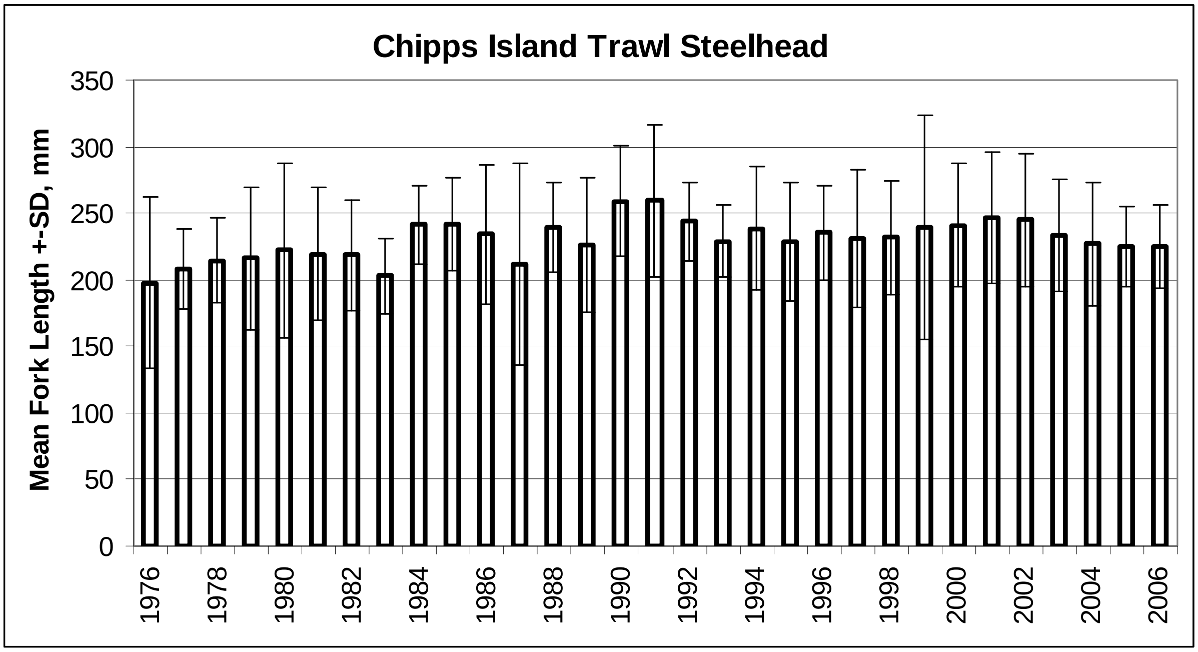


Figure 3-5 Mean FL (mm) plus standard deviation of steelhead collected in the FWS Chipps Island Trawl, 1976-2006 (data from BDAT).

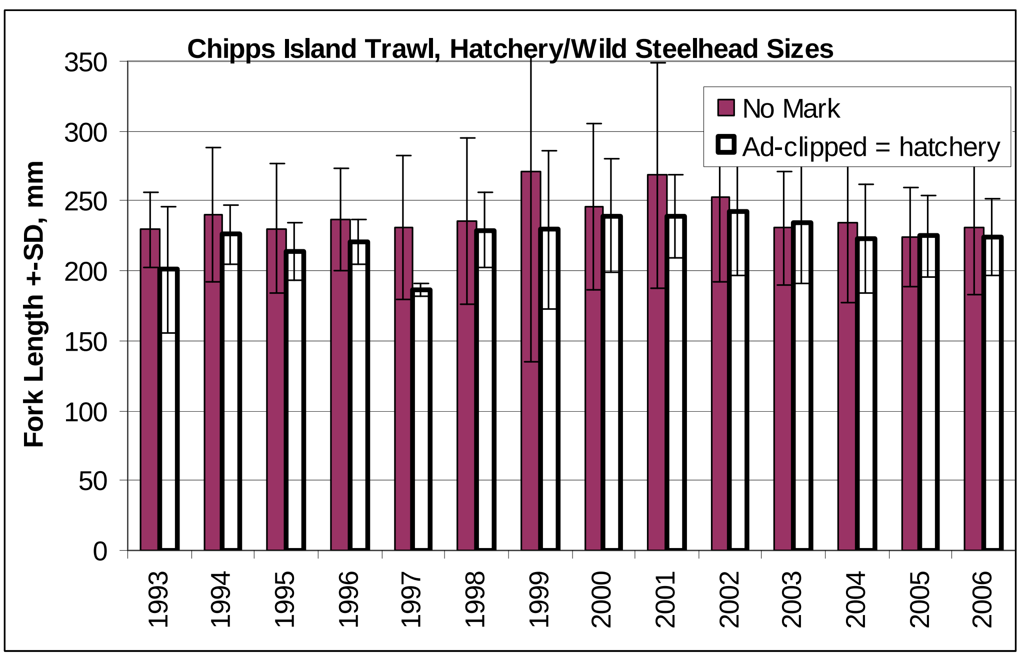


Figure 3-6 Comparison of hatchery and wild steelhead sizes collected in the Chipps Island Trawl, 1993 – 2006 (data from BDAT). 100% adipose clipping of hatchery fish began in 1998.

During their downstream migration, juveniles undergo smoltification, a physiologic transformation enabling them to tolerate the ocean environment and its increased salinity. In addition, the juvenile steelhead lose their parr marks, become silvery, and produce deciduous scales. Temperatures under 57°F are considered best for smolting. Data for steelhead smolts emigrating past Chipps Island generally agree with these findings. Slightly more than 60 percent of the unmarked steelhead smolts collected in the FWS Chipps Island trawl between 1998 and 2000 were collected at temperatures > 57°F, the actual smolting temperature was likely lower upstream than recorded at Chipps Island (Figure 3-7). However, this is likely biased by high proportions of hatchery fish that migrate over a shorter period of time than naturally spawned fish and many other factors. According to Cech and Myrick (2001) steelhead transform from parr to smolt successfully at 44 to 52°F and show little saltwater adaptation above 59°F.

Steelhead are present at Chipps Island between at least October and July, according to catch data from the FWS Chipps Island Trawl (Figure 3-8). It appears that adipose fin-clipped steelhead have a different emigration pattern than unclipped steelhead. Adipose fin-clipped steelhead showed distinct peaks in catch between January and March corresponding with time of release, whereas unclipped steelhead CPUE were more evenly distributed over a period of six months or more. These differences are likely an artifact of the method and timing of hatchery releases.

Once in the ocean, steelhead remain there for one to four growing seasons before returning to spawn in their natal streams (Burgner et al. 1992, as cited in McEwan and Jackson 1996). Little data are available on the distribution of Central Valley stocks in the ocean, but at least some California steelhead stocks may move into the North Pacific Ocean, as do the more northerly distributed stocks.

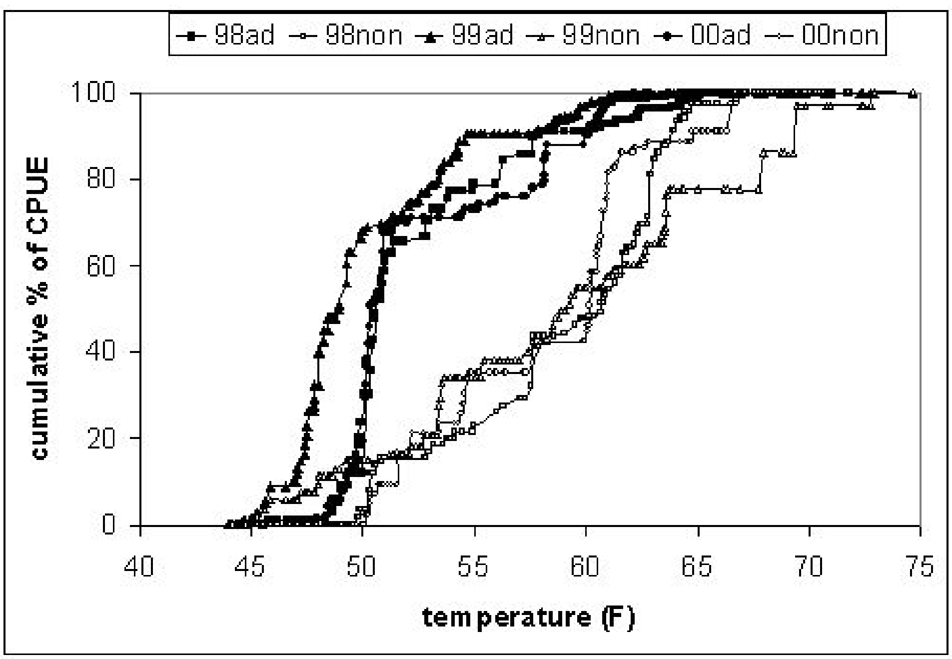


Figure 3-7 Cumulative percentage of steelhead per 10,000 m^3 in the FWS Chipps Island Trawl vs. surface water temperature at Chipps Island. Solid symbols represent hatchery fish (adipose-clipped) and open symbols represent wild fish (non adipose-clipped). 98ad means adipose clipped fish in 1998 and 98non means non-adipose clipped in 1998.

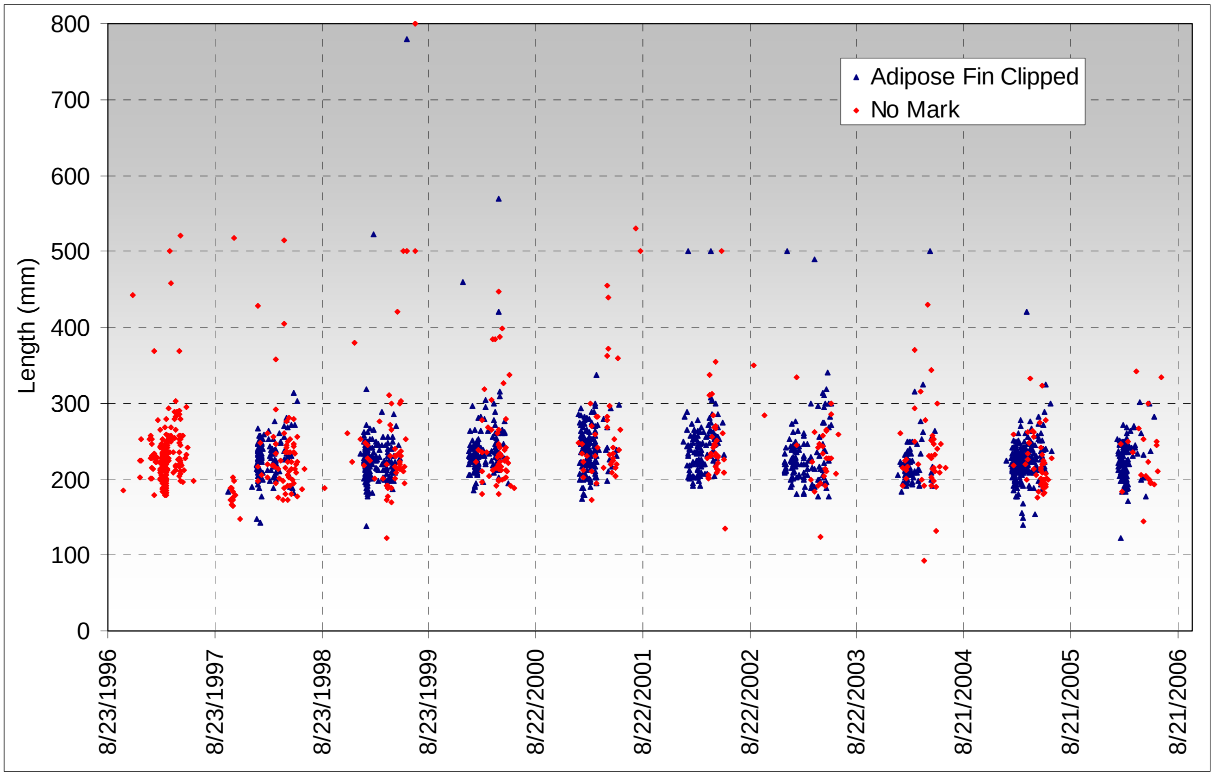


Figure 3-8 Adipose clipped and un-clipped steelhead captured in the Chipps Island Trawl, 1996 – 2006 (BDAT…USFWS unpublished data).

Historical and Current Distribution and Abundance of Central Valley Steelhead

Monitoring data for Central Valley steelhead is limited in comparison with Chinook salmon. Steelhead present more challenges to monitoring programs but a Central Valley wide steelhead monitoring framework is being developed by DFG in cooperation with other agencies. Steelhead ranged throughout many of the tributaries and headwaters of the Sacramento and San Joaquin Rivers prior to dam construction, water development, and watershed perturbations of the 19th and 20th centuries (McEwan and Jackson 1996). Based on the historical distribution of Chinook salmon, steelhead probably inhabited tributaries above Shasta Dam such as the Little Sacramento, McCloud, Fall, and Pit Rivers, and many tributaries on the west side of the Sacramento Valley, such as Stony and Thomes Creeks (Yoshiyama et al. 1996, 1998).

There is little historical documentation regarding steelhead distribution in the San Joaquin River system, presumably due to the lack of an established steelhead sport fishery in the San Joaquin basin (Yoshiyama et al. 1996). However, based on historical Chinook salmon distribution in this drainage and on the limited steelhead documentation that does exist, it appears that steelhead were present in the San Joaquin River and its tributaries from the Kern River northward. During very wet years, steelhead could potentially access the Kern River through the Tulare Basin.

Steelhead distribution in Central Valley drainages has been greatly reduced (McEwan and Jackson 1996). Steelhead are now primarily restricted to a few remaining free-flowing tributaries and to stream reaches below large dams, although a few steelhead may also spawn in intermittent streams during wet years. Naturally spawning steelhead populations have been found in the upper Sacramento River and tributaries below Keswick Dam, Mill, Deer, and Butte Creeks, and the Feather, Yuba, American, and Mokelumne Rivers (CMARP 1998). However, the records of naturally spawning populations depend on the presence of fish monitoring programs. Recent implementation of monitoring programs has found steelhead in additional streams, such as Auburn Ravine, Dry Creek, and the Stanislaus River. It is possible that naturally spawning populations exist in many other streams but are undetected due to lack of monitoring or research programs. Although impassable dams prevent resident rainbow trout from emigrating, populations with steelhead ancestry may still exist above some dams (Dennis McEwan, personal communication, 1998).

As stated above, the adult Central Valley steelhead population was estimated to number about 27,000 during the early 1960s (DFG 1965, as cited in McEwan and Jackson 1996). Historical counts of steelhead passing RBDD, which included both Coleman Hatchery and naturally spawned fish, are shown in Figure 3-1. The counts showed an obvious decline in steelhead returns to the upper Sacramento River between 1967 and 1993. Current escapement data are not available for naturally spawned steelhead in most tributaries, in large part because the gates at RBDD are now open more frequently in order to allow for fish passage. In addition there is a general lack of steelhead population monitoring in most of the Central Valley. A continual decline is not apparent in the time series of returning steelhead trapped at Nimbus (Figure 3-9) and Feather River (Figure 3-10) hatcheries, where data for post-drought years are available. The number of steelhead returning to Nimbus and Feather River hatcheries appears not to be related (Figure 3-11) even though both hatcheries use the same release strategy and release about the same number of smolts each year. The estimated number of steelhead spawning in the American River in 2002 was 32 percent of the number that entered Nimbus Hatchery (Hannon and Healey, 2002). An estimated 201–400 steelhead spawned in the American River in 2002, and 243–486 spawned in 2003, based on one to two redds per female. Some escapement monitoring surveys have been initiated in upper Sacramento River tributaries (Beegum, Deer, and Antelope Creeks) using snorkel methods similar to spring-run Chinook escapement surveys.

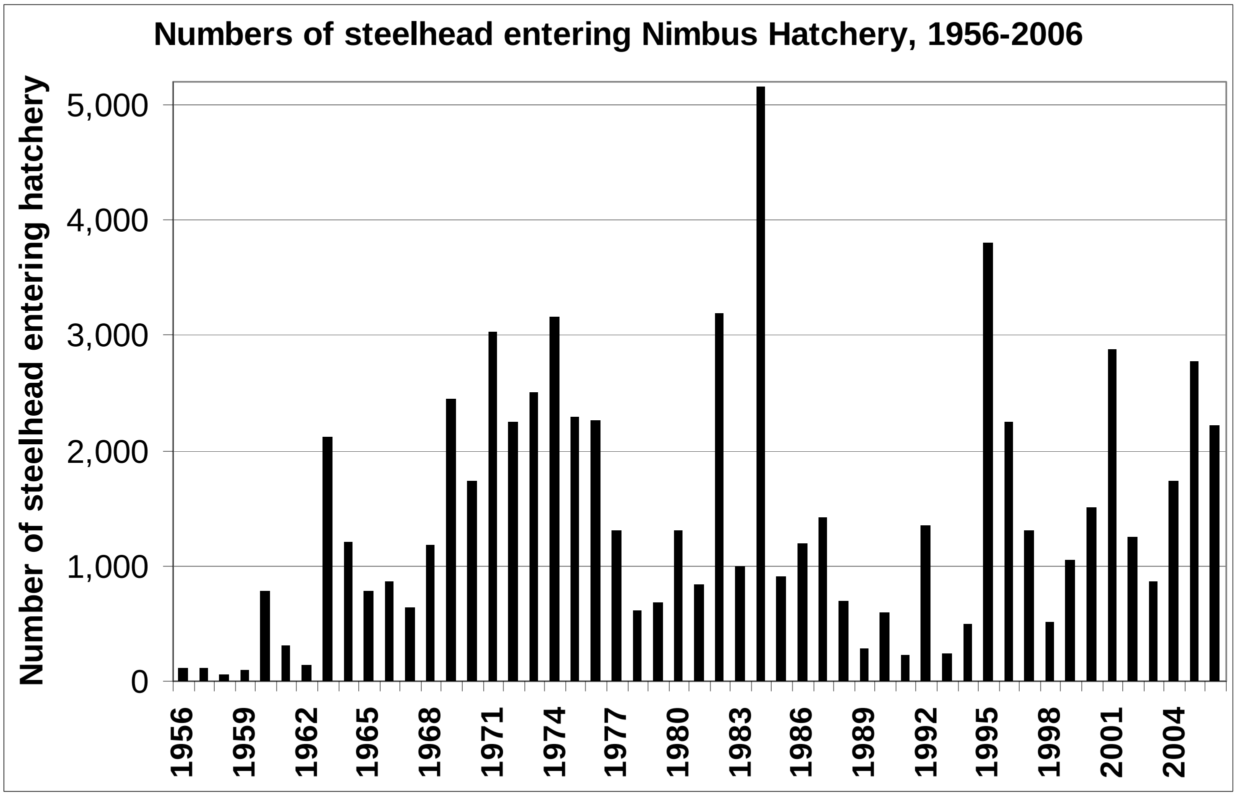


Figure 3-9 Adult steelhead counts at Nimbus Hatchery, 1956-2006.

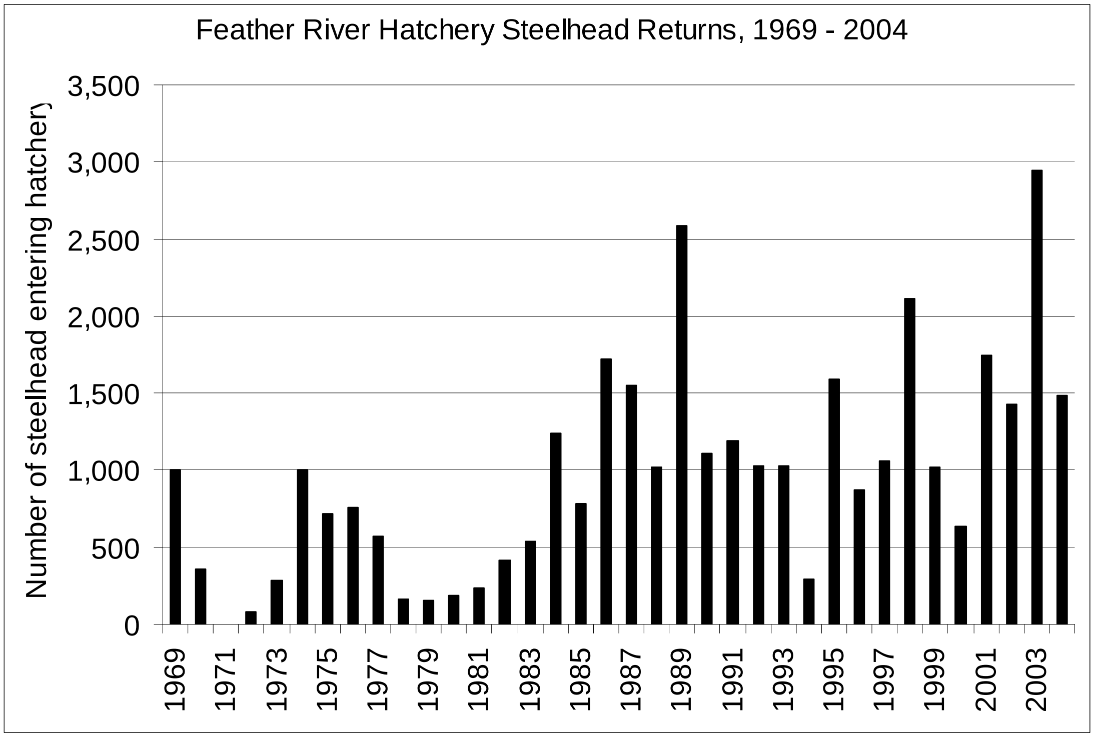


Figure 3-10 Adult steelhead counts at Feather River Hatchery, 1969-2004.

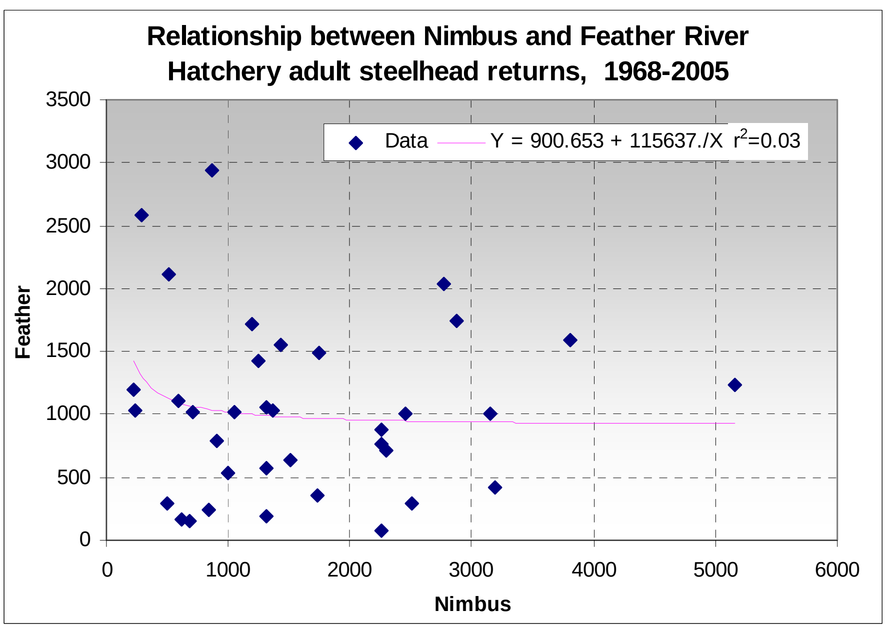


Figure 3-11 Relationship between Nimbus Hatchery and Feather River Hatchery steelhead returns, 1969 – 2004.

Although Coleman Hatchery production was included in counts at RBDD, these time series data presented in Figure 3-1 indicate that abundance patterns may differ between wild and hatchery stocks (and also between individual hatchery stocks), confounding interpretation of factors influencing Central Valley steelhead at the population or regional levels. Abundance patterns are conversely related for wild and hatchery fish and may influence each other as shown in Oregon and Washington (NOAA Fisheries 2003). The following provides an overview of the status of steelhead in Sacramento and San Joaquin tributaries under consultation. More detailed assessments of steelhead status in the Central Valley were provided by McEwan and Jackson (1996) and Busby et al. (1996).

Clear Creek

Historically, steelhead probably ascended Clear Creek past the French Gulch area, but access to the upper basin was blocked by Whiskeytown Dam in 1964 (Yoshiyama et al. 1996). Operation of Whiskeytown Dam can produce suitable coldwater habitat downstream to Placer Road Bridge depending on flow releases (DFG 1998). McCormick-Saeltzer Dam, which limited steelhead migrations through ineffective fish ladders, was removed in 2000, allowing steelhead potential access to good habitat up to Whiskeytown Dam. The FWS has conducted snorkel surveys targeting spring-run Chinook (May through September) since 1999. Steelhead/rainbow are enumerated and separated into small, medium, and large (>22 inches) during these surveys; but because the majority of the steelhead run is unsurveyed, no spawner abundance estimates have been attempted (Jess Newton, personal communication, 2001). Redd counts were conducted during the 2001-02 run and found that most spawning occurred upstream, near Whiskeytown Dam. Because of the large resident rainbow population, no steelhead population estimate could be made (Matt Brown, personal communication, June 2002). A remnant “landlocked” population of rainbow trout with steelhead ancestry may exist in Clear Creek above Whiskeytown Dam (Dennis McEwan, personal communication, 1998).

Summertime water temperatures are often critical for steelhead rearing and limit rearing habitat quality in many streams. Figure 3-12 shows that water temperatures in Clear Creek at Igo are maintained below 65°F year-round using releases of cool Whiskeytown Reservoir water. Figure 3-13 shows the daily water temperature fluctuation in Clear Creek at Igo for 1996-2006. This cool water source is maintained by diverting Trinity River water over into Clear Creek.

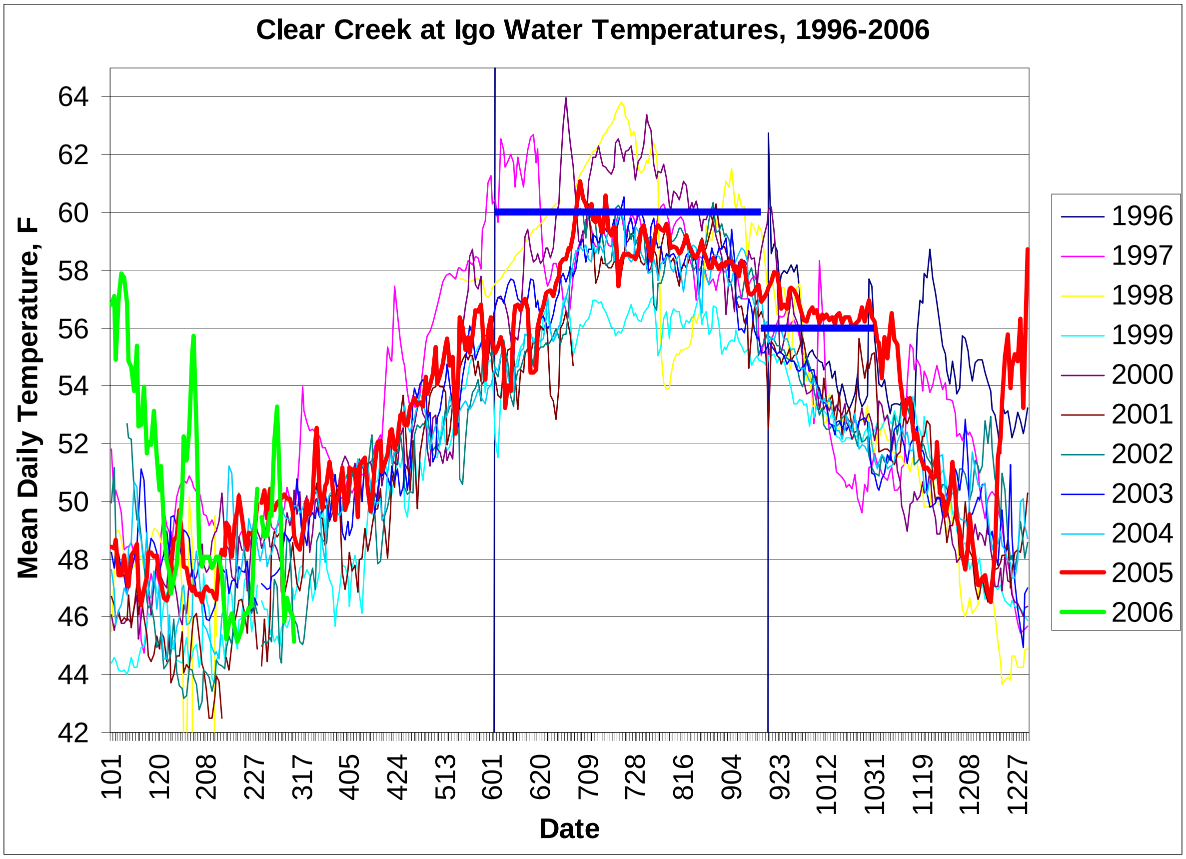


Figure 3-12 Clear Creek water temperature at Igo, 1996-2006 (CDEC). Dates are expressed like 101=January 1, 208=February 8, etc.

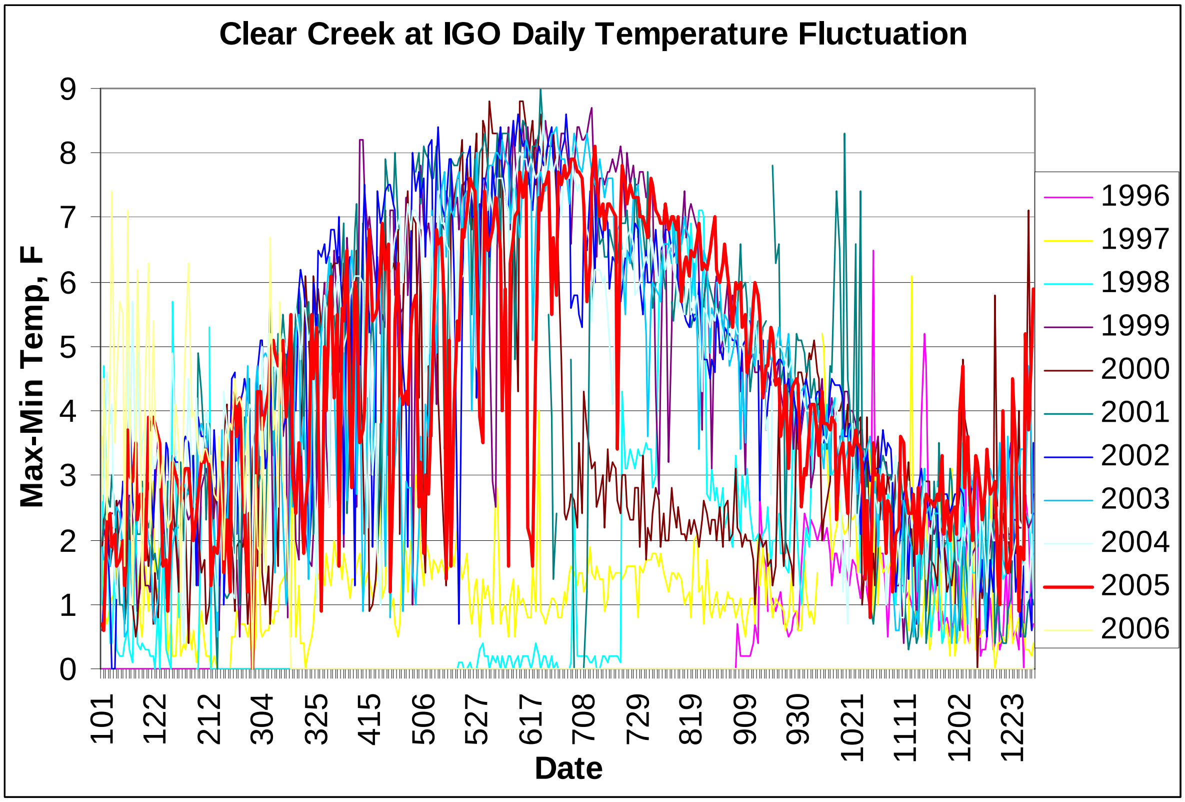


Figure 3-13 Clear Creek daily water temperature fluctuation at Igo, 1996-2006 (CDEC). Dates are expressed like 101=January 1, 208=February 8, etc.

Feather River

Historically, the Feather River supported a large steelhead population (McEwan and Jackson 1996). Today the run is supported almost entirely by the Feather River Hatchery. The hatchery produces about 450,000 yearling steelhead each year to mitigate for Oroville Dam and losses at the SWP Delta facilities. The current run is restricted to the river downstream of the Fish Barrier Dam at the hatchery.

California Department of Water Resources (DWR) initiated fish studies in the Lower Feather River in 1991. The focus and methods used for these studies were altered in 2003 as a result of consultations with NMFS, California Department of Fish and Game (DFG), and others to gather information needed to relicense the Oroville facilities with the Federal Energy Regulatory Commission (FERC). http://orovillerelicensing.water.ca.gov/documents.html .

Since the signing in 2006 of the Settlement Agreement for the FERC relicensing process, the monitoring program refocused on increasing understanding of the listed fish species in the Lower Feather River. The present program consists of several elements to monitor salmonid spawning, rearing, and emigration, including steelhead, and to document any potential impacts of project operations on fish species. A wide variety of equipment and monitoring methods are used including rotary screw traps, fyke traps, snorkel surveys, electrofishing, radio and acoustic tagging, carcass surveys, redd mapping, etc. Reports summarizing the results and findings are prepared and submitted to the regulatory agencies annually. http://wwwdes.water.ca.gov/ecological_studies_branch/frp_program/technicalreports.htm .

Although angler surveys by Painter et al. (1977) indicated adult steelhead were present in the Feather River from September through April, peak immigration probably occurs from September through January. Most of the fish spawn in the hatchery, although some spawn in the low-flow channel. During 2003, redd formation probably began in late December, peaked in late January, and was essentially complete by the end of March. Redd surveys counted 75 steelhead redds and revealed that 48 percent of all redds were in the upper mile of the river between Table Mountain Bicycle Bridge and lower auditorium riffle in 2003 (Kindopp and Kurth 2003).

Screw trap monitoring indicates steelhead fry are present in the river as early as March (DWR 1999b). Snorkel surveys in 1999, 2000, and 2001 showed young steelhead reared through the summer at suitable locations throughout the low-flow channel, primarily along the margins of the channels under riparian cover and in secondary channels with riparian cover (Cavallo et al. 2003). The highest densities of young-of-the-year (YOY) steelhead were observed at the upstream end of the low-flow channel and in an artificial side channel fed by hatchery discharge. Summer water temperatures below Thermalito Afterbay Outlet are relatively high (>70°F), and snorkel surveys in 1999, 2000, and 2001 found almost no steelhead rearing below the outlet. Most YOY steelhead observed in the surveys were 55 to 75 mm FL by August and September, when many fish moved into higher velocity areas in the channel, away from channel margins. Snorkel surveys conducted in September and October 1999 found many steelhead in the 200 to 400 mm size range. These fish apparently represent early adult returns or resident rainbows. Adipose fin-clipped steelhead were also observed among these fish. By mid-September and October, some YOY steelhead were still present, but most YOY steelhead appear to leave the system before fall of their first year. Rotary screw trapping (RST) indicates most steelhead leave before summer (Cavallo et al. 2003).

There appears to be little mixing of hatchery and wild gene pools in the FRFH. This conclusion is based on study findings that show that only adipose clipped steelhead (hatchery-produced, presumably mostly from the FRFH) ever reach the FRFH. Spawned steelhead are released back to the river—there are no data to determine how many of these fish survive to spawn again. A hatchery and genetic management plan (HGMP) is being completed for the FRFH in consultation with NMFS.

Nevertheless, the commingling of spawning adults due to the blockage of fish to historical spawning and rearing habitat in headwater streams presumably provides an opportunity of mixing between FRFH-produced and wild steelhead. Homogenization of the wild Feather River steelhead genetic structure cannot be ascertained as there are no data to show if the river spawners are of direct hatchery origin or the progeny of previous natural spawners. Moreover, as there are no pre-Oroville Facilities genetic data, it is not possible to characterize the distinctness of historical steelhead in the Feather River. However, the existing data suggest that some of the original genetic attributes remain in the current steelhead populations in the Feather River.

American River

Historically, steelhead occurred throughout the upper reaches of the American River (McEwan and Jackson 1996). From 1850 through 1885, hydraulic mining caused the deposition of large quantities of sediment in the American River basin, silting over spawning gravel and nearly exterminating the salmon runs (Gerstung 1989, as cited in Yoshiyama et al. 1996). A series of impassable dams was constructed between 1895 and 1939. Fish ladders were later constructed around these dams, but many of them had passage problems. Access was restricted to the 27-mile reach below Old Folsom Dam after floodwater destroyed its fish ladder in 1950 (Gerstung 1971, as cited in Yoshiyama et al. 1996). Nimbus and Folsom Dams were completed in 1955 and 1956, respectively. Steelhead habitat is now limited to the 23-mile stretch between Nimbus Dam and the Sacramento River, although a remnant population of rainbow trout with steelhead ancestry may exist in the north fork of the American River (Dennis McEwan, personal communication, 1998).

Adult steelhead migrate into the Lower American River from November through April, with peak immigration during December through March (SWRI 2001, Figure 3-4). Juvenile steelhead rear in the Lower American River for one or more years and migrate out of the river during January through June (Snider and Titus 2000). Juvenile steelhead were monitored from July to October 2001 to detect the effects of warmer than normal water temperatures on steelhead abundance and distribution. Juvenile steelhead with good condition factors were found as far downstream as Paradise Beach through July and at Watt Avenue through August. Water temperatures during this period in these areas regularly rose to above 70 °F (Figure 3-14). All steelhead recaptures occurred in the same reach of the river as tagging occurred, indicating many fish remained in the same location for extended periods.

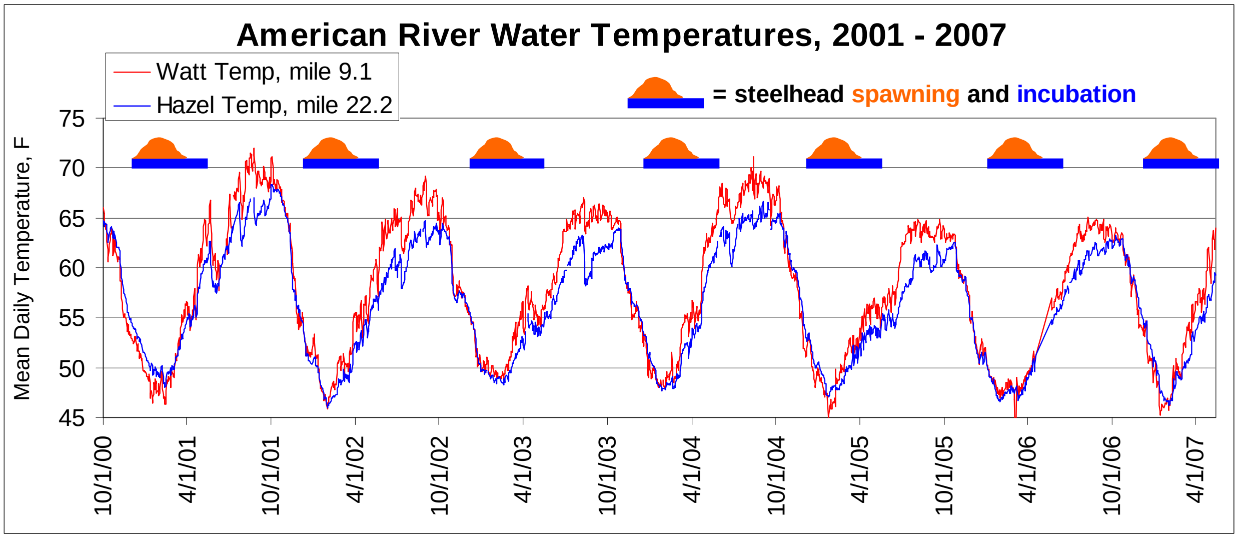


Figure 3-14 American River water temperature 2000 – 2007 (CDEC data).

The Lower American River population is supported mostly by Nimbus Hatchery, although natural spawning does occur (Hannon and Deason 2007). The hatchery produces about 430,000 steelhead yearlings annually to mitigate for Nimbus Dam. The hatchery included Eel River steelhead in its founding stock. Genetic analysis indicates Nimbus Hatchery-produced steelhead are more closely related to Eel River steelhead than other Central Valley stocks and are therefore not considered part of the Central Valley ESU (Busby et al. 1996; NMFS 1997b).

Since 1998, all hatchery-produced steelhead have been adipose fin-clipped to identify them as hatchery fish. Occasionally a few are missed, but the majority get clipped. During 2001 – 2007, 1 percent to 6 percent of the adult steelhead entering Nimbus Hatchery were wild (unclipped) fish (Table 3-1). Steelhead spawning surveys showed around 300 steelhead spawning in the river each year compared to hatchery returns during the same years of 1,200 to 2,700 steelhead (Hannon and Deason 2005). Many of the in-river spawners are hatchery produced fish. Spawning density is higher in the upper 7-mile reach, but spawning occurs down to the lowest riffle in the river at Paradise Beach. Redd depths were measured to assess affects from flow changes. The shallowest redds measured had 20 centimeters (cm) (8 inches) of water over them.

Table 3-2 shows American River steelhead spawning distribution delineated into the reaches used in the Chinook salmon egg mortality model. Figure 3-15 and Figure 3-16 show American River steelhead in-river spawning population estimates between 2002 and 2007.

Table 3-1 Adipose clip status of adult steelhead entering Nimbus Hatchery on the American River.

Year	Steelhead Entering Hatchery	Number Unclipped	Percent Unclipped
2001	2,877	50	1.7%
2002	1,253	69	5.5%
2003	873	27	3.1%
2004	1,741	17	1.0%

2005	2,772	118	4.3%
2007	2,673	116	4.3%

Table 3-2 American River steelhead spawning distribution, 2002-2007 (Hannon and Deason 2007). Data was not collected in 2006.

American River Steelhead redd distribution

		Redds per mile					Summary			
Reach	**Reach Miles**	**2002**	**2003**	**2004**	**2005**	**2007**	**Total redds 2002 2007**	**Average redds/mile**	**Steelhead Total %**	**Chinook %**
Above weir										
Nimbus to Sunrise bridge	2.86	28	30	27	28	24	334	**29**	**38%**	31%
Sunrise to Ancil Hoffman	4.73	7	11	9	4	28	213	**11**	**24%**	59%
Ancil Hoffman to Goethe bike bridge	1.89	2	13	15	9	42	84	**11**	**10%**	5%
Arden Rapids (Goethe bridge) to Watt bridge	4.1	7	12	9	3	9	151	**9**	**17%**	3%
Watt to Fairbairn water intake	2.02	0	0	1	0	13	6	**1**	**1%**	1%
Fairbairn to H Street bridge	0.75	0	0	0	0	1	0	**0**	**0%**	0%
H Street bridge to Paradise Beach	1.09	12	0	1	13	0	28	**6**	**3%**	1%
Paradise Beach to 16th st	3.49	0	0		0		0	**0**	**0%**	0%
16th st to Sacramento River	2.01	0	0		0		0	**0**	**0%**	0%
Total	22.94	7	9	8	6	8	874	**10**	**100%**	100%

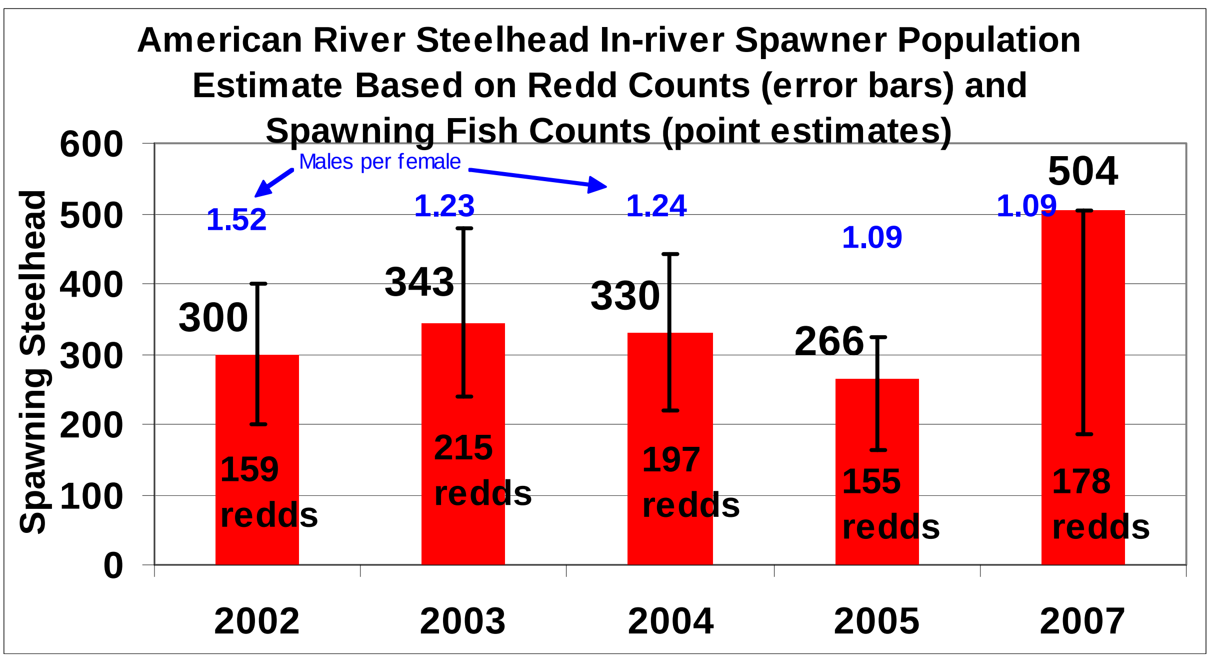


Figure 3-15 American River steelhead in-river spawning population estimate based on redd counts and spawning fish counts (Hannon and Deason 2007).

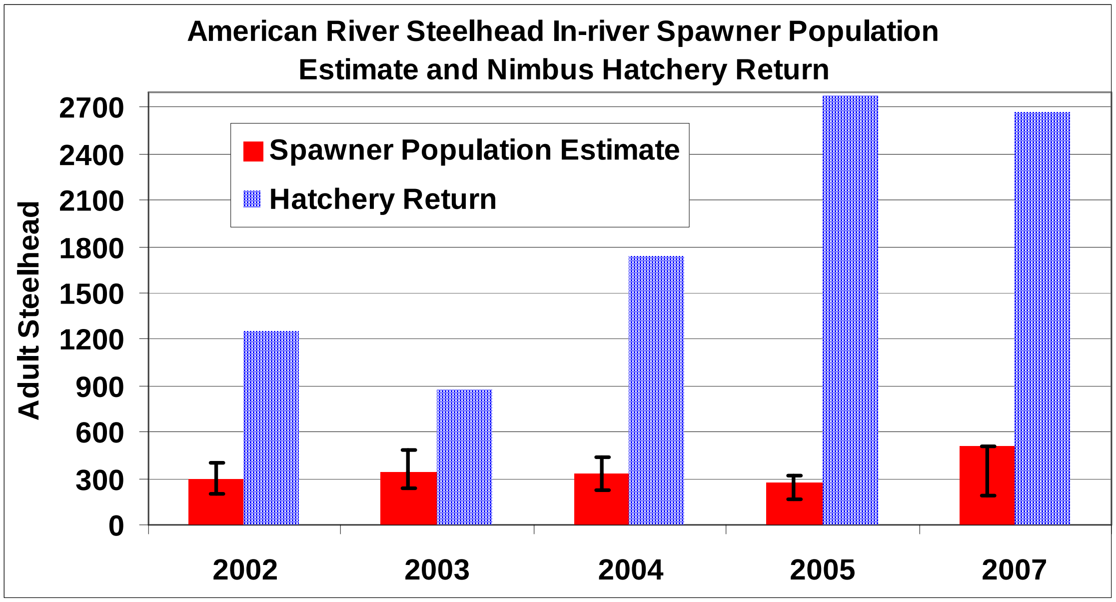


Figure 3-16 American River steelhead in-river spawning population estimate and Nimbus hatchery return (Hannon and Deason 2007).

Stanislaus River

Historically, steelhead distribution extended into the headwaters of the Stanislaus River (Yoshiyama et al. 1996). Dam construction and water diversion for mining and irrigation purposes began during and after the Gold Rush. Goodwin Dam, constructed in 1913, was probably the first permanent barrier to significantly affect Chinook salmon access to upstream habitat. Goodwin Dam had a fishway, but Chinook could seldom pass it. Steelhead may have been similarly affected. The original Melones Dam, completed in 1926, permanently prevented access to upstream areas for all salmonids. Currently, steelhead can ascend over 58 miles up the Stanislaus River to the base of Goodwin Dam. Although steelhead spawning locations are unknown in the Stanislaus, most are thought to occur upstream of the City of Oakdale where gradients are slightly higher and more riffle habitat is available.

The Fishery Foundation of California (Kennedy and Cannon 2002) has monitored habitat use by juvenile steelhead/rainbow since 2000 by snorkeling seven sites from Oakdale to Goodwin Dam every other week. Steelhead fry begin to show up in late March and April at upstream sites, with densities increasing into June and distribution becoming more even between upstream and downstream sites through July. Beginning in August and continuing through the winter months, densities appeared highest at upstream sites (Goodwin to Knights Ferry). Age 1-plus fish were observed throughout the year with densities generally higher at upstream sites (Goodwin to Knights Ferry). Low densities were observed from late December until April. It is unknown whether fish left the system in December or if, with the cooler winter water temperatures, they were less active and more concealed during the day.

Since 1993, catches of juvenile steelhead/rainbow in rotary screw traps (RSTs) indicate a small portion of the Stanislaus River steelhead/rainbow population displays downstream migratory characteristics at a time that is typical of steelhead migrants elsewhere. The capture of these fish in downstream migrant traps and the advanced smolting characteristics exhibited by many of the fish indicate that some steelhead/rainbow juveniles might migrate to the ocean in spring. However, it is not known whether the parents of these fish were anadromous or fluvial (they migrate within freshwater). Resident populations of steelhead/rainbow in large streams are typically fluvial, and migratory juveniles look much like smolts. Further work is needed to determine the parental life histories that are producing migratory juveniles. The Stanislaus River Weir has been installed annually since 2003 at RM 31.4. The primary purpose of the weir is to monitor escapement of fall-run Chinook salmon, so it is installed from September through June each year. Fish passing the weir are monitored using a Vaki infrared RiverWatcher Fish Counter. From 2003 through 2007, *O. mykiss* have been observed passing the weir a total of 16 times. Scale analysis of one individual indicated that it was a steelhead.

Smolts have been captured each year since 1995 in RSTs at Caswell State Park and at Oakdale (Demko et al. 2000). Captures occurred throughout the time the traps were run, generally January through June. Most fish were between 175 and 300 mm at the Caswell site, with only six fish in seven years less than 100 mm. Larger numbers of fry were captured upstream at Oakdale. During 2001, 33 smolts were captured at Caswell and 55 were captured at Oakdale, the highest catch of all years. Although improved traps were used, the higher catch in 2001, was likely due to more fish present and not due to better trap efficiencies (Doug Demko, personal communication, 2001). RSTs are generally not considered efficient at catching fish as large as steelhead smolts and the number captured is too small to estimate capture efficiency so no steelhead smolt outmigration population estimate has been calculated.

Genetic analysis of rainbow trout captured below Goodwin Dam shows that this population has closest genetic affinities to upper Sacramento River steelhead (NMFS 1997b).

The most consistent data available on rainbow/steelhead in the San Joaquin River are collected at the Mossdale trawl site on the lower San Joaquin River (Marston 2003). Figure 3-17 shows that counts were highest in the initial years of the Mossdale trawl survey in 1988–90.

Sacramento-San Joaquin Delta

The Delta serves as an adult and juvenile migration corridor, connecting inland habitat to the ocean. The Delta may also serve as a nursery area for juvenile steelhead (McEwan and Jackson 1996). Estuaries are important nursery grounds for other coastal steelhead populations. However, the historical and current role of the Delta as a steelhead nursery habitat is unknown. Based on fish facility salvage data, most steelhead move through the Delta from November through June, with the peak salvage occurring during February, March, and April. The majority of steelhead salvaged range from 175–325 mm, with the most common size in the 226–250 mm range (Figure 3-18). Unclipped fish tended to have a higher proportion of larger individuals than clipped fish.

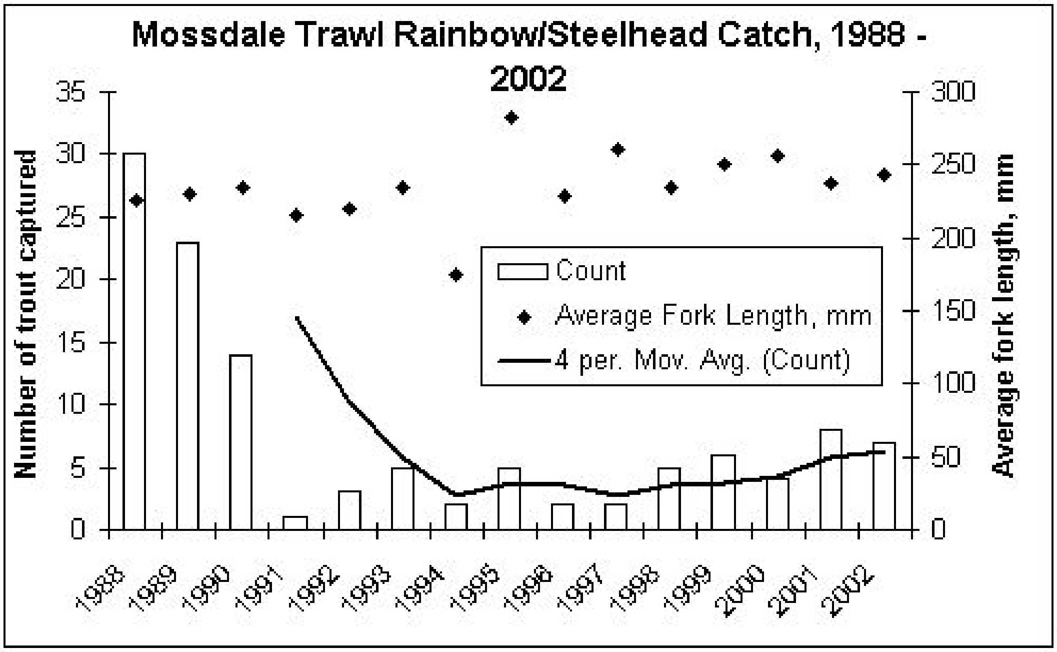


Figure 3-17 Mossdale Trawl rainbow/steelhead catch, 1988-2002 (Marston 2003).

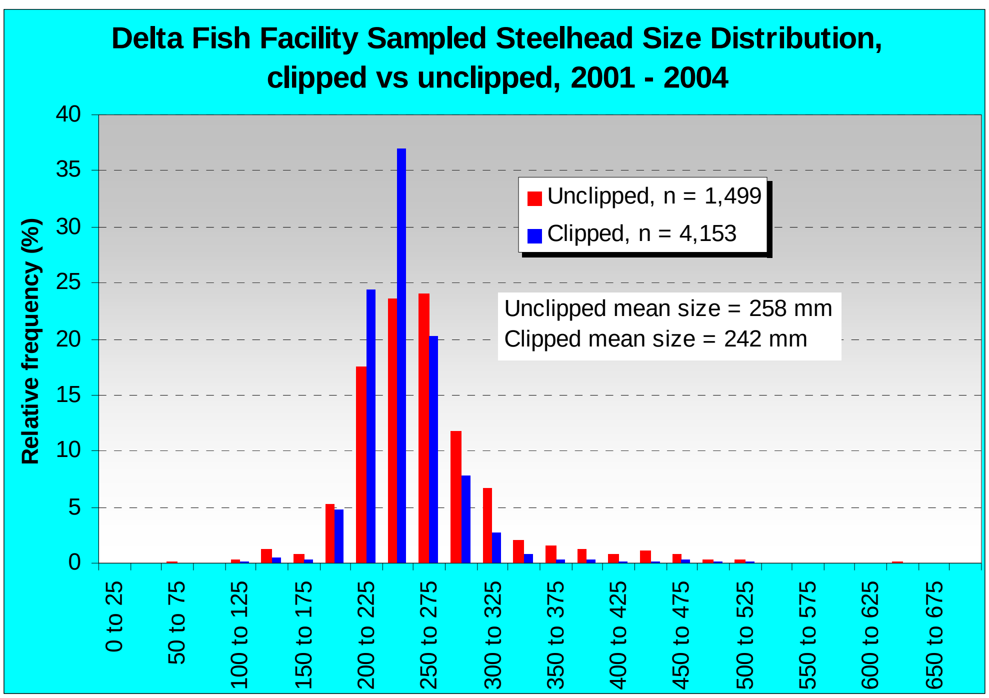


Figure 3-18 Length frequency distribution of clipped and unclipped steelhead salvaged at the CVP and SWP in 2001-2004.

Critical Habitat

The critical habitat designation (70 FR 52488, September 2, 2005) lists primary constituent elements (PCEs) which are physical or biological elements essential for the conservation of the listed species. The PCEs include sites essential to support one or more life stages of the ESU (sites for spawning, rearing, migration, and foraging). The specific PCEs include:

1. Freshwater spawning sites
2. Freshwater rearing sites
3. Freshwater migration corridors
4. Estuarine areas
5. Nearshore marine areas
6. Offshore marine areas

Water operations can affect habitat conditions in the first four of the PCEs. These four PCEs are present in the action area. The designated critical habitat is shown in Figure 3-1.

The Central Valley steelhead critical habitat potentially affected by CVP and SWP operations includes the Sacramento – San Joaquin Delta channels, the San Joaquin River up to the mouth of the Stanislaus River, the Stanislaus River up to Goodwin Dam, the Sacramento River up to Keswick Dam, Clear Creek up to Whiskeytown Dam, the Feather River up to the fish barrier dam, and the American River up to Nimbus Dam (Figure 3-19). The following is a brief summation of the primary constituent elements of the habitat in each of the rivers.

Spawning Habitat

Steelhead in the Sacramento River spawn primarily between Keswick Dam and Red Bluff Diversion Dam during the winter and spring. The highest density spawning area is likely in the upstream portion of this area in the vicinity of the city of Redding, although detailed surveys of steelhead spawning in the mainstem Sacramento River are not available. Most Sacramento River steelhead probably spawn in the tributary streams. Steelhead spawn in Clear Creek mostly within a couple miles of Whiskeytown Dam but spawning extends for about 10 miles downstream of the dam (Matt Brown, pers comm.). Steelhead spawn in the Feather River from the fish barrier dam downstream to Gridley with nearly 50% of all spawning occurring the first mile of the low flow channel (DWR 2003; http://orovillerelicensing.water.ca.gov/pdf_docs/07-30-03_env_att_11.pdf). Steelhead spawn in the American River from Nimbus Dam (mile 23) downstream to the lowest riffle in the river at Paradise Beach (mile 5). Most spawning is concentrated in the upper seven miles of the river (Hannon and Deason 2007). Steelhead (and/or rainbow trout) spawn in the Stanislaus River from Goodwin Dam downstream to approximately the city of Oakdale. Steelhead spawning surveys have not been conducted in the Stanislaus River so detailed spawning distribution is unknown but based on observations of trout fry, most spawning occurs upstream of Orange Blossom Bridge.

Freshwater Rearing Habitat

Juvenile steelhead reside in freshwater for a year or more so they are more dependent on freshwater rearing habitat than are the ocean type Chinook salmon in the Central Valley. Steelhead rearing occurs primarily in the upstream reaches of the rivers where channel gradients tend to be higher and, during the warm weather months, where temperatures are maintained at more suitable levels by cool water dam releases. The Sacramento River contains a long reach of suitable water temperatures even during the heat of the summer. Steelhead rearing in the Sacramento River occurs mostly between Keswick Dam (RM 302) and Butte City (RM 169) with the highest densities likely to be upstream of Red Bluff Diversion Dam. Steelhead rearing in Clear Creek is concentrated in the upper river higher gradient areas but probably occurs down to the mouth. Steelhead rearing in the Feather River is concentrated in the low flow channel where temperatures are most suitable (DWR 2004; http://orovillerelicensing.water.ca.gov/pdf_docs/04-28-04_att_10_f10_3A_steelhead_hab_use.pdf). Steelhead rearing in the American River occurs down to Paradise Beach with concentrations during the summer on most major riffle areas and highest densities near the higher density spawning areas. Steelhead rearing in the Stanislaus River occurs upstream of Orange Blossom Bridge where gradients are highest. The highest rearing densities are upstream of Knights Ferry (Kennedy and Cannon 2005).

Freshwater Migration Corridors

Steelhead migrate during the winter and spring of the year, as juveniles, from the rearing areas described above downstream through the rivers and the Delta to the ocean. The habitat conditions they encounter from the upstream reaches of the rivers downstream to the delta become generally further from their preferred habitat requirements until they reach the ocean. The generally non-turbulent flows and sand substrates found in the lower river reaches are not preferred types of habitat so steelhead do not likely reside for extended periods in these areas except when food supplies, such as smaller young fish, are abundant and temperatures are suitable. Predatory fishes such as striped bass tend to be more abundant in the lower rivers and the Delta. Emigration conditions for juvenile steelhead in the Stanislaus River down through the San Joaquin River and the south Delta tend to be less suitable than conditions for steelhead emigrating from the Sacramento River and its tributaries.

Adult steelhead migrate upstream from the ocean to their spawning grounds near the terminal dams primarily during the fall and winter months. Flows are generally lower during the upstream migrations than during the outmigration period. Areas where their upstream progress can be affected are the Delta Cross Channel Gates, Red Bluff Diversion Dam, and Anderson Cottonwood Irrigation District Diversion Dam.

Estuarine Areas

Steelhead use the San Francisco estuary as a rearing area and migration corridor between their upstream rearing habitat and the ocean. The San Francisco Bay estuarine system includes the waters of San Francisco Bay, San Pablo Bay, Grizzley Bay, Suisuin Bay, Honker Bay, and can extend as far upstream as Sherman Island during dry periods. At times steelhead likely remain for extended periods in areas of suitable habitat quality where food such as young herring, salmon and other fish and invertebrates is available.

Central California Coast Steelhead

Central California Coast steelhead are present only at the downstream end the area affected by CVP and SWP operations. The upstream extent of their habitat is San Pablo Bay and Napa River. The spawning habitat, freshwater rearing habitat, and freshwater migration corridors in Napa

River and other rivers with critical habitat in San Francisco Bay is not affected by CVP and SWP operations. The San Francisco estuary is the portion of the Central California Coast steelhead critical habitat potentially affected by water operations.

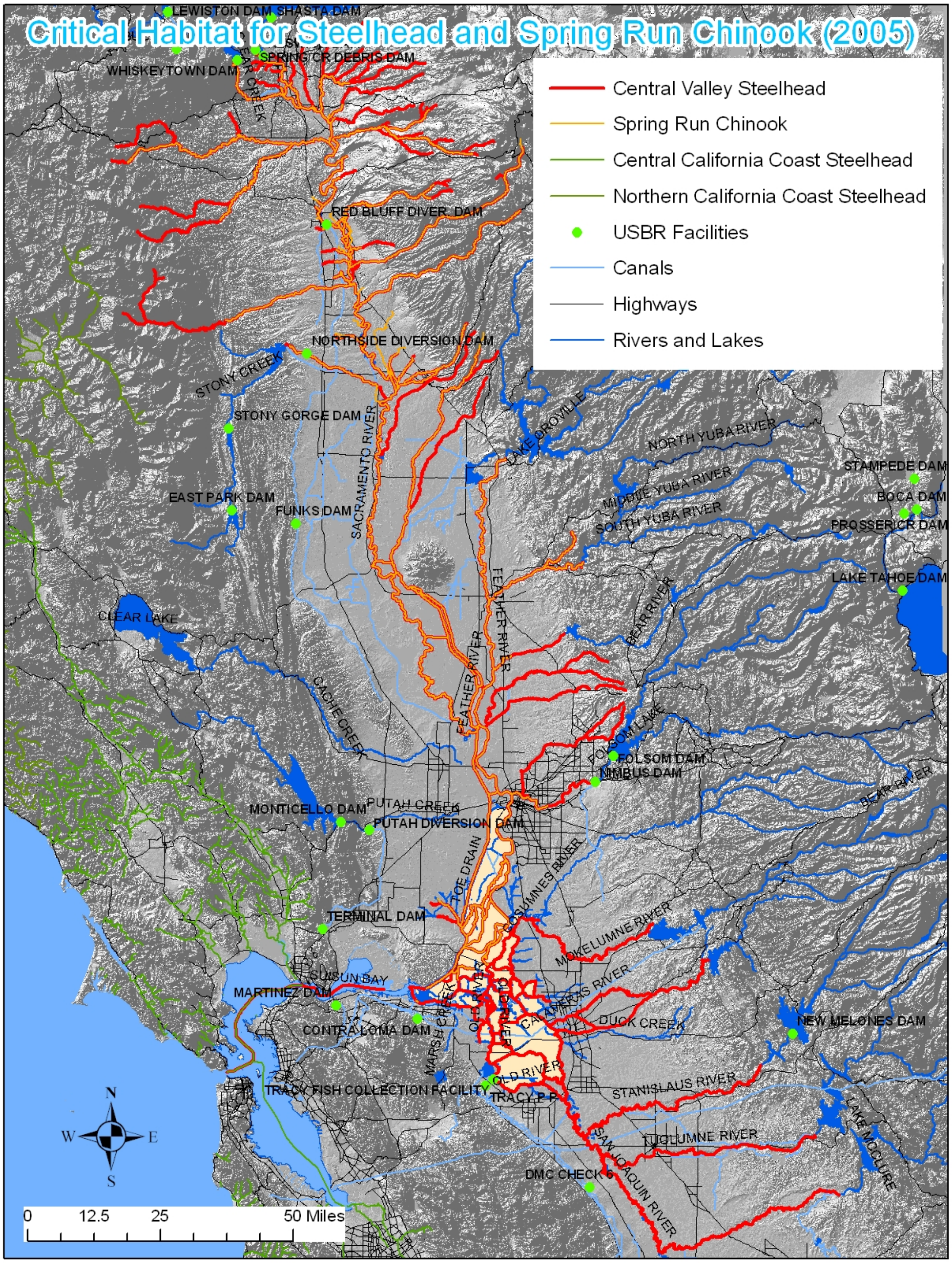


Figure 3-19 Designated critical habitat for Central Valley steelhead, Central Valley spring run Chinook salmon, and Central California Coast steelhead. Note: spring-run Chinook plotted over the top of steelhead (critical habitat GIS coverage from NMFS).

Streamflow

Figure 3-20 through Figure 3-24 show how monthly flows downstream of the terminal dams in each of the affected rivers have changed since operations of the respective dams began. The plots were generated from daily USGS stream gauge data using the Index of Hydrologic Alteration software (Richter et al 1996). The general change has been an increase in flows during the summer and fall months, the time of the historically lowest streamflows, and a decrease in flows during the winter and spring months, the time of the historically highest flows. The result of the change in flows has been a decrease in hydrologic variability and a loss of complexity in the freshwater aquatic habitat. These changes to the habitat are a part of the baseline.

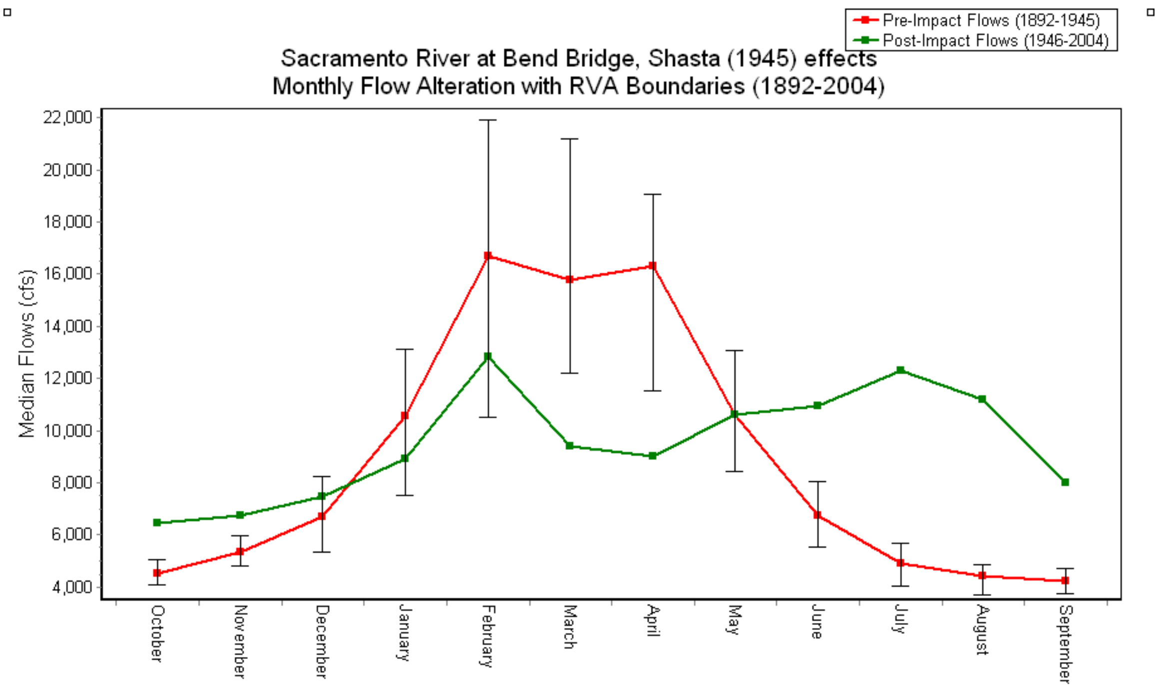


Figure 3-20 Sacramento River at Bend Bridge monthly flows comparing pre-Shasta Dam (1892-1945) to post Shasta (1946-2004) flows. The vertical lines represent range of variability analysis boundaries.

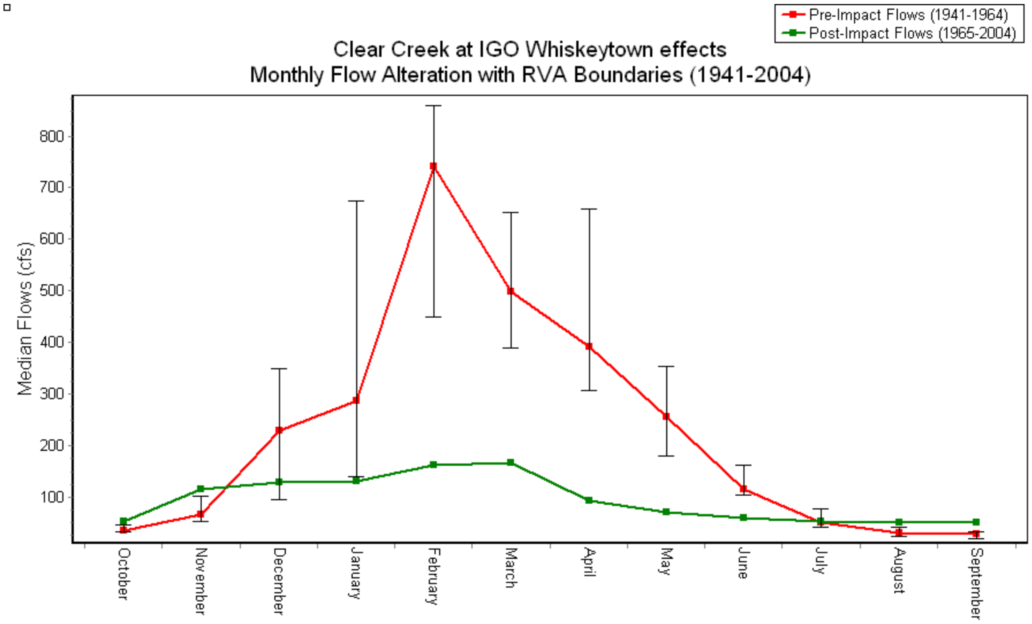


Figure 3-21 Clear Creek monthly flows comparing pre-Whiskeytown Dam (1941-1964) to post Whiskeytown (1965-2004) flows. The vertical lines represent range of variability analysis boundaries.

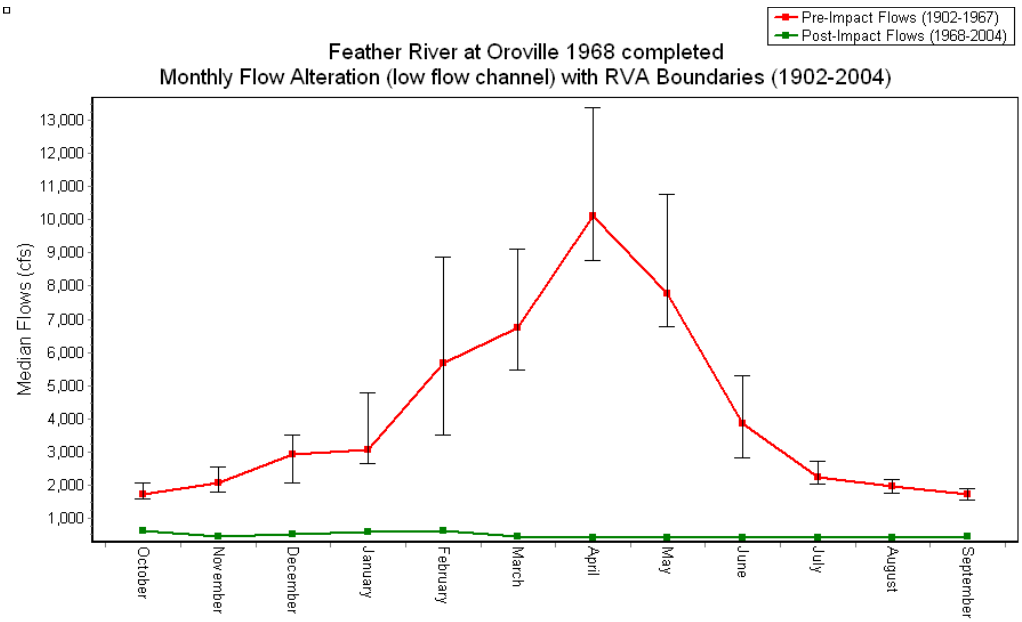


Figure 3-22 Feather River monthly flows comparing pre-Oroville Dam (1902-1967) to post Oroville (1966-2004) flows in the low flow channel, total releases from Oroville Dam are much higher than those reported here. The vertical lines represent range of variability analysis boundaries.

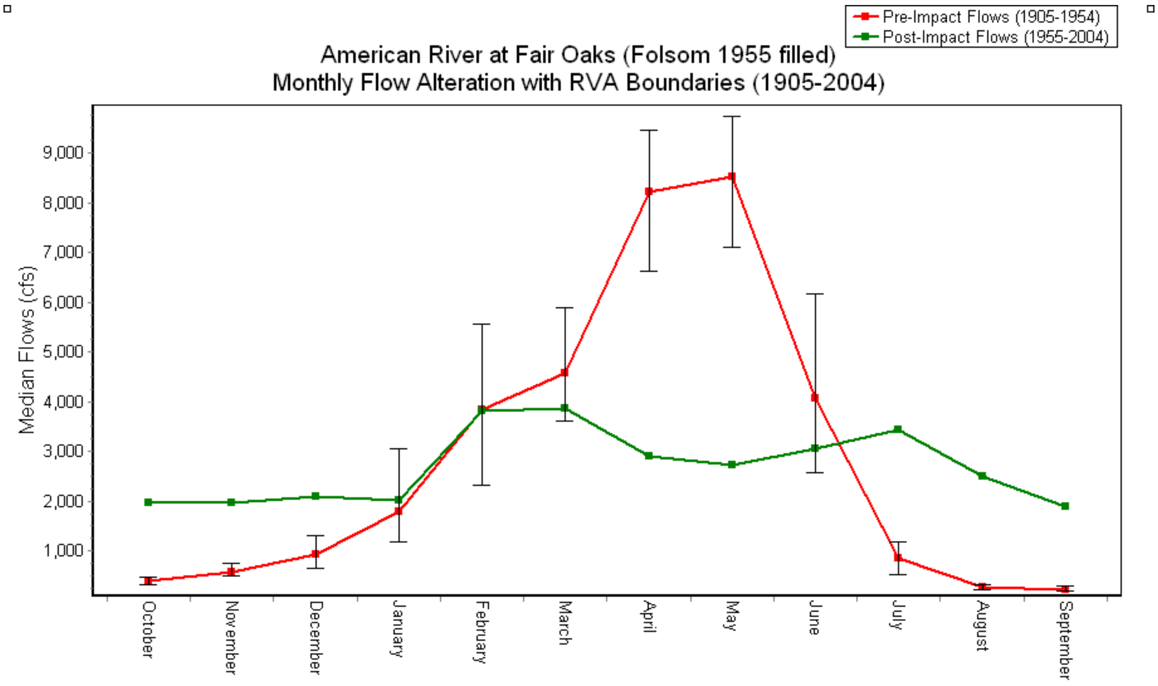


Figure 3-23 American River at Fair Oaks monthly flows comparing pre-Folsom Dam (1905-1954) to post Folsom (1955-2004) flows. The vertical lines represent range of variability analysis boundaries.

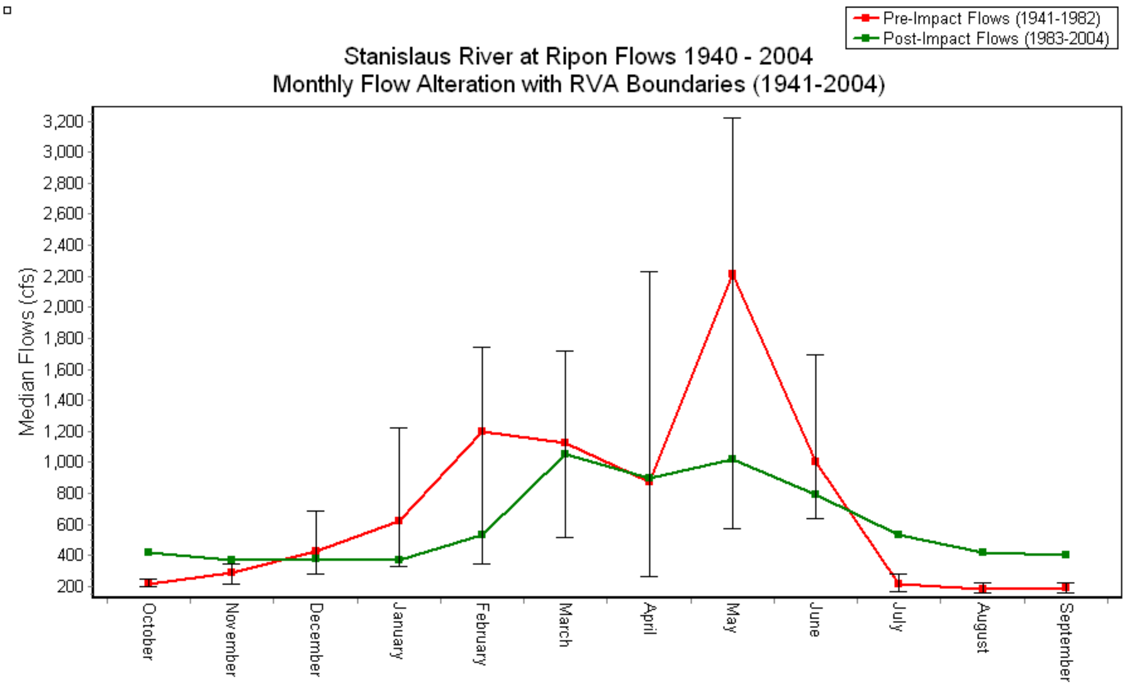


Figure 3-24 Stanislaus River at Ripon monthly flows comparing pre-New Melones Dam (1941-1982) to post New Melones (1983-2004) flows. The vertical lines represent range of variability analysis boundaries.

Water Temperature

Water temperatures in tailwater reaches in the area currently designated as critical habitat are cooler during the summer and warmer during the winter than what occurred historically. This moderation in water temperatures is due to the volume of water stored in each reservoir dampening the seasonal variation in inflow water temperatures. Historically when Chinook and steelhead had access higher into the watersheds the area currently used for spawning and rearing of Chinook salmon and steelhead was less suitable because of higher water temperatures during the summer and fall. During winter and spring water temperatures were cooler in the currently accessible habitat than what occurs now within the tailwater influenced reaches.

The change in temperature regime experienced by Chinook and steelhead may have changed the life history of the fish. For example warmer temperatures during the spring run and steelhead egg incubation period may result in earlier emergence than occurred historically. Current water temperature conditions throughout the year for each of the rivers is shown in Figure 3-25 through Figure 3-31.

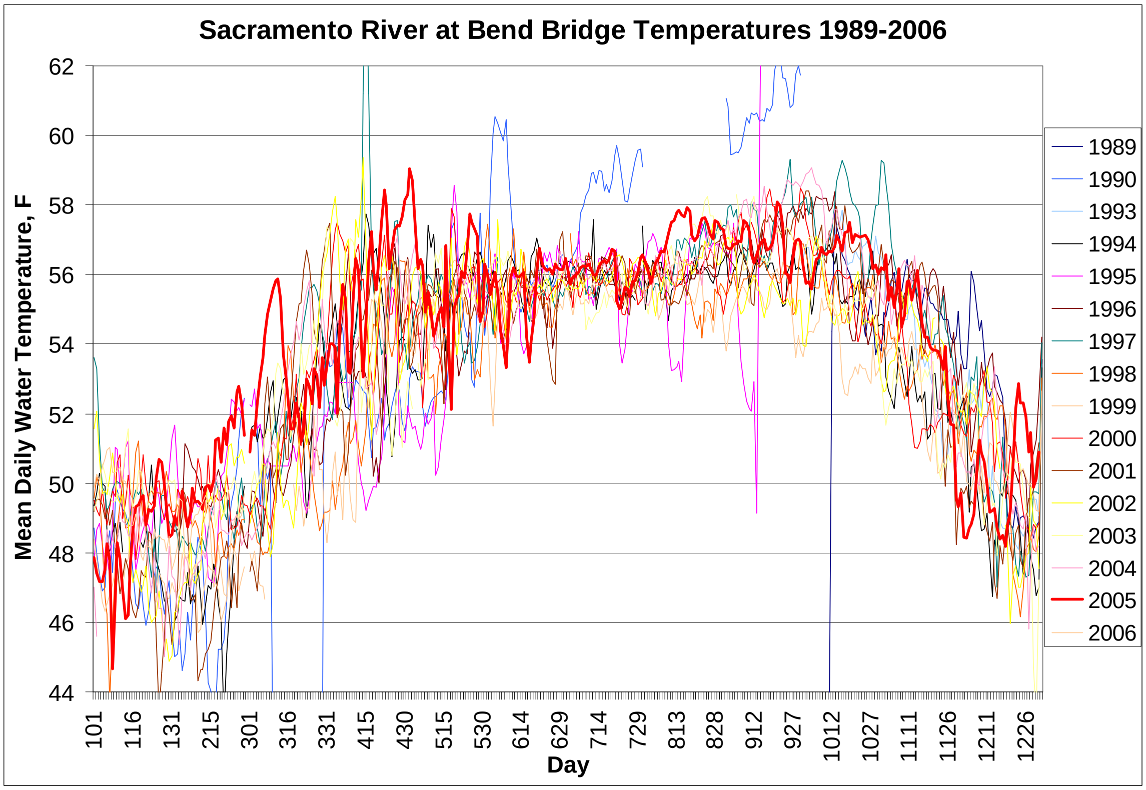


Figure 3-25 Sacramento River at Bend Bridge mean daily water temperatures 1998 – 2006.

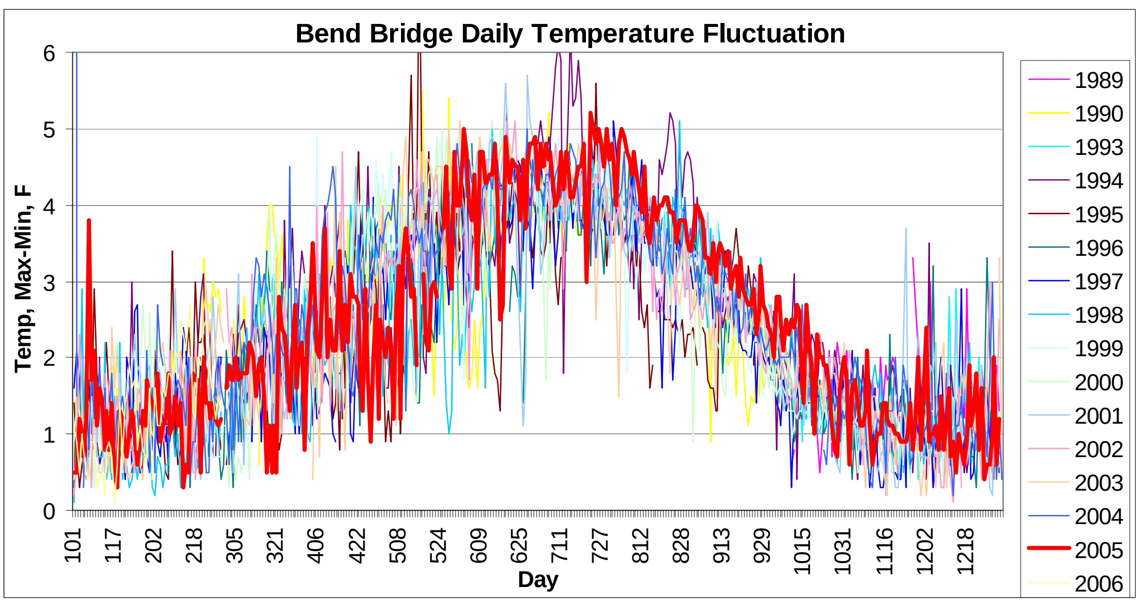


Figure 3-26 Sacramento River at Bend Bridge daily water temperature fluctuation (daily high temperature minus daily low temperature).

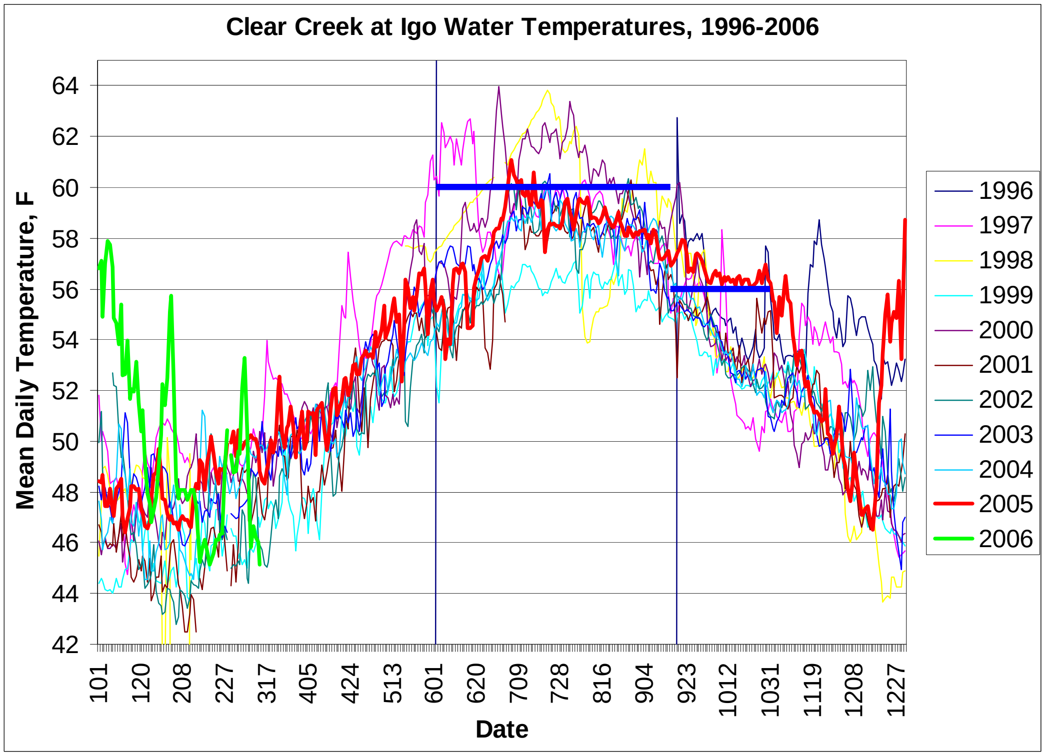


Figure 3-27 Clear Creek at Igo mean daily water temperatures 1996 – 2006.

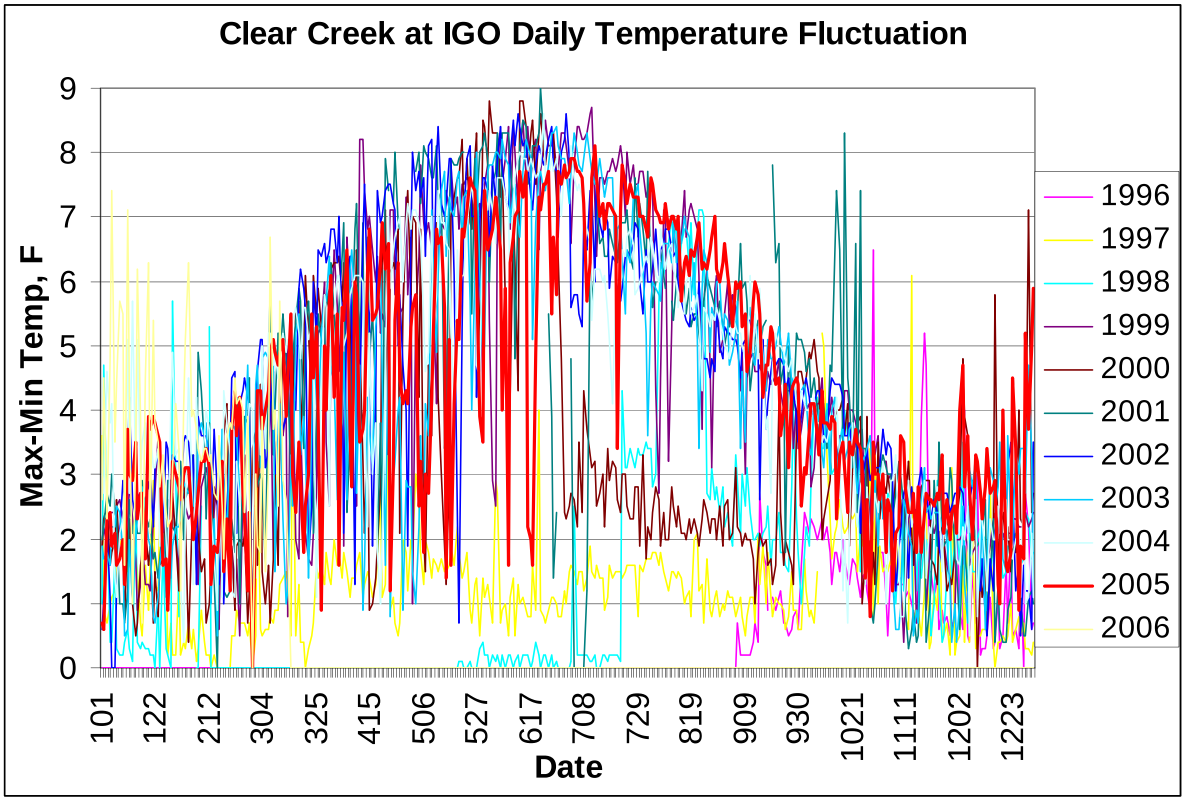


Figure 3-28 Clear Creek at Igo daily water temperature fluctuation (maximum daily minimum daily temperature).

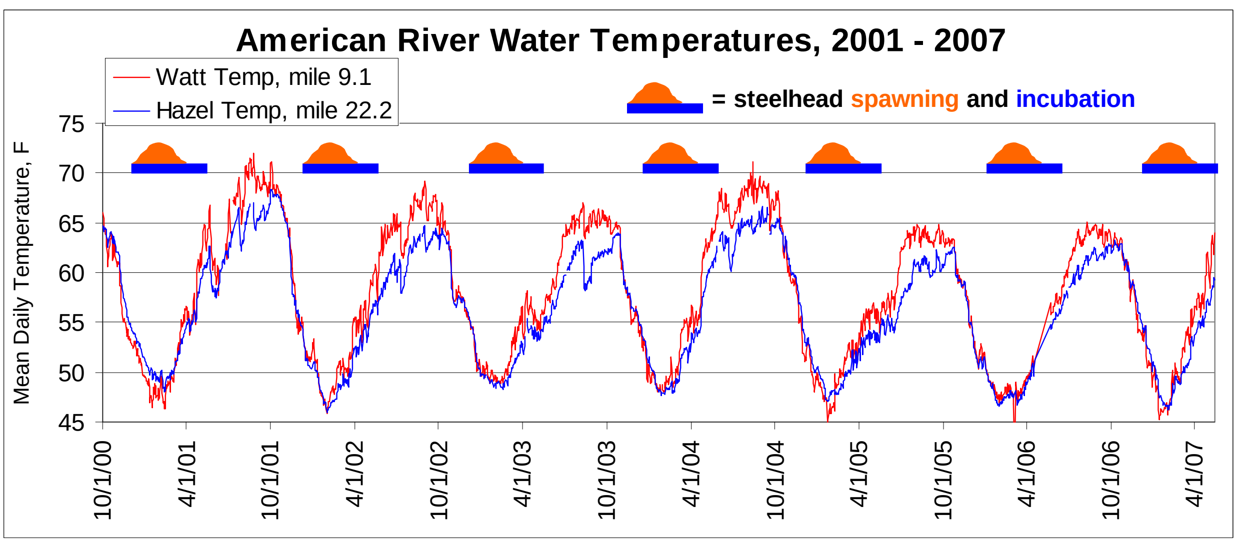


Figure 3-29 American River mean daily water temperatures, 2000 – 2007 at Hazel Avenue and Watt Avenue.

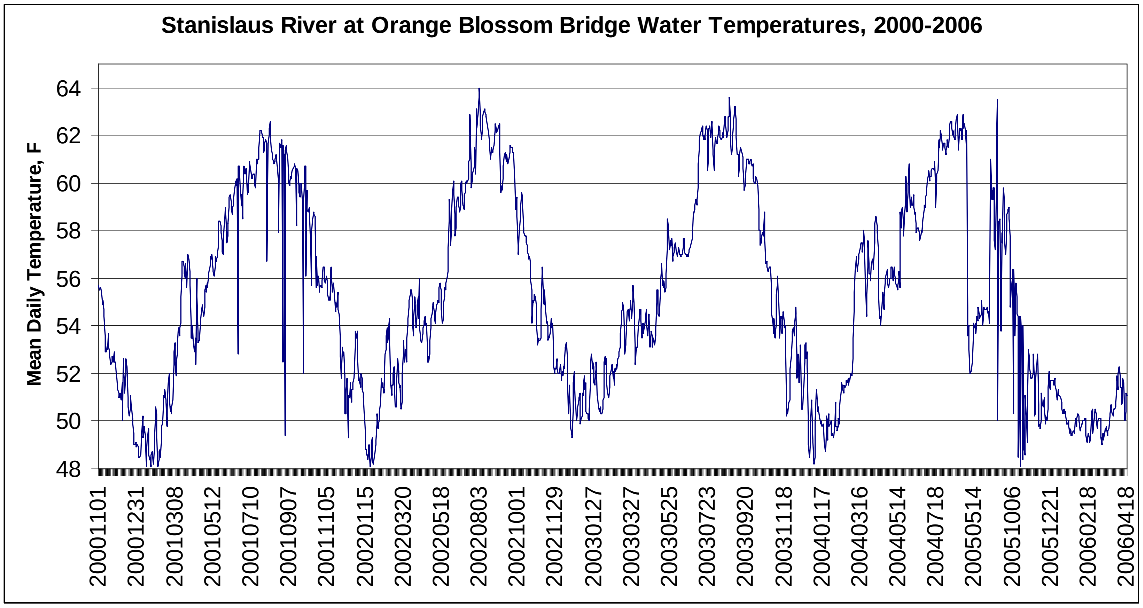


Figure 3-30 Stanislaus River at Orange Blossom Bridge water temperatures, 2001 – 2005. Note: some gaps in data exist.

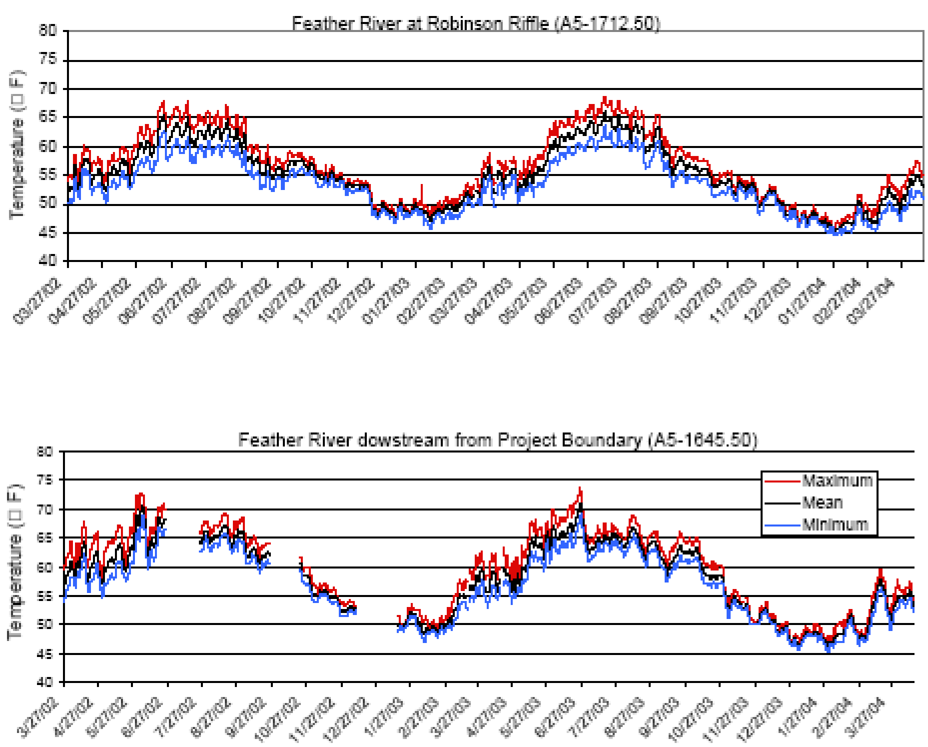


Figure 3-31 Feather River water temperatures, 2002 – 2004.

Effect of Cool Summer Time Dam Releases on Steelhead Habitat

The critical habitat of the Sacramento River below Keswick Dam is managed for cool water during the summer to protect winter-run Chinook salmon. This area was historically warmer and was not as suitable for juvenile steelhead during the summer. Prior to dam construction most trout probably reared further upstream, above the Shasta Lake area. The cool water provided over the summer downstream of Shasta Dam for winter-run Chinook salmon has been implicated in potentially decreasing the steelhead population due to an increase in the resident trout population (Cramer 2006). A similar situation occurs in the Stanislaus River downstream of Goodwin Dam and Clear Creek downstream of Whiskeytown Dam where cool water releases are maintained throughout the summer and resident rainbow trout populations are high. The larger resident trout populations may potentially compete with juvenile steelhead, reducing the juvenile steelhead population. The existence of the large, stable areas of habitat conditions in the dam tailwaters may promote residualism of the anadromous trout. The Cantara chemical spill occurred July 14, 1991 in the upper Sacramento River five miles upstream of the city of Dunsmuir. An estimated 309,000 trout were killed by the spill in an approximately thirty mile reach of the river, upstream of Shasta Lake (Hankin and McCanne 2000). Scale analysis and genetic analysis indicated 83-96% of these fish were wild (non-hatchery produced) trout. This population size amounts to 10,300 trout per mile (two trout per linear foot of river). This may be the best estimate of trout population size in any part of the Sacramento River. The population has since recovered to a similar density of trout in this reach. Water temperatures in this reach of the river are probably not much changed (or potentially higher due to Lake Siskiyou) compared to historic temperatures. The high trout population in this reach is probably similar to what existed in the upper Sacramento River historically in the presence of steelhead. Therefore we expect that the high resident trout population supported by cool water downstream of Central Valley Dams such as Keswick, Goodwin, and Whiskeytown is not a major factor in decreasing the anadromous populations in those systems. In any event the resident fish do produce anadromous individuals and maintain a supply of fish for the anadromous population.

San Joaquin River Flows

San Joaquin River flows in the critical habitat from the Merced River downstream are managed for one life history type of Chinook salmon. Flows are managed for fall-run Chinook salmon to enter the river in October, spawn in November, and incubate and rear in the river until late spring. Since 2000, flows are increased and delta exports decreased from generally mid-April to mid-May to aid emigration of the large (~75-100 mm) Chinook salmon juveniles out of the river and improve survival through the Delta to the estuary as part of the Vernalis Adaptive Management Program (VAMP). Flows prior to April 15 are managed for in-river rearing of Chinook and steelhead with no pulses, other than that provided by brief tributary inflows, to aid emigration of yearling Chinook, Chinook fry, or steelhead from the system. Little data on steelhead in the San Joaquin system exists so it is assumed that the flows that are managed for fall-run Chinook will adequately support the steelhead life history. Data from the Stanislaus River weir shows that the adult steelhead population in the Stanislaus is very low compared to the large resident rainbow trout population that is evident when snorkeling the river.

Predation

Species that prey on steelhead and Chinook salmon in the critical habitat of the project area include striped bass, Sacramento pikeminnow, smallmouth bass, trout, largemouth bass, seagulls, mergansers, cormorants, river otters, herons, sea lions, and seals. Striped bass, smallmouth bass, and largemouth bass are the introduced species that prey on salmonids and probably represent the greatest change (increase) in predation that has been experienced in the critical habitat compared to historical conditions.

Tucker et al (1998) found salmonids present in pikeminnow and striped bass stomachs at Red Bluff Diversion Dam. Salmonids outweighed other food in striped bass stomachs by a three to one margin. Reese and Harvey (2002) studied interactions between steelhead and Sacramento pikeminnows in laboratory streams. They found that growth of dominant steelhead was unaffected by presence of pikeminnow in water 15-18 ºC while at 20-23 ºC growth of dominant steelhead was reduced by over 50% in trials with steelhead alone compared to trials of steelhead with pikeminnows.

Merz (1994) measured striped bass predation on salmonids and estimated that striped bass consumed 11%-28% of the estimated Mokelumne River natural Chinook salmon production in 1993 at the Woodbridge Dam afterbay.

Connor et al (2003) describe a relationship in the Snake River where emigrating juvenile Chinook salmon survival generally increased with increasing flow and decreased with increasing temperature. They postulate that the clearer water and lower water velocities during lower flows increase the time the fish are exposed to predators while moving downstream and that higher water temperatures disrupt downstream movement exacerbating predation. A similar relationship is possible in the Central Valley rivers.

Consideration of Variable Ocean Conditions

Salmon and steelhead spend the majority of their lives in the ocean. Therefore, conditions in the ocean exert a major influence on the growth and survival of these fish from the time they leave the critical habitat in the Action Area (freshwater) until they return as adults to reproduce. Mantua et al (1997) described a recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude North Pacific basin. Over the past century, the amplitude of this climate pattern has varied irregularly at interannual-to-interdecadal time scales. They refer to this pattern as the Pacific Decadal Oscillation (PDO). Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States, while cold PDO eras have seen the opposite north-south pattern of marine ecosystem productivity.

Another pattern, called the *El Niño/Southern Oscillation (ENSO),* occurs on a shorter time scale of six to eighteen months compared to 20 to 30 years for the PDO. The same general pattern is evident with warm periods showing inhibited productivity along the Pacific coast offshore of California and enhanced ocean biological productivity in Alaska.

Sierra snowpack and streamflow are also correlated with ENSO and PDO. During the warm phases lower snowpack and streamflows occur and during cool phases above average snowpack and streamflows occur (Mantua et al, 1997).

During the cooler phases of ENSO and PDO, California salmonid populations generally experience increased marine survival. In addition, higher streamflows tend to occur during the cooler phases, enhancing freshwater production and providing the opportunity for more diverse life history types of juvenile salmonids. The inverse effects on California salmonid populations tend to occur during warm cycles. These alternating patterns of productivity, not caused by water operations, can mask and override most changes in populations that occur due to water operations. Therefore, any effects need to be considered in light of variable and difficult to quantify ocean conditions and climate variability.

Mitigation Hatchery Steelhead Effects on Wild Steelhead

Kostow and Zhou (2006) investestigated the effect of a hatchery program for summer steelhead on the productivity of a wild winter steelhead population in the Clackamas River, Oregon. They found that when high numbers of hatchery summer steelhead adults were present the production of wild winter steelhead smolts and adults was significantly decreased. Large releases of hatchery smolts also contributed to the decrease in adult productivity. They concluded that over the duration of the hatchery program the number of hatchery steelhead in the basin regularly caused the total number of steelhead to exceed carrying capacity, triggering density-dependent mechanisms that impacted the wild population.

Levin and Williams (2002) tested the hypothesis that hatchery-reared steelhead released into the Snake River Basin negatively affect the survival of wild Snake River steelhead and Chinook salmon. They demonstrated that the survival of wild Chinook salmon is negatively associated with hatchery releases of steelhead but observed no relationship between survival of wild steelhead and steelhead hatchery releases. Steelhead Straying and Genetic Introgression

- The lack of distinction between San Joaquin and Sacramento steelhead populations suggests either a common origin or genetic exchange between the basins. Findings of a recent genetic study on Central Valley (CV) steelhead populations (Nielson et al. 2003) indicate that:Feather River steelhead populations (natural and FRFH-produced populations) are more similar to populations from streams in the same general geographic location—i.e., Clear Creek, Battle Creek, upper Sacramento River, Coleman National Fish Hatchery, and Cottonwood, Mill, Deer, and Antelope creeks.
- Feather River steelhead populations are not closely linked to Nimbus Hatchery and American River populations.
- Feather River steelhead population’s closest relative is the FRFH-produced steelhead and both are distinct from other Central Valley steelhead populations.
- There are no data on the potential effects (e.g., reduced fitness) of inbreeding or outbreeding of FRFH-produced steelhead.

These data suggest that there appears to be considerable genetic diversity within the CV steelhead populations and that, although fish from the San Joaquin and Sacramento River basins cannot be distinguished genetically, there is still significant local genetic structure to CV steelhead populations. For example, Feather River and FRFH-produced steelhead are closely related, as are American River and Nimbus Hatchery fish. American River steelhead stocks are greatly influenced by Eel River transplants used to rebuild the run after Nimbus and Folsom Dams were built.

Estimates of straying rates only exist for Chinook salmon produced at the FRFH. However, general principles and the potential effects of straying are also applicable for steelhead. However, based on available genetic data, the effects of hatcheries that rear steelhead appear to be restricted to the population on hatchery streams (DWR 2004a). These findings suggest that, although ongoing operations may impact the genetic composition of the naturally spawning steelhead population in these rivers, hatchery effects appear to be localized. It should be noted that genetic data for steelhead are limited (DWR 2004a).

Summary of the Environmental Baseline

Environmental baseline, as defined in 50 CFR 402.02, “includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process”. The prior information in this chapter provides the status of steelhead in the action area which has resulted from the past and present impacts of activities in the action area.

The majority of Central Valley steelhead are restricted to non-historical spawning and rearing habitat below dams within the action area. Populations of steelhead occur outside the action area (Yuba River, Deer Creek, Mill Creek, Antelope Creek), but the abundance of these populations is unknown. Existing spawning and rearing habitat within the action area can sustain steelhead at the current population level. Monitoring data indicates that much of the anadromous form of the species is hatchery supported. There remains a strong resident component that interacts with and produces anadromous individuals (Zimmerman et al. 2008).

Chapter 4 describes the factors that affect the species and critical habitat in the action area. A large factor affecting the listed salmonids is the loss of spawning and rearing habitat upstream of impassable dams. High water temperatures in these lower elevations are a stressor to adult and juvenile life stages. The factors that affect the survival are high temperatures, low flows, limited spawning and rearing habitat, blocked or delayed passage, unscreened diversions, and flow fluctuations.

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Chapter 4 Factors That May Influence Steelhead Distribution and Abundance

This chapter describes the factors that affect steelhead and critical habitat in the action area. A large factor affecting all the listed salmonids is the loss of spawning and rearing habitat upstream of various dams. The limiting factors that affect steelhead survival are high water temperatures, low flows and flow fluctuations, limited spawning and rearing habitat, blocked or delayed passage, and unscreened river diversions. Other factors that may influences steelhead distribution and abundance include: predation and competition; food abundance in the Delta; contaminants, harvest, hatchery operations, and disease.

Water Temperature

Water temperatures that are too low or too high can kill steelhead by impairing metabolic function, or indirectly by increasing the probability of disease, predation, or other secondary mortality factors (Myrick and Cech 2001, Leitritz and Lewis 1980; Reiser and Bjornn 1979, all as cited in McEwan and Jackson 1996). Steelhead temperature tolerances vary among life stages (Bovee 1978; Reiser and Bjornn 1979; Bell 1986, all as cited in McEwan and Jackson 1996) and stocks (Myrick 1998, 2000; Nielsen et al. 1994a) (Table 4-1). In this biological assessment (BA), temperature recommendations of McEwan and Jackson (1996) are used for all life stages except fry and juveniles, which have recently been studied using local stocks in a laboratory situation (Myrick 1998, 2000).

Myrick (1998, 2000) found the preferred temperatures for Mokelumne River Fish Installation, Feather River Hatchery, and naturally spawned Feather River juvenile steelhead placed into thermal gradients were between 62.5 °F and 68°F (17 and 20 degrees Celsius [°C]). Myrick and Cech (2005) also found that Nimbus-strain steelhead had a higher growth rate at 66°F (19°C) than groups of steelhead raised at lower temperatures. This is considerably warmer than the rearing temperature recommended by McEwan and Jackson (1996). Feather River snorkel survey observations and temperature data from summer 1999 also appear to corroborate Myrick's (1998, 2000) results. Young-of-the-year (YOY) steelhead in the American River have been observed in snorkel surveys, captured by seining, and passive integrated transponder (PIT) tagged in habitats with a daily average temperature of 72 °F and a daily maximum over 74 °F (California Department of Fish and Game [DFG] and the U.S. Bureau of Reclamation [Reclamation] unpublished data).

Table 4-1 Recommended water temperatures (°F) that provide for highest survival for life stages of steelhead in Central Valley streams from McEwan and Jackson (1996), Myrick (1998, 2000), Piper et al 1982, Bell 1991 Myrick and Cech (2001).

Life stage	Temperature recommendation (°F)
Migrating adult	46–52
Holding adult	50-56

Life stage	Temperature recommendation (°F)
Spawning	39–52
Egg incubation	48–52
Juvenile rearing	<65
Smoltification	<57

Flow

Adverse effects to steelhead stocks in the Sacramento and San Joaquin rivers have been mostly attributed to water development (McEwan and Jackson 1996). Specific examples include inadequate instream flows caused by water diversions, rapid flow fluctuations due to water conveyance needs and flood control operations, inadequate coldwater releases from upstream reservoirs, loss of spawning and rearing habitat due to dams, and juvenile entrainment into unscreened or poorly screened water diversions.

Measures to minimize effects on salmon will usually result in concomitant effects on steelhead. However, life history differences between steelhead and Chinook salmon may also lead to different, and potentially conflicting, flow requirements for each species. Although the most important flow needs for steelhead in Central Valley rivers are for cold water during the summer and early fall, increased flows for Chinook salmon are typically scheduled for the spring and mid-fall migration periods. In some cases, such as the temperature criteria for winter-run Chinook from Keswick to Red Bluff Diversion Dam (RBDD), reservoir operations coincide with steelhead requirements. Differences in the timing of flow needed by different species can create difficult management dilemmas, particularly during an extended drought.

In the upper Sacramento River basin, problems of outflow and temperature are closely related (McEwan and Jackson 1996). Low summer and fall outflows can reduce the quality of steelhead rearing habitat because of associated increases in water temperature. In addition, adequate habitat conditions must be maintained all year for steelhead to benefit.

PHABSIM Flow Studies

Sacramento River

The U.S. Fish and Wildlife Service (FWS) (2003) developed spawning flow-habitat relationships for steelhead spawning habitat in the Sacramento River below Keswick Dam using the Physical Habitat Simulation (PHABSIM) component of the Instream Flow Incremental Methodology (IFIM). Relationships were developed by cross section and by stream segments but were not aggregated into riverwide flow-habitat relationships.

Steelhead spawning-weighted-usable-area peaked at river flows of 3,250 cubic feet per second (cfs) in the reach upstream of the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam. This habitat relationship holds regardless of whether the dam boards are in or out. The reach between ACID dam and Cow Creek, spawning usable area also peaked at river flows of

3,250 cfs. In the lower reach, from Cow Creek to Battle Creek, spawning usable area peaked at river flows of about 13,000 cfs, but did not vary significantly in a flow range between about 6,000 and 14,000 cfs.

The minimum required Sacramento River flow is 3,250 cfs. This flow level provides adequate physical habitat to meet the needs of all steelhead life stages in the Sacramento River. Flows during the summer generally well exceed this amount in order to meet temperature requirements for winter-run Chinook salmon. The winter-run temperature requirements result in water temperatures suitable for year-round rearing of steelhead in the upper Sacramento River.

Clear Creek

Denton (1986) used the IFIM to estimate optimal Clear Creek flows for salmon and steelhead. The resultant estimate of optimal Whiskeytown Dam release schedule from the IFIM study is shown in Figure 5–4. Summer-rearing habitat resulting from high water temperatures appeared to be the limiting factor for steelhead. Optimal steelhead flows in the upstream (above the former Saeltzer Dam site) reach were 87 cfs for spawning and 112 cfs for juvenile rearing. Optimum flows for steelhead in the reach below Saeltzer Dam were predicted to be 250 cfs in all months except April when they drop to 225 cfs and May 1 through 15 when they are 150 cfs. Denton (1986) recommended that tributary streamflows occurring below Whiskeytown Dam be included in computing the additional releases required from Whiskeytown Dam to meet the total recommended fishery flow needs.

Feather River

In 2002, DWR conducted an IFIM habitat analysis for the lower Feather River (DWR 2004). This analysis drew on the earlier IFIM work of Sommer et al. (2001), but added an additional 24 transects and included additional fish observations. The river segments above (the low-flow channel [LFC]) and below (the high-flow channel [HFC]) the Thermalito Afterbay Outlet (TAO) were modeled separately because of their distinct channel morphology and flow regime. The weighted usable (spawning) area (WUA) for steelhead spawning in the LFC had no distinct optimum over the range of flow between 150 and 1,000 cfs. However, in the HFC, a maximum WUA was observed at a flow just under 1,000 cfs. The difference in these results can be attributed to the relative scarcity of suitable steelhead spawning gravels in the LFC segment of the Feather River.

American River

FWS (1997) measured 21 cross sections of the American River in high-density Chinook spawning areas. They estimated the flows at which the greatest usable spawning area would be available to steelhead and Chinook based on measurements of water velocity, water depth, and substrate size from steelhead and Chinook redds in the American River. There was low variability in WUA throughout the range of flows analyzed (1,000-6,000 cfs). Table 4-2 shows the average of the WUA from the 21 cross sections expressed as 1,000 square feet of spawning area per 1,000 feet of stream. The WUA for steelhead peaked at a flow of 2,400 cfs. All flows from 1,000-4,000 cfs provided at least 84 percent of the maximum WUA.

Table 4-2 Average WUA (expressed as 1,000 square feet of spawning area per 1,000 feet of stream) from 21 cross sections measured in 1995 in high-density Chinook spawning areas. Summarized from FWS 1997.

Nimbus Release (cfs)	Steelhead Average WUA	Chinook Average WUA
1,000	31	62
1,200	33	71
1,400	34	78
1,600	35	82
1,800	36	84
2,000	36	83
2,200	36	81
2,400	37	78
2,600	36	74
2,800	36	69
3,000	36	65
3,200	36	60
3,400	35	56
3,600	34	52
3,800	32	48
4,000	31	45
4,200	29	42
4,400	27	38
4,600	26	36
4,800	24	33
5,000	23	31
5,200	22	28
5,400	21	26
5,600	20	25
5,800	19	23
6,000	19	21

Snider et al. (2001) evaluated effects of flow fluctuations in the American River on steelhead and salmon. They defined flow fluctuations as unnatural rapid changes instream flow or stage over short periods resulting from operational activities of dams and diversions. They recommended ramping flows in the American River of 100 cfs/hour or less at flows less than 4,000 cfs to reduce stranding of steelhead caused by rapid dewatering of habitat. They further recommended avoiding flow increases to 4,000 cfs or more during critical rearing periods. These critical rearing periods are January through July for YOY salmon and steelhead, and October through March for yearling steelhead and non-natal rearing winter-run Chinook salmon, unless the higher flows can be maintained throughout the entire period. For the maintenance of sufficient spawning habitat and to keep water flowing through redds, they recommended precluding flow fluctuations that decrease flow below 2,500 cfs during critical spawning periods (December through May).

Ayres Associates (2001) used detailed topography of the river to model sediment mobilization at various flows in the American River. They found that at 115,000 cfs (the highest flow modeled), particles up to 70 millimeters (mm) median diameter would be moved in the high-density spawning areas around Sailor Bar and Sunrise Avenue. Preferred spawning gravel size is 6–125 mm (1/4–5 inches) in diameter.

Snider et al. (2001) produced survival indices for Chinook salmon based on number of redds versus the population estimate of outmigrating juveniles over a period of 7 years of monitoring in the 1990’s. They found that high flows in January had the largest effect on survival according to the following equation: Survival = 11,200*(January maximum flow, cfs)$^{-0.28}$. The higher the flow in January, the lower the survival index, although the confidence bounds in this relationship are large. January is the period with the greatest number of Chinook eggs in the gravel; thus, the high flows are supposedly reducing survival of incubating eggs by scouring or suffocating the eggs and alevins in redds. Because steelhead spawn in similar habitat and require similar incubation conditions, high flows could affect incubating steelhead eggs in a similar manner.

Monitoring has shown that juvenile steelhead numbers in the river decrease throughout the summer such that the available rearing habitat is not fully seeded with fish. Therefore, the rearing population in the river is not likely limited by density-dependent factors. More likely, water temperature and, potentially, predator fish species such as striped bass limit the rearing population of steelhead in the American River. Flows of about 1,500 cfs or greater have sufficient thermal mass to maintain much of the water temperature benefits of cool Folsom releases downstream to Watt Avenue. During years with a low coldwater pool, there may not be enough cold water to provide optimal water temperatures through summer and fall into the peak Chinook spawning period in November. Table 4-3 shows a calculation of estimated fry to smolt survival in the American River.

Table 4-3 Estimates of wild steelhead smolt production and hatchery smolt survival in the American River based on adult hatchery counts, spawner surveys and hatchery yearling releases (Hannon and Deason 2007).

Adult Spawning Year	2007	2006	2005	2004	2003	2002	2001	2000
Year smolts released or outmigrated	2005	2004	2003	2002	2001	2000	1999	1998
Hatchery smolts released in Jan/Feb. of above year[3]	400,000	400,000	419,160	414,819	467,023	402,300	416,060	385,887
In-river spawning adults	504		266	330	343	300		
Total Hatchery Produced Adult Return[1]	3,613	2,660	3,472	2,425	1,386	1,745	3,392	2,057
Unclipped Adults in hatchery	116		118	17	27	69	50	
Percent return of hatchery fish (clipped adult return divided by smolts released two years prior)	0.90%	0.67%	0.83%	0.58%	0.30%	0.43%	0.82%	0.53%
Wild smolts that outmigrated (two years prior)[2]	18,424		17,457	8,552	20,661	22,827	6,132	
Estimate of fry produced based on redd surveys	448,749		220,987	405,445	446,017	333,900		
Fry to smolt survival estimated	available 2010		available 2008	5%		5%		

[1] assumes 20% recreational harvest based on angler surveys in 1999 and 2001

[2] assumes same smolt to adult survival of wild smolts as for hatchery released smolts and that 10% of in-river spawners are naturally produced fish

[3] values for 2004 and 2005 are estimates

Stanislaus River

Aceituno (1993) applied the IFIM to the Stanislaus River between Riverbank and Goodwin Dam (24 river miles) to help to determine instream flow needs for Chinook salmon and steelhead. Table 4-4 gives the resulting instream flow recommendations for rainbow trout and steelhead based on PHABSIM results. Macrohabitat conditions such as water quality, temperature, and the value of outmigration, attraction, and channel maintenance flows were not included in the analysis.

Table 4-4 In-stream flows that would provide the maximum weighted usable area of habitat for rainbow trout and steelhead trout in the Stanislaus River between Goodwin Dam and Riverbank, California (Aceituno 1993).

Life Stage	Instream Flow (cfs)	
	Rainbow Trout	Steelhead
Spawning	100	200
Fry	50	50
Juvenile	150	150
Adult	400	500

Habitat Availability

Large-scale loss of spawning and rearing habitat has been attributed as having the single greatest effect on steelhead distribution and abundance (McEwan and Jackson 1996). Historically, steelhead spawned and reared primarily in mid- to high-elevation streams where water temperatures remained suitable all year. Yoshiyama et al. (1996) estimated that 82 percent of the historical Chinook salmon spawning and rearing habitat has been lost. The percentage of habitat loss for steelhead is presumably greater, because steelhead were more extensively distributed upstream than Chinook salmon. Steelhead could have used numerous smaller tributaries not used by Chinook salmon due to the steelhead's upstream migration during periods of higher flow, superior leaping ability, ability to use a wider variety of spawning gravels, and ability to pass through shallower water. The estimated number of historical, pre-impassable dam, and post-impassable dam river miles available to steelhead in the Sacramento, Feather, American, and Stanislaus rivers and Clear Creek is provided in Table 4-5. Potential migration barriers also occur in many other streams (Table 4-6).

Table 4-5 Estimated number of historical, pre-dam, and post-dam river miles available to steelhead (includes mainstem migratory, spawning, and rearing habitat). The extent of historical habitat is based on Chinook salmon distribution and should be considered minimum estimates for steelhead.
Source: Yoshiyama et al. (1996).

	Historical	Pre-dam	Post-dam	Lower Dam Completed
Clear Creek	25	25	16	1963
Sacramento River	493	493	286	1945
Feather River	211	<211	67	1968
American River	161	27	23	1955
Stanislaus River	113	113	58	1912

Table 4-6 Summary of potential salmonid migration barriers on Central Valley streams. Adapted from Yoshiyama et al. (1996).

Stream[a] and Passable Structures	Notes	First Impassable Barrier	Operator
Sacramento River			
Red Bluff Diversion Dam	FB, SC, FLD	Keswick Dam	Reclamation
Anderson-Cottonwood Irrigation District Diversion Dam	FB, SC, FLD		ACID
Clear Creek			
		Whiskeytown Dam	Reclamation
Battle Creek			
Coleman National Fish Hatchery Weir and various Pacific Gas & Electric (PG&E) dams (e.g. Wildcat)	FLD[b]	Coleman South Fork Diversion Dam; Eagle Canyon Dam (being laddered as part of restoration program)	PG&E
Antelope Creek	DW	Mouth	Edwards Ranch; Los Molinos Mutual Water Co.
Mill Creek			
Ward Diversion Dam	SC, SL, FLD	Morgan Hot Spring	Los Molinos Mutual Water Co.

Stream[a] and Passable Structures	Notes	First Impassable Barrier	Operator
Clough Diversion Dam	BR		
Upper Diversion Dam	SC, SL, FLD		Los Molinos Mutual Water Co.
Deer Creek			
Stanford-Vina Diversion Dam	SC, FLD	Upper Deer Creek Falls	Stanford-Vina Irrigation Co.
Cone-Kimball Diversion Dam	SC, SO		Stanford-Vina Irrigation Co.
Deer Creek Irrigation Co. Diversion	SC, SO		Deer Creek Irrigation Co.
Lower and Upper Deer Creek Falls	FLD		
Butte Creek			
Parrott-Phelan Diversion Dam	SC, FLD	Centerville Head Dam or Quartz Bowl Barrier (barrier most years)	M&T Ranch
Durham-Mutual Diversion Dam	SC, FLD		Durham-Mutual Water Co.
Gorrill Diversion Dam	SC, FLD		Gorrill Ranch
Adams Diversion Dam	SC, FLD		Rancho Esquon Investment Co.
Butte Slough Outfall Gates			
Sanborn Slough	FLD		FWS/RD1004
East-West Weir	FLD		Butte Slough Irrigation District
Weir 2	FLD		DWR
Weir 5	FLD, SC		Butte Slough Irrigation District
Weir 3	FLD		Butte Slough Irrigation District
Weir 1	FLD		FWS
Stony Creek			
Glenn-Colusa Irrigation District (GCID) Canal (Formerly a gravel berm was used, but water canal is now piped under river.)	BR	Black Butte Dam	U.S. Army Corps of Engineers (Corps)
Tehama Colusa Canal Authority (TCCA) rediversion berm (Absent during adult migration)	UN		
Orland North Canal Diversion	FB, UN		
Yuba River			
Daguerre Point Dam	UN, FLD	Englebright Dam	Corps and Yuba County Water Agency
Feather River		Feather River Fish Barrier Dam	DFG
American River		Nimbus Dam	Reclamation
Putah Creek		Putah Diversion Dam	Solano County Water Agency
Yolo Bypass		Fremont Weir	DWR
Mokelumne River			

Stream[a] and Passable Structures	Notes	First Impassable Barrier	Operator
Woodbridge (Lodi Lake) Dam	FLD, FB	Camanche Dam	East Bay Municipal Utility District (EBMUD)
Central Valley Project (CVP)- and State Water Project (SWP)-influenced channels			
Calaveras River[d]			
Bellota Dam	UN with FB	New Hogan Dam	USACE
Stanislaus River		Goodwin Dam	Reclamation
Tuolumne River		La Grange Dam	Tulare Irrigation District
Merced River			
		Crocker-Hoffman Dam	Maxwell Irrigation District
San Joaquin River			
Hill's Ferry Fish Barrier	10/1 - 12/31	Alaskan Weir	DFG

[a] Only streams with barriers are listed.

[b] Not currently operational.

[c] Harrell and Sommer, In press.

[d] Tetra Tech (2001).

BR = breached
DW = dewatered at some point throughout the year
FB = flashboards removed during winter
FLD = fish ladder
SC = screened diversion
SL = sloped dam
SO = salmon can swim over dam
UN = unscreened diversion

Habitat Suitability

Fish Passage, Diversion, and Entrainment

As described above, upstream passage of steelhead has been most severely affected by large dams blocking access to headwaters of the Sacramento and San Joaquin rivers on most major tributaries (McEwan and Jackson 1996). The remaining areas below major dams may not have optimal habitat characteristics. For example, lower elevation rivers have substantially different flow, substrate, cover, nutrient availability, and temperature regimes than headwater streams. In addition, small dams and weirs may impede upstream migrating adults, depending on the effectiveness of fish ladders at various flows or whether the boards are removed from the weirs during the migration period. Salmonids are able to pass some of these dams and weirs under certain conditions, but studies have not been conducted to fully evaluate fish passage at all structures at all flows. In particular, there is concern that high flows over small dams and weirs may obscure the attraction flows at the mouths of the ladders, effectively blocking upstream migration (CALFED 1998).

Sacramento River

Until recently, three large-scale, upper Sacramento River diversions (RBDD, ACID, and GCID) have been of particular concern as potential passage or entrainment problems for steelhead (McEwan and Jackson 1996). The GCID diversion is now screened using large flat-plate screens. Operational controls in effect to protect winter-run Chinook (a reduction in diversion rate to reduce approach velocities to 0.33 ft/s) are likely to provide protection to steelhead as well. In addition, construction to double the screen area, increase the number of bypass structures, and provide a new downstream control structure was completed in 2001. A gradient control structure in the mainstem of the river at mile 206 was completed in 2001 to provide suitable flow conditions through the side channel for operation of the diversion.

In the past, the ACID diversion dam created fish passage problems. However, new fish ladders and fish screens were installed around the diversion and were operated starting in the summer 2001 diversion period. Prior to the 1990s, the dam required a temporary but substantial reduction in Keswick Reservoir releases to manually adjust the dam flashboards, which resulted in dewatered redds, stranded juveniles, and high water temperatures. Reclamation helped modify the flashboards in the 1990s to facilitate adjustment at higher flows, reducing the risk of dewatering redds.

Salmonid passage problems at RBDD have been well-documented (Vogel and Smith 1986; Hallock 1989; FWS 1987, 1989, 1990b; Vogel et al. 1988, all as cited in DFG 1998). Vogel (1989, as cited in DFG 1998) estimated the entrainment of young salmon from 1982 through 1987 averaged approximately 350,000 fish per year. The fish louver and bypass system originally constructed at RBDD was replaced with rotary drum screens and an improved bypass system, which began operation in April 1990. The drum screen facility was monitored to assess juvenile salmon entrainment into the Tehama-Colusa Canal through 1994 (FWS 1998). No fish were collected in monitoring efforts in 1990 to 1992 or 1994. In 1993, 33 salmon were entrained, resulting in an estimated 99.99 percent screening efficiency. The drum screen facility at RBDD is highly efficient at reducing salmonid entrainment.

Facilities improvements have been second only to the implementation of “gates-out” operation of RBDD for improving juvenile salmonid survival (FWS 1996). The RBDD gates were raised during the non-irrigation season beginning in 1986-87 to improve fish passage conditions, especially for winter-run Chinook salmon. The initial gates-out period of 4 months was incrementally increased to 8 months by 1994-95. Run timing past RBDD is shown in Figure 4-1. The initial four month gates out period resulted in a blockage of steelhead during the peak of their upstream migration, forcing them to use the fish ladders to obtain passage. Under these operations only the earliest migrating steelhead arrive at RBDD before the gates are raised.

During the current gates-out operation (September 15 through May 14), fish passage conditions are “run of the river,” and essentially all adverse effects associated with fish passage are eliminated. Water deliveries at RBDD are limited during these 8 months to diversions through a series of screened, temporary pumps and at the RBDD Research Pumping Plant (FWS 1998). Although the historical counts of juvenile steelhead passing RBDD do not differentiate steelhead from resident rainbow trout, approximately 95 percent of steelhead/rainbow trout juvenile emigrants pass during the gates-out period based on historical emigration patterns at RBDD (DFG 1993, as summarized in FWS 1998).

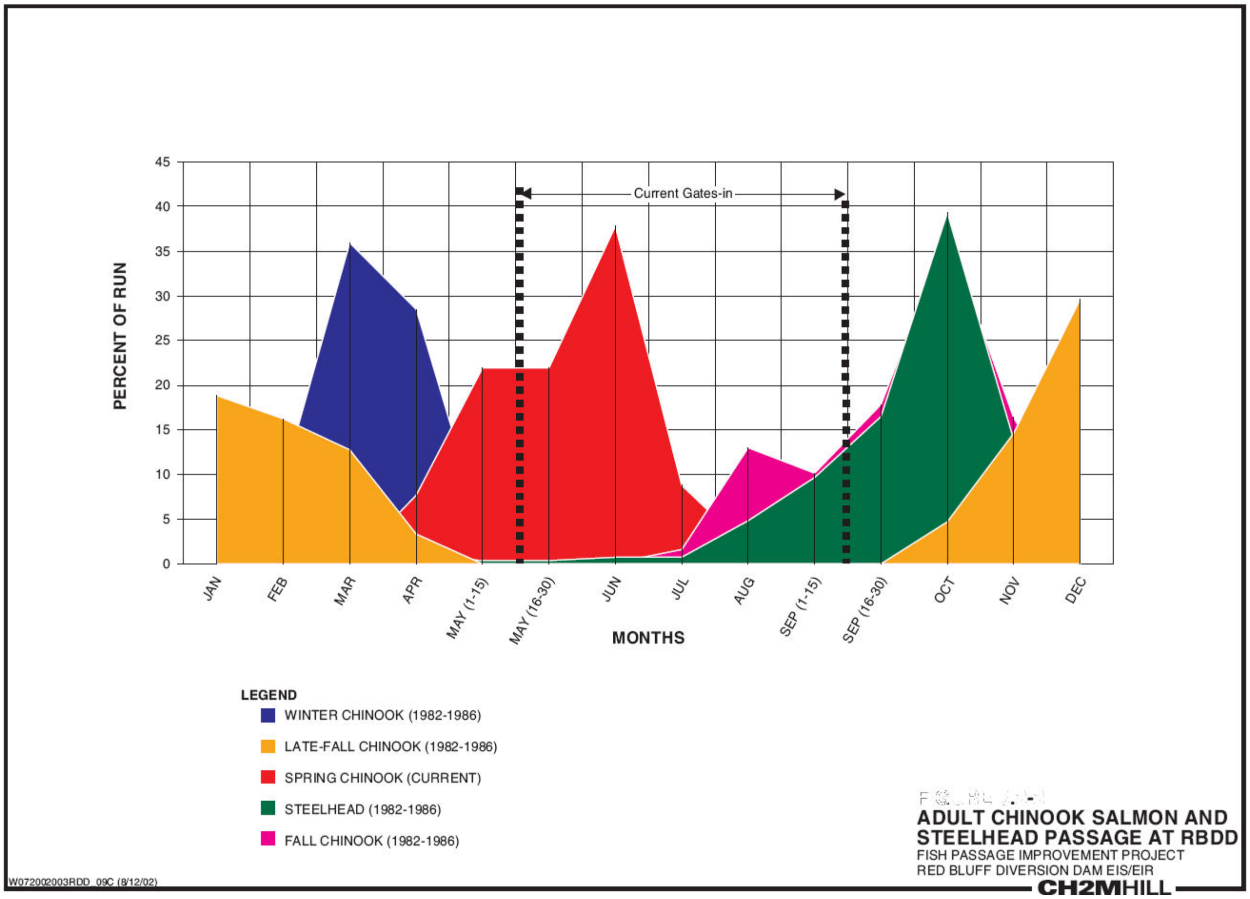


Figure 4-1 Run timing of adult steelhead and Chinook salmon past RBDD (from TCCA and Reclamation 2002).

Immigrating adult steelhead must also negotiate RBDD to gain access to natal streams, including the upper Sacramento River, Clear Creek, and Battle Creek. Approximately 84 percent of adult steelhead immigrants pass RBDD during the gates-out period based on average run timing at RBDD. Therefore, most steelhead have had unimpeded passage past RBDD since 1994-95 (FWS 1998; TCCA and Reclamation 2002). During the late summer and fall months, the steelhead immigration season, delays were typically less than four days for fall-run Chinook salmon (Vogel et al 1988).

In addition to the problems created by large canal diversions, there are an estimated 300 smaller unscreened diversions on the Sacramento River between Keswick Dam and the Delta (McEwan and Jackson 1996) and another 2,000 or so in the Delta itself (DFG diversion database). Operation of these diversions likely entrain juvenile steelhead. However, no steelhead were observed during several years of sampling agricultural diversions in the Delta (Cook and Buffaloe 1998), and only one steelhead was collected during a 2-year study of the large Roaring River Diversion in Suisun Marsh before it was screened (Pickard et al. 1982b).

The diversions at RBDD during the gates-out period are supplemented by rediversions of CVP water stored in Black Butte Reservoir through the Constant Head Orifice (CHO) on the Tehama-Colusa Canal. This rediversion requires the use of a temporary berm across Stony Creek that potentially blocks upstream passage and impedes downstream passage of salmonids and creates an entrainment hazard for downstream migrating juveniles. Over 90 percent of the flow is into the CHO at peak diversions during late May. Although few salmonids are present above the CHO, it creates a significant hazard for those that are present. Recent monitoring data, following installation of the GCID siphon downstream of the CHO, caught few salmonids, suggesting this rediversion hazard poses little risk to salmonids. Although the data are limited, it appears the salmonids move downstream to the mouth of the creek before rediversions begin, which generally coincides with the rise of temperature above 56°F (Reclamation 1998, 2002, and 2003).

The Sacramento-San Joaquin Delta

The Delta serves as a migration corridor to the upper Sacramento and San Joaquin River basins for adult and juvenile steelhead. It also serves as a rearing habitat for juveniles that move into the Delta before they enter saltwater. Presumably, one of the anthropogenic factors that might influence steelhead abundance and distribution in the Delta is CVP and SWP operations. Little data are available to determine the extent to which CVP and SWP Delta operations affect steelhead population abundance.

DWR and Reclamation (1999) reported that significant linear relationships exist between total monthly export (January through May) and monthly steelhead salvage at both Delta fish facilities. The months included in the analysis were based on months that steelhead consistently appeared at the salvage facilities between 1992 and 1998. Scatterplots of 1993 through 2006 CVP and SWP steelhead salvage versus exports are shown in Figure 4-2 and Figure 4-3, respectively.

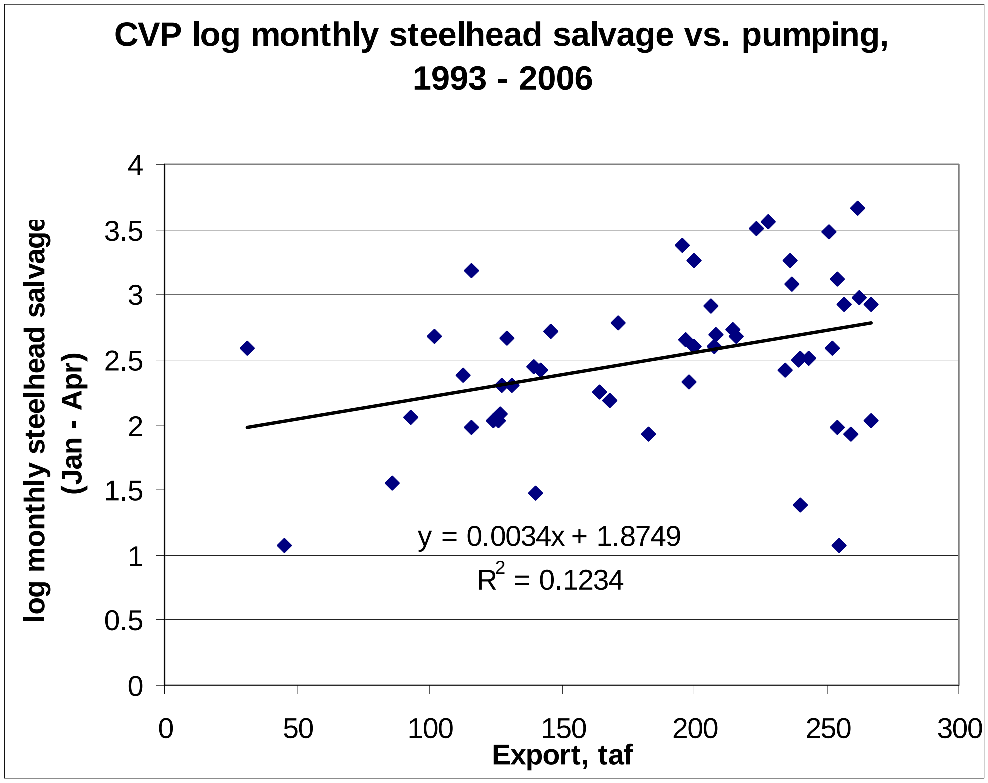


Figure 4-2 Scatterplot of total monthly CVP export in acre feet vs. log_{10} total monthly CVP steelhead salvage, 1993-2006.

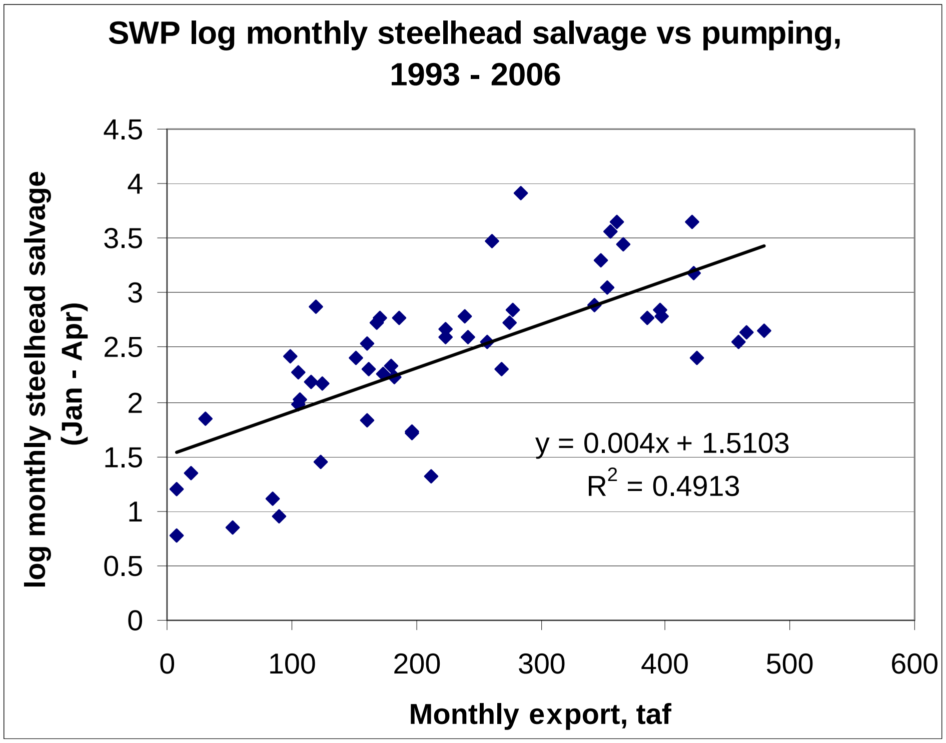


Figure 4-3 Scatterplot of total monthly SWP export in acre-feet vs. $\log_{10}$ total monthly SWP steelhead salvage, 1993-2006.

Figure 4-4 shows steelhead salvage since 1992 (Figure 4-4). Implementation of the Bay-Delta Accord likely helped to reduce steelhead entrainment that otherwise would have occurred. Steelhead presence in the south delta is likely related to yearly population flucuations and water flows from upstream tributaries. Returns to Nimbus and Feather River Hatcheries since 1992 are not correllated (Figure 3-10). These hatcheries release relatively equal numbers of steelhead smolts each year. The lack of correlation in returns to Nimbus and Feather River Hatcheries indicates that factors associated with steelhead survival are complex.

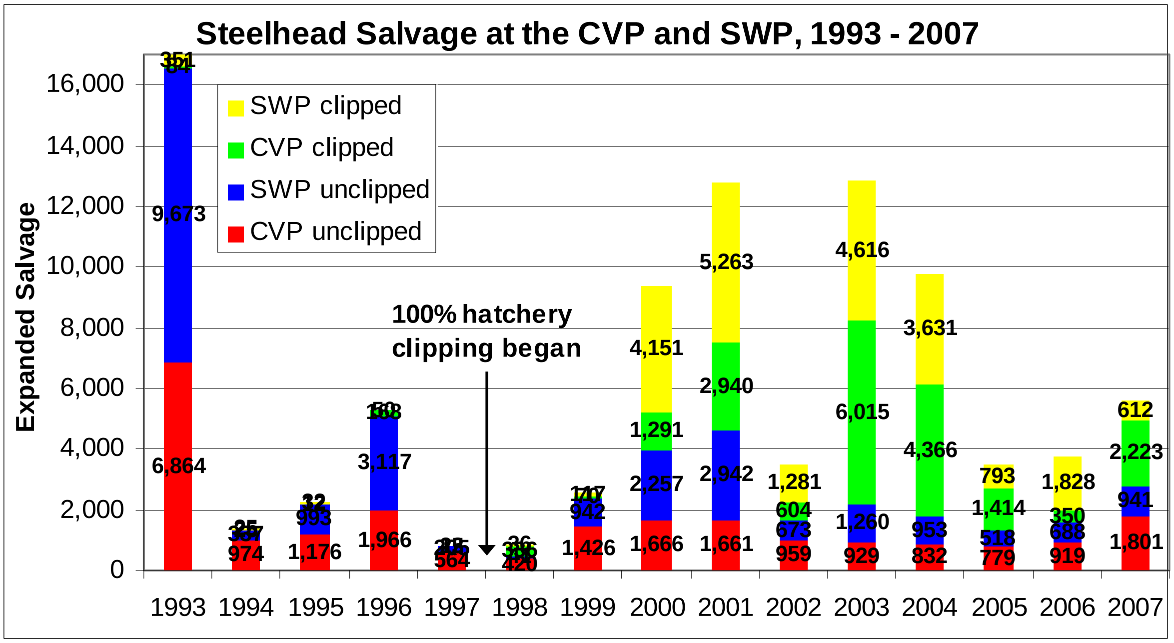


Figure 4-4 Steelhead salvage, 1993 – 2007 by adipose clip status and facility.

In addition to being correlated to amount of water exported, steelhead salvage is positively correlated to December through June catch per unit effort (CPUE) of steelhead in the FWS Chipps Island Trawl (Spearman $R = 0.89$, $P = 0.02$; Figure 4-5), which is considered the best available estimate of juvenile steelhead year-class strength. In other words, the Delta facilities take more steelhead when there are more steelhead. This suggests steelhead salvage at the facilities is an indicator of juvenile year-class strength. Steelhead that are captured at Chipps Island Trawl (Figure 4-6) do not appear to have decreased since 1998 when hatcheries began clipping all steelhead they released. Prior to 1998 abundances may have been higher but there is no way to know if the higher numbers were hatchery or wild fish.

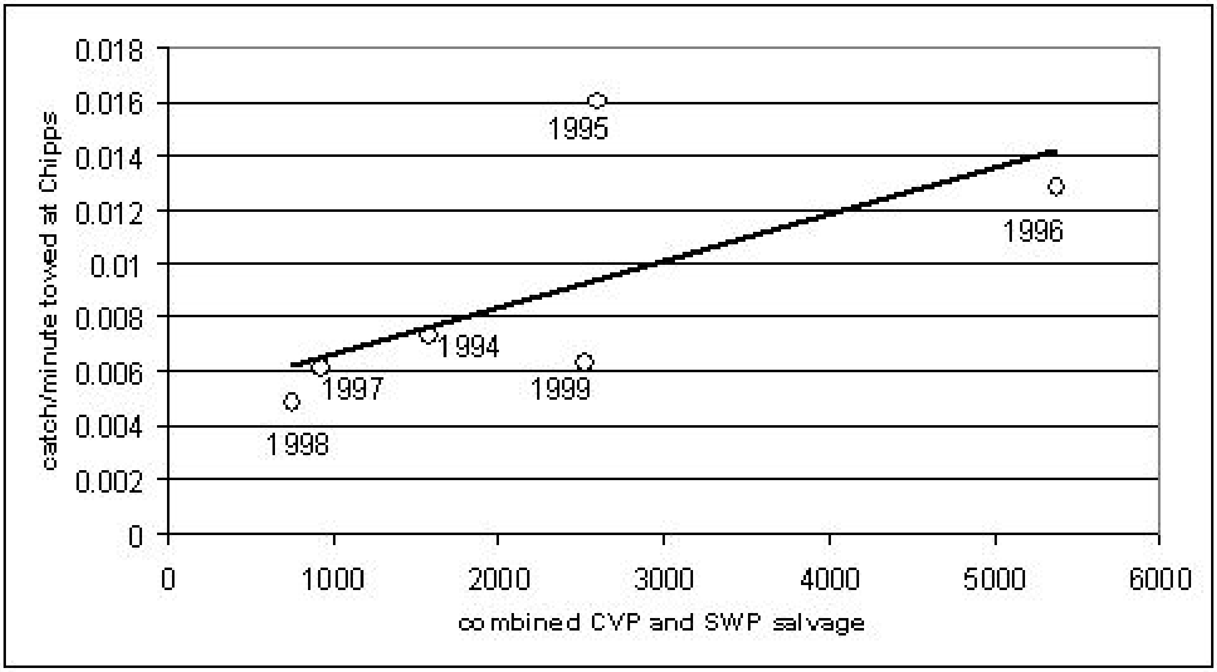


Figure 4-5 Relationship between total combined CVP and SWP steelhead salvage December through June, and December through June steelhead catch per minute trawled at Chipps Island, December 1993 through June 1999.

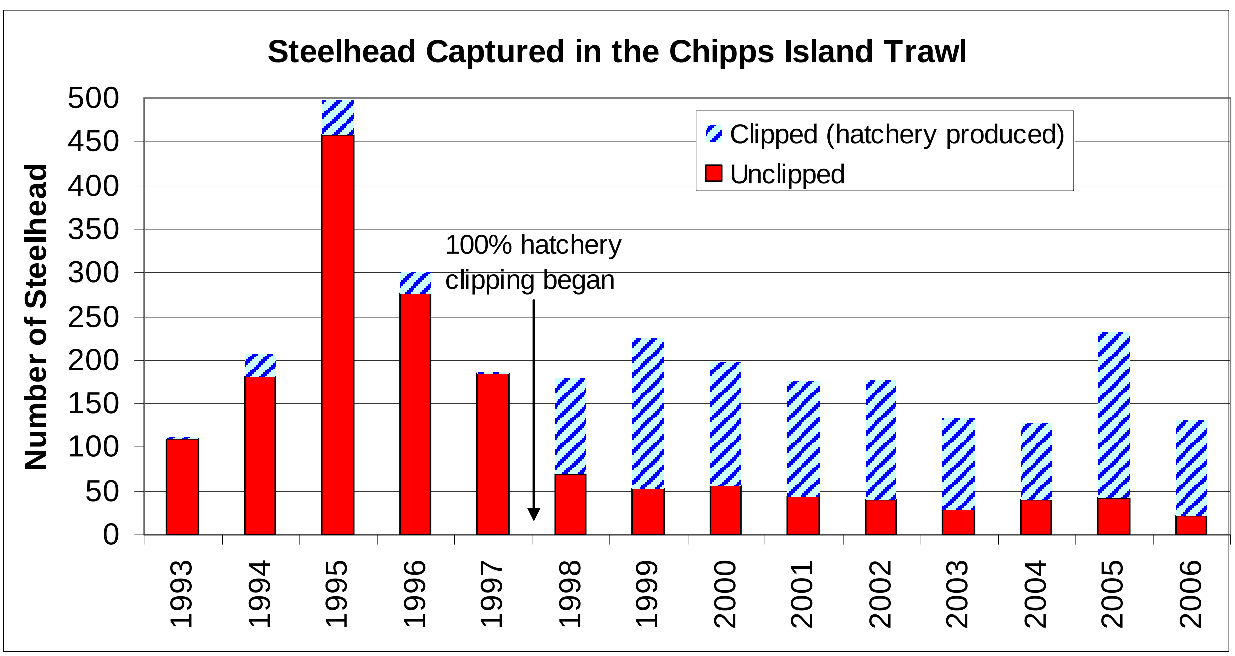


Figure 4-6 Steelhead captured in the Chipps Island Trawl, 1993 – 2006 (data from BDAT) note: 100% hatchery steelhead clipping began in 1998.

The currently available data suggest salvage represents small percentages of hatchery and wild steelhead smolts. The estimated percentages of hatchery smolts in combined (SWP and CVP) salvage ranged from 0.01 to 0.4 percent of the number released from 1998 through 2000. The estimated percentages of the wild steelhead smolt populations salvaged were higher, but were still less than 1 percent each year and ranged from 0.06 percent to 0.9 percent (Nobriga and Cadrett 2001). For salmonids, typically 1-2 percent of smolts survive to return as adults. At a 2 percent smolt-to-adult survival, each steelhead smolt lost represents 0.02 adult or one potential adult for each 50 smolts lost at the pumps. A high percentage of the unclipped steelhead captured at the CVP salvage facility in 2003 had fin erosion, indicating they were likely hatchery fish that missed getting clipped. These fish are currently counted as unclipped and assumed to be wild. Lloyd Hess (personal communication 2003) recommended updating the data sheet for salvage monitoring to include unclipped steelhead that display physical characteristics of hatchery reared steelhead.

The assessment of effects of operations of the CVP and SWP on the Central Valley steelhead DPS is confounded by hatchery fish, which constitute the majority of steelhead in the Central Valley. Since 1998, Central Valley hatcheries have attempted to clip the adipose fins of all hatchery-produced steelhead, enabling an estimate of the proportion of naturally spawned steelhead smolts emigrating through the Delta. The proportions of adipose fin-clipped steelhead are shown in Figure 4-7. This figure shows that wild (unclipped) steelhead are larger on average than hatchery (clipped) fish.

If hatcheries continue to clip the adipose fins of all hatchery-reared steelhead, the FWS Chipps Island Trawl may eventually also be a useful tool for devising an emigration abundance index specifically for naturally spawned steelhead that can be compared to salvage or other potential influencing factors.

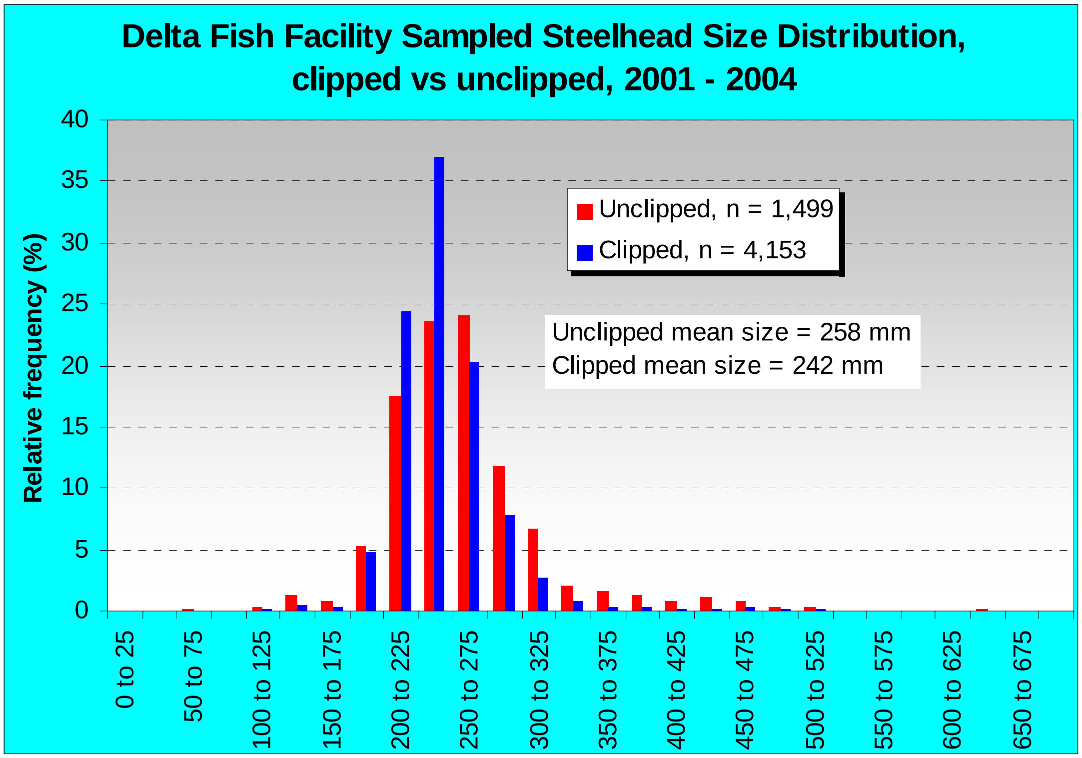


Figure 4-7 Steelhead length frequency, 2001 - 2004. Unclipped fish were significantly larger than clipped fish (t=9.7, P<0.001).

Steelhead salvage and loss density at the SWP and CVP fish salvage facilities are shown in Figure 4-8 through Figure 4-11. Steelhead loss was calculated using a simplified salmon loss equation (at the SWP: LOSS = SALVAGE x 4.34 and at the CVP: LOSS = SALVAGE x 0.579). These densities are indicative of the density of fish in the water in the vicinity of the water intakes for each month.

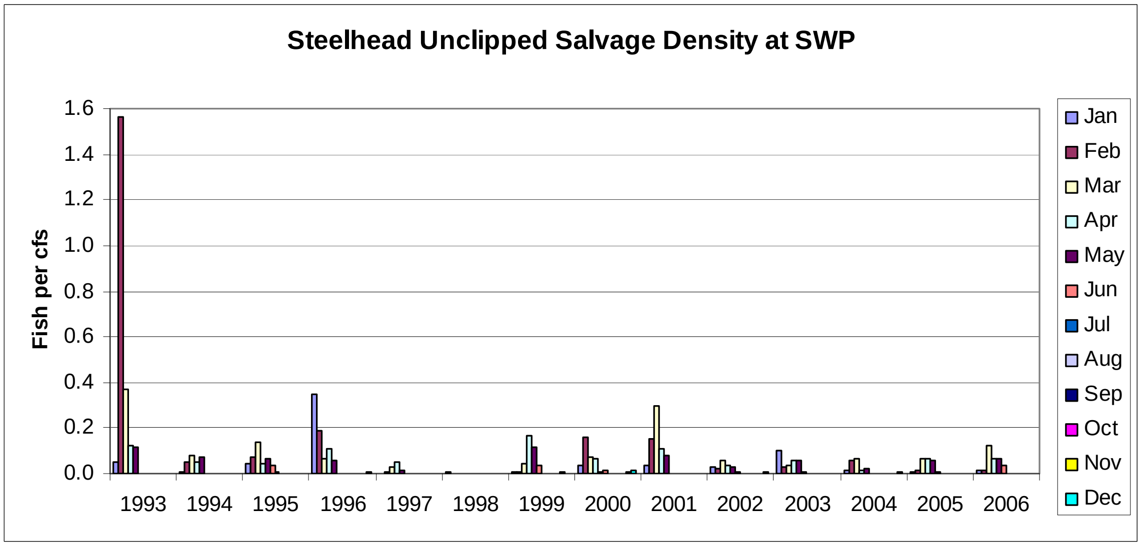


Figure 4-8 Unclipped steelhead salvage density at the SWP, 1993 – 2006.

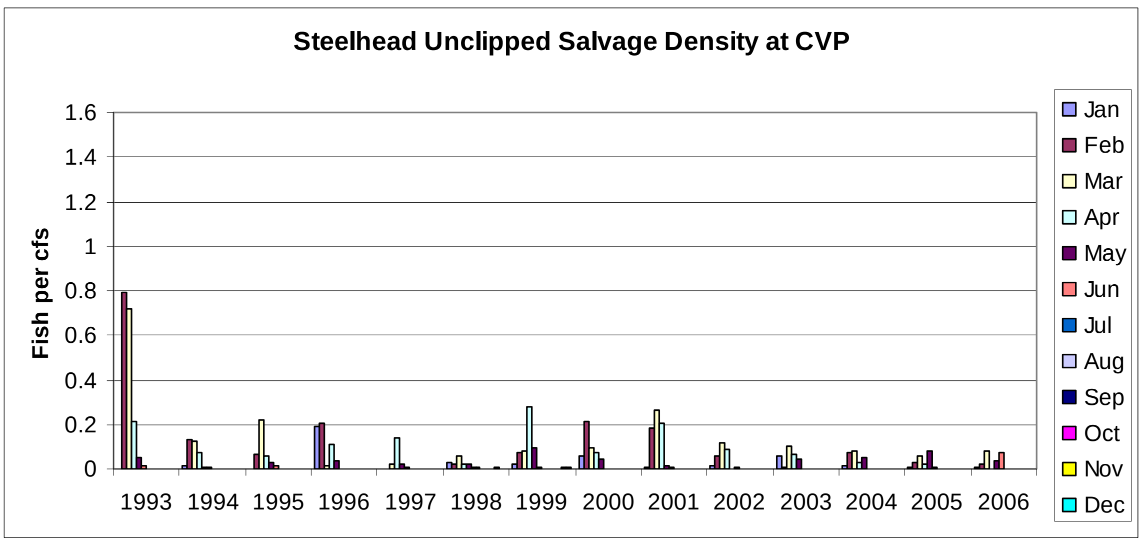


Figure 4-9 Unclipped steelhead salvage density at the CVP, 1996 – 2006.

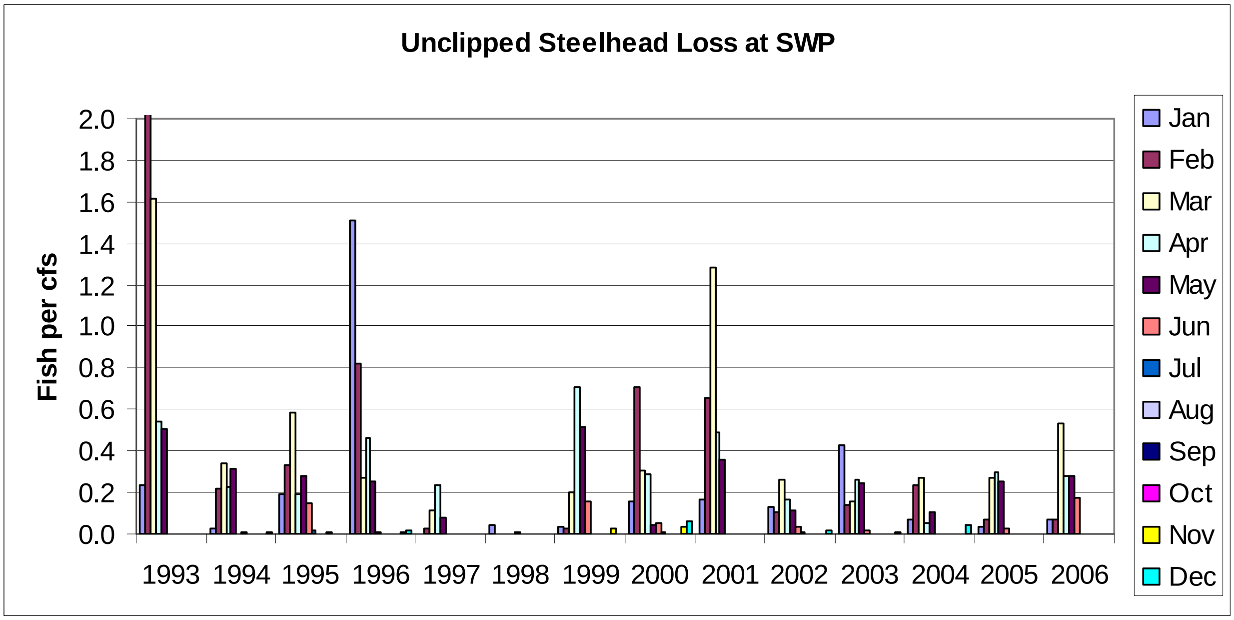


Figure 4-10 Unclipped steelhead loss density at the SWP, 1993 – 2006.

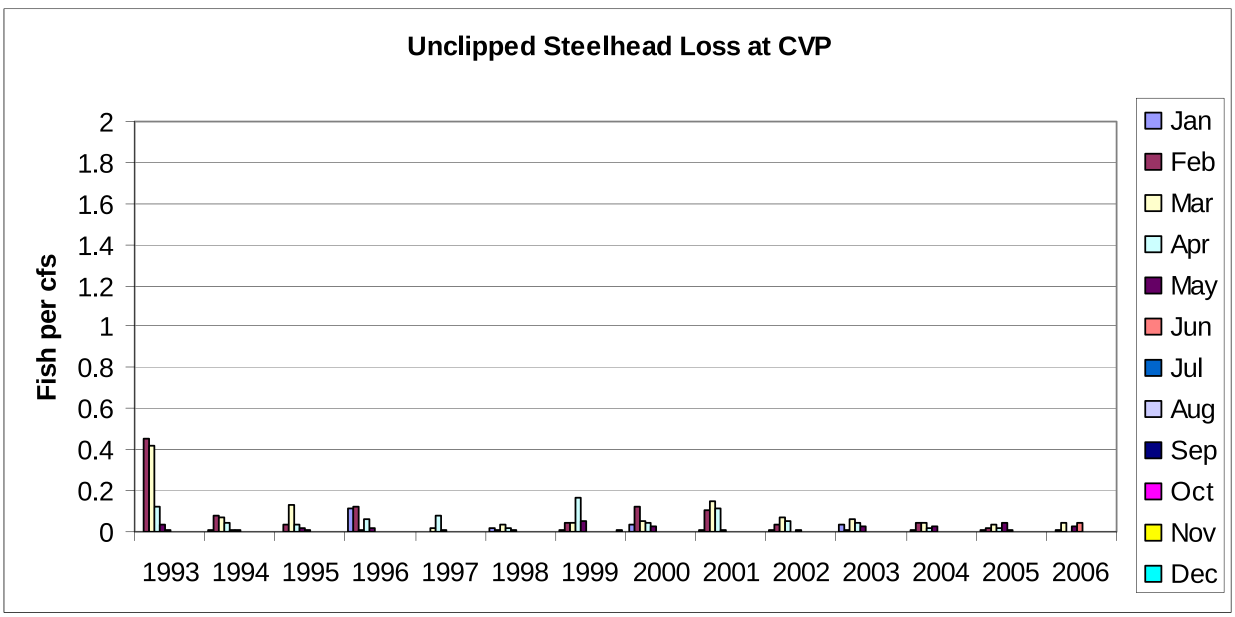


Figure 4-11 Unclipped steelhead loss density at the CVP, 1993 – 2006.

Yolo Bypass

The Yolo Bypass is the primary floodplain of the Sacramento River basin. It is a 59,000-acre leveed basin that conveys flood flows from the Sacramento Valley including the Sacramento River, Feather River, American River, Sutter Bypass, and westside streams. The 40-mile-long floodplain seasonally floods in winter and spring in about 60 percent of water years, when it is designed to convey up to 500,000 cfs. Under typical flood events, water spills into the Yolo

Bypass via the Fremont Weir when Sacramento River basin flows surpass approximately 75,000 cfs. Water initially passes along the eastern edge of the Bypass through the Toe Drain channel, a riparian corridor, before spreading throughout the floodplain. During dry seasons, the Toe Drain channel remains inundated as a result of tidal action. At higher levels of Sacramento Basin flow, the Sacramento Weir is also frequently operated by removal of flashboards. Westside streams such as Cache and Putah creeks and Knight's Landing Ridge Cut may also be substantial sources of flow. The habitat types include agriculture, riparian, wetlands, and permanent ponds.

DWR staff have been conducting fish studies in the Yolo Bypass for the past several years (Harrell and Sommer 2003). They believe that Fremont Weir, the northernmost part of the Yolo Bypass, is a major impairment to fish passage in the lower Sacramento basin. The key problems are summarized below.

Adult Passage during Low-flow Periods

Fyke trap monitoring by DWR from 2000 – 2002 shows that adult salmon and steelhead migrate up through the Toe Drain in autumn and winter regardless of whether Fremont Weir spills (Harrell and Sommer 2003). The Toe Drain does not extend all the way to Fremont Weir because the channel is blocked by roads or other higher ground at several locations. Even if the channel extended all the way to Fremont Weir, there are no facilities at the weir to pass upstream migrants at lower flows. Therefore, unless there is overflow into the Yolo Bypass, fish cannot pass Fremont Weir and migrate farther upstream to reach the Sacramento River. DWR staff has evidence that this is a problem for fall-run, winter-run, and spring-run Chinook salmon and steelhead.

Adult Passage during High-flow Periods

During high-flow events, water spills into the bypass from the Sacramento River via Fremont Weir. These flow events attract substantial numbers of upstream migrants through the Yolo Bypass corridor, which can often convey the majority of the Sacramento basin flow (Harrell and Sommer 2003). At all but the highest flows (for example, 100,000 cfs), there is an elevation difference between Yolo Bypass and Sacramento River at the weir. This creates a 1.5-mile-long migration barrier for a variety of species, but fish with strong jumping capabilities, such as salmonids, may be able to pass the barrier at higher flows. Although there is a fish ladder (maintained by DFG) at the center of the weir, the ladder is tiny, outdated, and exceptionally inefficient. Field and anecdotal evidence suggests that this creates major problems for sturgeon and sometimes salmonids. These species are attracted by high flows into the basin, and then become "concentrated" behind Fremont Weir. They are subject to heavy legal and illegal fishing pressure.

Juvenile Passage

Yolo Bypass has the potential to strand salmonids as floodwaters recede (Sommer et al. 1998). Sixty-two juvenile steelhead were captured during the 1998-99 Yolo Bypass study (58 in 1998; 4 in 1999) (DWR unpublished data). Twenty-four (38.7 percent) were adipose fin-clipped; 54 (87 percent) of the steelhead were captured in a rotary screw fish trap (RST) in the Yolo Bypass Toe Drain. The remainder were captured in beach seine hauls in the scour ponds immediately below the Fremont and Sacramento weirs.

The 1998 Yolo Bypass Toe Drain RST CPUE for steelhead is shown in Figure 4-12. The data indicate steelhead emigrate off the floodplain near the end of drainage cycles. However, small sample size, hatchery releases, and improved gear efficiency during drainage events may confound results. Stranding estimates were not attempted because steelhead were not collected in beach seine sampling outside the scour ponds mentioned above. Although 50-foot beach seines are inefficient at sampling large fish, it is not believed that steelhead were stranded in large numbers. Sommer et al. (1998) found most juvenile salmon emigrated off the floodplain as it drained. In later studies, they found that young salmon grew significantly faster in the Yolo Bypass than the adjacent Sacramento River, with some evidence of higher survival rates (Sommer et al. 2001). The available evidence suggests steelhead show a similar response to floodplain drainage.

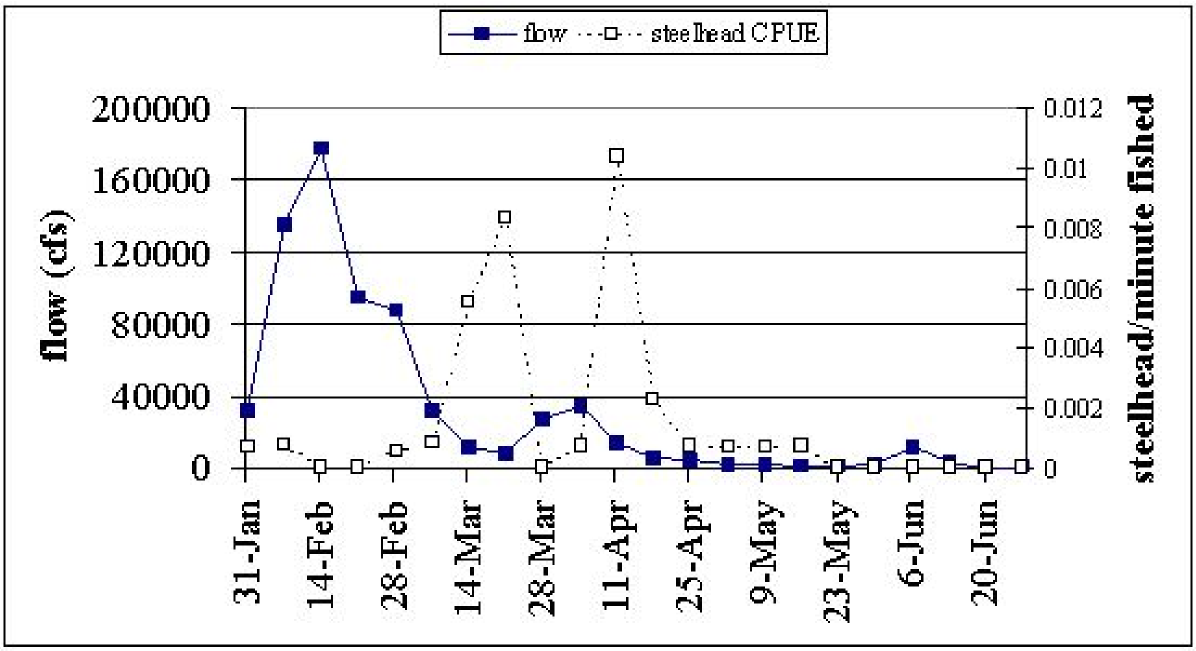


Figure 4-12 Steelhead catch per minute from the Yolo Bypass Toe Drain RST and total Yolo Bypass flow, 1998.

The stomach contents of eight adipose fin-clipped steelhead captured during the 1998 screw trap survey were examined before they were turned over to FWS for coded-wire-tag (CWT) extraction (Table 4-7). The diet data are biased by the artificial feeding opportunities present in the screw trap live box, but they support the hypothesis that steelhead may use the Yolo Bypass as a rearing habitat because they were feeding as they emigrated.

Table 4-7 Stomach contents of adipose fin-clipped steelhead captured in Toe Drain of Yolo Bypass 1998 (DWR unpublished data).

Collection date	Water temperature (°F)	Fork length (mm)	Stomach contents
3/1	53	225	8 Chinook salmon (30-50 mm FLD); 1 pikeminnow (50 mm FLD); 1 unidentified fish; 1 dipteran pupa
3/6	52	217	Empty, but gut distended as if prey recently evacuated
3/6	52	247	4 Chinook salmon (40-50 mm FLD); 2 inland silversides (70 mm FLD)
3/7	51	234	Empty
3/10	55	234	Empty
3/10	55	206	Larval chironomid remains; Damselfly remains
3/10	55	238	Empty
4/17	61	208	1 damselfly nymph

Suisun Marsh Salinity Control Gates

Work completed by Edwards et al. (1996) and Tillman et al. (1996) found the Suisun Marsh Salinity Control Gages (SMSCG) have the potential to impede all four races of Chinook salmon immigrating through Montezuma Slough. However, population-level effects have not been demonstrated. No work has been completed to specifically test the effects of the SMSCG on immigrating adult steelhead, but it is reasonable to expect similar results.

It is possible for SMSCG operations to affect adult steelhead immigration any time the gates are operated from September through May, given the life history of Central Valley steelhead. An evaluation of a method for minimizing gate effects through modification of the flashboards indicated that the modified flashboards were not successful in improving salmonid immigration. Following the evaluation, the regular flashboards are re-installed as long as the gates are needed to control salinity. Based on the results showing that the modification was not successful, another solution was developed for evaluation. The modification implemented for study years 2001-03 is a continuously open boat lock, with full flashboards in when the gate is operational. The effort to minimize the adverse effects of the SMSCG on salmonid immigration through Montezuma Slough is ongoing. Because the gates are operated only to meet salinity standards, avoidance measures (in other words, flashboards removed and gates out of water) are already in place during periods when the gates are not needed to control salinity.

Predation and Competition

Restriction of steelhead to mainstem habitats below dams may expose eggs and rearing juveniles to higher predation rates than those encountered in historical headwater habitats (McEwan and

Jackson 1996). Predatory fish are more abundant and diverse in mainstem rivers than headwater streams. Thus, predation loss is probably greater in mainstem rivers than in the historical spawning areas (CALFED 1998). However, essentially very little is known about predation on Central Valley steelhead. There are specific locations (e.g., dams, bridges, or diversion structures) where predation has become a significant problem for Chinook salmon. Some of these locations may also pose predation problems for rearing and migrating steelhead. During snorkel observations of juvenile steelhead in the American River, steelhead tended to hold in moderately swift currents in riffles during the summer. In most cases, adult striped bass and pikeminnows were holding within 100 feet downstream from these areas in deeper and slower moving water. When there was structure in faster currents such as bridge pilings or rootwads, adult pikeminnows were congregated in the eddies behind the structures. Steelhead were usually nearby. Anglers report that the most effective bait for stripers in the American River is a rainbow trout imitation.

Large constructed structures like diversion dams increase resting and feeding habitat for predatory fish. As an example, RBDD formerly impeded upstream passage, or provided a predator refuge and feeding area, for Sacramento pikeminnow and striped bass, resulting in increased densities of these two predators downstream of the dam. Current estimates of pikeminnow densities around RBDD were substantially lower than they were when the gates were left in year-round, although some aggregations still occur (FWS 1998). Furthermore, pikeminnow densities around RBDD appear to be much lower than the densities found to be a problem in the Columbia River system. Gate removal during March through May, the peak pikeminnow spawning migration period, is considered important in preventing the large aggregations that previously occurred. Approximately 81 percent of adult pikeminnow immigrants should pass during the gates-out period based on average run timing at RBDD (FWS 1998).

Predation rates on fishes are usually size-dependent, with the highest level of predation incurred upon smaller size classes. The available data from the FWS Chipps Island Trawl indicate an extremely small percentage of steelhead emigrate as YOY (see above). Therefore, it is expected that most steelhead predation occurs upstream of the Delta, where the habitat use of small size classes has been shown to be affected by the presence of potential predators (Brown and Brasher 1995) and predation risk appears to be affected by habitat use (DWR unpublished). The small percentages of YOY steelhead emigrating through the Delta would presumably face the same predation pressures as Chinook salmon smolts (Dennis McEwan, personal communication, 1998). However, steelhead were not listed as a prey item for any Delta fish by DFG (1966), even though they were more abundant at that time. The lack of steelhead in the stomachs of Delta piscivores is consistent with the observation that few steelhead emigrate as YOY, and also suggests predation pressure on the relatively large steelhead smolts migrating through the Delta may typically be low. An Interagency Ecological Program (IEP) funded study (#2000-083 Predator-Prey Dynamics in Shallow Water Habitats of the Sacramento-San Joaquin Delta) investigated the feeding ecology of piscivorous fishes in nearshore habitats of the Delta during 2001 and 2003. No steelhead were found in any of the 570 striped bass stomachs, 320 largemouth bass stomachs, or 282 Sacramento pikeminnow foreguts examined (Nobriga and Feyrer 2007).

The highest ocean mortality for steelhead occurs soon after their initial ocean entry (McEwan and Jackson 1996). Predation is presumed to be the principal cause of mortality, although this has not been studied. The effect may be more substantial during El Niño years when warm water off the California coast increases the metabolic demands of predators and attracts additional piscivorous species such as the Pacific mackerel.

Competition for spawning space among steelhead, resident rainbow trout, and Chinook salmon can be a source of egg mortality in mainstem rivers below dams. Substantial superimposition of salmon redds has been documented in the Feather River at a time of year when some steelhead may be attempting to spawn (Sommer et al. 2001a). Superimposition of salmon redds has also been documented in the upper Sacramento River below Keswick Dam (DFG 1998), and may be a problem for steelhead there as well.

Competition between steelhead and other species for limited food resources in the Pacific Ocean may be a contributing factor to declines in steelhead populations, particularly during years of low productivity (Cooper and Johnson 1992, as cited in McEwan and Jackson 1996). Pacific hake and Pacific salmon may compete with steelhead for food resources. Releases of hatchery salmonids may also increase competition and decrease survival and/or growth of hatchery and wild fish in the ocean. During years of lowered ocean productivity, smolt-to-adult survival rates indicated increased competition and mortality occurred when large numbers of hatchery and wild smolts were present together (McCarl and Rettig 1983; Peterman and Routledge 1983; McGie 1984; Lin and Williams 1988, all as cited in Pearcy 1992). Recent studies are also finding evidence that the reduced returns of adult salmonids to streams throughout the North Pacific could be seriously limiting the input of marine-derived nutrients to spawning and rearing streams (Gresh et al. 2000). The ecological importance of salmonid carcasses and surplus eggs to stream productivity and juvenile steelhead growth has been demonstrated experimentally (Bilby et al. 1996, 1998). Bilby et al. (1998) also presented evidence that juvenile steelhead may actively seek out areas of streams with abundant carcasses to prey on unspawned eggs.

Food Abundance in the Delta

Food supply limitation and changes to invertebrate species composition, which influence food availability for young fish in the estuary, have been suggested as factors in the decline of estuarine-dependent species such as delta smelt and striped bass (Bennett and Moyle 1996). However, food limitation for steelhead in the Delta or lower estuary has not been studied. Steelhead smolts tend to migrate through the Delta at the same time that many small Chinook are present. The abundance of the smaller Chinook likely provides a readily available food supply for outmigrating steelhead and may be an important food source during the early stages of ocean rearing.

Contaminants

The introduction of contaminants into steelhead habitat could negatively affect steelhead abundance and distribution directly and/or indirectly (McEwan and Jackson 1996). However, there is little direct information on individual impacts, and population-level effects are unknown.

Runoff from the Iron Mountain Mine complex into the upper Sacramento River is known to adversely affect aquatic organisms (USRFRHAC 1989). Spring Creek Dam was built to capture pollution-laden runoff from the Iron Mountain Mine complex so lethal effects of the pollutants could be attenuated by controlled releases from the reservoir. Spring Creek Reservoir has insufficient capacity to perform under all hydrologic conditions, and uncontrolled spills resulted in documented fish kills in the 1960s and 1970s. Greater releases from Shasta Reservoir are required to dilute the uncontrolled releases, diminishing storage needed to maintain adequate flows and water temperatures later in the year (McEwan and Jackson 1996).

The role of potential contaminant-related effects on steelhead survival in the Delta also has not been examined, but some common pollutants include effluent from wastewater treatment plants and chemical discharges such as dioxin from San Francisco Bay petroleum refineries (McEwan and Jackson 1996). In addition, agricultural drain water, another possible source of contaminants, can contribute up to 30 percent of the total inflow into the Sacramento River during the low-flow period of a dry year.

During periods of low flow and high residence time of water through the Stockton deep-water ship channel, high oxygen demand from algae concentrations can deplete dissolved oxygen to lethal levels. This can result in a barrier to upstream and downstream migrating steelhead and could kill steelhead present in the area of low dissolved oxygen.

Harvest

There is little information on harvest rates of Central Valley steelhead. Prior to listing in 1998, steelhead were vulnerable to over-harvest because anglers could catch them as juveniles and adults. McEwan and Jackson (1996) did not believe over-harvest had caused the overall steelhead decline, but suggested it could have been a problem in some places. For example, estimates of juvenile harvest, including hatchery-produced juveniles from the American River and Battle Creek, were as high as 51 percent and 90 percent, respectively. The proportion of naturally spawned steelhead harvested and the incidence and effects of hooking mortality are unknown. Most of the steelhead sports fishing effort occurs in the American and Feather Rivers. Regulations in place since 1999 prohibit the harvest of naturally produced (no adipose fish clip) steelhead greater than 16 inches long.

There is no longer a commercial ocean fishery for steelhead (McEwan and Jackson 1996). However, steelhead may be caught in either unauthorized drift net fisheries, or as bycatch in other authorized fisheries such as salmon troll fisheries. Based on very limited data collected when drift net fishing was legal, the combined mortality estimates for these fisheries were between 5 and 30 percent. Steelhead are routinely captured and often retained for personal consumption in salmon seine fisheries in Alaska and British Columbia. McEwan and Jackson (1996) did not think these mortality estimates were high enough to explain the steelhead decline, but they could have been a contributing factor. As mentioned above, the substantial declines in marine-derived nutrients to streams due to overall salmonid declines may also affect growth and survival of juvenile salmonids (Bilby et al. 1996, 1998). Levels of ocean harvest that result in minimum escapements to spawning grounds may exacerbate stream nutrient deficiencies (Gresh et al. 2000). Hatcheries currently remove the carcasses of spawned Chinook salmon and excess Chinook that ascend the hatchery ladders. The fish are used in food programs and not returned to the rivers. Approximately 20% of the marine derived nutrients may be removed from the Central Valley watershed by the current hatchery practices.

Hatcheries

Four Central Valley steelhead hatcheries (Mokelumne River, Feather River, Coleman, and Nimbus hatcheries) collectively produce approximately 1.5 million steelhead yearlings annually when all four hatcheries reach production goals (CMARP 1998). The hatchery steelhead programs originated as mitigation for the habitat lost by construction of dams. Steelhead are released at downstream locations in January and February at about four fish per pound, generally the time period that the peak of outmigration is believed to begin (Table 4-8).

Table 4-8 Production and release data for hatchery steelhead.[a]

Hatchery	River	Yearly production goal	Number released in 1999	Release location
Coleman	Battle Creek	600,000 smolts	496,525	Battle Creek and Balls Ferry
Feather R.	Feather	450,000 yearlings	345,810	Gridley
Nimbus	American	430,000 yearlings	400,060	Sacramento R. below American R.
Mokelumne R.	Mokelumne	100,000 yearlings [b]	102,440	Lower Mokelumne R.

[a] Source: DFG and National Marine Fisheries Service 2001.
[b] From American or Feather reared at Mokelumne.

The hatchery runs in the American and Mokelumne rivers are probably highly introgressed mixtures of many exotic stocks introduced in the early days of the hatcheries (McEwan and Jackson 1996; NMFS 1997b, 1998). Beginning in 1962, steelhead eggs were imported into Nimbus Hatchery from the Eel, Mad, upper Sacramento, and Russian rivers and from the Washougal and Siletz Rivers in Washington and Oregon, respectively (McEwan and Nelson 1991, as cited in McEwan and Jackson 1996). Egg importation has also occurred at other Central Valley hatcheries (McEwan and Jackson 1996).

Stock introductions began at the Feather River Hatchery in 1967, when steelhead eggs were imported from Nimbus Hatchery to raise as broodstock. In 1971, the first release of Nimbus-origin fish occurred. From 1975 to 1982, steelhead eggs or juveniles were imported from the American, Mad, and Klamath rivers and the Washougal River in Washington. The last year that Nimbus-origin fish were released into the Feather River was 1988. Based on preliminary genetic assessments of Central Valley steelhead, NMFS Fisheries (1998) concluded the Feather River Hatchery steelhead were part of the Central Valley ESU despite an egg importation history similar to the Nimbus Hatchery stock, which NMFS did not consider part of the Central Valley ESU. It is possible the Feather River Hatchery stock maintained substantial genetic affinity to other Central Valley stocks because it was not completely extirpated before the construction of

Feather River Hatchery, as the American River stock possibly was (Dennis McEwan, personal communication, 1999).

Hatcheries have come under scrutiny for their potential effects on wild salmonid populations (Bisson et al. 2002, Araki it al. 2007). The concern with hatchery operations is two-fold. First, they may result in unintentional, but maladaptive genetic changes in wild steelhead stocks (McEwan and Jackson 1996). DFG believes its hatcheries take eggs and sperm from enough individuals to avoid loss of genetic diversity through inbreeding depression and genetic drift. However, artificial selection for traits that improve hatchery success (fast growth, tolerance of crowding) are not avoidable and may reduce genetic diversity and population fitness (Araki et al. 2007).

The second concern with hatchery operations revolves around the potential for undesirable competitive interactions between hatchery and wild stocks. Intraspecific competition between wild and artificially produced stocks can result in wild fish declines (McMichael et al. 1997, 1999). Although wild fish are presumably more adept at foraging for natural foods than hatchery-reared fish, this advantage can be negated by density-dependent effects resulting from large numbers of hatchery fish released at a specific locale, as well as the larger size and more aggressive behavior of the hatchery fish.

Hallock et al. (1961, as cited in McEwan and Jackson 1996) reported that the composition of naturally produced steelhead in the population estimates for the 1953-54 through 1958-59 seasons ranged from 82 to 97 percent and averaged 88 percent. This probably does not reflect the present composition in the Central Valley due to continued loss of spawning and rearing habitat and increased hatchery production. During the latter 1950s, only Coleman and Nimbus Hatcheries were in operation.

Current data are not available to estimate the relative abundance of naturally spawned and hatchery-produced steelhead adults in the Central Valley. Since 1998 however, Central Valley hatcheries have attempted to clip the adipose fins of all hatchery-produced steelhead. This provides an opportunity to estimate the proportion of naturally spawned steelhead smolts emigrating through the Delta. Data from the FWS Chipps Island Trawl indicate the proportion of juvenile steelhead that are adipose-clipped is between 60 percent and 80 percent. Estimates of clipped and unclipped steelhead proportions are very difficult to obtain during adult steelhead spawning surveys (Hannon and Deason 2007).

Hatchery and Genetic Management Plans (HGMP) are under development for Nimbus, Feather River, Coleman, and Trinity River hatcheries. These are intended as a mechanism for addressing take of ESA-listed species that may occur as a result of artificial propagation activities and are occurring under separate ESA consultations for each hatchery.

Disease and Parasites

Steelhead are presumed to be susceptible to the same diseases as Chinook salmon (Dennis McEwan, personal communication, 1998). Loss of heterogeneity in hatchery fish can affect resistance to diseases (Arkush et al. 2002). Disease problems are often amplified under crowded hatchery conditions and by warm water. See DFG (1998) for a detailed discussion of Central Valley salmonid diseases.

Chapter 5 Basic Biology, Life History, and Baseline for Winter-run and Spring-run Chinook Salmon and Coho Salmon

This chapter provides information on the basic biology, life history, and status of winter-run and spring-run Chinook salmon, and Coho salmon in the study area. In general, the major factor affecting all listed salmonids in the Central Valley and Coho salmon on the Trinity River is the loss of spawning and rearing habitat due to large dams. For example, access to approximately 58 percent of the original winter-run Chinook salmon habitat has been blocked by dam construction. The remaining accessible habitat occurs in the Sacramento River below Keswick Dam and in Battle Creek.

The Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU) is restricted to one population entirely contained within the action area. Construction of the Livingston Stone National Fish Hatchery in 1996 has safeguarded the natural population since the critically low abundance of the 1990's. Improvements in Central Valley Project (CVP) operations since 1993 include: changes in operations to directly protect winter-run Chinook salmon, construction of a temperature control device on Shasta Dam in 1998, opening the gates at Red Bluff Diversion Dam (RBDD) for longer periods of time, and periodic closures of Delta Cross Channel (DCC) gates. These required actions have helped to bring the run to within 50 percent of the recovery goal. In addition, improvement of critical habitat from Central Valley Project Improvement Act (CVPIA) gravel augmentation projects and increased restrictions on recreational and commercial ocean harvest of Chinook salmon since 1994, likely have had a positive impact on winter-run Chinook salmon adult returns to the upper Sacramento River.

The Central Valley spring-run Chinook salmon ESU is comprised mainly of three self-sustaining wild populations (Mill, Deer and Butte Creeks) which are outside of the action area; however, all migratory life stages must past through the action area. In addition, spring-run Chinook salmon inhabit the Feather River and Clear Creek, which are within the action area. These three populations have been experiencing positive growth rates since the low abundance levels of the late 1980s. Restrictions on ocean harvest to protect winter-run Chinook salmon and improved ocean conditions have likely had a positive impact on spring-run Chinook salmon adult returns to the Central Valley. Abundance for the key indicator streams, Mill, Deer and Butte Creeks, have recently been at historical levels. Current risks to the remaining populations include stream habitat degradation, high water temperatures during the summer adult holding period, and the operations of the Feather River Hatchery.

The Trinity River portion of the Southern Oregon/Northern California Coast coho salmon ESU is predominately of hatchery origin. Termination of hatchery production of coho salmon at the Mad River and Rowdy Creek facilities has eliminated further potential adverse risks associated with hatchery releases from these facilities. Likewise, restrictions on recreational and commercial harvest of coho salmon since 1994 likely have had a positive impact on coho salmon adult returns.

Status

Sacramento River winter-run Chinook salmon were originally listed as threatened in August 1989, under emergency provisions of the Federal Endangered Species Act (ESA), and formally listed as threatened in November 1990 (55 FR 46515). The Sacramento River winter-run Chinook salmon ESU consists of only one population that uses spawning habitat confined to the upper Sacramento River in California's Central Valley. The National Marine Fisheries Service (NMFS) designated critical habitat for winter-run Chinook salmon on June 16, 1993 (58 FR 33212). They were reclassified as endangered on January 4, 1994 (59 FR 440) due to increased variability of run sizes, expected weak returns as a result of two small year classes in 1991 and 1993, and a 99 percent decline between 1966 and 1991. Critical habitat area was delineated as the Sacramento River from Keswick Dam, (River Mile [RM] 302) to Chipps Island (RM 0) at the westward margin of the Sacramento- San Joaquin Delta, including Kimball Island, Winter Island, and Brown's Island; all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge. The critical habitat designation identifies those physical and biological features of the habitat that are essential to the conservation of the species and that may require special management consideration and protection. Within the Sacramento River this includes the river water, river bottom (including those areas and associated gravel used by winter-run Chinook salmon as spawning substrate), and adjacent riparian zone used by fry and juveniles for rearing. In the areas west of Chipps Island, including San Francisco Bay to the Golden Gate Bridge, this designation includes the estuarine water column and essential foraging habitat and food resources utilized by winter-run Chinook salmon as part of their juvenile outmigration or adult spawning migrations.

Central Valley spring-run Chinook salmon were listed as threatened on June 18, 2005 (70 FR 37160). This ESU consists of spring-run Chinook salmon occurring in the Sacramento River Basin. Critical habitat was designated for spring-run Chinook on September 2, 2005 (70 FR 52488).

Southern Oregon/Northern California Coast (SONCC) coho salmon were listed as threatened under the ESA on June 18, 2005 (70 FR 37160). This ESU consists of populations from Cape Blanco, Oregon, south to Punta Gorda, California, including coho salmon in the Trinity River. NMFS designated critical habitat for SONCC coho salmon on May 5, 1999 (64 FR 24049) as accessible reaches of all rivers (including estuarine areas and tributaries) between the Elk River in Oregon and the Mattole River in California, inclusive). The critical habitat designation includes all waterways, substrate, and adjacent riparian zones, excluding: 1) areas above specific dams identified in the Federal Register notice (including Lewiston Dam); 2) areas above longstanding, natural impassable barriers (*i.e.*, natural waterfalls in existence for at least several hundred years); and 3) Indian tribal lands.

NMFS listed winter-run Chinook as threatened under emergency provisions of the ESA on August 4, 1989 (54 FR 32085), and formally listed the species as threatened on November 5, 1990 (55 FR 46515). The State of California listed winter-run Chinook as endangered in 1989 under the California Endangered Species Act (CESA). On January 4, 1994, NMFS reclassified the winter-run Chinook as an endangered species. The Central Valley spring-run Chinook salmon ESU is listed as a threatened species under both the California and the Federal ESAs. The State and Federal listing decisions were finalized in February 1999 and September 1999, respectively. The fall and late-fall runs of Chinook salmon are currently Federal Species of Concern, but have not been listed. They are included in this consultation to cover Essential Fish Habitat (EFH) consultation requirements as specified in the Magnuson Stevens Fisheries Conservation and Management Act, as amended in 1996.

Taxonomy

Chinook salmon (*Oncorhynchus tshawytscha*) (Walbaum) is one of nine *Oncorhynchus* species distributed around the North Pacific Rim (California Department of Fish and Game [DFG] 1998). The Chinook is most closely related to the coho salmon (*Oncorhynchus kisutch*) (Walbaum). The Chinook is physically distinguished from other salmon species by its large size (occasionally exceeding 50 pounds.), the presence of small black spots on both lobes of the caudal fin, black pigment along the base of the teeth, and a large number of pyloric cecae (Moyle 2002). The anal fin of Chinook fry and parr is not sickle-shaped with the leading edge longer than the base as seen in coho salmon fry and parr (Pollard et al. 1997). Juvenile characteristics are highly variable, however, and in areas where several salmon species co-occur, reliable identification can be dependent on branchiostegal and pyloric cecae counts. The Chinook, like other Pacific salmon, is anadromous. Adults spawn in fresh water and juveniles emigrate to the ocean where they grow to adulthood. Upon their return to freshwater, adults spawn and then die. On the North American coast, spawning populations of Chinook salmon are known to be distributed from Kotzebue Sound, Alaska, to central California (Healey 1991). The southernmost populations of Chinook salmon occur in the Sacramento-San Joaquin River systems.

Central Valley Chinook Salmon Biology and Life History

Chinook salmon stocks exhibit considerable variability in size and age of maturation, and at least some portion of this variation is genetically determined. The relationship between fish size and length of migration may also reflect the earlier timing of river entry and the cessation of feeding for Chinook salmon stocks that migrate to the upper reaches of river systems. Body size, which is correlated with age, may be an important factor in migration and redd (nest) construction success. Roni and Quinn (1995) reported that under high-density conditions on the spawning ground, natural selection may produce stocks with exceptionally large returning adults.

Among Chinook salmon, two distinct types have evolved: stream and ocean-rearing types (Groot and Margosis 1991). The stream-type is found most commonly in headwater streams. Stream-type Chinook salmon have a longer freshwater residency, and perform extensive offshore migrations before returning to their natal streams in the spring or summer months. Stream-type juveniles are much more dependent on freshwater stream ecosystems because of their extended residence in these areas. A stream-type life history may be adapted to areas that are more consistently productive and less susceptible to dramatic changes in water flow, allowing juveniles to survive a full year or more in freshwater and grow larger prior to smolting. At the time of saltwater entry, stream-type (yearling) smolts are much larger, averaging 73 to 134 millimeters (mm) depending on the river system, than their ocean-type (subyearling) counterparts and are, therefore, able to move offshore relatively quickly. Stream-type Chinook salmon are found migrating far from the coast in the central North Pacific (Healey 1991).

Ocean-type Chinook are commonly found in coastal streams in North America. Ocean-type Chinook typically migrate to sea within the first 3 months of emergence, but a few spend up to a year in freshwater prior to emigration. They also spend their ocean life in coastal waters. Ocean-type Chinook salmon return to their natal streams or rivers as spring-run, winter-run, summer-run, fall-run, and late-fall-run, but summer and fall-runs predominate. Ocean-type Chinook salmon tend to use estuaries and coastal areas more extensively for juvenile rearing. The development of the ocean-type life history strategy may have been a response to the limited carrying capacity of smaller stream systems and unproductive watersheds, or a means of avoiding the effects of seasonal floods. Ocean-type Chinook salmon tend to migrate along the coast. Populations of Chinook salmon south of the Columbia River drainage, including Central Valley stocks, appear to consist predominantly of ocean-type fish, although many Central Valley winter-run and spring-run juveniles do remain in their natal streams for up to a year.

The DFG (1998) recognizes four Chinook salmon runs in the Central Valley, which are differentiated by the timing of the adult spawning migration (fall-run, late-fall-run, winter-run, and spring-run). NMFS (1999) determined the four Central Valley Chinook races comprise only three distinct ESUs: the fall/late-fall-run, the spring-run, and the winter-run. NMFS (1999) determined that the Central Valley spring-run Chinook salmon ESU specifically comprises fish occupying the Sacramento River basin, which enter the Sacramento River between March and July and spawn between late August and early October.

Molecular data, including variability in multiple microsatellites (Banks et al. 2000), major histocompatibility complexes (Kim et al. 1999), and mitochondrial DNA (NMFS 1999) have been used to demonstrate genetic distinction between Central Valley Chinook salmon ESUs. This work complements long-recognized differences in life history (DFG 1998), but also adds to our understanding of Chinook salmon population genetics in the Central Valley. The historical Chinook phenotypes were differentiated by the timing of spawning migration, degree of sexual maturity when entering fresh water, spawning habitats, and to some degree, by the timing of the juvenile emigration (Moyle 1976, 2002; DFG 1998). However, recent results by Banks et al. (2000) suggest the spring-run phenotype in the Central Valley is actually shown by two genetically distinct subpopulations, Butte Creek spring-run and Deer and Mill Creeks spring-run. Spring-run acquired and maintained genetic integrity through spatio-temporal isolation from other Central Valley Chinook salmon runs. Historically, spring-run Chinook was temporally isolated from winter-run, and largely isolated in both time and space from the fall-run. As discussed below, much of this historical spatio-temporal integrity has broken down, due to spatial constraints on spawning habitat by dam construction, resulting in intermixed life history traits and hybridization in many remaining habitats.

Spawning

Spawning occurs in gravel beds that are often located at the tails of holding pools (US Fish and Wildlife Service [FWS] 1995a, as cited in DFG 1998). Adults have been observed spawning in water as shallow as 0.8 foot deep and in water velocities of 1.2 to 3.5 feet per second (Puckett and Hinton 1974, as cited in DFG 1998). Montgomery et al. (1999) reported adult Chinook tend to spawn in stream reaches characterized as low-gradient pool-riffle or forced pool-riffle reaches. Like steelhead, Chinook dig a redd (nest) and deposit their eggs within the stream sediment where incubation, hatching, and subsequent emergence take place. Optimum substrate for embryos is a gravel/cobble mixture with a mean diameter of 1 to 4 inches and a composition including less than 5 percent fines (particles less than 0.3 inch in diameter) (Platts et al. 1979; Reiser and Bjornn 1979 both as cited in DFG 1998). Spawning habitat requirements are similar for all races of Chinook salmon. Spawning habitat defined by habitat suitability models is generally found in riffles but when structure such as woody debris, boulders, pools, and overhanging vegetation is present salmonids often preferentially select these areas for spawning (Wheaton et al. 2004, Merz 2001).

Winter-run Life History and Habitat Requirements

The following information on winter-run Chinook salmon biology is from the proposed winter-run Chinook recovery plan (NMFS 1997).

Adult winter-run Chinook salmon return to freshwater during the winter but delay spawning until the spring and summer. Juveniles spend about 5 to 9 months in the river and estuary systems before entering the ocean. This life-history pattern differentiates the winter-run Chinook from other Sacramento River Chinook runs and from all other populations within the range of Chinook salmon (Hallock and Fisher 1985, Vogel 1985, DFG 1989).

In addition to their unique life-history patterns, the behavior of winter-run Chinook adults as they return to spawn differentiates the population. Adults enter freshwater in an immature reproductive state, similar to spring-run Chinook, but winter-run Chinook move upstream much more quickly and then hold in the cool waters below Keswick Dam for an extended period before spawning (Moyle et al. 1989.)

The habitat characteristics in areas where winter-run adults historically spawned suggest unique adaptations by the population. Before the construction of Shasta Dam, winter-run Chinook spawned in the headwaters of the McCloud, Pit, and Little Sacramento rivers and Hat Creek as did spring-run Chinook salmon. Scofield (1900) reported that salmon arriving "earlier" than spring-run (presumably winter-run) ascended Pit River Falls and entered the Fall River while the succeeding spring-run Chinook remained to spawn in the waters below. This indicates that winter-run Chinook, unlike the other runs, ascended to the highest portions of the headwaters, and into streams fed mainly by the flow of constant-temperature springs arising from the lavas around Mount Shasta and Mount Lassen. These headwater areas probably provided winter-run Chinook with the only available cool, stable temperatures for successful incubation egg over the summer (Slater 1963).

Adult Spawning Migration and Distribution

Sacramento River winter-run Chinook salmon enter San Francisco Bay from November through May or June. Their migration past RBDD at river mile 242 begins in mid-December and continues into early August. The majority of the run passes RBDD between January and May, with the peak in mid-March (Hallock and Fisher 1985). In general, winter-run Chinook spawn in the area from Redding downstream to Tehama. However, the spawning distribution, as determined by aerial redd surveys is somewhat dependent on the operation of the gates at RBDD, river flow, and probably temperature. At present, winter-run Chinook salmon are found only in the Sacramento River below Keswick Dam.

Timing of Spawning and Fry Emergence

Winter-run Chinook spawn from late-April through mid-August with peak spawning in May and June. Fry emergence occurs from mid-June through mid-October. Once fry emerge, storm events may cause en masse emigration pulses. Martin et al. (2001) evaluated brood years (BYs) 1995 through 1999 and found that emergence began in July during all BYs with peak dispersal occurring in September and October (based on RBDD data through 2007).

Juvenile Emigration

From 1995 through 1999, the pre-smolt/smolt emigration (greater than 45 mm fork length) started in September with 100 percent of production passing RBDD 2 to 3 months prior to the next brood year. Between 44 and 81 percent of winter-run production used areas below RBDD for nursery habitat and the relative use above and below RBDD appeared to be influenced by river discharge during fry emergence (Martin et al. 2001). Emigration past Red Bluff (RM 242) may begin in late July, generally peaks in September, and can continue until mid-March in drier years (Vogel and Marine 1991). Juveniles are found above Deer Creek from July through September and spread downstream to Princeton (RM 164) between October and March (Johnson et al. 1992). The peak emigration of winter-run through the Delta generally occurs in January and extends through April (USFWS data at Sacramento and DFG data at Knights Landing). Winter-run are detected leaving the Delta from September to June with a peak in March and April (USFWS trawl data at Chipps Island). Distinct emigration pulses appear to coincide with high precipitation and increased turbidity (Hood 1990 and Data Assessment Team).

Scale analysis indicates that winter-run Chinook smolts enter the ocean at an average fork length of about 118 mm, while fall-run smolts average about 85-mm fork lengths (DFG unpublished data). This suggests that winter-run juveniles reside in fresh and estuarine waters for 5 to 9 months, exceeding freshwater residence of fall-run Chinook by 2 to 4 months.

It is believed that winter-run Chinook salmon, like all Central Valley Chinook, remain localized primarily in California coastal waters. Coded wire tag (CWT) returns indicate that only 4 percent of winter-run hatchery production recoveries from ocean waters occurred in Oregon (Regional Mark Information System [RMIS] database). The majority of ocean tag recoveries were from the Monterey Bay, San Francisco Bay, and North Coast regions.

Historical and Current Distribution and Abundance of Winter-run Chinook Salmon

Following is a summary of original winter-run distribution from Yoshiyama et al. (2001):

> The winter-run, unique to the Central Valley (Healey 1991), originally existed in the upper Sacramento River system (Little Sacramento, Pit, McCloud, and Fall rivers) and in Battle Creek. There is no evidence that winter runs naturally occurred in any of the other major drainages before the era of watershed development for hydroelectric and irrigation projects. The winter-run typically ascended far up the drainages to the headwaters (CFC 1890). All streams in which winter-run were known to exist were fed by cool, constant springs that provided the flows and low temperatures required for spawning, incubation,

and rearing during the summer season (Slater 1963) when most streams typically had low flows and elevated temperatures.

Access to approximately 58 percent of the original winter-run habitat has been blocked by dam construction (Table 5-1). The remaining accessible habitat occurs in the Sacramento River below Keswick Dam and in Battle Creek. Shasta and Keswick dams blocked access to the original winter-run spawning habitat in the Sacramento River. The population now spawns downstream of Keswick Dam. Until recent years, salmon passage was not allowed above the Coleman Hatchery barrier weir located on Battle Creek. In recent years, there has been no winter-run spawning observed in Battle Creek but winter-run Chinook were detected above the weir in 2006 (high flow year). All winter-run production occurs in the Sacramento River (DFG 2003).

Table 5-1 Historical upstream limits of winter-run Chinook salmon in the California Central Valley drainage (from Yoshiyama et al. 2001).

Stream	Upstream Distributional Limit	Miles of Stream Historically Available	Miles of Stream Currently Available	Miles Lost	Percent Lost
Mainstem Sacramento River	none	299	286	13	4
Pit River	Mouth of Fall River	99	0	99	100
Fall River	Source springs near Dana, about 9 miles above mouth				
McCloud River	Lower McCloud Falls	50	0	50	100
Upper (Little) Sacramento River	Vicinity of Box Canyon Dam (Mt. Shasta City) and Lake Siskiyou (Box Canyon Reservoir)	52	0	52	100
Battle Creek North Fork	Falls 3 miles above Volta Powerhouse	43	43*	0	0
Digger Creek	Vicinity of Manton, possibly higher				
South Fork	Falls near Highway 36 crossing				
Total		543	329	214	39

* Yoshiyama et al. (2001) lists Battle Creek as having unobstructed passage for winter-run but according to Kier Associates (2000) the fish ladders around existing dams are ineffective and need replacement. Length of habitat below/above the lower barriers was not given.

Yearly winter-run escapement was estimated by counts in traps at the top of fish ladders at RBDD and more recently has been estimated using carcass counts (Figure 5-1). Escapements have declined from that which occurred in the 1960’s and 1970’s. The low escapements during dry years in the early 1990’s prompted the listing. Escapement subsequently increased after RBDD operations were modified and temperature control shutters were installed on Shasta Dam.

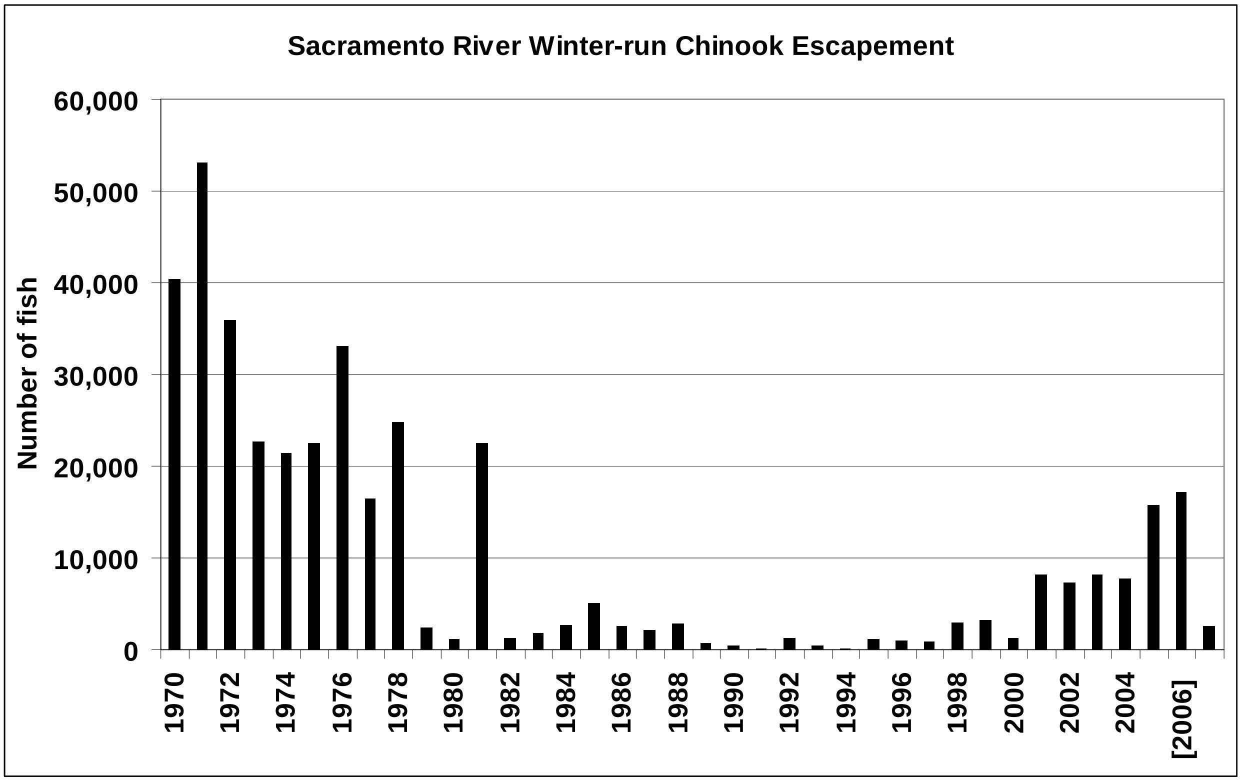
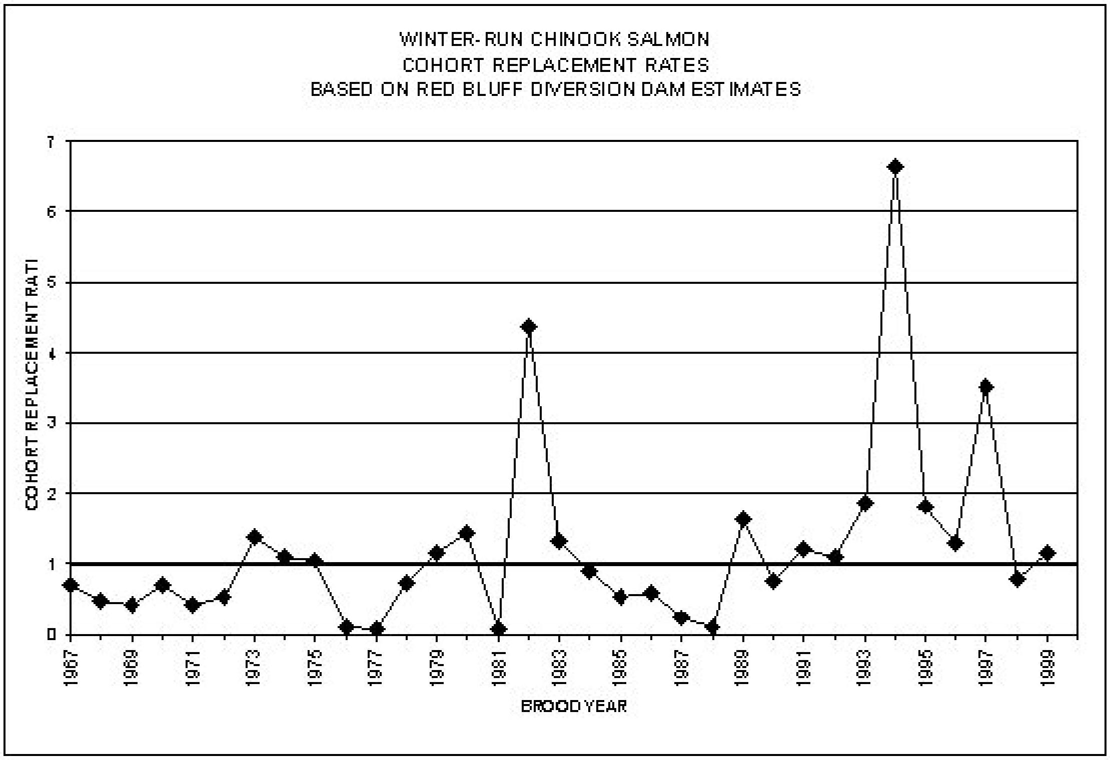


Figure 5-1 Sacramento River winter-run Chinook escapement. (brackets indicate preliminary data).

The Cohort Replacement Rate (CRR) is a parameter used to describe the number of future spawners produced by each spawner and is thus a measure of whether the population is increasing or decreasing. This spawner-to-spawner ratio is defined as the number of naturally produced and naturally spawning adults in one generation divided by the number of naturally spawning adults (regardless of parentage) in the previous generation. As such, the ratio describes the rate at which each subsequent generation, or cohort, replaces the previous one, and can be described as a natural CRR. When this rate is 1.0, the subsequent cohort exactly replaces the parental cohort and the population is in equilibrium, neither increasing nor decreasing. When the rate is less than 1.0, subsequent cohorts fail to fully replace their parents and abundance declines. If the ratio is greater than 1.0, there is a net increase in the number of fish surviving to reproduce naturally in each generation and abundance increases.

Figure 5-2 and Table 5-2 show that winter-run CRRs were generally less than 1 for the data up to 1990, i.e., the population was declining. CRRs have been mostly greater than 1 every year since 1990, indicating a generally increasing population in recent years. The winter-run population declined in 2007, consistent with the larger decline in fall-run Chinook.



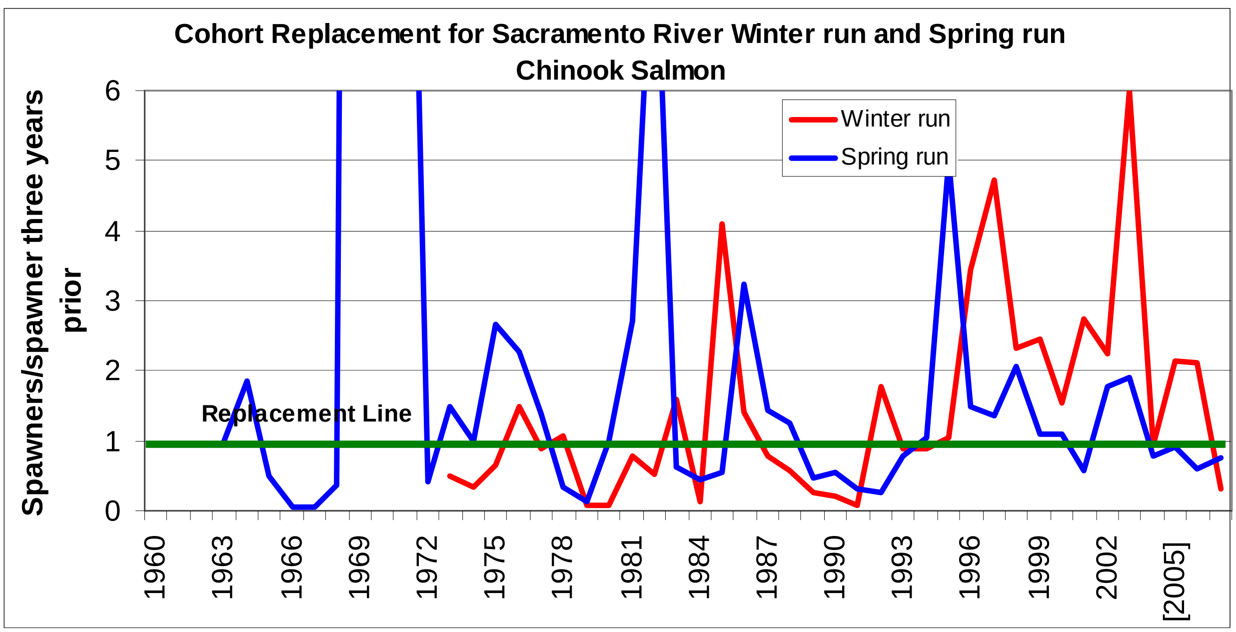


Figure 5-2 Sacramento River winter-run and spring run Chinook salmon cohort replacement rates (brackets indicate that the escapement estimate is preliminary).

Rates in the top chart were calculated by taking the BY escapement and dividing it by the sum of grilse 2 years later, 3-year olds 3 years later, and 4-year olds 4 years later; assuming that 95 percent of adults are 3-year olds and 5 percent are 4 years old, i.e., the 1999 CRR is based on adult returns in 2000 - 2002 (age distributions based on 2001 scale data).

Table 5-2 Sacramento River winter-run and Central Valley spring-run escapements and cohort replacement rates. Brackets around years indicate preliminary data (data from DFG's Grandtab spreadsheet dated 3-7-2008).

	Escapement		Cohort Replacement Rates	
Year	Winter run	Spring run	Winter run	Spring run
1960		11,068		
1961		4,327		
1962		3,642		
1963		10,817		0.98
1964		8,021		1.85
1965		1,788		0.49
1966		427		0.04
1967		476		0.06
1968		663		0.37
1969		21,378		50.07
1970	45,673	7,672		16.12
1971	53,089	9,281		14.00
1972	35,929	8,844		0.41
1973	22,651	11,430	0.50	1.49
1974	18,536	9,251	0.35	1.00
1975	23,079	23,578	0.64	2.67
1976	33,529	25,840	1.48	2.26
1977	16,470	12,730	0.89	1.38
1978	24,885	8,126	1.08	0.34
1979	2,339	3,116	0.07	0.12
1980	1,142	12,464	0.07	0.98
1981	19,795	22,105	0.80	2.72
1982	1,233	27,890	0.53	8.95
1983	1,827	7,958	1.60	0.64
1984	2,762	9,599	0.14	0.43
1985	5,048	15,221	4.09	0.55
1986	2,596	25,696	1.42	3.23
1987	2,186	13,888	0.79	1.45
1988	2,885	18,933	0.57	1.24
1989	696	12,163	0.27	0.47
1990	430	7,683	0.20	0.55
1991	211	5,927	0.07	0.31
1992	1,240	3,044	1.78	0.25
1993	387	6,075	0.90	0.79
1994	186	6,187	0.88	1.04
1995	1,297	15,238	1.05	5.01
1996	1,337	9,082	3.45	1.49
1997	880	8,448	4.73	1.37
1998	3,002	31,471	2.31	2.07
1999	3,288	9,835	2.46	1.08
2000	1,352	9,234	1.54	1.09
2001	8,224	17,698	2.74	0.56
2002	7,348	17,409	2.23	1.77
2003	8,105	17,570	5.99	1.90
2004	7,784	13,986	0.95	0.79
[2005]	15,730	16,117	2.14	0.93
[2006]	17,153	10,652	2.12	0.61
[2007]	2,488	10,571	0.32	0.76

The number of grilse in the population is probably over-estimated in the current RBDD counts. Current RBDD estimates are based on the late portion of the run, passing the dam after May 15 when the dam gates are closed. Historically, when dam counts were made year-round, there was a greater proportion of grilse in the later portion of the run. The proportion of grilse tends to be highly variable from year-to-year. The carcass count escapement data are believed to provide better abundance estimates, but there is not enough carcass survey data yet to draw any conclusions. Table 5-3 shows a comparison between RBDD fish ladder counts and carcass counts.

Table 5-3 Comparison of RBDD winter-run Chinook escapement vs. carcass count (Peterson estimate) winter-run escapement.

	Grilse RBDD	Adult RBDD	Total RBDD	Carcass Count
1996	629	708	1,337	820
1997	352	528	880	2,053
1998	924	2,079	3,002	5,501
1999	2,466	822	3,288	2,262
2000	789	563	1,352	6,670
2001	3,827	1,696	5,523	12,797
		Mean	2,564	5,017
		Standard Deviation	1,748	4,416

Aerial redd counts provide information on spatial distribution of spawners and number of redds constructed by winter-run Chinook. DFG has conducted yearly aerial redd surveys for Chinook spawning in the upper Sacramento River since 1969. The surveys attempted to enumerate winter-run redds beginning in the 1980s. Table 5-4 shows the distribution of redds by reach summarized by time. RBDD gate operations were changed from 1989 through 1993 to the current September 15 through May 15 gates-up operation. Redd distribution showed a clear shift to nearly all redds now occurring in locations upstream of RBDD. New fish ladders at the Anderson-Cottonwood Irrigation District (ACID) diversion dam began operating in 2001. Almost no winter-run redds were counted upstream of the ACID dam prior to 2001. Surveys counted 484 winter-run redds upstream of the ACID dam in 2001 and 297 redds in 2002. Table 5-5 shows winter-run spawning distribution 2001-2005. The spawning distribution over this period is used in the temperature model for assessing water temperature effects on spawning and incubating Chinook salmon eggs.

Table 5-4 Sacramento River winter-run Chinook salmon spawning distribution from aerial redd surveys grouped by 1987-92, 1993-2005, and all years combined.

	years 87-92	yearly average	% distrib	years 93-2005	yearly average	% distrib	years 87-2005	overall average	% distrib.
Keswick to A.C.I.D. Dam.	17	3	1	2,563	197	33	2,580	136	27
A.C.I.D. Dam to Highway 44 Bridge	411	69	23	2,282	176	30	2,693	142	28
Highway 44 Br. to Airport Rd. Br.	544	91	30	2,566	197	33	3,110	164	33
Airport Rd. Br. to Balls Ferry Br.	159	27	9	127	10	2	286	15	3
Balls Ferry Br. to Battle Creek.	62	10	3	65	5	1	127	7	1
Battle Creek to Jellys Ferry Br.	88	15	5	15	1	0	103	5	1
Jellys Ferry Br. to Bend Bridge	166	28	9	55	4	1	221	12	2
Bend Bridge to Red Bluff Diversion Dam	23	4	1	0	0	0	23	1	0
Red Bluff Diversion Dam to Tehama Br.	226	38	12	17	1	0	243	13	3
Tehama Br. To Woodson Bridge	124	21	7	0	0	0	124	7	1
Woodson Bridge to Hamilton City Br.	4	1	0	0	0	0	4	0	0
Hamilton City Bridge to Ord Ferry Br.	0	0	0	0	0	0	0	0	0
Ord Ferry Br. To Princeton Ferry.	0	0	0	0	0	0	0	0	0
Total	1,824	304	100	7,690	592	100	9,514	501	100

Table 5-5 Sacramento River winter-run and spring-run redd distribution 2001 through 2005 (winter) and 2001-2004 (spring).

	Winter Redds	Percent	Spring redds	Percent
Keswick to A.C.I.D. Dam.	1,931	42%	9	5%
A.C.I.D. Dam to Highway 44 Bridge	1,269	27%	38	19%
Highway 44 Br. to Airport Rd. Br.	1,332	29%	63	32%
Airport Rd. Br. to Balls Ferry Br.	68	1%	35	18%
Balls Ferry Br. to Battle Creek.	5	0%	21	11%
Battle Creek to Jellys Ferry Br.	2	0%	30	15%
Jellys Ferry Br. to Bend Bridge	8	0%	3	2%
Bend Bridge to Red Bluff Diversion Dam	0	0%	0	0%
Red Bluff Diversion Dam to Tehama Br.	9	0%	1	1%
Tehama Br. To Woodson Bridge	0	0%	0	0%
Woodson Bridge to Hamilton City Br.	0	0%	0	0%
Hamilton City Bridge to Ord Ferry Br.	0	0%	0	0%
Ord Ferry Br. To Princeton Ferry.	0	0%	0	0%
	4,624	100%	200	100.0%

Spring-Run Life History and Habitat Requirements

Adult Upstream Migration, Holding, and Spawning

Adult Sacramento River spring-run Chinook probably begin to leave the ocean for their upstream migration in late January to early February based on time of entry to natal tributaries (DFG 1998). They enter the Feather River as immature adults from March to September (DFG 1998; Sommer et al. 2001). Spring-run in other tributaries sometimes hold downstream and migrate later in the summer (Marcotte 1984). Spring-run Chinook are sexually immature when they enter freshwater. Their gonads mature during the summer holding period. Adult Chinook salmon of any race do not feed in freshwater. Stored body fat reserves are used for maintenance and gonadal development. During their upstream migration, adults require sufficient streamflow to provide olfactory and other orientation cues to locate their natal streams. Adequate streamflow is also necessary to allow adult passage to holding and spawning habitat. The timing of the spring-run migration is believed to be an adaptation that allowed the fish to use high spring outflow to gain access to upper basin areas (NMFS 1998).

The most complete historical record of spring-run Chinook migration timing and spawning is contained in reports to the U.S. Fish Commissioners of Baird Hatchery operations on the McCloud River (Stone 1893, 1895, 1896a, 1896b, 1896c, 1898; Williams 1893, 1894; Lambson 1899, 1900, 1901, 1902, 1904, all as cited in DFG 1998). Spring-run Chinook migration in the upper Sacramento River and tributaries extended from mid-March through the end of July with a peak in late May and early June. Baird Hatchery intercepted returning adults and spawned them from mid-August through late September (Table 5-6). Peak spawning occurred during the first half of September. The average time between the end of spring-run spawning and the onset of fall-run spawning at Baird Hatchery was 32 days from 1888 through 1901.

Table 5-6 Dates of spring-run and fall-run Chinook salmon spawning at Baird Hatchery on the McCloud River (DFG 1998).

Year	Spring-run	Fall-run	Reference
1888	8/15-9/24	10/29-12/15	Stone 1893
1889	8/27-9/26	No egg take	Williams 1893
1890	8/15-9/23	11/6-11/25	Williams 1893
1891	8/31-9/19	10/30-11/10	Williams 1894
1892	8/13-9/12	10/20-11/26	Stone 1895
1893	8/22-9/15	10/21-11/28	Stone 1896
1894	8/24-9/30	10/22-11/23	Stone 1896
1895	8/26-9/30	10/18-11/14	Stone 1896
1896	8/2-9/20	No egg take	Stone 1898
1897	8/14-9/20	10/8-12/8	Lambson 1897
1898	8/15-9/17	11/5-12/27	Lambson 1900
1899	8/21-9/27	10/18-11/9	Lambson 1901
1900	8/18-9/22	No egg take	Lambson 1902
1901	8/16-9/25	10/25-11/25	Lambson 1904

Adult Holding

Spring-run adults may hold in their natal tributaries for up to several months before spawning (DFG 1998). Pools in the holding areas need to be sufficiently deep, cool (about 64 F or less), and oxygenated to allow over-summer survival. Adults tend to hold in pools near quality spawning gravel. DFG (1998) characterized these holding pools as having moderate water velocities (0.5 to 1.3 feet per second) and cover, such as bubble curtains.

Spawning

Spawning occurs in gravel beds that are often located at the tails of holding pools (FWS 1995a, as cited in DFG 1998). Adult Chinook have been observed spawning in water greater than 0.8 foot deep and in water velocities of 1.2 to 3.5 feet per second (Puckett and Hinton 1974, as cited in DFG 1998). Montgomery et al. (1999) reported adult Chinook tend to spawn in stream reaches characterized as low-gradient pool-riffle or forced pool-riffle reaches. Like steelhead, Chinook dig a redd and deposit their eggs within the stream sediment where incubation, hatching, and subsequent emergence take place. Optimum substrate for embryos is a gravel/cobble mixture with a mean diameter of 1 to 4 inches and a composition including less than 5 percent fines (particles less than 0.3 inch in diameter) (Platts et al. 1979; Reiser and Bjornn 1979 both as cited in DFG 1998).

Currently, adult Chinook that DFG consider spring-run, spawn from mid to late August through early October, with peak spawning times varying among locations (Figure 5-3). For instance, in Deer Creek, spawning begins first at higher elevations, which are the coolest reaches. Spawning occurs progressively later in the season at lower elevations as temperatures cool (Harvey 1995, 1996, 1997, all as cited in DFG 1998). Water temperatures between 42 F and 58 F are considered most suitable for spawning.

Sex and Age Structure

Fisher (1994) reported that 87 percent of spring-run adults are 3-year olds based on observations of adult Chinook salmon trapped and examined at RBDD between 1985 and 1991. Studies of CWT'ed Feather River Hatchery spring-run recovered in the ocean fishery indicated harvest rates average 18 to 22 percent for 3-year-old fish, 57 to 85 percent for 4-year-old fish, and 97 to 100 percent for 5-year-old fish (DFG 1998). These data are consistent with Fisher's (1994) finding that most of the spawning population are 3-year olds.

Fecundity

DFG (1998) developed a regression model to predict Sacramento River Chinook fecundity from fork length. Using this model, they estimated Central Valley spring-run fecundity ranged from 1,350 to 7,193 eggs per female, with a weighted average of 4,161 eggs per female. These values are very similar to the fecundity of spring-run estimated for the Baird Hatchery in the latter nineteenth century using the number of females spawned and total egg take. Baird Hatchery estimates ranged from 3,278 to 4,896 eggs and averaged 4,159 eggs per female between 1877 and 1901.

Egg and Larval Incubation

Egg survival rates are dependent, in part, on water temperature. Chinook salmon eggs had the highest survival in the American River when water temperatures were 53 to 54 degrees Fahrenheit (°F) (Hinze et al. 1959, as cited in Boles et al. 1988). Incubating eggs from the Sacramento River showed reduced viability and increased mortality at temperatures greater than 58°F, and suffered 100 percent mortality at temperatures greater than 65°F (Seymour 1956 as cited in Boles et al. 1988). Healey (1979) observed greater than 82% mortality in Sacramento River fall-run Chinook eggs at temperatures over 57 F and that post-hatching mortality was higher in warmer water. He concluded that Sacramento River fall-run eggs are no more tolerant of high water temperatures than more northern Chinook stocks. Velson (1987) (as cited in DFG 1998) found developing Chinook salmon embryos also experienced 100 percent mortality at temperatures less than or equal to 35°F. The time for incubating eggs to reach specific embryonic developmental stages is determined by water temperature. At an incubation temperature of 56°F, eggs would be in the gravel approximately 70 days. Chinook eggs and alevins are in the gravel (spawning to emergence) for 900 to 1,000 accumulated temperature units. One accumulated temperature unit is equal to a temperature of 1°C for 1 day. Expressed in degrees Fahrenheit, the range is 1,652 to 1,832 accumulated temperature units.

Juvenile Rearing and Emigration

Juvenile spring-run rear in natal tributaries, the Sacramento River mainstem, nonnatal tributaries to the Sacramento River, and the Delta (DFG 1998). Emigration timing is highly variable (Figure 5-3). Juvenile spring-run from Mill and Deer creeks are thought to emigrate as yearlings in greater proportions than spring-run from other tributaries (DFG 1998).

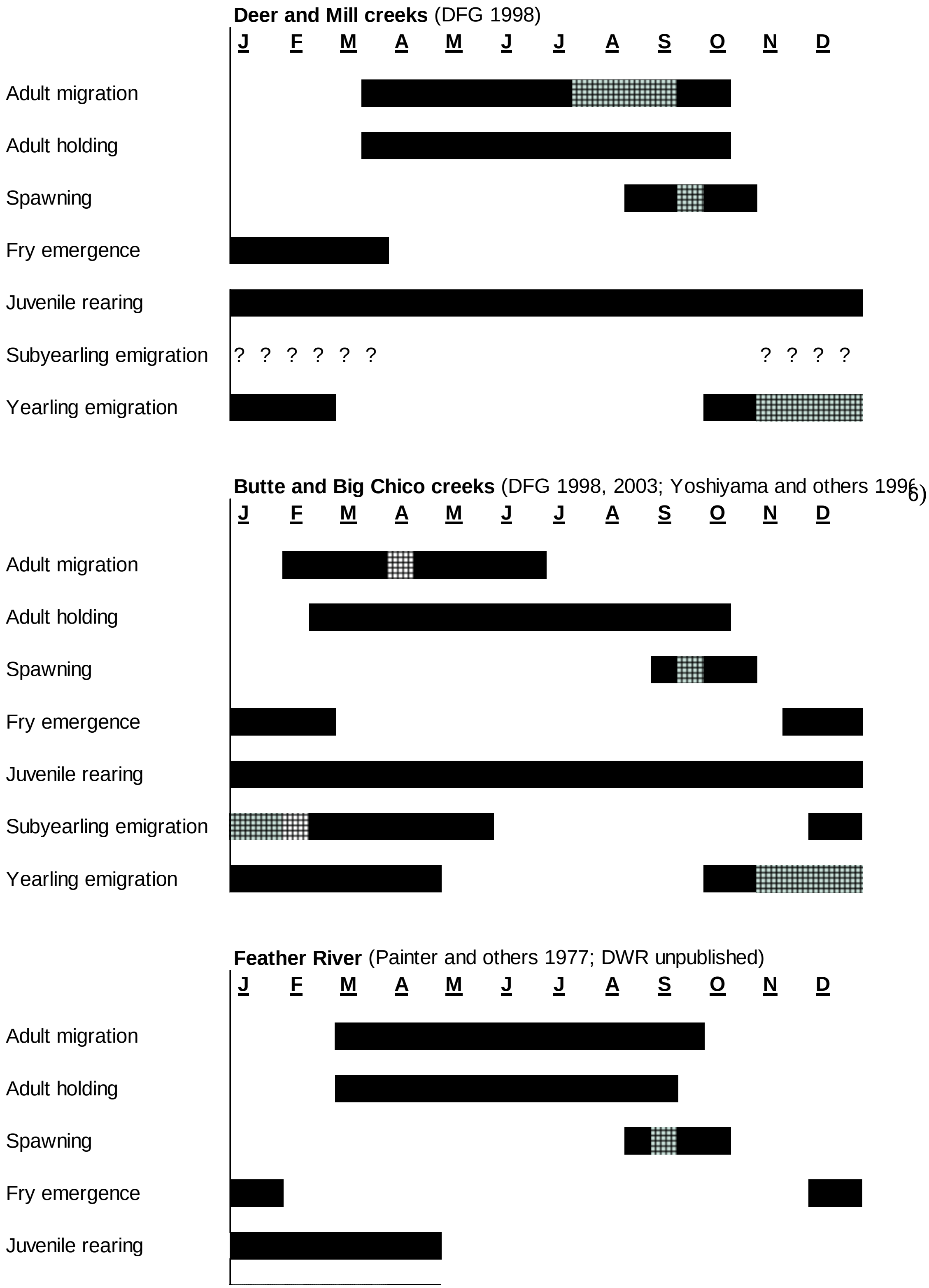


Figure 5-3 Spring-run Chinook salmon life cycle for various Central Valley streams. Cross hatching indicates period of peak occurrence.

This was apparently not the typical historical emigration pattern for the majority of Central Valley spring-run Chinook (NMFS 1998). Yearling emigration occurs from October through March and may be triggered in part by precipitation events. In some years however, under certain flow and/or water temperature conditions, greater proportions of juveniles in Mill and Deer Creeks may emigrate as fry or fingerlings soon after emergence. The bulk of Butte and Big Chico Creek production emigrates as fry from natal tributaries in December and January (Brown 1995 as cited in DFG 1998). Some also emigrate as fingerlings from February through May, and as yearlings from October through February. In contrast, no yearling emigration has been detected in the Feather River (DWR 1999c, 1999d). Instead, rotary screw trap (RST) data from 1998 to 2000 suggest that emigration of spring-run sized Chinook salmon from the Feather River peaks in December and is followed by another pulse of juvenile young-of-the-year (YOY) emigrants at Live Oak in April and May (DWR 2003, Seesholtz et al. 2004).

Juvenile rearing habitat must provide adequate space, cover, and food supply (DFG 1998). Optimal upstream habitat includes abundant instream and overhead cover (for example, undercut banks, submergent and emergent vegetation, logs, roots, other woody debris, and dense overhead vegetation) to provide refuge from predators, and a sustained, abundant supply of invertebrate and larval fish prey. Further downstream, fry use low-velocity areas where substrate irregularities and other habitat features create velocity refuges and they may increasingly rely on turbidity as cover (Gregory and Levings 1998).

Juvenile Chinook, including spring-run, also rear in ephemeral habitats including the lower reaches of small intermittent streams (Maslin et al. 1997) and in floodplain areas (Sommer et al. 2001b). Growth rates and mean condition factors were higher for juvenile Chinook rearing in intermittent tributaries than in the heavily channelized Sacramento River (Moore 1997). Similarly, growth rates and bioenergetic status were found to be significantly higher for juvenile Chinook rearing in the intermittent habitat of the Yolo Bypass floodplain than in the adjacent reach of the Sacramento River (Sommer et al. 2001b). These results highlight the importance of off-channel seasonal rearing habitats to young Central Valley salmon.

It is not known how similar the rearing patterns of Central Valley spring-run are to the fall-run because the Delta rearing patterns of spring-run Chinook have not been studied. Juvenile emigration is thought to alternate between active movement, resting, and feeding. The amounts of time spent doing each are unknown (DFG 1998), but studies have generally shown feeding is most intense during daylight or crepuscular periods (Sagar and Glova 1988). Juvenile outmigration monitoring results from throughout the Central Valley and elsewhere indicate that active emigration is most prevalent at night. Juvenile fall-run salmon may rear for up to several months within the Delta before ocean entry (Kjelson et al. 1982). Rearing within the Delta occurs principally in tidal freshwater habitats. Juveniles typically do not move into brackish water until they have smolted, after which NMFS studies indicate they move quickly to the ocean.

Chironomidae (midges) are typically cited as an important prey for juvenile Chinook upstream of the Delta (Sasaki 1966; Merz and Vanicek 1996; Moore 1997; Sommer et al. 2001b), whereas crustaceans may be more important in the western Delta (Sasaki 1966; Kjelson et al. 1982). Juvenile Chinook diets often vary by habitat type, resulting in differences in caloric intake and growth rate (Rondorf et al. 1990; Moore 1997; Sommer et al. 2001b). However, it remains unclear whether these spatial differences in feeding and growth translate into improved survival (Sommer et al. 2001b).

Before entering the ocean, juvenile Chinook smolt, a physiologic transformation that prepares them for the transition to salt water (Moyle 1976, 2002). The transformation includes lowered swimming stamina and increased buoyancy, which make the fish more likely to be passively transported by currents (Saunders 1965, Folmar and Dickhoff 1980, Smith 1982, all as cited in DFG 1998). It is believed to be optimal for smoltification to be completed as fish near the low-salinity zone of an estuary (DFG 1998). Too long a migration delay after the process begins may cause the fish to miss a biological window of optimal physiological condition for the transition (Walters et al. 1978, as cited in DFG 1998). Chinook salmon that complete the juvenile and smolt phases in the 55 to 61°F range are optimally prepared for saltwater survival (Marine and Cech 2004). The optimal thermal range during smoltification and seaward migration was estimated to be 50 to 55°F (Boles et al. 1988), based largely on studies of steelhead and coho salmon in the Northwest.

Ocean Distribution

CWT recoveries from harvested hatchery-released adult spring-run Chinook provide information on ocean distribution and harvest of adult spring-run. Table 5-7 shows that most recoveries of hatchery-released spring-run (all from Feather River Hatchery) occur off the California Coast but some do occur along the Oregon Coast. Recent CWT studies conducted on Butte Creek spring-run have shown 12 percent were harvested in the Garibaldi to Coos Bay area, 14 percent from Crescent City to Fort Bragg, 44 percent from Fort Ross to Santa Cruz, and 30 percent from Monterey to Point Sur (DFG 2003).

Table 5-7 Recovery locations of hatchery-released spring-run and estimated number recovered, 1978 – 2002 (RMIS database). All are from the Feathery River Hatchery. Location identifiers with less than 8 recoveries (48 of them) are not shown.

Sum of estimated_number	run_year																						
recovery_location_name	1978	1979	1980	1981	1983	1984	1985	1986	1987	1988	1989	1990	1993	1994	1995	1996	1998	1999	2000	2001	2002	Grand Total	percentag
FORT ROSS-PIGEON PT	787	1,981	539	51	12	177	248	400	412	488	404		11	96	236	8	129	568	430			6,976	23.3%
FEATHER RIVER																			414	42	4,412	4,867	16.2%
PIGEON PT.-POINT SUR	159	478	219	14		116	33	375	320	260	186	17		5	216	22		244	970	744	315	4,693	15.7%
FEATHER R HATCHERY																			342	749	420	1,511	5.0%
NEWPORT TROLL 4						6	3	60	58	104	66				60	6		37	63	773	236	1,470	4.9%
PT.REYES-PIGEON PT.																				631	829	1,460	4.9%
C.VIZCAINO-NAVARR.HD	87	424	71	8		9	16	84	15	140	24				6	5		11	23	57	89	1,068	3.6%
FORT ROSS-POINT SUR											139	10		24	45			551	280			1,049	3.5%
COOS BAY TROLL 5						5	18	106	60	118	58	4						107	108	298	108	989	3.3%
POINT SUR-CA/MEX.BOR						4		141	95	60				10	168	3			146	76	41	744	2.5%
PT.ARENA-PT.REYES																				476	239	715	2.4%
SPAN.FLAT-C.VIZCAINO						15	18	81	85	149	44	3			3			14	33	60	55	560	1.9%
BIG LAG.-CENTERV.BEA	8	147	15		3		20	11	53	3	18	3			5			35	29	54	33	438	1.5%
NAVARRO HD-FORT ROSS							5	32	154	44	11			2					2			249	0.8%
COLUSA TO RBDD																				239		239	0.8%
GARIBALDI TROLL 3								14	11	10	5				12			15	19	94	38	218	0.7%
AMERICAN RIVER																			43		126	169	0.6%
SPAN.FLAT-PT.ARENA																				32	135	167	0.6%
CA/OR BOR-FA.KLAM.RC	18	20	4	4		31	17	6	14	8	16								14	5		157	0.5%
WINCHESTER B TROLL 5							4	29	15	33	18							11	12	25	5	153	0.5%
LOW FLOW AREA																				153		153	0.5%
WINCHESTER B SPORT 5					4		3		14	26	2								10	56	29	144	0.5%
BROOKINGS SPORT 6					3	2	22	3	28	27	4	2				2		3	7	18	21	142	0.5%
NAVARRO HD-PIGEON PT										40	66											106	0.4%
PIGEON PT-CA/MEX.BOR															11			2	38		37	88	0.3%
MARINE AREA 2						1	6	9	10	19	2						3	19		9	8	85	0.3%
AMER.R. TO COLUSA																				40	40	80	0.3%
SIUSLAW BAY TROLL 5									12	29	14							10	6			71	0.2%
HIGH FLOW AREA																				66		66	0.2%
SPAN.FLAT-NAVARRO HD										41	11								8			60	0.2%
PORT ORFORD TROLL 5								3	3	1	5							5	2	23	11	53	0.2%
C.VIZCAINO-FORT ROSS										28	10							13				50	0.2%
CA/OR BDR.- HMBT.JET																				27	21	48	0.2%
PT.REYES-PT.SUR																				40	4	44	0.1%
NEWPORT TROLL 5							1		11		1							2	3	12	13	44	0.1%
MARINE AREA 4									4	7	3	3						12	3	7	2	40	0.1%
BROOKINGS TROLL 6								12	9	4				2				6	2	3		38	0.1%
NEWPORT SPORT 4					3		3	3											6	12	7	34	0.1%
COOS BAY TROLL	6	17	11																			34	0.1%
BROOKINGS TROLL		30		2																		32	0.1%
BATTLE CREEK																				17	15	32	0.1%
COOS BAY SPORT 5								4		4									5	4	15	32	0.1%
ASTORIA TROLL 2							2	5		9										10		27	0.1%
MARINE AREA 1	4	3						5		3								3			7	25	0.1%
YUBA RIVER																			2		21	23	0.1%
COOS BAY TROLL 4															7					10	4	22	0.1%
PT.ARENA-PIGEON PT.																					20	20	0.1%
ASTORIA SPORT 2																				15	4	19	0.1%
PT.SN.PEDRO-PIGN.PT.																				6	14	19	0.1%
NEWPORT TROLL		19																				19	0.1%
RBDD TO ACID																				18		18	0.1%
TEHAMA-COLUSA FF		4	8	2		1	2															17	0.1%
NEWPORT TROLL 3								2	1		6									5	3	17	0.1%
WSPT LONG BE											14							3				17	0.1%
1A PLUS 1B										16												16	0.1%
DEPOE BAY SPORT 4								2	2	2								1			10	16	0.1%
FLORENCE SPORT 5									4	9	2											15	0.0%
SWTR 114-000						8				4												13	0.0%
1A (BUOY10 - BRIDGE)																				6	6	12	0.0%
WSPT CREE IS																			12			12	0.0%
OCEAN SPORT AREA 72						4			4	2												10	0.0%
MARINE AREA 3										9								1				10	0.0%
FA.KLA.RC-BIG LAGOON										10												10	0.0%
SWTR 111-000										10												10	0.0%
CLEAR CREEK																				7	3	9	0.0%
PACIFIC CITY TROLL 3									3	6												9	0.0%
SWTR 021-000						9																9	0.0%
HIGH SEAS 1 47N 124W																			9			9	0.0%
MARINE AREA 5 TROLL									7	2												8	0.0%
SWTR 023-234						8																8	0.0%
COLEMAN NFH			1						5	2												8	0.0%
OCEAN SPORT AREA 82							3		2		2											8	0.0%
NWTR 025-000										4								4				7	0.0%

Historical and Current Distribution and Abundance of Spring-Run Chinook Salmon

Spring-run Chinook salmon populations once occupied the headwaters of all major river systems in the Central Valley up to any natural barrier (Yoshiyama et al. 1996, 1998). DFG (1998) reported that historically spring-run abundance was second only to fall-run abundance in the Central Valley, but NMFS (1998) indicated spring-run may actually have been the most abundant run in the Central Valley during the nineteenth Century. The gill-net fishery, established around 1850, operated in the Delta and initially targeted spring- and winter-run Chinook salmon due to their fresher appearance and better meat quality than fall-run, which return to freshwater in a more advanced spawning condition (Stone 1874, as cited in DFG 1998). Early gill-net landings reported in excess of 300,000 spring-run per year (CFC 1882, as cited in DFG 1998). Commercial fishing along with residual effects of mining probably contributed to spring-run declines by the early part of the twentieth century (DFG 1998).

Recent estimates indicate roughly 2,000 miles of salmon spawning and rearing habitat were available before dam construction and mining, but 82 percent of that habitat is unavailable or inaccessible today (Yoshiyama et al. 1996). The available habitat may be less when the quality of remaining habitat is considered. Stream reaches below major dams may be accessible to spring-run, but competition and/or introgression with fall-run may render these reaches marginally useful to the spring-run. Moreover, it is possible that spring-run prefer to spawn in smaller channels similar to their historical upstream habitat, rather than the existing broad, low-elevation reaches available below dams. Most of these habitat modifications were in place before more recent declines occurred however, suggesting other factors and gradual habitat degradation below dams have also affected spring-run abundance in the Central Valley.

Currently, the bulk of the remaining spring-run Chinook are produced in Deer, Mill, and Butte creeks, the Feather River, and perhaps the mainstem Sacramento River. Small numbers of spring-run have intermittently been observed in the recent past in other Sacramento River tributaries as well (DFG 1998). Of the three tributaries producing naturally spawned spring-run (Mill, Deer, and Butte Creek), Butte Creek has produced an average of two-thirds of the total production over the past 10 years. Some distribution and abundance data are presented below for current spring-run producing streams. Additional details on these and other streams can be found in DFG (1998) and NMFS (1998).

Estimation methods for spring-run in the tributaries have varied through the years. Confidence intervals are usually not developed on the escapement estimates making comparison of estimates between years problematic. The recent (last 10 years) preferred method is a snorkel survey in tributaries other than Mill Creek. Snorkel surveys are good for identifying population trends when experienced observers use consistent methods, but they usually underestimate the actual number of fish present. Comparisons during 2001 and 2002 on Butte Creek of the snorkel survey with a rigorous Schaefer carcass survey suggest that the snorkel survey underestimates by as much as 50 percent (DFG 2003). The underestimate is probably greater on a stream like Butte Creek with fish in higher densities than in some of the other tributaries.

Clear Creek

Prior to European settlement, Clear Creek supported spring-run, fall-run, and late-fall-run Chinook salmon and steelhead. Absent from Clear Creek for 30 years, approximately 30 adult spring-run Chinook salmon reappeared in the lower reaches of Clear Creek in 1999. Historical accounts of spring-run Chinook in Clear Creek are sparse and population estimates are nonexistent. Spring-run were observed in Clear Creek upstream of Saeltzer Dam in 1956 for the first time since 1948. Construction of Whiskeytown Dam in 1963 permanently eliminated access to the upper reaches of the creek to salmon. Previous observations of spring-run indicate that they likely held over and spawned in cooler water present in the upper watershed upstream of Whiskeytown Dam. A waterfall at French Gulch restricted upstream migration to periods of high runoff in the spring.

Attempts to re-establish the spring-run Chinook on Churn Creek have been made. In 1991, 1992, and 1993, 200,000 juvenile spring-run Chinook salmon from the Feather River Hatchery were planted in Clear Creek. A number of these fish returned to Clear Creek in the fall of 1995 rather than in the spring as expected. They may have remained in the cooler Sacramento River until Clear Creek cooled or they may be offspring of hybrid spawning of spring- and fall-run for several generations at Feather River Hatchery. FWS conducts snorkel surveys for spring run in Clear Creek (Table 5-8).

Table 5-8 Clear Creek adult spring-run Chinook escapement, 1999-2006 (Source: FWS, unpublished data).

1999	2000	2001	2002	2003	2004	2005	2006
30	19	9	66	25	98	69	70

The FWS operates a rotary screw trap at river mile 1.7 on Clear Creek, upstream of the sheet pile dam associated with the ACID canal siphon crossing. Spring-run-sized juvenile Chinook salmon are enumerated in the trap according to length criteria developed for the upper Sacramento River. In late 1999, approximately 2,300 spring-run sized juvenile Chinook were collected in the trap after many Chinook had spawned in lower Clear Creek during September. In late 2000, 41 spring Chinook juveniles were collected in the trap. During 2001, the first spring-run-sized juvenile was captured in the trap on November 14. The estimated number of potential spring-run captured in the trap in 2001 was 1,083 in November and December (DFG 2002). The estimate for 2002 was 7,722 and the estimate in 2003 was 11,144 (DFG 2004). Currently a segregation weir is installed yearly after spring run have migrated upstream. This weir prevents fall run from migrating upstream to the spawning area used by spring run, thereby preventing fall run from spawning over the top of spring run redds.

Denton (1986) used the PHABSIM module of the IFIM approach to estimate optimal Clear Creek flows for salmon and steelhead. The resultant estimate of optimal flows from the IFIM study is shown in Figure 5-4. The timing of these flows was based on the fall-run Chinook life cycle, but the recommended steelhead flows would provide the needed flows for spring-run, except potentially in April and May when an extra 25 cubic feet per second (cfs) would be required to bring the flows up to the salmon recommendation. The recommended spawner attraction flow releases shown in October and November could be provided around April and May for spring-run.

Although the optimum flows that were recommended for fall-run of 250 cfs may provide a maximum amount of suitable spring-run spawning and rearing habitat because the number of spring-run in Clear Creek is low, the population does not appear to be currently habitat-limited as long as temperatures are suitable. The section of Clear Creek from the mouth to the former Saeltzer Dam is fall and late-fall Chinook habitat. The Clear Creek Road Bridge to Whiskeytown Dam reach is the section of creek more suitable for spring-run Chinook because temperatures are cooler than in the downstream reach in the summer. The IFIM study showed higher flow needs in the downstream habitat than in the upstream habitat. Optimal flows for salmon in the upstream reach where spring-run are located were 62 cfs for spawning and 75 cfs for rearing from the IFIM study (Denton 1986). Optimal steelhead flows in the same upstream reach were 87 cfs for spawning and 112 cfs for juvenile rearing.

Flows in Clear Creek likely resulted from a general flow schedule developed for salmon and steelhead maintenance. The schedule was intended as an interim flow release schedule for monitoring purposes to be fine-tuned as the fishery effects were determined (Denton 1986). Studies are underway by a Clear Creek flow group to fine-tune the flow schedule.

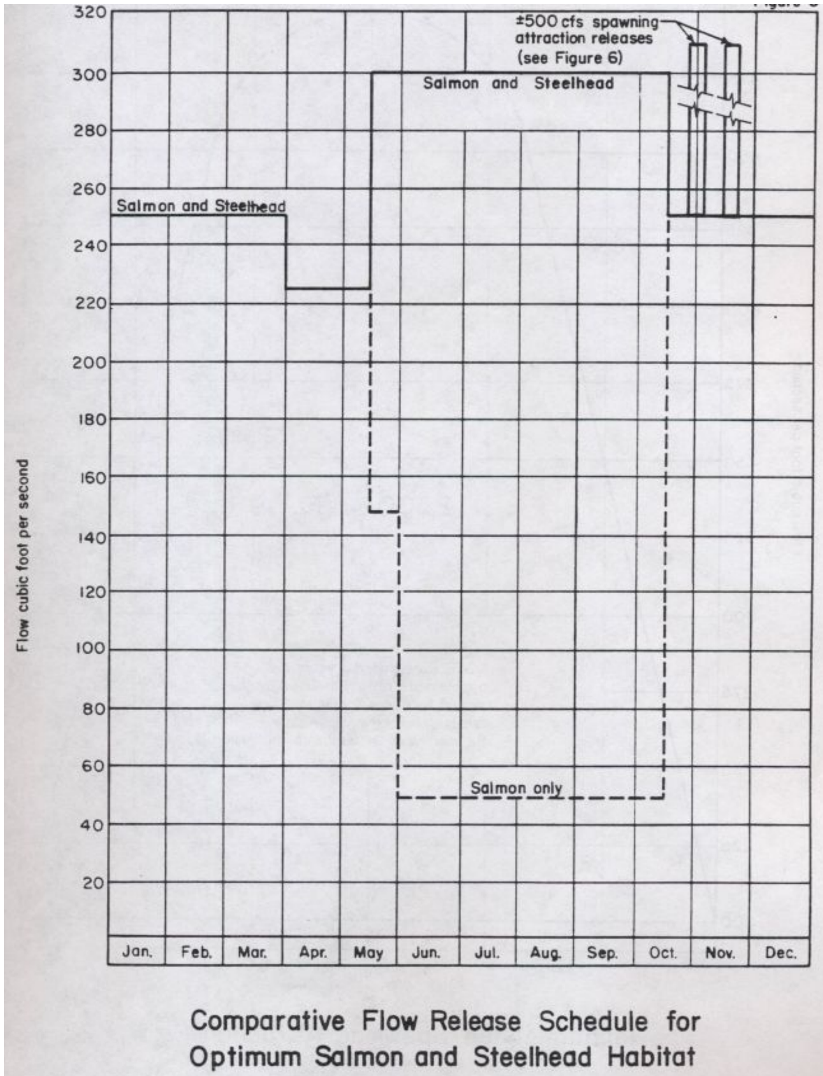


Figure 5-4 Clear Creek flows for optimum salmon and steelhead habitat.

Sacramento River Mainstem

Some spring-run Chinook may spawn in the Sacramento River between RBDD and Keswick Dam. Sacramento River main-stem spring-run abundance has declined sharply since the mid-1980s (Figure 5-5). The criteria for run classification at RBDD have changed so no conclusions can be reached about spring-run abundance changes in the Sacramento River. The variable abundance estimates may be an artifact of the counting methods used in different years and categorization of fish between runs. The 5-year geometric mean abundance reported by NMFS (1998) was 435 fish. There is evidence that the spring-run that pass RBDD are spring-run/fall-run hybrids (Figure 5-6). Historically, the onset of fall-run spawning occurred well after spring-run had completed spawning. The increasing overlap in spring-run and fall-run spawning periods is evidence that introgression is occurring. Because spring-run and fall-run Chinook now use the same spawning riffles, fall-run spawners may reduce survival of eggs in the spring-run redds. This redd displacement is called superimposition. The criteria used to distinguish spring-run from fall-run between 1970 and 1988 (timing) probably resulted in many fall-run fish being classified as spring-run (DFG 2003), so the increasing overlap may be simply an artifact of the variable run classification.

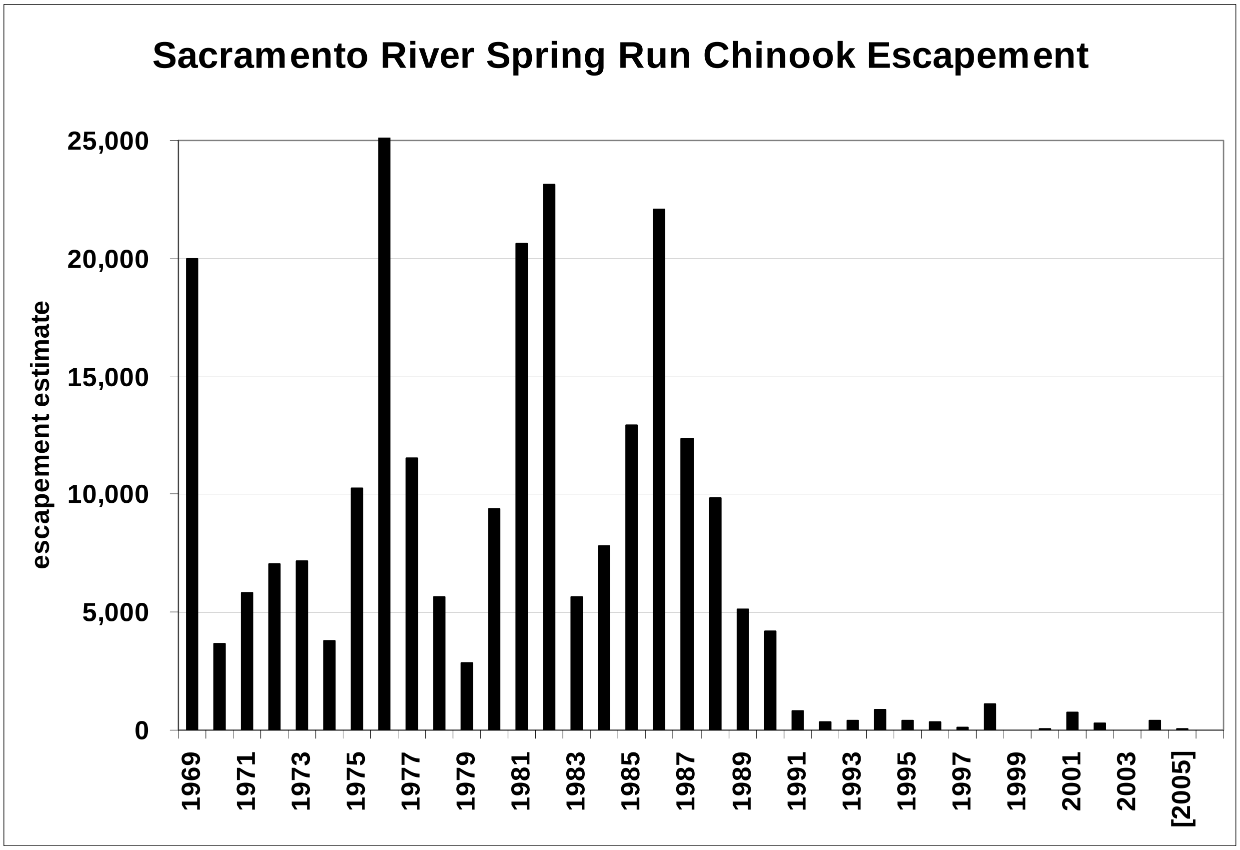


Figure 5-5 Estimated adult spring-run Chinook salmon population abundance in the upper Sacramento River. Brackets indicate the data for that year is preliminary.

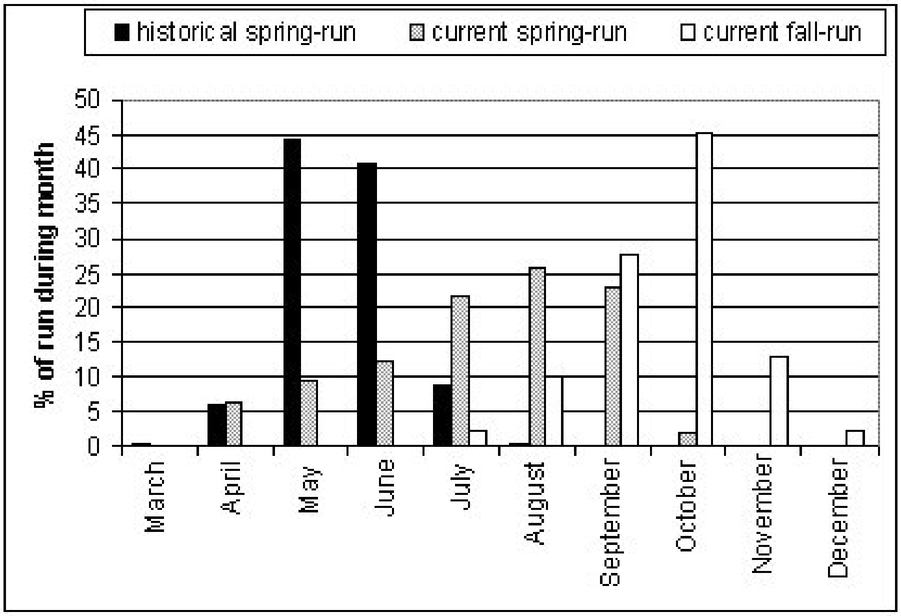


Figure 5-6 Migration timing of spring-run and fall-run Chinook salmon.

Historical distribution of timing is based on composite data from Mill and Deer Creeks, Feather River, and the upper Sacramento River prior to Shasta Dam. Present distributions are for spring-run and fall-run timing past RBDD (1970-1988). Data were taken from DFG 1998.

Cohort Replacement Rates Used for Mill, Deer, and Butte Creeks

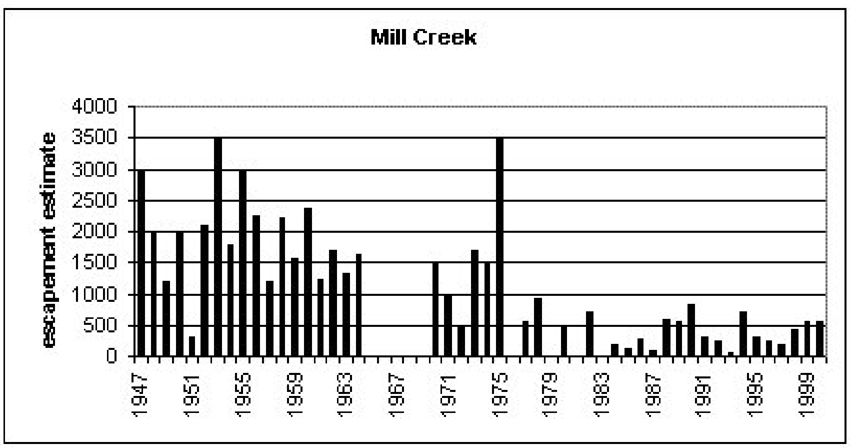
DFG (1998) evaluated spring-run Chinook population trends by examining the strength of BY lineages with a CRR. The varied methods used over the years to estimate population abundance in each tributary left few data adequate for such analyses. DFG (1998) considered the more recent data for Mill, Deer, and Butte Creeks to be the most consistent and robust. Individual brood year data are lacking altogether on rates of grilse (2-year old) returns, age structure, and sex ratio of returning adults. In estimating CRR, DFG (1998) assumed the following: (1) spawning adults return as 3-year olds; (2) there is a 1:1 male to female sex ratio; and (3) there is not much variation in these factors between BYs. The CRR for spring-run was estimated by dividing the number of returning adults in a given BY by the number of returning adults 3 years prior. Values greater than 1.0 suggest the cohort abundance is increasing, while values less than 1.0 indicate cohort abundance is decreasing. A value around 1.0 suggests the cohort has replaced itself. CRR data are provided in the discussions of abundance in Mill, Deer, and Butte Creeks, and also for the Feather River.

Mill Creek

The present range and distribution of spring-run Chinook salmon in Mill Creek is the same as it was historically (DFG 1998). Adults migrate upstream and hold in a 20-mile reach from the

Lassen National Park boundary downstream to the confluence of Little Mill Creek. There are no early records of population size for Mill Creek. Spring-run counts were initiated by FWS in 1947 (DFG 1998). Although some of these counts were incomplete, they ranged from 300 to 3,500 fish from 1947 to 1964. The average run size for the 1947 to 1964 period was about 1,900 fish (geometric mean = 1,717).

During the 1990s, the geometric mean spring-run escapement to Mill Creek was 299, an order of magnitude lower than 1947 to 1964 (Figure 5-7). The Mill Creek spring-run population trend during the 1990s was somewhat uncertain. The mean CRR for 1990-99 was 2.2, indicating a population increase (Table 5-9). However, the more conservative geometric mean CRR was only 1.05, suggesting the population was merely replacing itself. More recent cohorts show a trend of CRR less than 1.0 (Table 5-9) reflecting a declining trend in recent adult abundance.This agrees with the 1990 through 1999 3-year running average escapement, which shows no consistent trend of either increase or decrease (Figure 5-8). The escapement has increased since the 1990s.



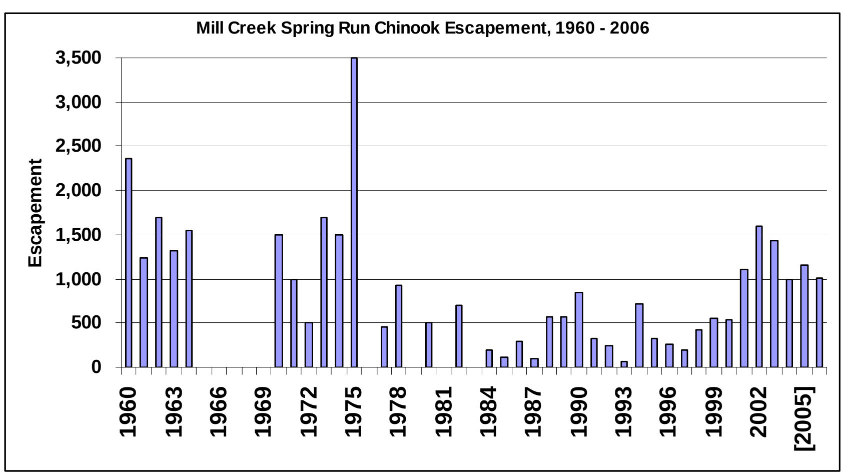


Figure 5-7 Adult spring-run Chinook counts in Mill Creek. Figure on top shows escapement back to 1947.

Table 5-9 Mill Creek spring-run Chinook salmon CRR.

Cohort	BY	CRR
1	1957	1203/1789 = 0.7
2	1958	2212/2967 = 0.7
3	1959	1580/2233 = 0.7
1	1960	2368/1203 = 2.0
2	1961	1245/2212 = 0.6
3	1962	1692/1580 = 1.1
1	1963	1315/2368 = 0.6
2	1964	1628/1245 = 1.3
3	1990	844/89 = 9.5
1	1991	319/572 = 0.6
2	1992	237/563 = 0.4
3	1993	61/844 = 0.1
1	1994	723/319 = 2.3
2	1995	320/237 = 1.4
3	1996	252/61 = 4.1
1	1997	200/723 = 0.3
2	1998	424/320 = 1.3
3	1999	560/252 = 2.2
1	2000	544/200 = 2.7
2	2001	1100/424 = 2.6
3	2002	1,594/560 = 2.8
1	2003	1,426/544 = 2.6
2	2004	998/1,100 = 0.9
3	2005	1,150/1,594 = 0.7
1	2006	1,002/1,426 = 0.7

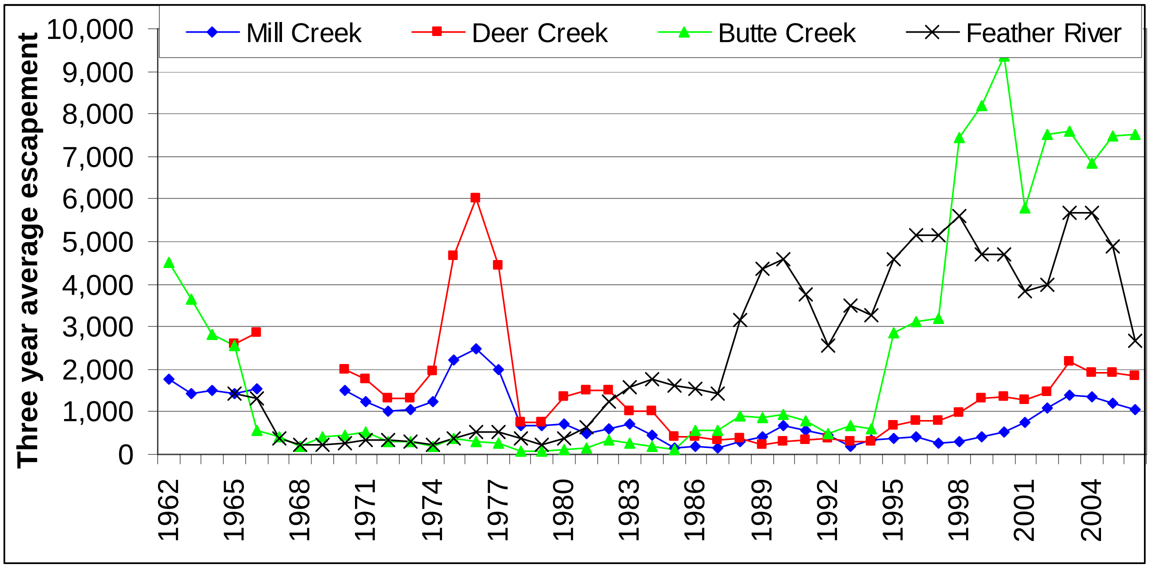


Figure 5-8 Three-year running average abundance of returning adult spring-run Chinook salmon in highest producing Central Valley spring run streams.

Deer Creek

The present spring-run range in Deer Creek has been extended beyond the historical range (DFG 1998). A fish ladder was constructed around Lower Deer Creek Falls in 1943, opening an additional 6 miles of holding and spawning habitat. The present habitat is a 22-mile reach extending from Dillon Cove to Upper Deer Creek Falls. Approximately 20 percent of the spawning now occurs in the 6-mile extension. A fish ladder constructed around Upper Deer Creek Falls allows steelhead passage, but not spring-run passage. Spring-run are excluded because the reach lacks the large holding pools needed to sustain a large salmon population. There are no early records of spring-run population size for Deer Creek either, but counts were initiated by FWS in 1940 (DFG 1998). As with Mill Creek, some counts were incomplete, but ranged from 268 to 4,271 fish between 1940 and 1964. The average run size for the 1940 through 1964 period was about 2,200 fish (geometric mean of 2,290). Again, as in Mill Creek, recent counts are lower, with a geometric mean escapement of 906 for the 1990 through 2006 period.

The mean Deer Creek CRR was 1.9 during 1990 through 2006, suggesting that, like Mill Creek, the population may be rebounding (Table 5-10). In addition, the geometric mean CRR of 1.5, and the 1990 through 2006 3-year running average escapement (Figure 5-8) also suggest a slight population increase during since the 1980’s.

Table 5-10 Deer Creek spring-run Chinook salmon CRR.

Cohort	BY	CRR
1	1990	458/200 = 2.3
2	1991	448/371 = 1.2
3	1992	209/77 = 2.7

Cohort	BY	CRR
1	1993	259/458 = 0.6
2	1994	485/448 = 1.1
3	1995	1295/209 = 6.2
1	1996	614/259 = 2.4
2	1997	466/485 = 1.0
3	1998	1879/1295 = 1.5
1	1999	1591/614 = 2.6
2	2000	637/466 = 1.4
3	2001	1622/1879 = 0.9
1	2002	2,185/1,591 = 1.4
2	2003	2,759/637 = 4.3
3	2004	804/1,622 = 0.5
1	2005	2,239/2,185 = 1.0
2	2006	2,432/2,759 = 0.9

Butte Creek

The present range of spring-run Chinook salmon in Butte Creek does not differ substantially from its historical range and is limited to the reach below the PG&E Centerville Head Dam downstream to the Parrott-Phelan Diversion Dam (DFG 1998). It is likely the historical limit of travel for spring-run salmon and steelhead during most years was a natural barrier (Quartz Bowl Barrier) 1 mile below the PG&E Centerville Head Dam. The only time recent DFG surveys have found fish above the Quartz Bowl barrier is when flows were atypically high into late-May. Even then, there were only 25 fish noticed out of an estimated total population of 22,000 (DFG 2003). There are numerous additional large impassable natural barriers immediately above the Centerville Head Dam. As with the above-mentioned streams, there are no early accounts of the number of spring-run in Butte Creek. During 1954, a counting station was maintained at the Parrott-Phelan Diversion Dam to record adult spring-run salmon passing through the fish ladder (Warner 1954 as cited in DFG 1998). From May 7 through 27, 1954, 830 fish were observed. Various census techniques have been employed to evaluate the Butte Creek spring-run population since 1954 (DFG 1998). The population has fluctuated significantly, from a low of 10 in 1979 to a high of 20,259 in 1998. The fluctuation may be explained in part by the variety of survey techniques used, but the population appears to have been nearly extirpated numerous times between the 1960s and the early 1990s.

The Butte Creek spring-run increased dramatically during the last decade. CRRs have been highly variable, but usually greater than 1.0 since 1993, ranging from 0.5 to 10.3, with a mean of 3.1 and a geometric mean of 2.2 (Table 5-11). The 3-year running average escapement for 1990 through 2006 suggests a comparatively rapid abundance increase as well (Figure 5-8).

Table 5-11 Butte Creek spring-run Chinook salmon CRR.

Cohort	BY	CRR
1	1993	650/100 = 6.5
2	1994	474/100 = 4.7
3	1995	7,500/730 = 10.3
1	1996	1,413/650 = 2.2
2	1997	635/474 = 1.3
3	1998	20,259/7,500 = 2.7
1	1999	3,600/1,413 = 2.5
2	2000	4,118/635 = 6.5
3	2001	9,605/20,259 = 0.5
1	2002	8,785/3,600 = 2.4
2	2003	4,398/4,118 = 1.1
3	2004	7,390/9,605 = 0.8
1	2005	10,625/8,785 = 1.2
2	2006	4,579/4,398 = 1.0

Feather River

Historically, the Feather River spring-run population was similar in magnitude to the size of the present hatchery run (Figure 5-9). Spring-run ascended the very highest streams and headwaters of the Feather River watershed prior to the construction of hydropower dams and diversions (Clark 1929, as cited in DFG 1998). Prior to Oroville Dam (1946-63), available population estimates ranged from 500 to 4,000 fish and averaged 2,200 per year (Painter et al. 1977, Mahoney 1958, 1960, all as cited in DFG 1998; DFG 1998). However, Feather River spring-run had probably been significantly affected by hydropower facilities in the upper watershed well before the completion of Oroville Dam. For instance, DFG (1998) found substantial overlap in the spawning distributions of fall-run and spring-run Chinook upstream of the Oroville Dam site.

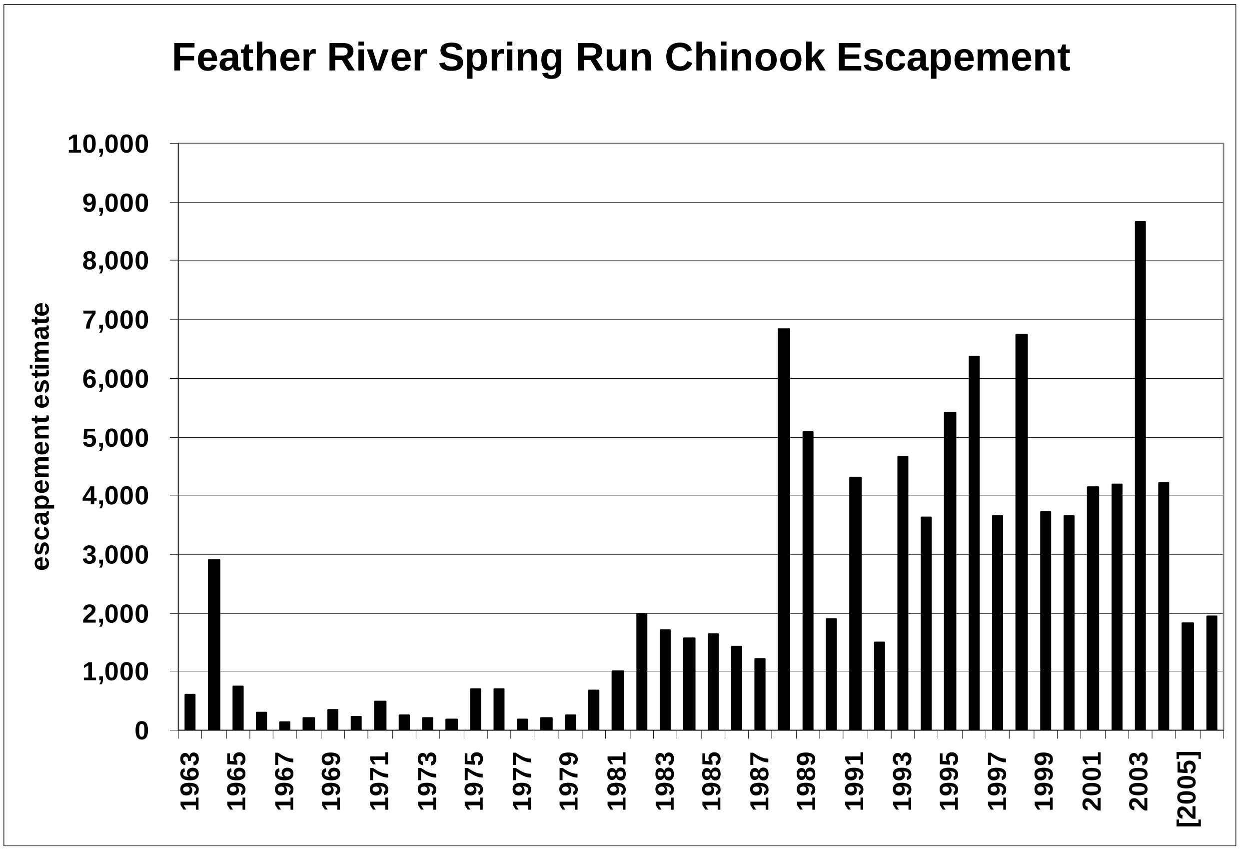


Figure 5-9 Estimated adult spring-run Chinook salmon population abundance in Feather River. Brackets indicate data is preliminary.

Following construction of Oroville Dam in 1967, the spring-run population dropped to 146 fish, but averaged 312 fish per year between 1968 and 1974 (Menchen 1968; Painter et al. 1977, both as cited in DFG 1998). The highest post-Oroville Dam population estimate was recorded in 1998 (8,430 adults) based on numbers of fish returning to Feather River Hatchery (FRH). The Feather River spring-run Chinook salmon CRR is presented in Table 5-10. All post-Oroville spring-run population estimates are based on counts of salmon entering FRH. The 10-year average from 1992 to 2002 was 4,727 adults returning to the FRH (NMFS 2004).

DWR initiated fish studies in the lower Feather River in 1991. The focus and methods used for these studies were altered in 2003 as a result of consultations with NMFS, DFG, and others to gather information needed to relicense the Oroville facilities with the Federal Energy Regulatory Commission (FERC) http://orovillerelicensing.water.ca.gov/documents.html.

Since the signing in 2006 of the Settlement Agreement for the FERC relicensing process, the monitoring program refocused on increasing our understanding of the listed fish species in the Lower Feather River. The present program consists of several elements to monitor salmonid spawning, rearing, and emigration, including spring-run Chinook salmon, and to document any potential impacts of project operations on fish species. A wide variety of equipment and monitoring methods are used including rotary screw traps, fyke traps, snorkel surveys, electrofishing, radio and acoustic tagging, carcass surveys, redd mapping, etc. Reports

summarizing the results and findings are prepared and submitted to the regulatory agencies annually.
http://wwwdes.water.ca.gov/ecological_studies_branch/frp_program/technicalreports.htm.

Like several of the other spring-run streams, both the mean (1.4) and the geometric mean (1.2) CRR for FRH spring-run suggest the population has been increasing slightly in the recent past (Table 5-12). The 3-year running average escapement suggests the same (Figure 5-8).

Table 5-12 Feather River Spring-run Chinook Salmon CRR.

Cohort	BY	CRR
1	1991	3448/6833 = 0.50
2	1992	1670/5078 = 0.33
3	1993	4672/1893 = 2.50
1	1994	3641/3448 = 1.06
2	1995	5414/1670 = 3.24
3	1996	6381/4672 = 1.37
1	1997	3653/3641 = 1.00
2	1998	8430/5414 = 1.56
3	1999	3731/6381 = 0.59
1	2000	3657/3653 = 1.00
2	2001	2468/8430 = 0.29
3	2002	4,189/3,731 = 1.1
1	2003	8,662/ 3,657 = 2.4
2	2004	4,212/ 2,468 = 1.7
3	2005	1,835/ 4,189 = 0.4
1	2006	1,952/ 8,662 = 0.2

Since the construction of Oroville Dam however, spring-run salmon have been restricted to the area downstream of the fish barrier dam near Oroville, where the intermixing with the fall-run observed by DFG (1959, as cited in DFG 1998) has probably increased (Figure 5-10 and Figure 5-11). Based on an assessment of FRH operations, the Feather River population was considered a likely hybrid of spring- and fall-run populations (Brown and Greene 1993). However, initial genetic studies of spring- and fall-run from FRH and Feather River found no distinction between spring- and fall-run (Dr. Dennis Hedgecock, presentation at the 1999 Salmon Symposium in Bodega Bay).

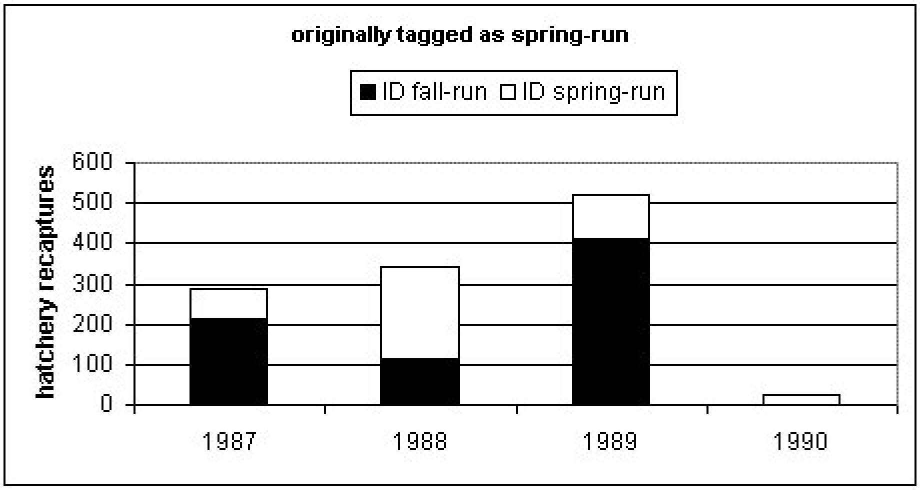


Figure 5-10 The disposition of Chinook salmon spawned, tagged, and released as spring-run from FRH.

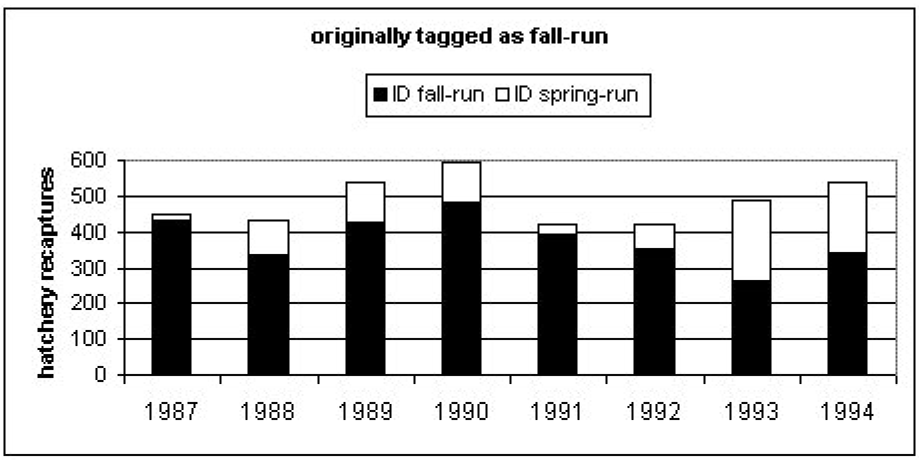


Figure 5-11 The disposition of Chinook salmon spawned, tagged, and released as fall-run from FRH.

Trinity River Coho Salmon

Coho Salmon (*Oncorhynchus kisutch*) in the Trinity River are in the Southern Oregon/Northern California Coast coho salmon ESU, which was listed as threatened under the ESA on June 18, 2005 (70 FR 37160). The Southern Oregon/Northern California Coast coho ESU extends from Punta Gorda on the south to Cape Blanco in Oregon.

Life History

Coho salmon exhibit a 3-year life cycle in the Trinity River and are dependent on freshwater habitat conditions year round because they spend a full year residing in freshwater. Most coho salmon enter rivers between August and January with some more northerly populations entering as early as June. Coho salmon river entry timing is influenced by a number of factors including genetics, stage of maturity, river discharge, and access past the river mouth. Spawning is concentrated in riffles or in gravel deposits at the downstream end of pools with suitable water depth, velocity, and substrate size. Spawning in the Trinity River occurs mostly in November and December.

Coho salmon eggs incubate from 35 to more than 100 days depending on water temperature, and emerge from the gravel 2 weeks to 7 weeks after hatching. Coho eggs hatch after an accumulation of 400 to 500 temperature units measured in degrees Celsius and emerge from the gravel after 700 to 800 temperature units. After emergence, fry move into areas out of the main current. As coho grow they spread out from the areas where they were spawned.

During the summer, juvenile coho prefer pools and riffles with adequate cover such as large woody debris with smaller branches, undercut banks, and overhanging vegetation and roots. Juvenile coho overwinter in large mainstem pools, beaver ponds, backwater areas, and off-channel pools with cover such as woody debris and undercut banks. Most juvenile coho salmon spend a year in freshwater with some northerly populations spending 2 full years in freshwater. Coho in the Trinity River are thought be be exclusively three year lifecycle fish (one year in freshwater). Because juvenile coho remain in their spawning stream for a full year after emerging from the gravel, they are exposed the full range of freshwater conditions. Most smolts migrate to the ocean between March and June with most leaving in April and May.

Coho salmon typically spend about 16 to 18 months in the ocean before returning to their natal streams to spawn as 3- or 4-year olds, age 1.2 or 2.2. Trinity River coho are mostly 3-year olds. Some precocious males, called jacks, return to spawn after only 6 months in the ocean.

Trinity River Coho Population Trends

Coho salmon were not likely the dominant species of salmon in the Trinity River before dam construction. Coho were, however, widespread in the Trinity Basin ranging as far upstream as Stuarts Fork above Trinity Dam. Wild coho in the Trinity Basin today are not abundant and the majority of the fish returning to the river are of hatchery origin. An estimated 2 percent (200 fish) of the total coho salmon run in the Trinity River were composed of naturally produced coho from 1991 through 1995 at a point in the river near Willow Creek (FWS 1998). This in part prompted the threatened status listing in 1997. Recapture estimates of coho salmon run size conducted since 1977 are shown in Figure 5-12. These estimates included a combination of hatchery produced and wild coho. Figure 5-13 shows the estimated natural and hatchery contribution to the coho run in 1997 – 2005. About 10 percent of the coho were naturally produced since 1995.

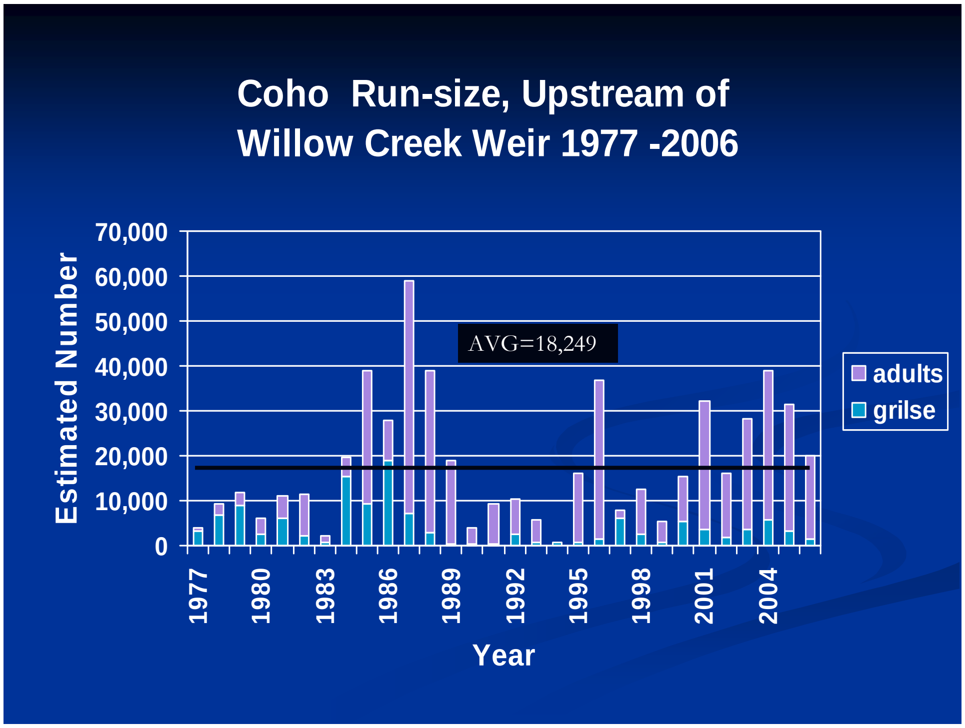


Figure 5-12 Trinity River adult coho salmon escapement, 1977 – 2006.

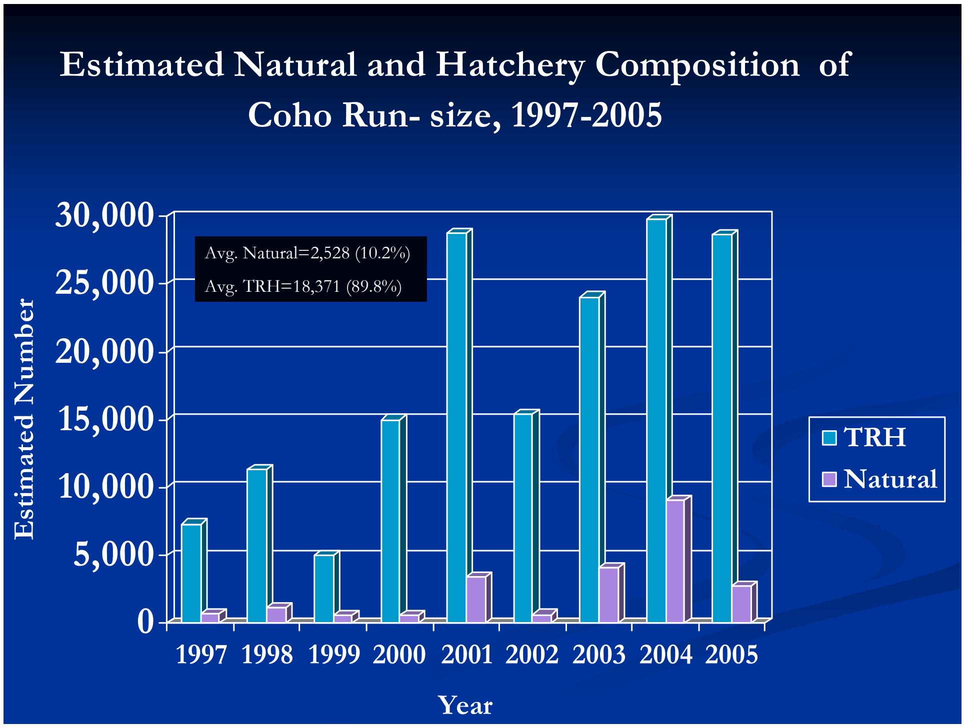


Figure 5-13 Trinity River adult coho salmon escapement 1997 – 2005 separated into hatchery and naturally spawned fish.

Critical Habitat

The spring run Chinook critical habitat potentially affected by CVP and SWP operations includes the Sacramento River up to Keswick Dam, Clear Creek up to Whiskeytown Dam, the Feather River up to the fish barrier dam, and the American River up to Watt Avenue. Winter run Chinook salmon critical habitat includes the Sacramento River from Keswick Dam downstream to the Delta and includes the northern Delta and northern part of San Francisco Bay to the Golden Gate Bridge (Figure 5-14).

Spawning Habitat

Winter run Chinook in spawn only in the Sacramento River mostly (99%) upstream of Balls Ferry based on current aerial redd survey data collected since passage was provided past the ACID diversion dam. Spawning occurs May through July with the peak in early June.

Spring run Chinook in the Sacramento River spawn mostly (99%) upstream of Jellys Ferry bridge, based on current aerial redd survey data (2001-2004) that was collected under current river conditions. Spring run spawning is not as concentrated in the upstream area immediately above and below ACID Dam as is the winter run spawning distribution. Spring run in Clear Creek spawn mostly upstream of a weir that is installed each year near Igo to prevent putative spring run from spawning with fall run. Spring run in the Feather River spawn primarily in the low flow channel with the highest concentration in the uppermost mile, near the hatchery fish ladder (DWR 2006, Brad Cavallo personal communication). The section of the American River denoted as critical habitat (up to Watt Avenue) serves only as juvenile rearing habitat. There is no spring run spawning in the American River. The Stanislaus River and San Joaquin River contain no spring run critical habitat.

Freshwater Rearing Habitat

Winter run begin to emerge in August and continue into October. A majority of the winter run fry move downstream past Red Bluff soon after emergence. A small proportion remains upstream into the winter and spring. The fry that move downstream early move slowly, and probably sporadically, stopping in suitable habitat to feed and grow. They begin to reach the Delta as early as November but generally peak past the first of the year.

Spring run in the Sacramento River start to emerge from the gravel in December. Many Chinook emigrate as fry but a small proportion of spring run rear for up to a year in the upstream portion of the river. Because of the timing overlap with the abundant fall run, separation of the juveniles of the run based on size is inaccurate, making spring run rearing habitats difficult to differentiate from fall run, but they likely use the same habitats. Rearing for most of the spring run occurs during the winter when water temperatures are suitable throughout the system. Some spring run hang out in the rivers near the spawning habitat until they are ready to emigrate. When they emigrate, either as fry or juveniles, they gradually make their way towards the ocean during winter and spring. Emigration from the upper rivers to the ocean generally takes about one to three months. The spring run juveniles that remain in the rivers over the summer are confined to the upstream areas of the rivers where cool water temperatures are maintained by dam releases. This includes over 100 miles of the Sacramento River, 10 miles in Clear Creek, and about 8 miles in the Feather River. The lower American River is classified as critical habitat for spring run rearing up to Watt Avenue. This area contains suitable water temperatures for Chinook rearing from about December through April of most years.

Freshwater Migration Corridors

Adult winter run migrate up to the spawning area during the winter and spring months. The juveniles emigrate downstream between August and May. Spring run Chinook emigrate during the winter and spring months (December through May). Strategic closure of the DCC gates, in tandum with river monitoring, helps facilitate the outmigration of juvinile Chinook salmon. Flows probably play a greater role in assisting emigration for spring run than for steelhead, due to their smaller size. Pulse flows that occur during precipitation events tend to stimulate downstream movement along the Sacramento River. The higher water velocities during the higher flow events assist juvenile Chinook in reaching the estuary safely. Once Chinook salmon reach the ocean their growth increases substantially in most years with abundant food resources.

Estuarine Areas

Winter and spring run Chinook use the San Francisco estuary as a rearing area and migration corridor between their upstream rearing habitat and the ocean. The San Francisco Bay estuarine system includes the waters of San Francisco Bay, San Pablo Bay, Grizzley Bay, Suisuin Bay, Honker Bay, and can extend as far upstream as Sherman Island during dry periods. Chinook gradually make their way downstream moving with the tidal currents. At times, juvenile Chinook likely remain for extended periods in areas of suitable habitat when food such as anchovies, young herring, large zooplankters and other aquatic invertebrates is available.

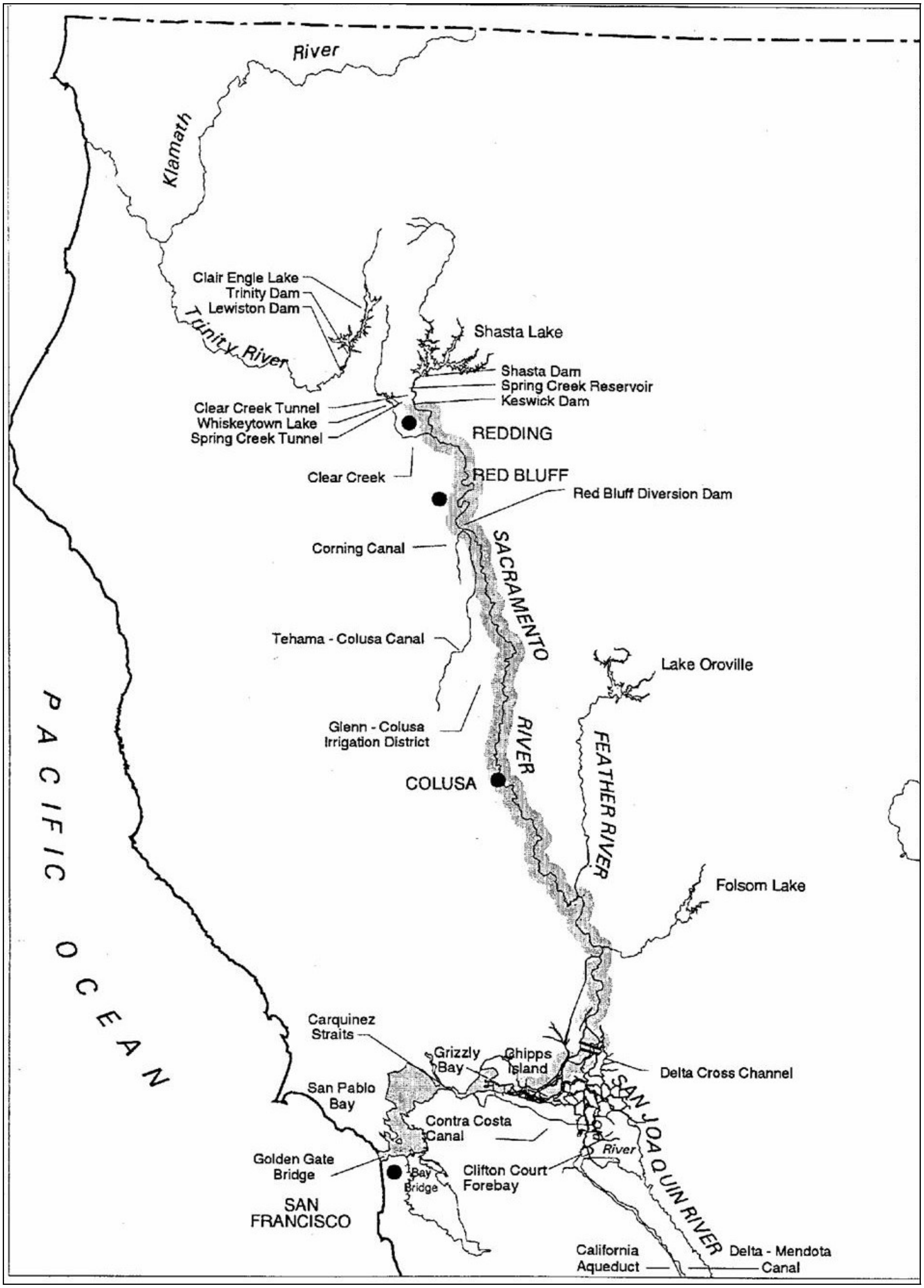
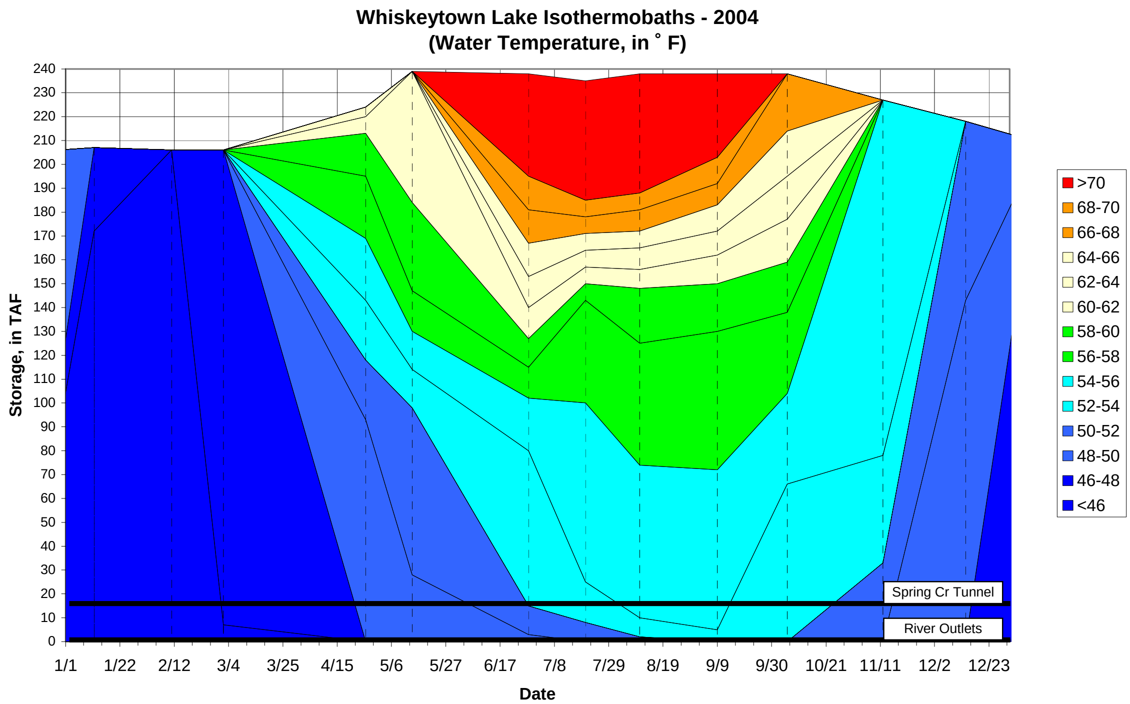


Figure 5-14 Winter Run Chinook salmon critical habitat.

Effect of Reduced Trinity River Diversions on Clear Creek Critical Habitat for Spring-run and Steelhead

Implementation of the Trinity River Restoration Program Record of Decision increased flows in the lower Trinity River and decreased diversions into the Sacramento River Basin. Now less water passes through Whiskeytown Reservoir than prior to the Trinity decision. Because less cool Trinity River water passes through Whiskeytown Reservoir there may be increased heating of the water as it passes through with the lower thermal mass. This appeared to result in a slightly warmer release into lower Clear Creek in 2005 than in prior years. The warmer temperatures occurred primarily during September and October (Figure 5-15). This period coincides with the incubation period for spring run Chinook salmon when the target temperature is a mean daily average of 56 °F or below at Igo (NMFS 2004). The mean of the mean daily temperatures during the period June 1 through September 15 in 1996 through 2004 was 58.1 °F and in 2005 it was also 58.1 °F. The mean of the mean daily temperatures during the period September 15 through October 31 in 1996 through 2004 was 54.2 °F. The mean of the mean daily temperatures for this same period in 2005 was 56.7 °F. The warmer temperatures that occurred in the latter part of the temperature control season in 2005 are a tradeoff for the improved flow and temperature conditions being provided in the Trinity River.

The higher temperatures occurred during the spring run incubation period and on average exceeded the 56 °F target temperature by 0.7 °F. Chinook salmon eggs in other rivers (eg. American River) survive at high rates, at least in the hatchery, when spawned at 60 °F as long as the water temperature quickly declines to 56°F. Temperatures in Clear Creek dropped to 50 °F by the end of November in 2005. Therefore, effects of the slightly higher temperatures during early incubation for spring run Chinook in 2005 were expected to be negligible. Similar temperature conditions will likely occur in future years. A larger volume of water from the Trinity River goes to the Sacramento River through the Spring Creek tunnel than goes to Clear Creek. The Spring Creek tunnel water is used primarily to help cool the Sacramento River during the heat of the summer for winter run Chinook spawning and incubation. The higher volume going to the Sacramento River necessitates operating the system primarily for Sacramento River temperature targets. Clear Creek receives the same temperature water as what goes to the Sacramento. This has generally provided suitable Clear Creek temperature conditions most of the time in the past. Daily temperature fluctuation in Clear Creek at Igo peaks in June and July when days are the longest at around 8 °F difference between the high and low temperature for the day (Figure 5-15).



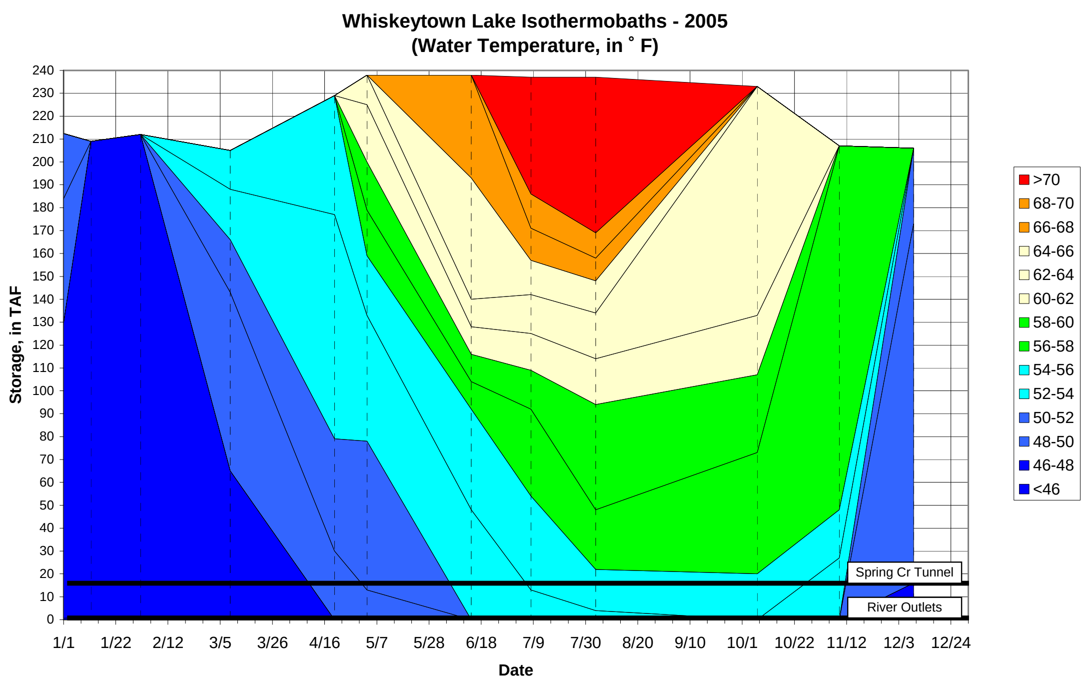


Figure 5-15 Whiskeytown Lake Isothermobaths, 2004 (top) and 2005 (bottom).

Table 5-13 Spring Creek tunnel release volume, 1999-2004 compared to 2005.

Spring Creek Tunnel Volume (thousand acre feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2005	28.7	26.2	60.2	10.0	60.2	47.7	51.7	70.2	68.7	62.6			
2004	54.4	111.7	202.6	123.8	19.4	89.0	133.6	89.8	95.0	156.3	8.7	26.3	1110.6
2003	84.0	84.1	86.7	47.7	114.2	109.4	92.8	150.7	137.1	122.4	65.9	49.5	1144.5
2002	71.1	27.6	23.2	7.2	41.1	103.8	131.2	131.0	57.8	80.8	16.4	84.0	775.2
2001	36.9	68.9	75.2	18.7	32.0	92.4	159.2	154.0	108.2	121.6	0.0	53.9	921.0
2000	42.0	89.8	148.9	122.3	158.7	167.6	193.8	203.4	117.5	31.6	5.4	16.8	1297.8
1999	102.0	86.0	130.6	100.0	95.1	128.9	142.0	95.5	91.0	31.7	45.8	38.8	1087.4
AVG 99-04 =	65.1	78.0	111.2	70.0	76.8	115.2	142.1	137.4	101.1	90.7	23.7	44.9	1056.1
2005 % Diff	-56%	-66%	-46%	-86%	-22%	-59%	-64%	-49%	-32%	-31%			

Consideration of the Risks Associated with Hatchery Raised Mitigation Fish

Reclamation funds the operation of Coleman Hatchery, Livingston Stone Hatchery, Nimbus Hatchery, and Trinity River Hatchery. DWR funds the operation of the Feather River Hatchery. The FWS operates Coleman and Livingston Stone Hatcheries and DFG operates Feather River, Nimbus, and Trinity Hatcheries. These hatcheries are all operated to mitigate for the anadromous salmonids that would be produced by the habitat if not for the dams on each respective river. Reclamation and DWR have discretion over how the hatcheries are operated but generally leave operational decisions on how to meet mitigation goals up to the operating agency.

Most hatchery production releases from the American and Feather Rivers are released in San Pablo Bay. The bay releases have been suspected of causing increased rates of returning adults straying into tributaries other than their tributary of origin. Examination of CWT data from the American River from 2001 and 2002 shows that straying was not as high as was suspected. Out of a contribution from Nimbus Hatchery to the Central Valley escapement of nearly 80,000 Chinook in run years 2002-2004 only about 2.8 percent (2,193 fish) returned to rivers other than the American (Table 5-14). This is well within a straying rate that could be considered normal for wild fish. The highest percentage of strays from the American (0.7%) occurred in the Feather/Yuba River system.

Table 5-14 Contribution of Nimbus Hatchery Chinook from brood year 2000 and 2001 to Central Valley rivers.

Contribution of Nimbus Hatchery Fish from BY 2000 and BY 2001 to Central Valley Rivers

Sum of Contribution	runyr					
sampsite	2002	2003	2004	Grand Total	Percent of total	
ABRB			142	142	0.2%	Sacramento River (abov
AMN	2,406	49,887	12,604	64,897	82.3%	American River, in-river
BUT		25	21	46	0.1%	Butte Creek
FEA	214			214	0.3%	Feather River
FRH		14	3	17	0.0%	Feather River Hatchery
GUAD		7		7	0.0%	?
LFC			90	90	0.1%	Feather Low Flow Chan
MER		76	52	128	0.2%	Merced
MOK	166	564	55	784	1.0%	Mokelumne
MRFI			65	65	0.1%	Mokelumne River hatch
MRH	116	50	22	188	0.2%	Merced Hatchery?
NFH	1,797	6,769	2,777	11,343	14.4%	Nimbus Hatchery
SAA	397			397	0.5%	Carquinez to American
STA		110	56	166	0.2%	Stanislaus
TUO	7	81	11	99	0.1%	Tuolumne
YUB	27	220		247	0.3%	Yuba
Grand Total	5,130	57,802	15,897	78,829	100.0%	

Total straying of Nimbus hatchery fish 2002-2004
(sum of contribution recovered in rivers other than American)
2,193
2.8% recovered in other rivers compared to American

Feather River Spring-Run Chinook Straying and Genetic Introgression

Prior to the construction of numerous dams (including the Oroville Dam) on the Feather River, spawning spring- and fall-run Chinook salmon were temporally and spatially separated—i.e., spring-run Chinook salmon spawned earlier and in higher reaches of the watershed compared to fall-run Chinook salmon. Although data are limited, there is a general consensus that there were once genetically distinct Chinook salmon runs in the Feather River system (Lindley et al. 2004; Yoshiyama et al. 2001).

Today, the Fish Barrier Dam blocks the early-returning (arriving in April through June) run of sexually immature adult Chinook salmon in the Feather River from moving upstream to historical spawning habitat. As there is overlap in the timing of spawning, this spring-run Chinook salmon now spawns in the same location as the more numerous later-returning fall-run Chinook salmon. Findings of recent genetic studies using microsatellite markers suggest that: (1) Feather River Hatchery (FRH) produced spring-run Chinook salmon are genetically similar to fall-run Chinook salmon and (2) phenotypic in-river spring-run Chinook salmon are genetically more similar to fall-run Chinook salmon than to spring-run Chinook salmon populations in Mill, Deer, and Butte creeks (Banks et al. 2000; Hedgecock et al. 2001; DWR 2004a).

A review of available literature suggests two opportunities for genetic introgression in the Feather River:

- Introgression between spring- and fall-run Chinook salmon in the Feather River;
- Introgression between hatchery-produced and wild spring-run Chinook salmon in the Feather River; and
- Straying and introgression between Feather River spring-run Chinook salmon and spring-run Chinook salmon in other systems.

Introgression Between Spring- and Fall-Run Chinook Salmon.

Under the No-Action Alternative, conditions will continue to promote the commingling of spring-run and early maturing fall-run Chinook salmon on common spawning grounds, leading to increased opportunities for genetic introgression (hybridization) between spring- and fall-run Chinook salmon in the Feather River. In fact, data collected over the past 5 years by DWR on spawning populations of Chinook salmon in the Feather River do not show a bimodal peak that would be expected if there were temporally distinct spawning populations (DWR 2004a). In addition, under the No-Action Alternative, continued hatchery practices—specifically, the inability to distinguish between spring- and fall-run Chinook salmon when artificially spawning—will continue to be an additional contributor to the observed genetic introgression. Data on the returns of tagged fish suggest that there may have been considerable cross-fertilization between nominal spring- and fall-run Chinook salmon at the FRH (DWR 2004a) over the past several years, and probably since the hatchery began operation in 1967.

Introgression Between Hatchery-Produced and Wild Spring-Run Chinook Salmon.

One of the key questions about Feather River Chinook salmon involves the genetic and phenotypic existence of a spring run, and the potential effects of the FRH on this run. The Feather River's nominal spring run is part of the spring-run ESU and is thus listed as threatened. Conversely, the hatchery population is not included in the ESU. The nominal spring- and fall-run Chinook salmon in the Feather River are genetically similar and are most closely related to CV fall-run Chinook salmon. There is a significant phenotypic spring run that arrives in the Feather River in May and June and enters the FRH when the ladder to the hatchery was opened. Observations of these early arriving Chinook salmon cast doubt on the presence of a Feather River spring-run, as opposed to a hatchery spring-run. Nonetheless, under the No-Action Alternative, conditions will continue the commingling of hatchery-produced and wild spring-run Chinook salmon, leading to increased opportunities for domestication of wild populations.

Due to the lack of pre-Oroville Facilities genetic data, the genetic identity of the historic Feather River spring-run Chinook salmon cannot be definitively ascertained. However, it appears that the early arriving, immature Chinook salmon run in the Feather River does not resemble current day spring-run populations in Mill, Deer, and Butte creeks. There are no data on the potential effects (e.g., reduced fitness) of inbreeding or outbreeding of FRH-produced Chinook salmon. In addition, there are no data indicating that spring-run timing on the Feather River is an inheritable trait and the loss of this phenotype would adversely affect the recovery of the CV spring-run Chinook salmon ESU (DWR 2004a). Nonetheless, under the No-Action Alternative, continued operation of the Oroville Facilities is anticipated to continue to contribute to the ongoing genetic introgression currently observed under existing conditions.

Straying and Introgression with Spring-Run Chinook Salmon in Other Systems.

As part of existing operations, FRH-produced Chinook salmon are transported and released into San Pablo Bay. This hatchery practice was intended to reduce/avoid the mortality associated with migrating through the Sacramento-San Joaquin Delta. However, data suggest that the practice of releasing to San Pablo Bay increased the incidence of straying of FRH-produced Chinook salmon (DWR 2004a). Straying can lead to increased competition for spawning habitat and exchange of genetic material between hatchery and naturally spawning Chinook salmon (Busack and Currens 1995).

To analyze the role that hatcheries play in influencing straying rates, DFG used mark-and-recapture data (coded wire recoveries) in the ocean fisheries to reconstruct the 1998 fall-run Chinook salmon cohort from the FRH (Palmer-Zwahlen et al. 2004). This analysis was used to determine the rate at which fish released in the estuary return to the Feather River and to other streams (the stray rate). DFG estimated that of the approximately 44,100 FRH-produced fish that returned to the Central Valley, 85 percent returned to the Feather River (including the FRH), 7 percent were caught in the lower Sacramento River sport fishery, and 8 percent strayed to streams outside the Feather River basin. If salmonids returned to the Feather River in the same proportion as observed in other river systems, the straying rate would be estimated to be approximately 10 percent (DWR 2004a). Although tags from FRH-produced fish were collected in most Central Valley streams sampled, about 96 percent of the 12,438 tags recovered during the 1997 to 2002 period were collected in the Feather River or at the FRH.

A lower percentage of in-basin releases than bay releases survived to reenter the estuary as adults (0.3 percent versus 0.9 percent); however, these fish returned to the Feather River with greater fidelity (approximately 95 percent as compared to around 90 percent for bay releases). Although the straying rate from bay releases is less than might be expected based on earlier studies, it is still higher than natural straying rates and higher than the 5 percent straying rate recommended as a maximum by NMFS. Before rendering definitive conclusions, it should be noted that there are several limitations in the existing data:

- Cohort analysis was only for one broodyear;
- Tag recovery efforts on most Central Valley streams do not provide statistically reliable estimates of the number of tagged fish in the spawning populations; and
- There is a significant inland sport fishery and, in recent years, sampling of this fishery and collecting tags has been spotty because of budget cuts.

It should be noted that based on tag return and genetic data, minimal interbreeding appears to have occurred between FRH spring-run Chinook salmon and spring-run Chinook salmon in Butte, Mill, and Deer creeks. Only a few FRH-produced Chinook salmon have been collected in the lower portions of Deer, Mill, and Butte creeks, in sections supporting fall-run spawning activity. In addition, the genetic structure of spring-run Chinook salmon in the Feather River is distinct from spring-run Chinook salmon from Deer, Mill, and Butte creeks.

Feather River Spring-Run Chinook Susceptibility to Disease

Susceptibility to disease is related to a variety of factors, including fish species, fish densities, the presence and amounts of pathogens in the environment, and water quality conditions such as temperature, DO, and pH. Oroville Facilities operations have the potential to affect all of these factors at the FRH and in the Feather River downstream of the Oroville Facilities.

Several endemic salmonid pathogens occur in the Feather River basin, including *Ceratomyxa shasta* (salmonid ceratomyxosis), *Flavobacterium columnare* (columnaris), the infectious hematopoietic necrosis (IHN) virus, *Renibacterium salmoninarum* (bacterial kidney disease [BKD]), and *Flavobacterium psychrophilum* (cold water disease) (DWR 2003a). Of the fish pathogens occurring in the Feather River basin, those that are main contributors to fish mortality at the FRH (IHN and ceratomyxosis) are of highest concern for fisheries management in the region. Although all of these pathogens occur naturally, the Oroville Facilities have the opportunity to produce environmental conditions that are more favorable to these pathogens than under historic conditions:

- Impediments to fish migrations may have altered the timing, frequency, and duration of exposure of anadromous salmonids to certain pathogens;
- Out-of-basin transplants may have inadvertently introduced foreign diseases; and
- Water transfers, pumpback operations, and flow manipulation can result in water temperature changes, which potentially increase the risk of disease.

The transmission of disease from hatchery fish to wild fish populations is often cited as a concern in fish stocking programs. There is, however, little evidence of disease transmission between hatchery fish and wild fish (Perry 1995). Further, the FRH has implemented disease control procedures (e.g., disinfecting procedures) that are intended to minimize both the outbreak of disease in the hatchery and the possibility of disease transmission to wild fish populations.

Field surveys indicated that IHN was not present in juvenile salmonids or other fish in the Feather River watershed (DWR 2004a). Eighteen percent of the adults returning to the Feather River watershed were infected with IHN, but there were no clinical signs of disease in these fish. The hypothesis advanced by DFG pathologists for the cause of the recent IHN epizootics at the FRH is that planting Chinook salmon in Lake Oroville (in the hatchery water supply) resulted in the virus entering the hatchery. Hatchery conditions can then lead to stress and the infections can rapidly escalate to clinical disease, as evidenced by high mortality. No additional epizootics have been observed since the plantings of Chinook salmon in the reservoir were brought to an end. Whether the cessation of stocking Chinook salmon will prevent future IHN outbreaks at the FRH is uncertain, as the cause of specific disease outbreaks in Oroville Facilities waters is poorly understood (DWR 2004a).

Under the No-Action Alternative, continued operations of the Oroville Facilities are anticipated to result in potential exposures to pathogens similar to that currently observed under existing conditions.

Summary of the Environmental Baseline

Environmental baseline, as defined in 50 CFR 402.02, “includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action are that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process.” The prior information in this chapter provides the status of winter-run Chinook, spring-run Chinook, and coho salmon in the action area, which has resulted from the past and present impacts of activities in the action area. The Sacramento River winter-run Chinook salmon ESU is restricted to one population entirely contained within the action area. Construction of the Livingston Stone National Fish Hatchery in 1996 has safeguarded the natural population since the critically low abundance of the 1990's. Improvements in CVP operations since 1993 include: changes in operations pursuant to the 1993 winter-run Chinook salmon biological opinion, construction of a temperature control device on Shasta Dam in 1998, opening the gates at RBDD for longer periods of time, and periodic closures of DCC gates. These required actions have helped to bring the winter-run Chinook population to within 50 percent of the recovery goal. In addition, improvement of critical habitat from CVPIA gravel augmentation projects and increased restrictions on recreational and commercial ocean harvest of Chinook salmon since 1994, likely have had a positive impact on winter-run Chinook salmon adult returns to the upper Sacramento River (NOAA Fisheries 2003, 69 FR 33102).

The spring-run Chinook salmon ESU is comprised mainly of three self-sustaining wild populations (Mill, Deer and Butte creeks) which are outside of the action area; however, all migratory life stages must past through the Project action area. These three populations have been experiencing positive growth rates since the low abundance levels of the late 1980s. Restrictions on ocean harvest to protect winter-run Chinook salmon and improved ocean conditions have likely had a positive impact on spring-run Chinook salmon adult returns to the Central Valley (NOAA Fisheries 2003, 69 FR 33102). Abundance for the key indicator streams, Mill, Deer and Butte Creeks, are at historical levels. Current risks to the remaining populations include continuing habitat degradation related to water development and use, high water temperatures during the summer adult holding period, and the operations of the Feather River Hatchery.

The Trinity River portion of the Southern Oregon/Northern California Coast coho salmon ESU is predominately of hatchery origin. Termination of hatchery production of coho salmon at the Mad River and Rowdy Creek facilities has eliminated further potential adverse risks associated with hatchery releases from these facilities. Likewise, restrictions on recreational and commercial harvest of coho salmon since 1994 likely have had a positive impact on coho salmon adult returns to SONCC coho salmon streams (NOAA Fisheries 2003, 69 FR 33102). The DFG developed a state-wide coho salmon recovery plan in 2004.

Chapter 6 describes the factors that affect the species and critical habitat in the action area. A large factor affecting the listed salmonids is the loss of spawning and rearing habitat upstream of impassable dams. High water temperatures in these lower elevations are a stressor to adult and juvenile life stages. The limiting factors that affect the likelihood of survival are high temperatures, low flows, limited spawning and rearing habitat, blocked or delayed passage, unscreened diversions, and flow fluctuations.

Chapter 6 Factors That May Influence Abundance and Distribution of Winter-Run and Spring-Run Chinook Salmon and Coho Salmon

This chapter describes the factors that may affect winter-run and spring-run Chinook salmon and critical habitat in the action area. A significant factor affecting all listed salmonids in the Central Valley is the loss of spawning and rearing habitat upstream of the major dams. Major limiting factors that affect survival of Chinook and Coho salmon include, but are not limited to, high water temperatures, low flows and flow fluctuations, and fish passage. Other factors that may affect various runs of Chinook salmon include changes in the Delta ecosystem. These changes that are of concern in the Delta include: altered flow patterns, varying salinity, contaminants, limited food supplies, and predation. In addition, ocean conditions and harvest, hatchery operations and disease can affect winter- and spring-run Chinook salmon.

Factors That May Influence Abundance and Distribution of Winter-Run and Spring-Run Chinook Salmon

Water Temperature

California's Central Valley is located at the extreme southern limit of Chinook salmon distribution (Moyle 2002). In particular, low water temperatures (< 5°C) are rarely of concern in the Sacramento – San Joaquin system because of the low frequency of periods of extreme cold in areas used by salmonids (Cech and Myrick 2001). However, because of the occurrence of temperatures stressful to salmonids in parts of the system, warm water temperatures are a critical management issue. Water temperatures in the lower Sacramento River mainstem regularly exceed 20°C by late spring (City of Sacramento water treatment plant, unpublished data); and statistical studies of coded-wire-tagged juvenile Chinook show that high temperatures are an important factor in mortality (Baker et al. 1995 as cited in Cech and Myrick 2001). Water temperatures that are too low or too high can kill Chinook salmon directly by impairing metabolic function or indirectly by increasing the probability of disease, predation, or other secondary mortality factors (Boles et al. 1988). Chinook salmon temperature tolerances vary by life stage, and may also vary among stocks, but the latter is not well studied. The recommendations included in this Biological Assessment (BA) were developed by Boles et al. (1988) based on previous temperature studies of Chinook salmon and other salmonids. An overview of temperature effects on Chinook salmon follows.

Table 6-1 Recommended water temperatures for all life stages of Chinook salmon in Central Valley streams as presented in Boles et al. (1988).[a]

Life stage	Temperature (°F)
Migrating adult	<65
Holding adult	<60
Spawning	53 to 57.5[b]
Egg incubation	<55
Juvenile rearing	53 to 57.5[c]
Smoltification	<64[d]

[a] The lower thermal limit for most life stages was about 38°F.

[b] Can have high survival when spawned at up to 60°F, provided temperatures drop quickly to less than 55°F.

[c] Temperature range for maximum growth rate based on Brett (1952, as cited in Boles et al. 1988).

[d] Marine and Cech 2004

Note: °F = degrees Fahrenheit.

The temperature recommendation for migrating adults was based on Hallock et al. (1970, as cited in Boles et al. 1988) who found Chinook immigration into the San Joaquin River was impeded by temperatures of 70°F, but resumed when the temperature fell to 65°F. There was also a low dissolved oxygen correlation in timing.

The temperature recommendations for adult holding and spawning, and for egg incubation were based on laboratory studies of Sacramento River Chinook egg survival (Seymour 1956, as cited in Boles et al. 1988). Egg mortality was high at constant temperature of 60°F, but was considerably reduced at temperatures between 55°F and 57.5°F. However, sac-fry mortality remained very high (greater than 50 percent) at temperatures above 56°F, presumably due to “aberrations in sequential physiological development.” These were long-duration experiences that are not representative of river conditions. Table 6-2 shows the relationship between water temperature and mortality of Chinook eggs and pre-emergent fry compiled from a variety of studies. This is the relationship used for comparing egg mortality between scenarios. FWS (1998) conducted studies to determine Sacramento River winter run and fall run Chinook early life temperature tolerances. They found that higher alevin mortality can be expected for winter-run between 56°F and 58°F. Mortality at 56°F was low and similar to fall-run Chinook mortality at 50°F. Their relationships between egg and pre-emergent fry mortality and water temperature were about the same as that used in the mortality model in this BA (Table 6-2).

Table 6-2 Relationship between water temperature and mortality of Chinook salmon eggs and pre-emergent fry used in the Reclamation egg mortality model.

Water Temperature (EF)[a]	Egg Mortality[b]	Instantaneous Daily Mortality Rate (%)	Pre-Emergent Fry Mortality[b]	Instantaneous Daily Mortality Rate (%)
41-56	Thermal optimum	0	Thermal optimum	0
57	8% @ 24d	0.35	Thermal optimum	0
58	15% @ 22d	0.74	Thermal optimum	0
59	25% @ 20d	1.40	10% @ 14d	0.75
60	50% @ 12d	5.80	25% @ 14d	2.05
61	80% @ 15d	10.70	50% @ 14d	4.95
62	100% @12d	38.40	75% @ 14d	9.90
63	100% @11d	41.90	100% @ 14d	32.89
64	100% @ 7d	65.80	100% @10d[c]	46.05

[a] This mortality schedule was compiled from a variety of studies each using different levels of precision in temperature measurement, the lowest of which was whole degrees Fahrenheit (±0.5°F). Therefore, the level of precision for temperature inputs to this model is limited to whole degrees Fahrenheit.

[b] These mortality schedules were developed by the FWS and DFG for use in evaluation of Shasta Dam temperature control alternatives in June 1990 (Richardson et al. 1990)

[c] This value was estimated similarly to the preceding values but was not included in the biological assumptions for Shasta outflow temperature control FES (Reclamation, 1991b).

A number of factors affect water temperatures, including meteorological conditions, air-water surface area of the stream, water-bed area, temperatures of inflows into storage, temperature at release to river, river flows, tributary inflows, river diversions, and the amount of river shading. To help address Sacramento River water temperature concerns, the Bureau of Reclamation (Reclamation) installed a temperature control device on Shasta Dam in 1997 to allow cool water releases to meet winter-run Chinook salmon life history needs.

Yearly water temperatures downstream at Balls Ferry and Bend Bridge are shown in Figure 6-1 through Figure 6-4. Temperature compliance points (Bend Bridge and Balls Ferry) vary by water year type and date between April 15 and October 31 for winter-run spawning, incubation, and rearing. The objective is to meet a daily average temperature of 56°F for incubation and 60°F for rearing. After October 31, natural cooling generally provides suitable water temperatures for all Chinook life cycles.

Rearing juvenile Chinook salmon can tolerate warmer water than earlier life stages. Nimbus Hatchery fall-run were able to feed and grow at temperatures up to at least 66°F (Cech and Myrick 1999), but this is not reflected in the Boles et al. (1988) temperature recommendation for juveniles. The relationship between temperature and growth rate seen in Cech's and Myrick's (1999) data parallels that observed in northerly salmon runs. Northern salmon (ie. Washington and north) exhibit maximum growth at 66°F when fed satiation rations. Nimbus Chinook had maximum growth rates at 66°F and lower rates at 59°F and 52°F (Myrick and Cech 2001).

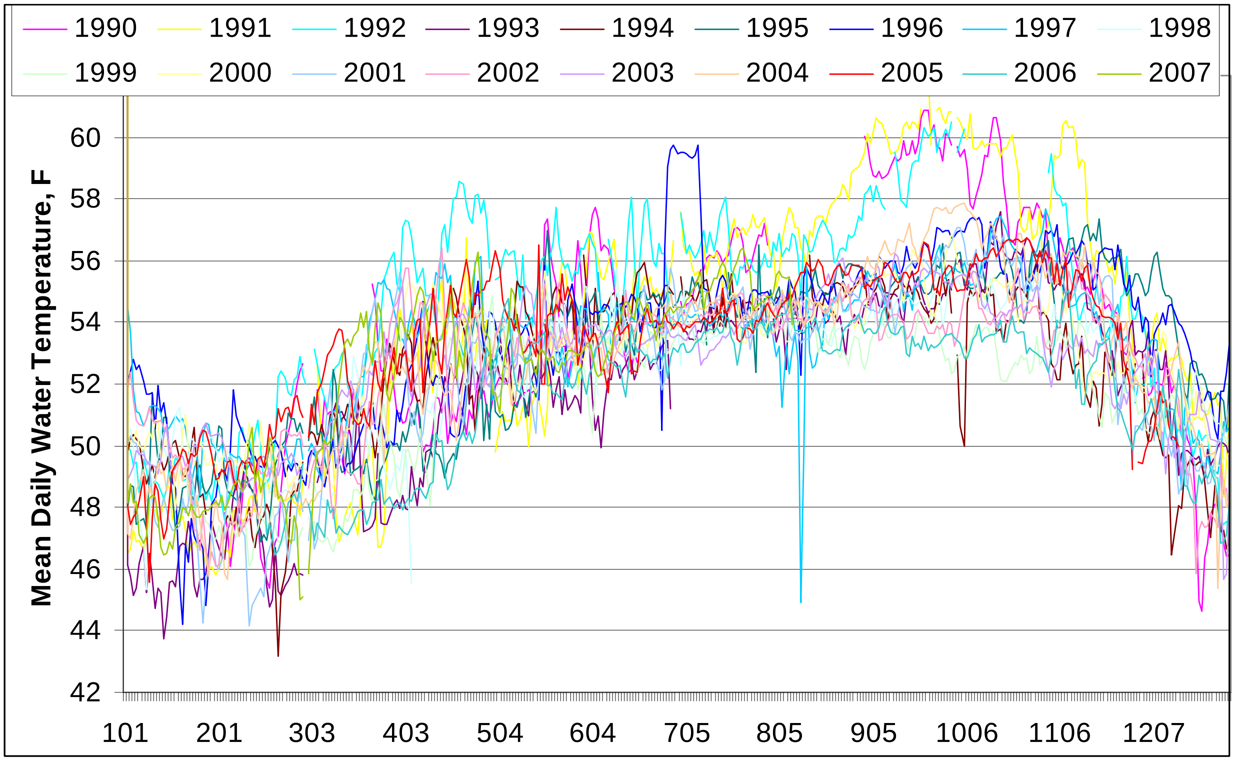


Figure 6-1 Sacramento River at Balls Ferry mean daily water temperatures, 1990 – 2007. Dates on the x-axis expressed like 101 = Jan 1, 303 = March 3, etc. (Source: cdec data)

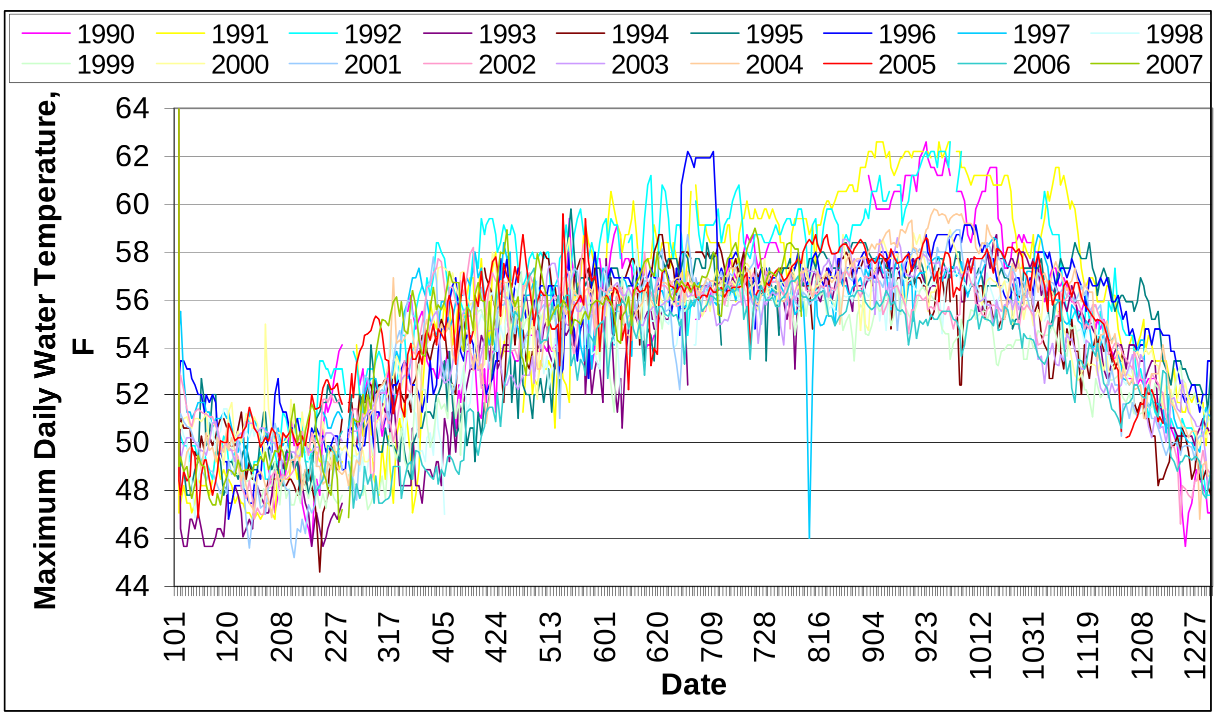


Figure 6-2 Sacramento River at Balls Ferry maximum daily water temperatures, 1990 – 2007. (Source: cdec data)

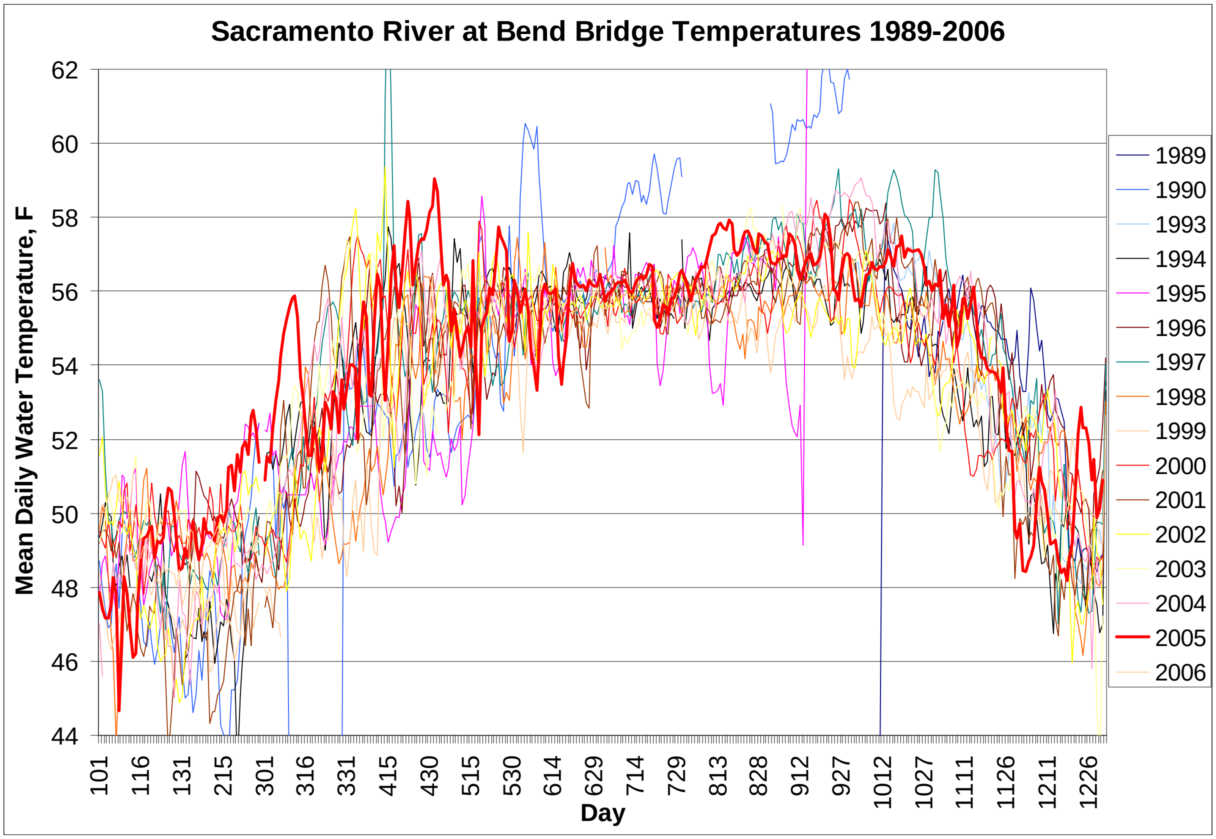


Figure 6-3 Sacramento River at Bend Bridge Water Temperatures 1989–2006. (Source: cdec data)

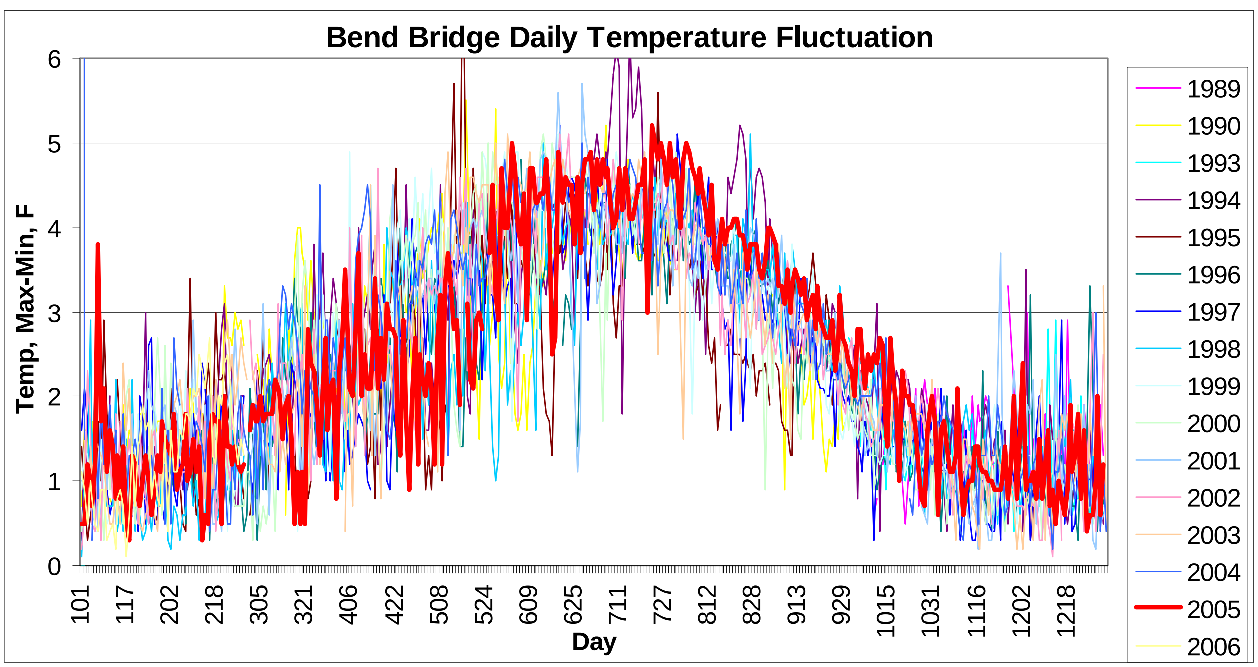


Figure 6-4 Bend Bridge Daily Temperature Fluctuation 1989–2006. Dates on the x-axis expressed like 101 = Jan 1, 303 = March 3, etc. (Source: cdec data)

The theoretical upper lethal temperature that Sacramento River Chinook salmon can tolerate has been reported as 78.5°F (Orsi 1971, as cited in Boles et al. 1988). However, this result must be interpreted with several things in mind.

First, the theoretical maximum corresponds to the most temperature-tolerant individuals. It is not a generality that can be applied to an entire stock. Second, it is only a 48-hour LT 50 (lethal time for 50 percent mortality). This means it is a temperature that can only be tolerated for a short period. It does not indicate a temperature at which a Chinook could feed and grow. Third, indirect mortality factors (for example, disease and predation) would likely lead to increases in total mortality at temperatures well below this theoretical laboratory-derived maximum. For example, Banks et al. (1971, as cited in Boles et al. 1988) found Chinook growth rates were not much higher at 65°F than at 60°F, but the fish had higher susceptibility to disease at 65°F. Subacute and sublethal temperature thresholds have been identified for Central Valley Chinook salmon by Marine and Cech (2004). Sublethal impairment of predator avoidance, smoltification, and disease begins in the range of about 64° to 68°F.

Myrick and Cech (2001) show that Chinook salmon that complete juvenile and smolt phases in the 50 to 62°F range are optimally prepared for saltwater survival. Marine and Cech (2004) identified a smoltification threshold of <64 F for Central Valley Chinook salmon.

Newman (2000) modeled the effect of temperature on coded wire-tagged (CWT) fall-run smolt survival from Fish and Wildlife Service (FWS) paired Delta release experiments. Newman's analysis indicated smolt survival would decrease by 40 percent as temperatures rose from 58 to 76°F. This result indicates that water temperature would be unlikely to affect spring-run smolt survival until it exceeded 58°F. On average, Delta temperatures have exceeded 58°F during April or May (Figure 6-5), when subyearling spring-run are emigrating. Newman's analysis is consistent with the lab findings of Marine and Cech 2004, where sublethal physiologic performance impairments were measured for CV Chinook salmon beginning at about 64° to 68°F. The level of resolution in Newman's data sets may not distinguish between 58-63°F, or there is an additional stressor in the Delta that further lowers temperature mortality relationship thresholds. Water project operations cannot effectively control water temperatures in the Delta.

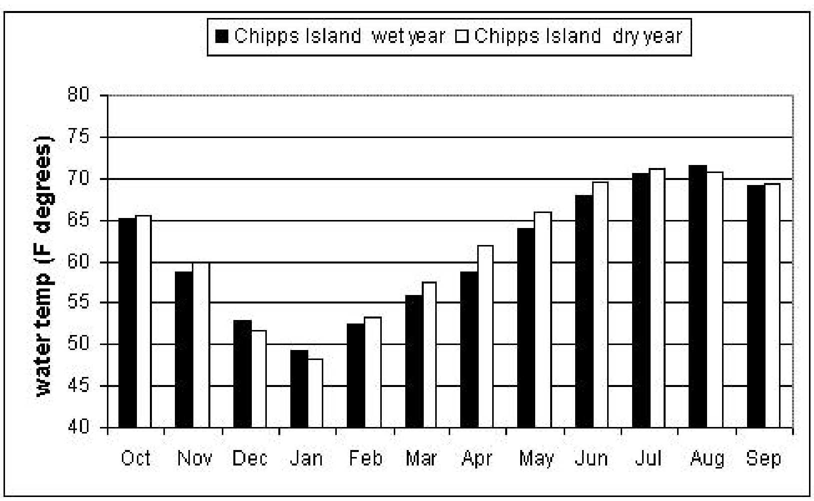


Figure 6-5 Monthly mean water temperatures for the Sacramento River at Chipps Island for water years 1975–1995.

It is also important to note that operation of CVP and SWP facilities cannot influence (1) the water temperatures on many of the tributaries to the Sacramento and San Joaquin Rivers or (2) those other factors that affect water temperatures that are unrelated to the appropriation of water for use by the CVP and SWP. Reclamation is not aware of any actions taken by others to address those other factors that are beyond the control of Reclamation and DWR that influence water temperatures.

Flow and Spawning

In-stream flow recommendations have been developed for Chinook salmon for most major Central Valley streams by AFRP and others. Many of the recommendations are intended to optimize habitat area for salmon spawning and egg incubation. High flows can affect redds by scouring the gravel away down to the depth of the eggs and washing the eggs out or by piling more gravel and fines on top of redds so that alevins are unable to emerge or are suffocated. Lowering flows to below the depth of the egg pockets following spawning can kill incubating eggs and alevins.

In-stream Flow Studies

Sacramento River

The FWS (2003) developed spawning flow-habitat relationships for winter, fall, and late-fall Chinook salmon and steelhead spawning habitat in the Sacramento River below Keswick Dam using the Physical Habitat Simulation (PHABSIM) component of the instream flow incremental methodology (IFIM). Relationships were developed by cross section and by stream segments but were not aggregated into river-wide flow-habitat relationships.

Winter-run Chinook salmon weighted usable spawning area (WUA) peaked at around 10,000 cubic feet per second (cfs) in the upstream reach above the Anderson-Cottonwood Irrigation District (ACID) Dam when the dam boards are in. With the boards out, the peak was around 4,000 to 5,000 cfs. In the next reach downstream (ACID Dam to Cow Creek) habitat peaked at 8,000-9,000 cfs. In the lower reach (Cow Creek to Battle Creek) spawning habitat peaked at around 4,000 cfs but had low variability in wetted usable spawning habitat area in the flow range analyzed (3,250-30,000 cfs). The highest density redd counts for winter-run occur in the upper and middle reach, although since the ACID fish ladder was built there has been a substantial increase in spawning upstream of the dam (Killam 2002). ACID puts the boards in during early April and they stay in until fall, so the flows dictated by water use would be compatible with maximization of habitat area during that time.

Fall-run and late-fall-run had different weighted usable spawning area values but the flow versus habitat relationship was about the same for the two runs. Upstream of the ACID Dam, spawning habitat peaked at 3,250 cfs with the dam boards out and at about 6,000 cfs with the boards in. Between ACID and Cow Creek spawning habitat peaked at around 4,000 cfs. Between Cow Creek and Battle Creek habitat peaked at about 3,500 cfs. The highest density redd counts for fall and late-fall-run occur in the middle reach.

Feather River

Chinook salmon spawning distribution in the Feather River has been studied in detail by Sommer et al. (2001a), although the data are not specific for spring-run. Approximately three-quarters of spawning occurs in the low flow channel, where the heaviest activity is concentrated in the upper three miles. By contrast, spawning activity below Thermalito Afterbay Outlet is fairly evenly distributed. The proportion of salmon spawning in the low flow channel has increased significantly since the completion of the Oroville Complex and Feather River Hatchery (FRH). The significant shift in the distribution of salmon spawning in the Feather River to the upper reach of the low flow channel is perhaps one of the major factors affecting any in-channel production of spring-run as a result of redd superimposition mortality. Since they spawn later in the fall, fall-run fish may destroy a significant proportion of the redds of earlier spawning spring-run.

The major factors that had a statistically significant effect on spawning location were flow distribution and escapement (Sommer et al. 2001a). Significantly more salmon spawned in the low-flow channel when a higher proportion of flow originated from that reach. Attraction flows are known to change the spawning distribution of salmon in other rivers. Higher escapement levels were also weakly associated with increased spawning below Thermalito Afterbay Outlet. Since salmon are territorial, increasing densities of salmon would be expected to force more fish to spawn downstream. As will be discussed in further detail in the “Hatchery” section of this chapter, Feather River Fish Hatchery (FRF) operations may also affect salmon spawning location.

In 2002, DWR conducted an IFIM habitat analysis for the lower Feather River (DWR 2004). This analysis drew on the earlier IFIM work of Sommer et al. (2001), but added an additional 24 transects, and included additional spawning observations. The river segments above the low-flow channel (LFC) and below the high-flow channel (HFC) were modeled separately due to their distinct channel morphology and flow regime. The weighted usable area (WUA) for Chinook salmon spawning in the LFC increased from 150 cfs to a peak at 800 cfs. Beyond the peak, the WUA index falls sharply again. Although the WUA curve peaks at 800 cfs, the current base flow in the LFC (600 cfs) represents 90 percent of the highest habitat index value. In the HFC, the WUA rises from the lowest modeled flow (500 cfs) and peaks near 1,700 cfs, above which it again declines out to 7,000 cfs.

Redd Scouring

High flows, such as those released from dams to draw down storage for flood control during heavy runoff periods, have the potential to scour salmon and steelhead redds and injure eggs or sac-fry in the gravel. These same flows are important for maintaining rearing habitat and high-quality spawning gravel. River-specific geomorphic studies evaluated the bedload mobilization flow for the affected rivers. The future probability of occurrence of flow releases exceeding the bedload mobilization flow is based on the historic hydrograph since the respective dam was constructed. This is because scouring flows are generally a result of flood control operations during high runoff periods, which will not likely change in the near future.

Clear Creek

Sampling was conducted in Clear Creek at the U.S. Geological Survey (USGS) Clear Creek near Igo gauge during high flows in January and February 1998 to estimate a flow threshold that initiated coarse sediment transport (McBain & Trush and Matthews 1999). Sampling bedload movement during a 2,600 cfs flow showed that mainly sand was being transported. During a 3,200 cfs flow, medium gravels were being transported. Particles slightly greater than 32 millimeters (mm) were being transported by the 3,200 cfs (D_{84} = 7.5 mm) flow while no particles larger than 11 mm were sampled during the 2,600 cfs flow (D_{84} = 1.8 mm). Their initial estimate for a coarse sediment transport initiation threshold is in the 3,000 to 4,000 cfs range. Marked rock experiments at Reading Bar, the first alluvial reach downstream of the Clear Creek canyon, suggest that large gravels and cobbles (the D_{84}) are not significantly mobilized by a 2,900 cfs flow.

The majority of post-Whiskeytown Dam floods are produced from tributaries downstream of Whiskeytown Dam, but floods larger than about 3,000 cfs are caused by uncontrolled spillway releases from Whiskeytown Dam, as happened in WY 1983 (19,200 cfs, the largest post-regulation flood), 1997 (15,900 cfs), and 1998 (12,900 cfs) floods. These flows are the result of heavy runoff from the upper Clear Creek watershed and are not affected by Reclamation water release operations. Reclamation does not make releases into Clear Creek that exceed the bedload mobilization point unless recommended by fishery agencies for the benefit of fish. A probability of exceedance plot for Whiskeytown Dam is shown in Figure 6-6. Instantaneous flows of 3,000 cfs occur on average about once every 2 years and flows of 4,000 cfs occur about once every 3 years (Figure 6-7). One-day average flows of 3,000 cfs occur about once every 5 years.

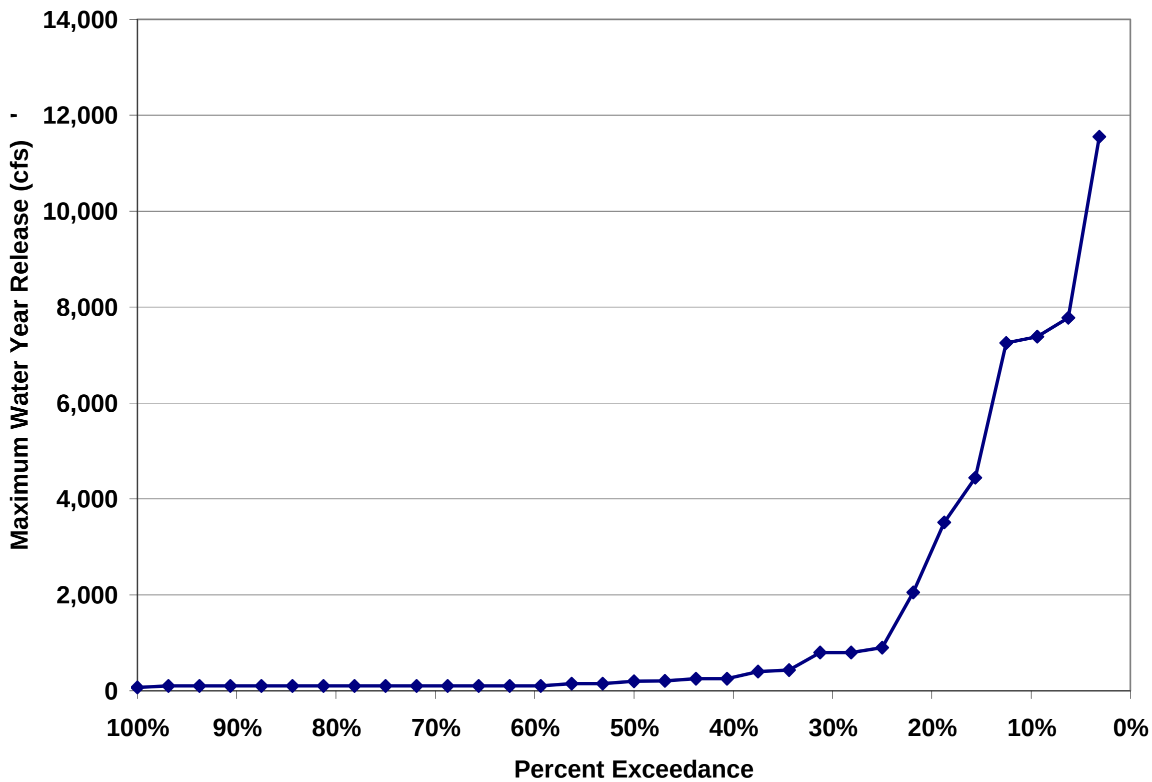


Figure 6-6 Yearly probability of exceedance for releases from Whiskeytown Dam on Clear Creek based on historical dam operations records.

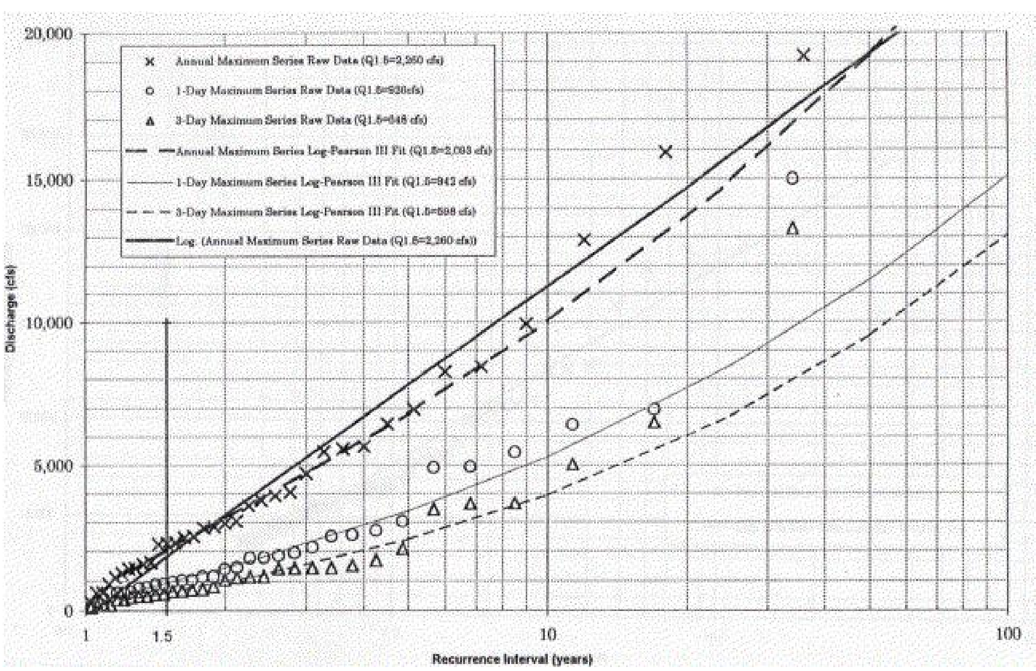


Figure 6-7 Clear Creek near Igo (Station 11-372000) flood frequency analysis of annual maximum, 1-day average, and 3-day average flood series for post-dam (1964–97) data.

Sacramento River

Buer (1980) conducted bedload movement experiments by burying a 50-gallon drum in a riffle below Redding. Gravel up to 3 inches in diameter began to accumulate in the barrel at about 25,000 cfs, indicating initiation of surface transport. Painted rocks moved 200 to 300 feet down the riffle at 25,000 cfs. Flows of 40,000 to 50,000 cfs would likely be required to move enough bedload to scour redds (Koll Buer, pers. comm. 2003.). The coarse riffles (small boulders and large cobbles), are probably armored from release of sediment-free flows from Shasta Dam. These armored riffles appear not to change and thus probably remain immobile even at flows exceeding 100,000 cfs (CALFED 2000). A bed mobility model was applied to four of the Army Corps of Engineers Comprehensive Study cross sections as another bed mobility estimate to compare to the empirical bed mobility observations. The bed mobility model suggests bed mobility thresholds between 15,000 and 25,000 cfs between River Miles 169 and 187, although the model is not considered appropriate for the Sacramento River (Calfed 2000).

Probability of occurrence for a release exceeding 25,000 cfs at Keswick Dam is approximately 50 percent each year and flows in the 40,000 to 50,000 cfs range occur in about 30 to 40 percent of years (Figure 6-8). Some redds could potentially be scoured in 10 – 25% of years when flows over 50,000 cfs occur while eggs are in the gravel. This would most likely occur during fall- and late-fall-run incubation. The significance to the population is difficult to determine, but based on the amount of scouring that occurs in unregulated rivers with large salmon runs compared to regulated rivers such as those in the Central Valley, long-term negative population effects from redd scouring are probably not very significant. On the Sacramento River, the 2-year return interval flood has been reduced from 119,000 cfs to 79,000 cfs since construction of Shasta Dam (as measured at Red Bluff, Figure 6-9).

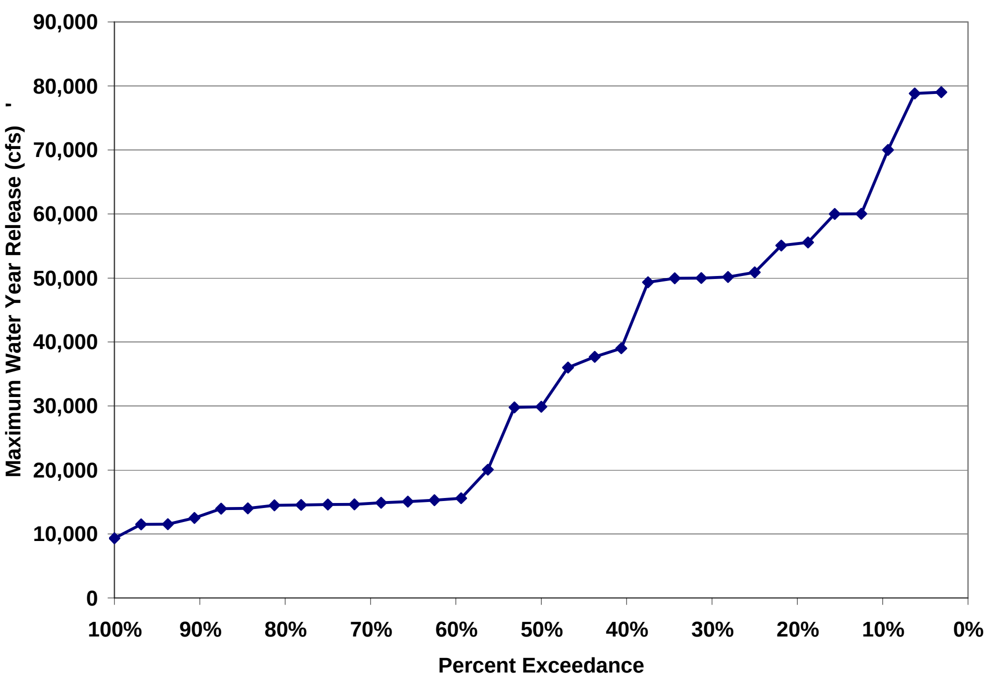


Figure 6-8 Yearly probability of exceedance for releases from Keswick Dam on the Sacramento River from historical dam operations records.

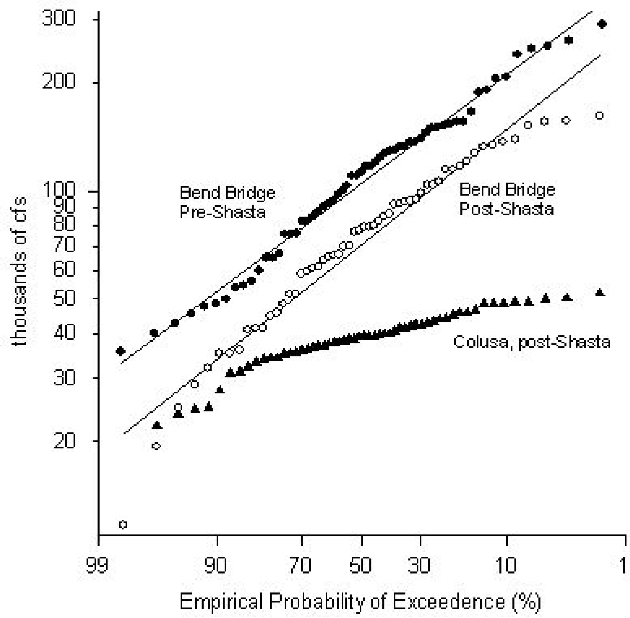


Figure 6-9 Empirical flood frequency plots for the Sacramento River at Red Bluff (Bend Bridge gauge) for pre- and post-Shasta periods, and downstream at Colusa for the post-Shasta period.

The reduced peak flows at Colusa reflect diversions into the Butte Basin between the two gauges. Data from U.S. Geological Survey internet site (www.usgs.gov), Red Bluff (Bend Bridge) and Colusa gauges. Chart from Calfed (2000).

American River

Ayres Associates (2001) used a two-dimensional model of the lower American River constructed on 2-foot topography to determine at what flows spawning beds would be mobilized. Their modeling results indicated that the spawning bed materials are moving for flows of 50,000 cfs or greater, although some movement may occur for flows between 30,000 and 50,000 cfs. Shear stress conditions tend to be highest upstream of Goethe Park, where the majority of salmon and steelhead spawning occurs.

Flood frequency analysis for the American River at Fair Oaks gauge shows that, on average, flows will exceed 30,000 cfs about once every 4 years and exceed 50,000 cfs about once every 5 years (Figure 6-10). Fair Oaks gauge flows result almost entirely from Folsom and Nimbus releases.

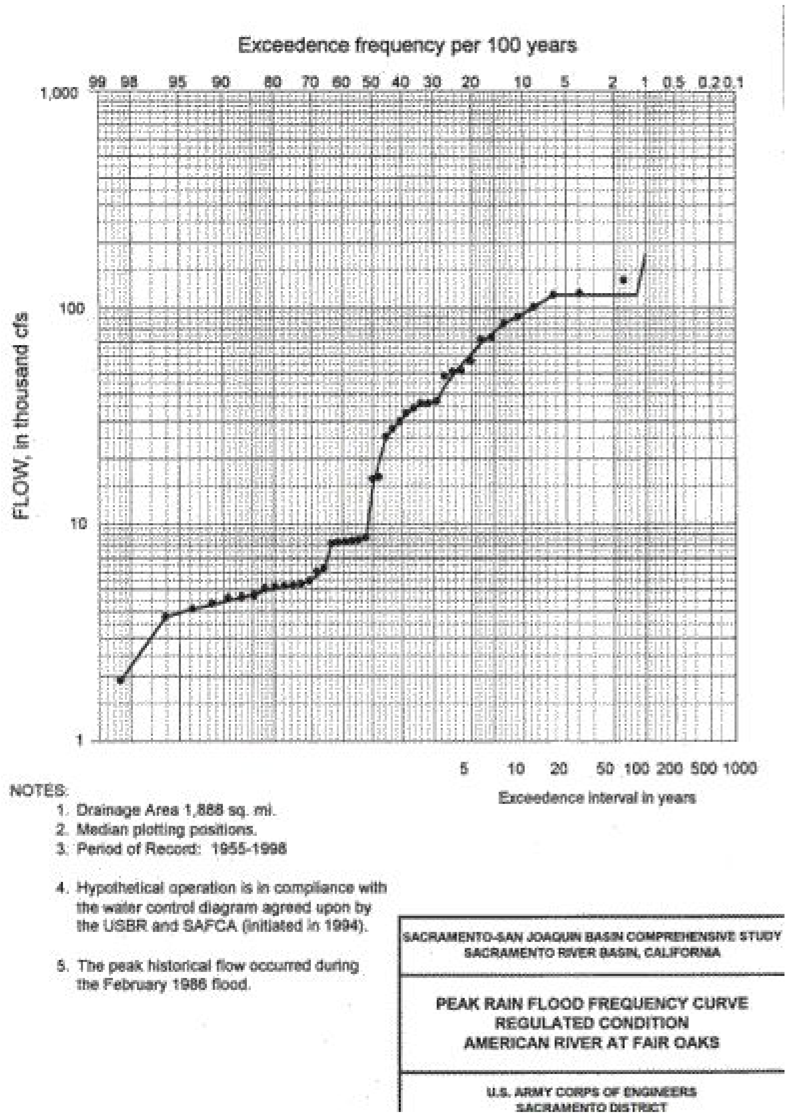


Figure 6-10 Flood frequency analysis for the American River at Fair Oaks Gauge (U.S. Army Corps of Engineers 1999).

Stanislaus River

Kondolf et al. (2001) estimated bedload mobilization flows in the Stanislaus River to be around 5,000 to 8,000 cfs to mobilize the D_{50} (median particle size) of the channel bed material. Flows necessary to mobilize the bed increased downstream from a minimal 280 cfs near Goodwin Dam to about 5,800 cfs at Oakdale Recreation Area.

Before construction of New Melones Dam, a bed mobilizing flow of 5,000 to 8,000 cfs was equivalent to a 1.5 to 1.8 year return interval flow. On the post dam curve, 5000 cfs is approximately a 5-year return interval flow, and 8,000 cfs exceeds all flows within the 21-year study period, 1979–99 (max flow = 7,350 cfs on January 3, 1997). The probability of occurrence for a daily average flow exceeding 5,330 cfs (the pre-dam bankfull discharge) is 0.01 per year. Figure 6-11 shows the yearly exceedance probability for Goodwin Dam releases.

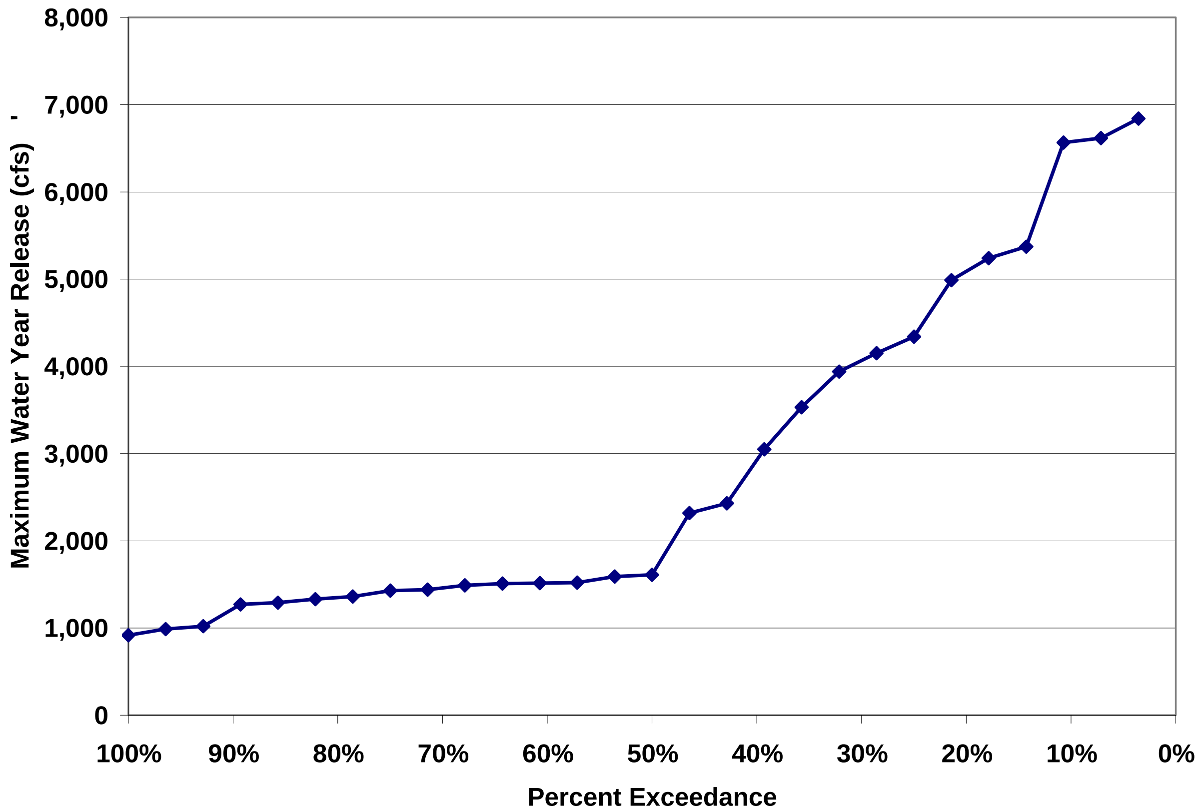


Figure 6-11 Exceedance probability for yearly Goodwin Dam releases from historical dam operations records.

Flow Fluctuations/Stranding

Flow fluctuations have the potential to dewater salmon and/or steelhead redds or isolate and strand juvenile salmonids below project reservoirs. Depending on the frequency and timing of flow fluctuations within and between years, salmon and steelhead populations can be affected.

Clear Creek

Table 6-3 shows the stage discharge relationship in Clear Creek at Igo. Using the 5-inch redd depth as the threshold for redd dewatering, a 100-cfs flow drop in the 100 to 300 cfs range could start to dewater the shallowest redds. A flow drop of 150 cfs in the 300 to 800 cfs range could start to dewater redds, and a flow drop of 300 cfs between 800 and 1,800 cfs could start to dewater redds. Flows over 500 cfs in Clear Creek are the result of uncontrolled runoff or pulse flows prescribed through collaboration with fishery agencies for the benefit of fish and habitat.

Table 6-3 Stage discharge relationship for the Clear Creek at Igo USGS gauge, Station 11372000.

Stage, inches	Discharge, cfs
33.12	101
38.52	200
42.72	301
46.2	400
49.32	501
52.2	602
54.72	702
57	803
59.16	903
61.08	1000

Sacramento River

Based on the Sacramento River at Bend Bridge gauge, drops in flow of approximately 800 cfs in the low end of the flow range up to about 20,000 cfs have the potential to start drying the shallowest redds 5 inches deep (Table 6-4). Areas of the river away from stream gauges where there is not as much confinement and more spawning activity probably experience less change in stage for a given flow change but the data were not available to evaluate other locations.

Table 6-4 Stage discharge relationship in the Sacramento River at Bend Bridge, gauge 11377100.

Stage, inches	Discharge, cfs
8	4190
10	4500
12	5020
15	5490
18	5990
21	6490
24	6990
27	7490
31	7990
34	8500
38	9000
41	9510
45	10000
48	10500

Stage, inches	Discharge, cfs
52	11000
55	11500
59	12000
62	12500
65	13000
68	13500
71	14000
74	14500
78	15000
81	15500
84	16000
87	16500
90	17000
92	17500
95	18000
98	18500
101	19000
103	19500
106	20000
110	21000
114	22000
118	23000
122	24000
126	25000
129	26000
133	27000
137	28000
140	29000
144	30000

American River

Snider et al. (2001) evaluated flow fluctuations relative to stranding in the American River and made the following recommendations for operations of the Folsom project. Reclamation implements the recommendations where feasible after consultation with the American River Operations Group. This has reduced instances of stranding.

- Ramping rates should not exceed 100 cfs per hour when flows are less than 4,000 cfs;
- Flow increases to 4,000 cfs or more should be avoided during critical periods (January through July for young of the year salmon and steelhead and October through March for yearling steelhead and non-natal rearing winter-run Chinook salmon) unless they can be maintained throughout the entire period; and
- Flow fluctuations that decrease flow below 2,500 cfs during critical spawning periods should be precluded: October through December for Chinook salmon and December through May for steelhead. They define flow fluctuations as unnatural rapid changes in stream flow or stage over short periods resulting from operational activities of dams and diversions.
- Reclamation implements the recommendations where feasible after consultation with the American River Operations Group. This has reduced instances of stranding.

The shallowest salmon redds observed prior to any flow changes were under 5 inches of water referenced to the original bed surface (Hannon, field observations 2002) and the shallowest steelhead redds observed were over 7-inches deep (Hannon and Healey 2002). Steelhead could likely spawn in water as shallow as Chinook, so this analysis is based on water depth reductions of 5 inches that could drop the water level to even with the top of the shallowest redds. Evenson (2001) measured Chinook egg pocket depth in the Trinity River. The shallowest egg depth found was 2.2 inches under the gravel referenced to the original bed surface and the mean depth to the top of the egg pocket was 9 inches. Ninety-three percent of the top of egg pockets were buried at least 5 inches under the gravel. Five-inch-deep eggs would not become dewatered until water drops at least 10 inches, but fry emergence could be prevented if no water is over the surface of the redd. Based on cross sections measured in 1998 by the FWS, flow changes of 100 cfs generally change the water depth by about 1 inch in a flow range of 1,000 to 3,000 cfs and by about 0.5 inch in a flow range from about 3,000 to 11,000 cfs. Therefore, when flows are 3,000 cfs or lower, flow drops of 500 cfs or more can begin to dewater redds. When flow is over 4,000 cfs, flow drops of 1,000 cfs or more can begin to dewater redds. Figure 6-12 shows the number of times by month that flow was raised above 4,000 cfs and then dropped back below 4,000 over a 30 year period. The annually maximum daily Nimbus release exceedance is shown in Figure 6-13.

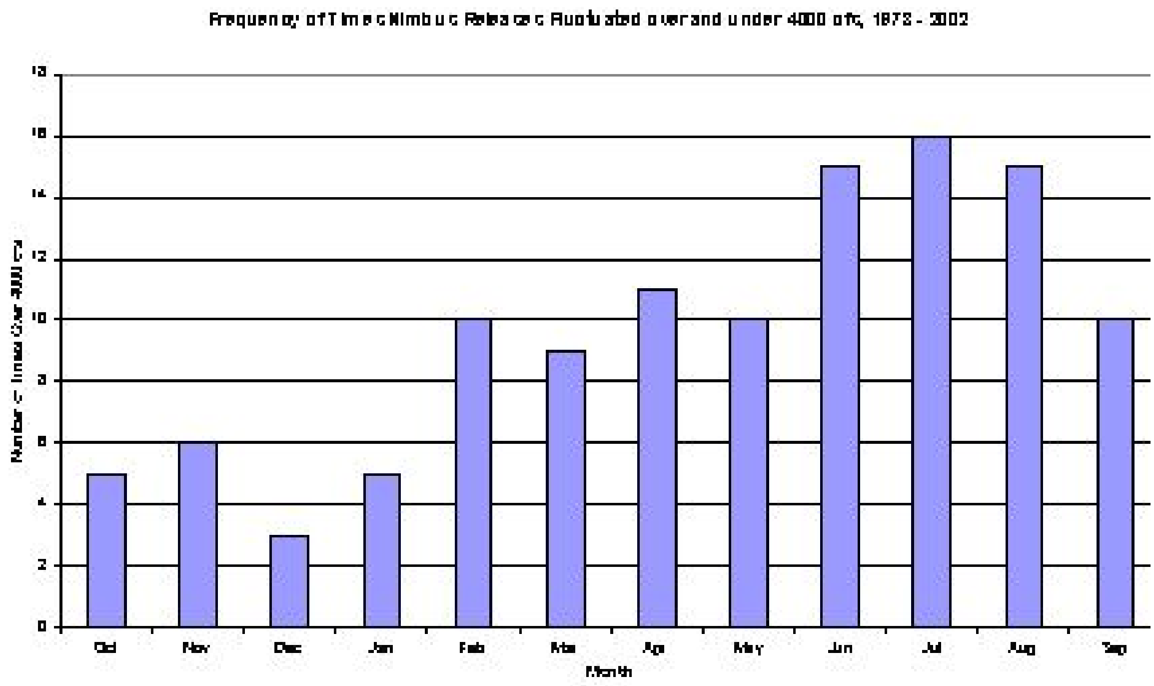


Figure 6-12 Frequency of times Nimbus releases fluctuated over and under 4000 cfs, 1972-2002.

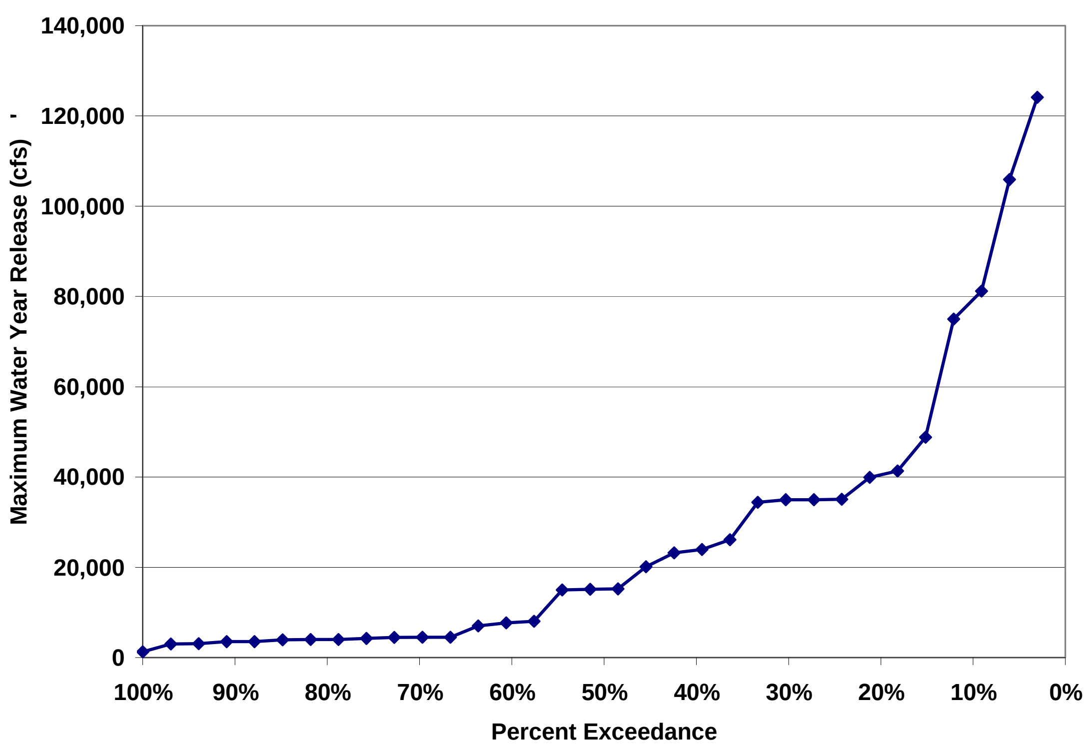


Figure 6-13 Annual Maximum Daily Nimbus Release Exceedance.

Stanislaus River

Based on the Stanislaus River at Ripon gauge, reductions in flow of approximately 50 cfs in the flow range of 100 to 300 cfs have the potential to start to dewater the shallowest redds 5-inches deep (Table 6-5). Although the Ripon gauge is downstream of spawning areas, the channel morphology at the gauging station is similar to that through much of the spawning area so the stage discharge relationship should be similar. Reductions in flow of 100 cfs in the flow range of about 150 to 1,000 cfs will cause a 5-inch drop in water surface elevation. Reductions in flow of about 175 cfs in the flow range of 1,000 to 2000 cfs will cause about a 5-inch drop in water level.

Table 6-5 Stage discharge relationship in the Stanislaus River at Ripon, gauge 11303000.

Stage, inches - 440	Discharge, cfs
3	100
5	125
8	150
10	174
13	200
17	251
21	300
24	350
27	400
32	501
37	601
43	700
49	800
54	900
58	1000
67	1200
76	1400
84	1600
92	1800
100	2000
120	2500
139	3000
175	4000
199	5000
215	6000

Flow and Its Importance to Sub-adult Chinook Salmon

Streamflow is important to subadult Chinook salmon (Healey 1991). Larger salmon populations tend to occur in larger river systems, suggesting a direct effect of discharge on the amount of suitable habitat area. River flows directly affect through-gravel percolation rates, which are very important to egg survival, and may help disperse swim-up fry to suitable rearing habitats.

Streamflows indirectly affect other environmental conditions, which in turn affect Chinook survival. Flow rates can affect instream temperatures downstream of reservoirs. For example, releases from Shasta Dam affects temperature for up to 200 miles downstream but can only effectively “control” temperature in the top 40 or so miles. In natural stream systems, flow is correlated with turbidity. Turbidity may be important in juvenile life stages. Juvenile salmon losses to predators may be reduced by at least 45 percent in turbid-water stream reaches relative to clear-water reaches (Gregory and Levings 1998). Turbid water may also stimulate faster migration rates, which reduces the time young fish are exposed to freshwater mortality risks. The relative survival benefits of longer versus shorter freshwater residence time in juvenile Chinook has not been determined for Central Valley stocks. Pink salmon, the most abundant of the salmon species, emigrate to the ocean immediately upon emergence from the gravel and presumably derive survival benefits from this trait, although pink salmon are generally less abundant in watersheds requiring freshwater migrations over longer distances. High outflows and sediment loads can increase egg mortality through scouring and suffocation (Healey 1991).

In the upper Sacramento River Basin, problems of flow and temperature are closely associated during the summer and fall. Low flows and limited cold water supplies make spring-run habitat in tributaries like Clear Creek, Cottonwood Creek, and Antelope Creek marginally usable, or even unsuitable. Problems with low flow and high temperature may also occur in current spring-run habitat like Butte and Big Chico Creeks. The likelihood that survival will be reduced in low-flow years could be greater in unregulated tributaries than in regulated tributaries where stored water can sustain releases longer through dry periods.

Fish Passage

As with steelhead and other salmon races, migration impediments and barriers are a problem for winter-run and spring-run Chinook (Table 4-5) as well as other salmonids. Spring-run Chinook salmon formerly spawned in the upper reaches of at least 22 major rivers and tributaries in the Central Valley. However, the construction of dams has blocked access to historical upstream spring-run Chinook salmon habitat in Central Valley rivers and streams.

The presence of dams also has resulted in the probable hybridization of some spring- and fall-run Chinook salmon stocks. Historically, stocks occupying the same stream were separated in space and time because adult spring-run Chinook salmon migrated earlier in the year, and to spawning grounds farther upstream compared to fall-run Chinook salmon. Presently, both spring- and fall-run Chinook salmon spawn together downstream of dams. Hybridization has the potential to occur because the spawning periods for spring- and fall-run Chinook salmon overlap and the fish intermingle while they spawn. In addition, migration may be slowed or prevented in smaller tributary streams by numerous smaller agricultural diversion facilities.

ACID Diversion Dam

The ACID diversion dam created fish passage problems that required a substantial reduction in Keswick Reservoir releases to adjust the dam flashboards, which resulted in dewatered redds, stranded juveniles, and higher water temperatures. Reclamation assisted in the redesign and renovation of the flashboards and related ACID facilities in the 1990s to reduce the risks of dewatering redds. New fish ladders and fish screens were installed around the diversion and were operated starting in the summer 2001 diversion period. During the spawning runs in 2001 and 2002, spawning upstream of the diversion dam substantially increased, which was attributable to the access provided by the fish ladders (Table 5-5 winter-run redd chart).

Red Bluff Diversion Dam

Problems in salmonid passage at Red Bluff Diversion Dam (RBDD) provide a well-documented example of a diversion facility impairing salmon migration (Vogel and Smith 1984; Hallock 1989; FWS 1987, 1989, 1990a; Vogel et al. 1988, all as cited in DFG 1998). The implementation of gates-out operations and construction of the rotary-drum screen facility have substantially improved fish passage conditions at RBDD (see discussion of RBDD in Chapter 4). All spring-run juvenile emigrants pass RBDD during the gates-out period based on historical average run timing at RBDD. However, only about 30 percent of adult spring-run immigrants that attempt to pass Red Bluff encounter gates-out conditions (FWS 1998, as cited in DFG 1998). The current gates-down operation potentially delays 15 percent of the adult winter-run, and 35 percent of the juveniles going downstream in July, August, and September encounter the lowered gates (NOAA Fisheries 2003). Based on winter-run population increases that have occurred since the current gate operations were initiated, the population seems capable of increasing under current operations.

Aerial redd surveys conducted for winter-run and spring-run spawning since 1987 by DFG show that since the gates-out period was moved to September 15 to May 15 in 1993, few winter-run have spawned below RBDD (Table 6-6). During 1994 and 1995, higher percentages of spring-run spawned below RBDD than in other years. The majority of spring-run production in recent years has continued to occur in Sacramento River tributaries downstream of RBDD (Mill Creek, Deer Creek, Big Chico Creek, Butte Creek, and Feather River) despite the partial elimination of migration delays. Not counting Feather River spring-run, which are primarily considered to be of hatchery origin, 92 percent of spring-run since 1992 occurred in the tributaries downstream of RBDD. The proportion of spring-run using these tributaries was not affected by migratory delays at RBDD. The 8 percent of spring-run in the Sacramento River and tributaries upstream of RBDD were potentially affected by migratory delays at RBDD.

Table 6-6 Percent of winter-run and spring-run redds counted below Red Bluff Diversion Dam, 1987-2005. Data from Doug Killam, DFG.

Year	Winter-Run % Spawning Below RBDD	Spring-Run % Spawning Below RBDD	Months RBDD Gates Raised
1987	5	no survey	December - March
1988	25	3	December - mid-February

Year	Winter-Run % Spawning Below RBDD	Spring-Run % Spawning Below RBDD	Months RBDD Gates Raised
1989	2	0	December - mid-April; gates in 11 days in February
1990	7	0	December - March
1991	0	0	December - April
1992	4	0	December - April
1993	2	0	September 15 - May 15
1994	0	15	September 15 - May 15
1995	1	9	September 15 - May 15
1996	0	0	September 15 - May 15
1997	0	1	September 15 - May 15
1998	3	0	September 15 - May 15
1999	0	no survey	September 15 - May 15
2000	0	0	September 15 - May 15
2001	0.4	3	September 15 - May 15
2002	0.2	0	September 15 - May 15
2003	0.3	0.6	September 15 - May 15
2004	0	0	September 15 - May 15
2005	0.1		September 15 - May 15

New redds constructed in the Sacramento River during the typical spring-run spawning period (late August and September) since redd surveys began have shown low numbers of new redds relative to new redds counted during winter-run spawning timing and fall-run spawning timing. Peaks in redd count numbers are evident during winter-run spawning and fall-run spawning but not during spring-run spawning. The number of new redds has decreased through July and then increased at the end of September before the large increase that occurs after October 1 when they become classified as fall-run. This suggests that the number of spring-run spawning in the Sacramento River is low (average of 26 redds counted) relative to the average spring-run escapement estimate between 1990 and 2001 in the main stem Sacramento River of 908. The additional fish have not been accounted for in the tributaries upstream of RBDD. The additional fish appear to spawn in October and get counted as fall-run redds.

Additional analysis of effects of RBDD on salmon and steelhead was analyzed in an Environmental Impact Statement (CH2M HILL 2002).

Suisun Marsh Salinity Control Gates

The Suisun Marsh Salinity Control Gates (SMSCG) can affect immigration of all four Chinook races as adults move upstream through Montezuma Slough. Edwards et al. (1996) and Tillman et al. (1996) reported that operation of the SMSCG delays and/or blocks the upstream migration of adult salmon. The studies were unable to provide an accurate estimate of the magnitude of the delay or blockage due to variable results, but a potential minimum delay of about 12 hours per tidal day is possible when the gates are closed. The biological significance of this potential increase in migration time to spring-run populations is unknown because DFG staff estimates that it takes a salmon 30 days to reach its spawning area from the bays (DFG 1998). Further, Montezuma Slough is only one path through the estuary, and its relative importance to the overall immigration of adult spring-run has not been studied.

Limited information is available regarding the behavior of adult Chinook in estuaries. Information from the literature indicates that tidal phase, natal origin, water temperature, dissolved oxygen, and changes in flow can all affect upstream immigration. Stein (2003) tracked 480 adult salmon, tagged with ultrasonic transmitters, through the Delta as part of multi-agency DCC studies. Salmon movements varied among individuals. Many salmon crossed back and forth between different channels for weeks while some moved upstream quickly. Transit times in the Delta ranged from 3-48 days.

Generally, adult spring-run may be present in Suisun Marsh from February through June, with peak occurrence in May. The SMSCG are operated only to meet salinity standards. Therefore, avoidance measures (flashboards and gates out of water) are already in place to minimize effects during months when specific conductance is below standards by more than 2 mS/cm. Measures to improve passage for adult spring-run would be most effective if implemented when adult spring-run are moving upstream in late March through May of dry and critical water years, and mid-April through May in above and below normal water years. In recent years DWR has substantially reduced the frequency and duration that the gates are closed, thereby reducing the potential to impact fish passage.

DWR (1997) discussed several specific measures to mitigate gate operation effects on immigrating salmon. The measures examined included: (1) structural modifications to the flashboard section of the control gate facility in the form of openings or passages in individual flashboards; (2) lowering the height of the flashboard structure; and (3) altering the timing of gate closure on flood tides.

The Suisun Marsh Salinity Control Gates Steering Group reviewed the results from the examination of mitigation alternatives and requested an evaluation of the potential effects of structural modifications to the flashboards. Under this evaluation, the flashboard structure was modified by removing one of the four, 6-foot-tall flashboards and creating two, 3-foot horizontal slots at two depths to potentially provide continuous unimpeded passage for adult salmon. To test the effectiveness of this modification, a three-year evaluation was initiated in the fall of 1998 by DFG and DWR to sonic tag adult fall-run Chinook and monitor their movement through the gate structure during three phases of operation: (1) when the gates are open; (2) during full-bore gate operation; and (3) during full-bore gate operation with the modified flashboard structure installed. The evaluation was repeated in two consecutive control seasons with the fish tagging and tracking occurring from approximately September 15 through October 31 of both years. The fish-tagging period was limited to the time when fall-run Chinook were present in Suisun Marsh. The Suisun Marsh Salinity Control Gates Steering Group decided, based on preliminary results from the modified SMSCG tests that the slots resulted in less adult passage than the original flashboards. The steering group decided to postpone the third year of the test until September 2001 and to reinstall the original flashboards when gate operation was needed during the 2000-2001 control season. DWR and Reclamation focused on data analysis from August 2000 through February 2001, and conducted the third year of the study during the 2001-2002 Control Season. Based on these results, another approach to improve passage was investigated, involving opening the boat lock and using full flashboards when gates are operational.

Results in 2001, 2003, and 2004 indicate that leaving the boat-lock open during the migration period when the flashboards are in place at the SMSCG and the radial gates are tidally operated provides a nearly equivalent fish passage to the Non-migration period configuration when the flashboards are out and the radial gates are open. This approach minimizes delay and blockage of adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead migrating upstream during the migration season while the SMSCG is operating. However, the boat-lock gates may be closed temporarily to stabilize flows to facilitate safe passage of watercraft through the facility.

Reclamation and DWR are continuing to coordinate with the SMSCG Steering Group in identifying water quality criteria, operational rules, and potential measures to facilitate removal of the flashboards during the migration period that would provide the most benefit to migrating salmonids. However, the flashboards would not be removed during the migration period unless it was certain that standards would be met for the remainder of the period without the flashboards installed.

See “Suisun Marsh Salinity Control Gates” in Chapter 12 for more information.

Bank Modification and Riparian Habitat Loss

Sacramento River winter-run Chinook salmon are affected by bank modification and riparian habitat loss in the same manner as Central Valley spring-run Chinook salmon. Because adverse modification of shaded river aquatic cover may impede the recovery of winter-run Chinook salmon, NOAA Fisheries (1993) included nearshore rearing areas and adjacent riparian habitats of the Sacramento River in its determination of critical habitat for the winter-run Chinook salmon.

Delta Emigration

The following discussion emphasizes spring-run yearling emigrants, which have been of particular management concern since spring-run were listed. This primarily addresses emigration from Mill and Deer Creeks (DFG 1998), which have a higher proportion of spring-run emigrating as yearlings than either Butte Creek (Brown 1995) or the Feather River (DWR 1999a, 1999b, 1999c). Sub-yearling spring-run emigrate during winter and spring when protections for delta smelt and winter-run Chinook salmon are in place. There is significant uncertainty regarding timing of emigration of yearling spring-run Chinook. Because a relatively small number of yearlings are emigrating, they are difficult to detect in the monitoring programs.

Yearlings are relatively large, strong swimmers, so they may also more easily avoid the monitoring gear (McLain 1998). Other juvenile Chinook in the main stem Sacramento River are in the same size range used to define yearling spring-run Chinook, confounding data interpretation.

Marked releases of Coleman Hatchery yearling late-fall-run (hereafter Coleman late-fall-run Chinook) juveniles have been used as surrogates to estimate the timing of yearling spring-run emigration and incidental take at the SWP and CVP export facilities for the Salmon Decision Tree process and the OCAP biological opinions. Since 1994, FWS has released approximately 17 percent of the Coleman Hatchery late-fall production in each of November, December, and January to evaluate hatchery operations. The fish were adipose fin-clipped and coded-wire tagged before release allowing identification of the members of individual release groups when they are recaptured downstream. The regulatory agencies considered Coleman late-fall-run Chinook salmon appropriate surrogates for yearling spring-run because they were reared to a similar size as spring-run yearlings and were released in the upper Sacramento River. Because they were large, they were expected to emigrate quickly. Some patterns have recently been revealed through the Butte Creek CWT program on naturally spawned spring-run. In particular, the potential effects of the Sutter Bypass (lower Butte Creek) potentially effects residence time for these fish in the Sutter Bypass seems to be 60 to 120 days and dependent on water levels in the bypass resulting from Sacramento River flows (DFG 2003).

Coleman late-fall Chinook released in November were captured at Red Bluff and the Glenn-Colusa Irrigation District (GCID) facility within 2 or 3 days of release. However, they were not captured downstream in the lower Sacramento River or the Delta, until about 3 days after the first significant, precipitation-induced flow event in November or December (Figure 6-14 through Figure 6-22). This suggests Chinook yearlings may use these flow events as migration cues. Based on captures in the FWS Chipps Island midwater trawl and salvage at the Central Valley Project’s (CVP) and State Water Project’s (SWP) Delta export facilities, some individuals may continue to emigrate for up to 5 months.

The Coleman late-fall Chinook released in December (Figure 6-14 through Figure 6-22) were released after the first significant, precipitation-induced flow event in the fall. However, they were not captured in the Delta until after a second significant precipitation event occurred unless there was significant Sacramento River flow associated with the earlier precipitation-induced events. Since precipitation events occurred sooner after the December releases than the November releases, these fish may have remained in the upper Sacramento River for a relatively short time (several days up to a week), then taken several more days to reach the Delta following a precipitation-induced flow event. Some emigration continued for up to 4 months.

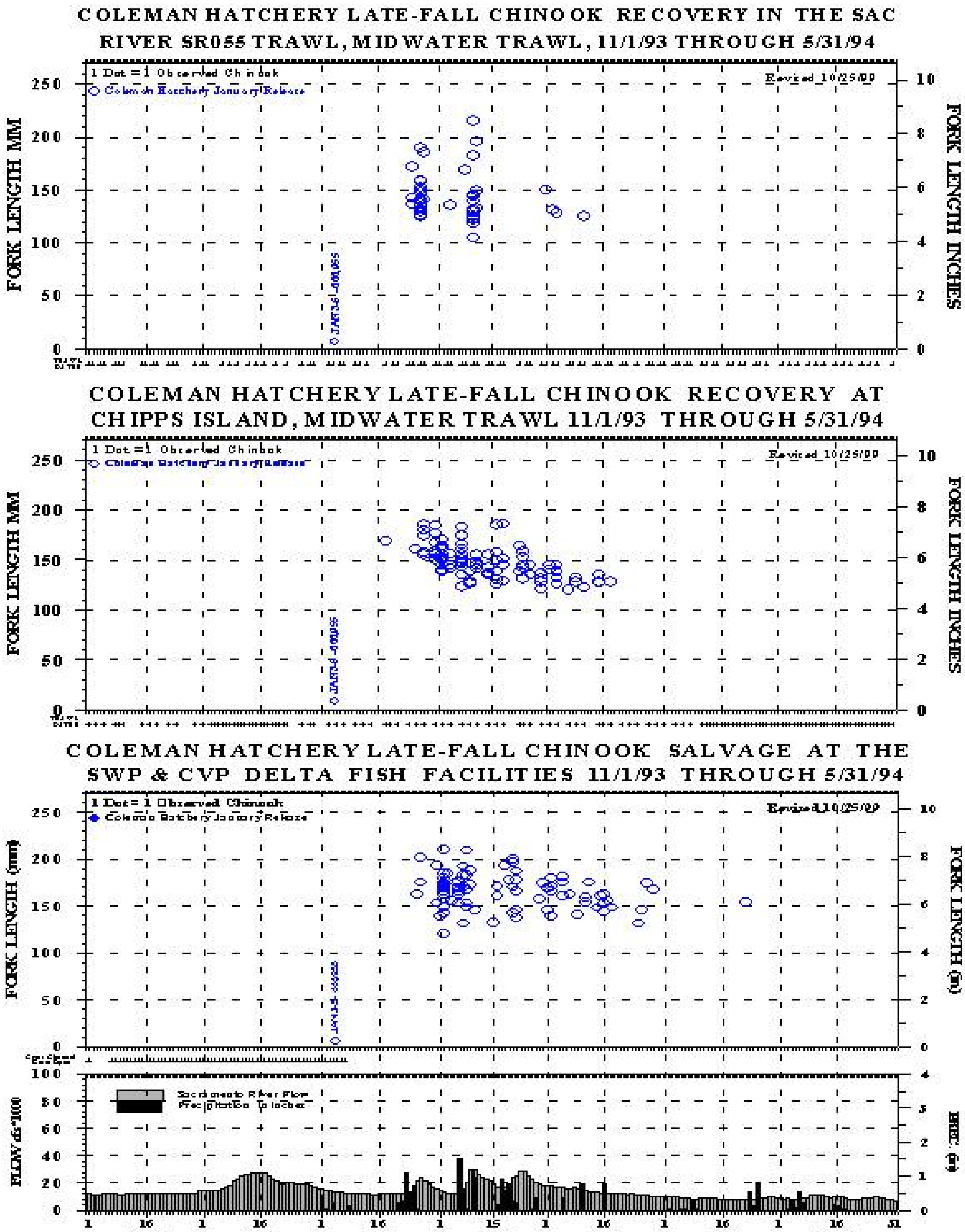


Figure 6-14 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late-fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1993–1994.

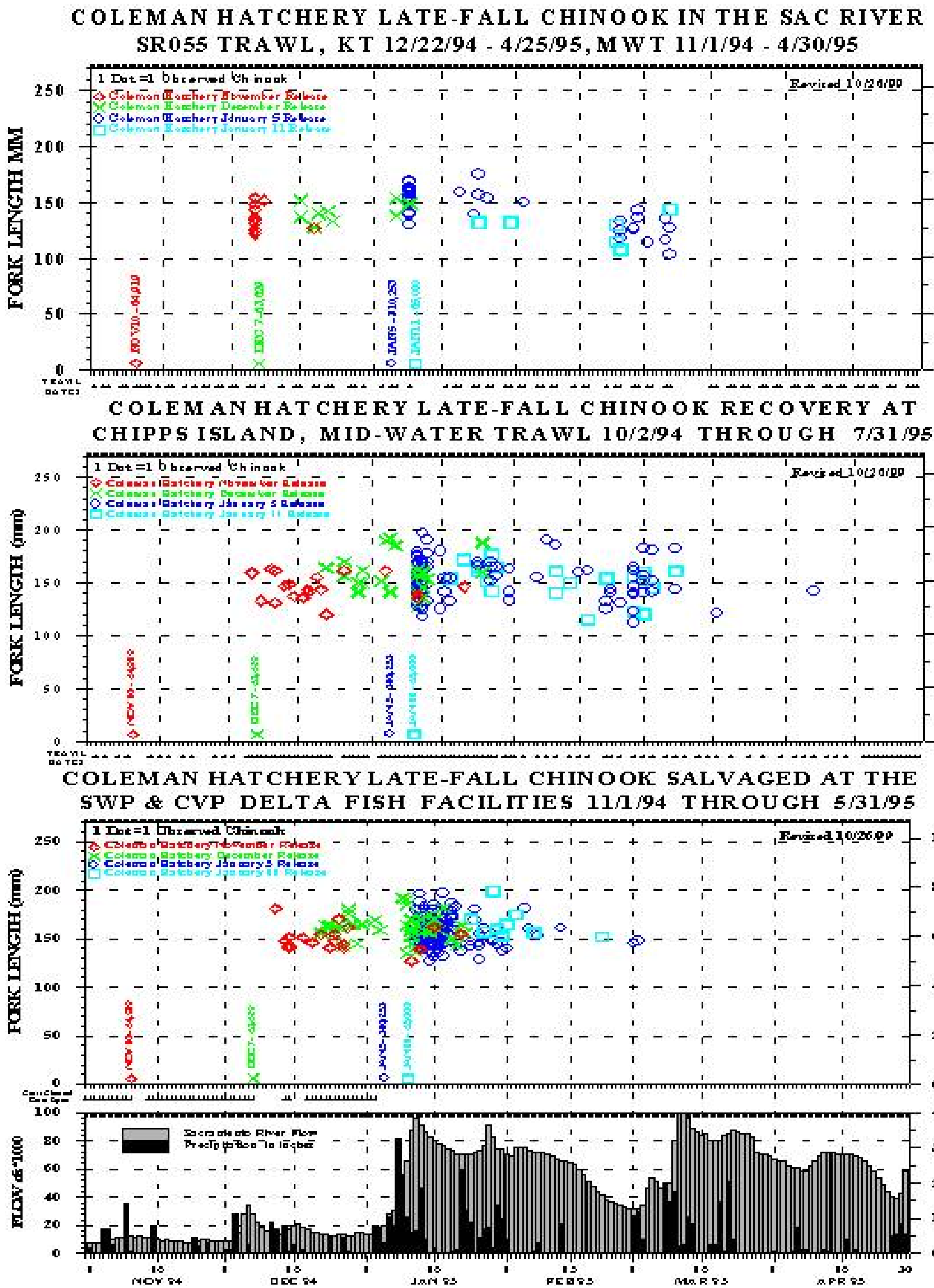


Figure 6-15 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late-fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1994–1995.

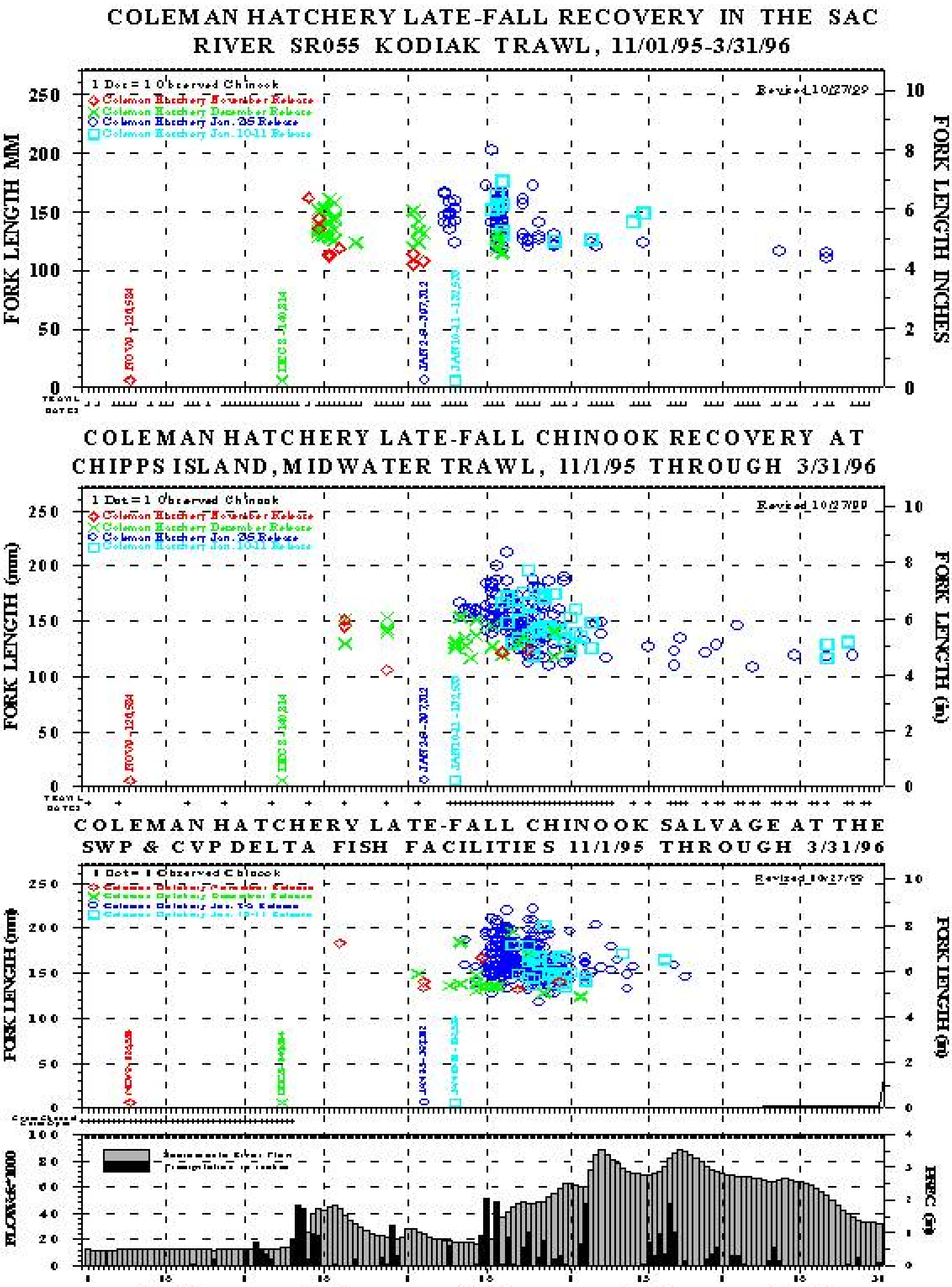


Figure 6-16 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late-fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1995–1996.

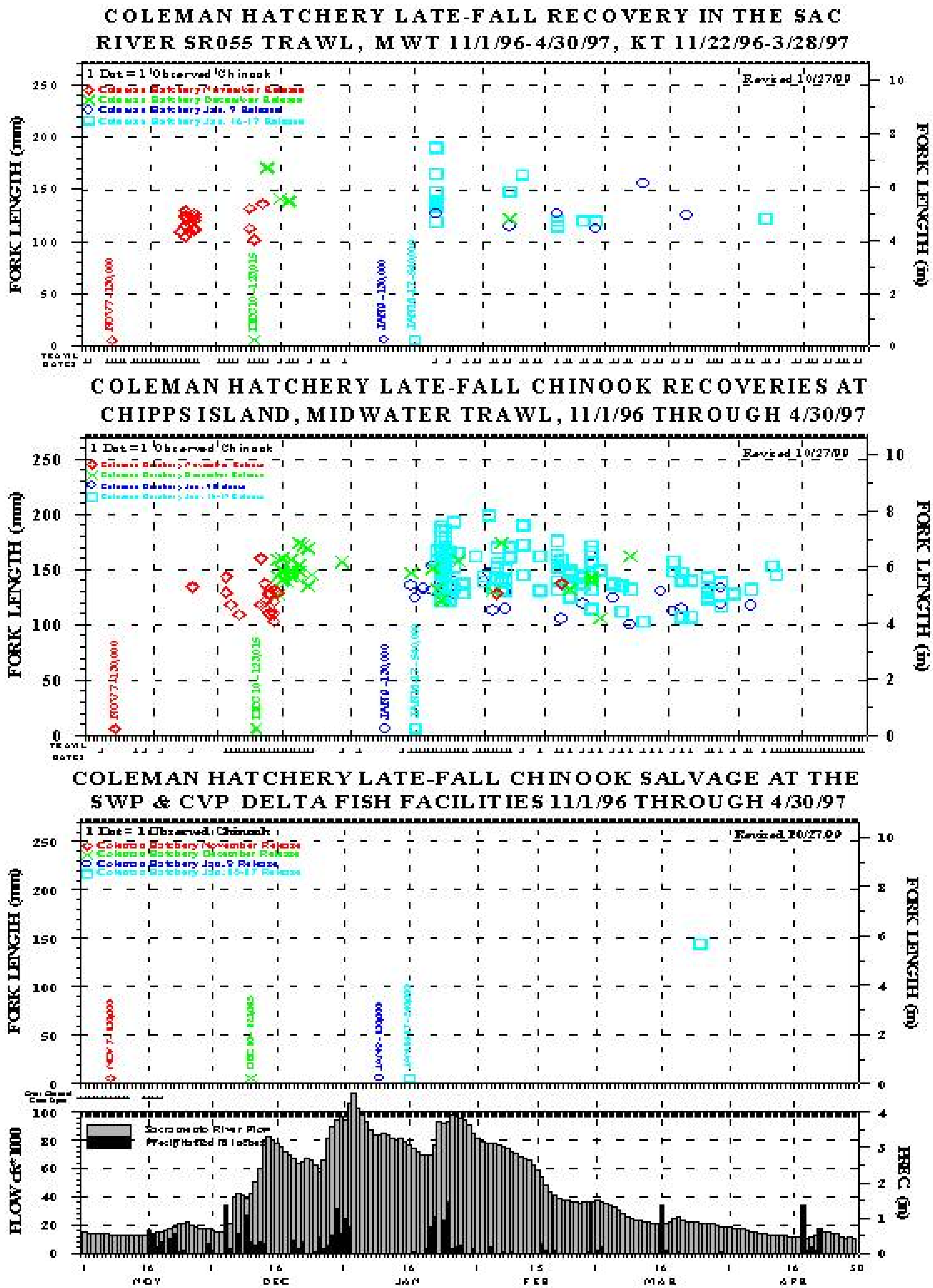


Figure 6-17 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late-fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1996–1997.

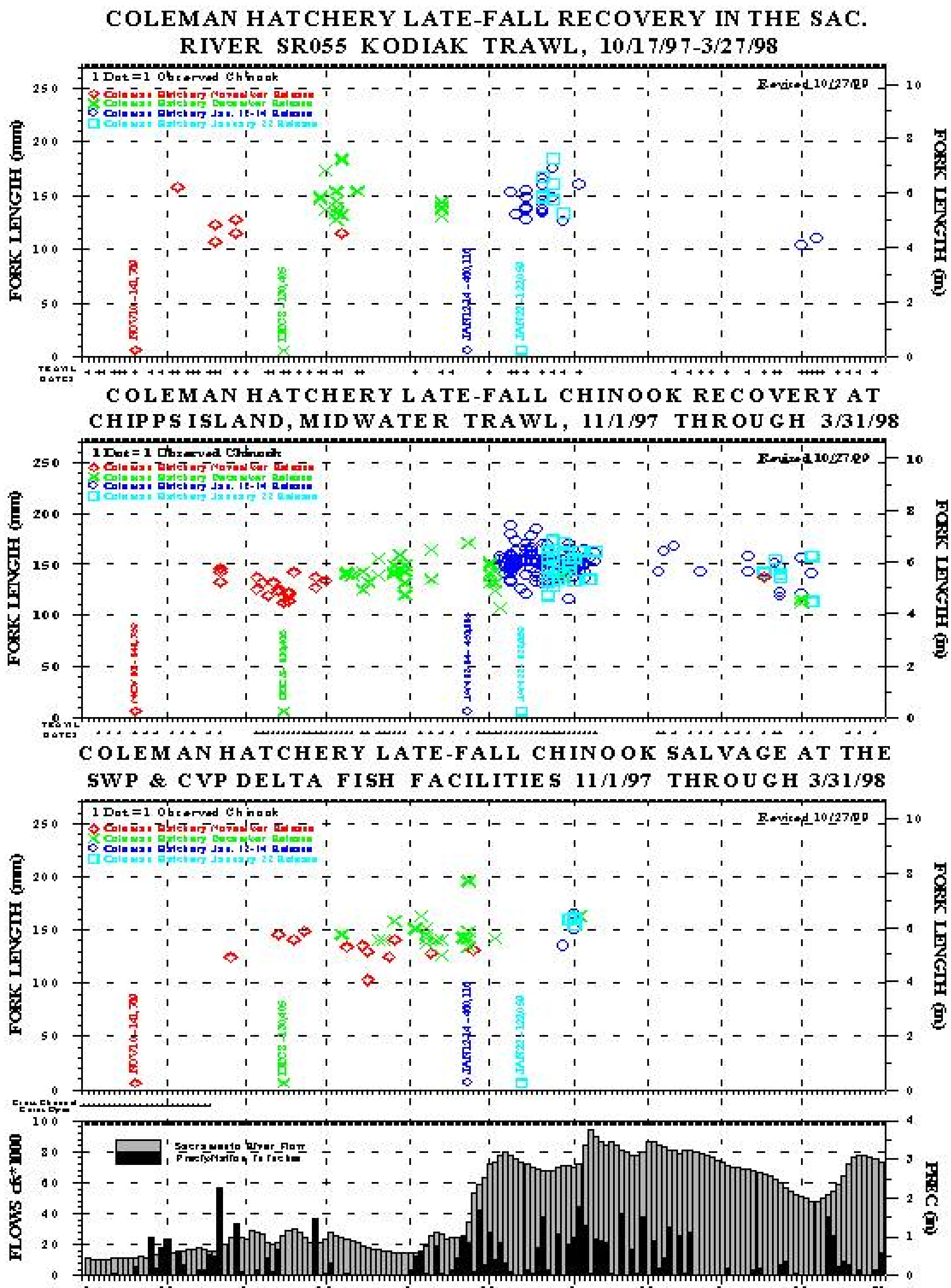


Figure 6-18 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late-fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1997–1998.

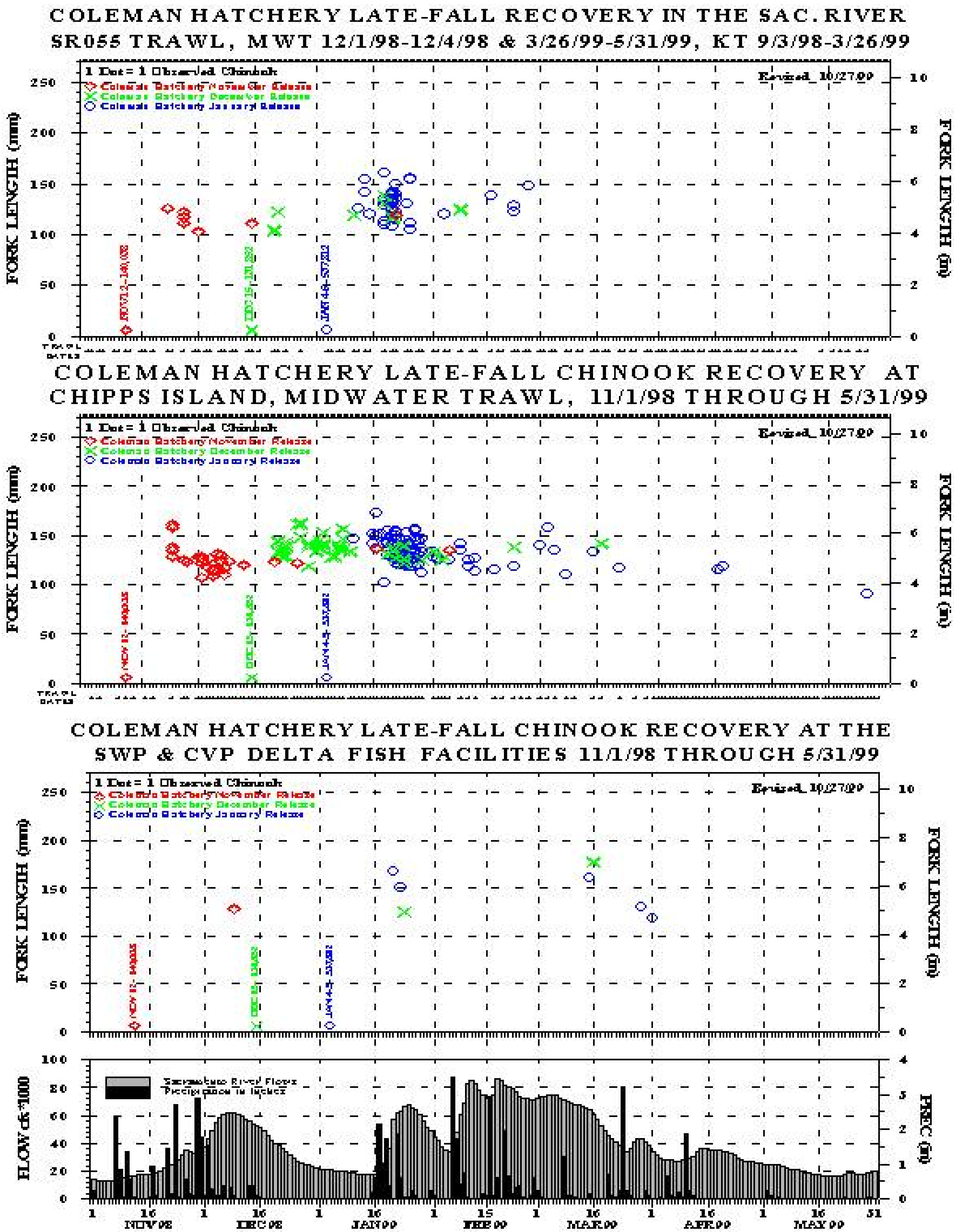


Figure 6-19 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late-fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1998–1999.

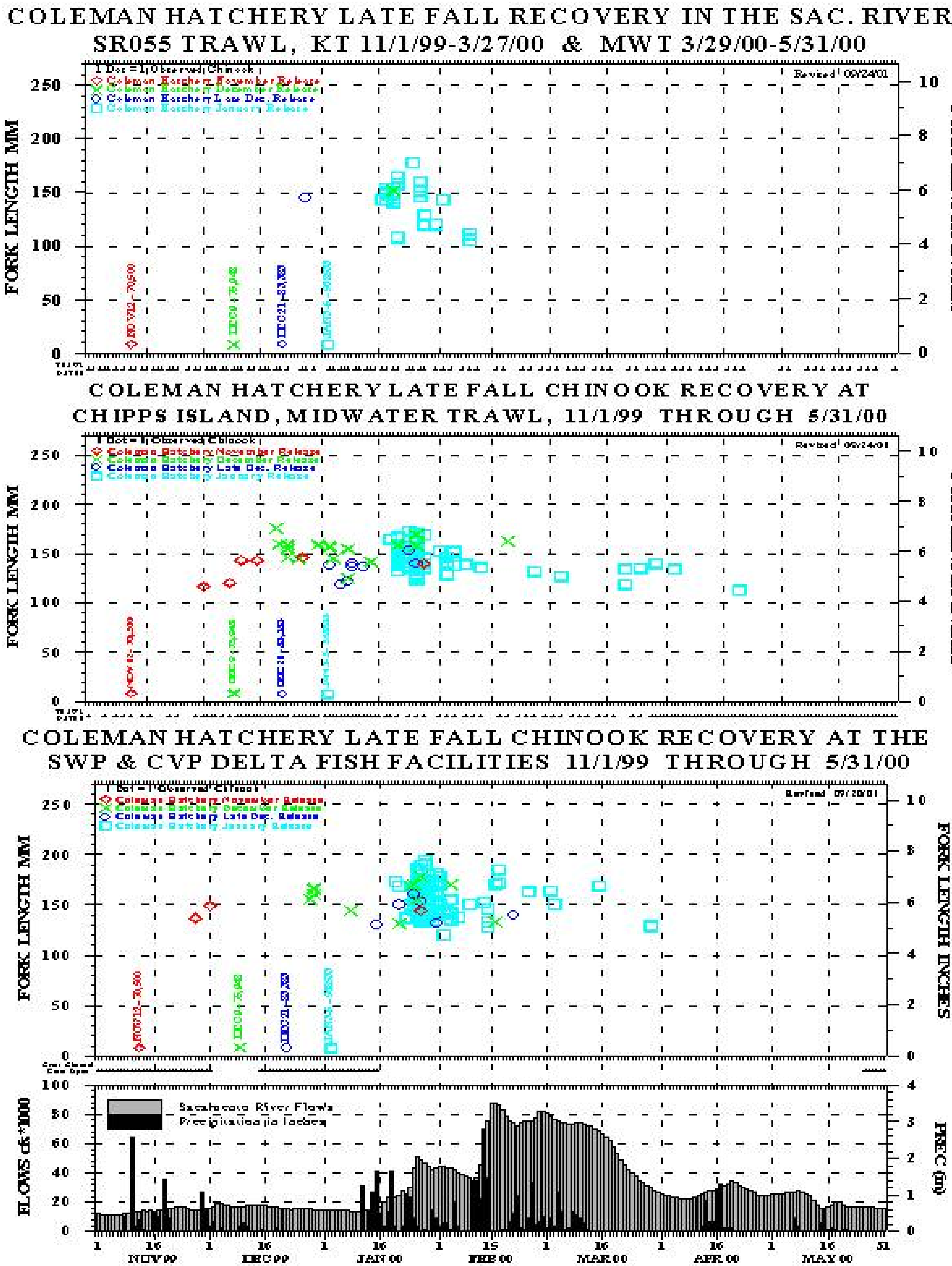


Figure 6-20 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late-fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1999–2000.

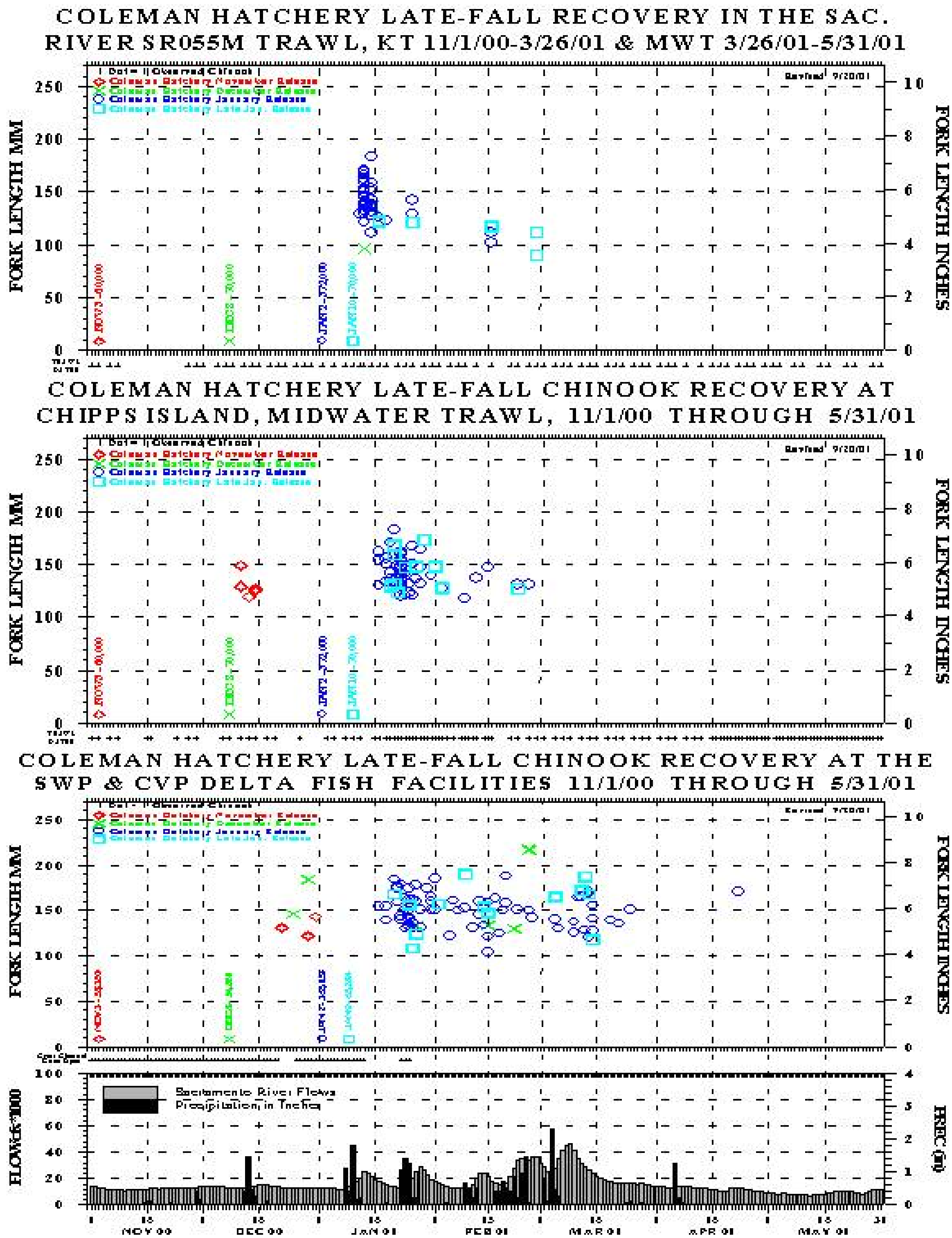


Figure 6-21 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late-fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 2000–2001.

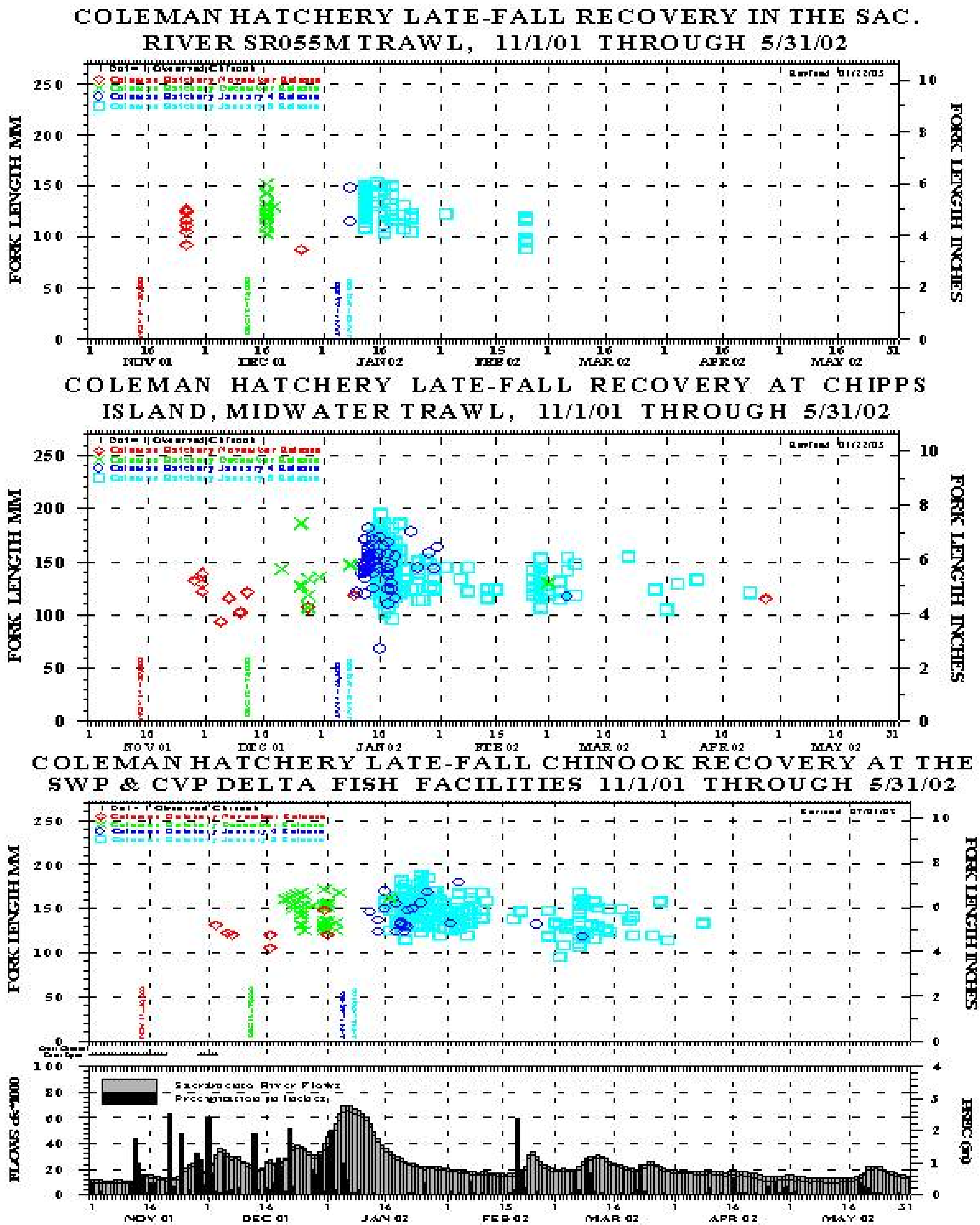


Figure 6-22 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late-fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 2001–2002.

The emigration of Coleman late-fall Chinook released in January (Figure 6-14 through Figure 6-22) was not as closely related to precipitation-induced flow events as the November or December releases; perhaps because significant precipitation and high flows had generally occurred prior to their release. The relationship between emigration and flow associated with precipitation events is variable, although the 1994 dry water year (Figure 6-14) is an example of January releases emigrating on precipitation-induced flow events throughout the winter and spring. Again, some emigration continued for up to 4 months.

Because Coleman late-fall and spring-run yearlings are similar in size and rear in the upper Sacramento River, their emigration patterns should be similar. Therefore, Sacramento River flow associated with precipitation events, along with related tributary flow events, probably provides the major cue for yearling spring-run emigration.

Pooling data for all late-fall-run yearling releases since November 1993, the average travel time from Coleman Hatchery to Sacramento has been 19 days, with a standard deviation of 12 days. The average travel time from the hatchery to Chipps Island has been 26 days (standard deviation = 11 days) and the average travel time from the hatchery to the Delta fish facilities has been 33 days (standard deviation = 18 days). The median travel times to Sacramento and the facilities are significantly different; other combinations are not (ANOVA $F = 4.33$; $p = 0.02$, + post hoc multiple comparison tests). Sacramento River flow for 30 days following release from the hatchery explains some of the variability in median travel time to Chipps Island (Figure 6-23)

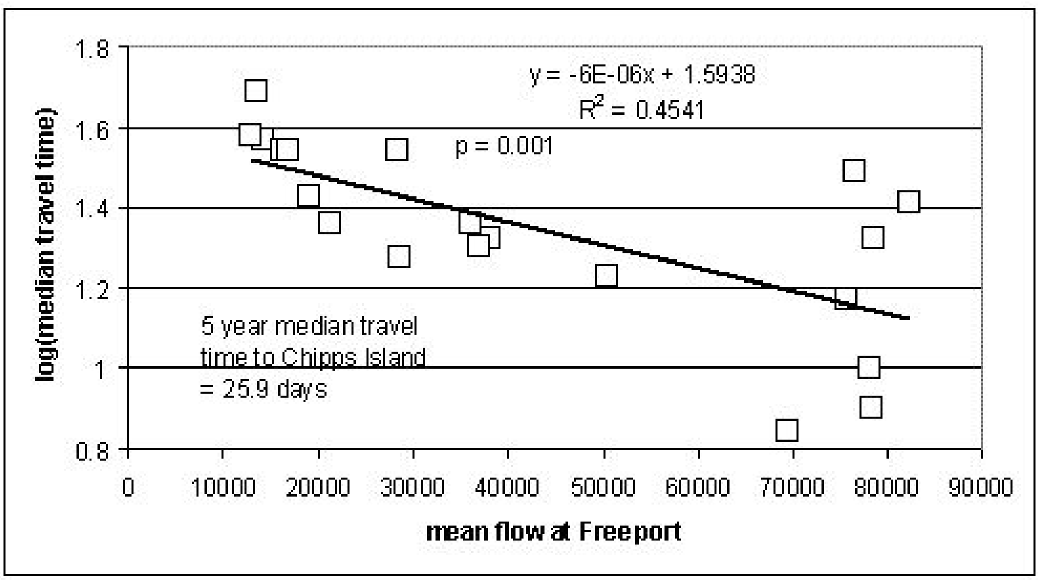


Figure 6-23 Relationship between mean flow (cfs) in the Sacramento River and the log10 time to recapture in the FWS Chipps Island Trawl for Coleman Hatchery late-fall-run Chinook salmon smolts. The explanatory variable is mean flow at Freeport for 30 days beginning with the day of release from Coleman Hatchery. The response variable is an average of median days to recapture for November through January releases during winter 1993–94 through 1998–99.

Winter-run migrate through the Delta primarily from December to April. NOAA Fisheries develops an estimate of winter-run juvenile production each year based on the estimated escapement and applying a set of standard survival estimates including prespawning mortality, fecundity, egg-to-fry survival, and survival to the Delta (Table 6-7). Figure 6-24 shows Winter-run and older juvenile Chinook loss at Delta fish facilities, October 2005-May 2006 and Figure 6-25 shows observed Chinook salvage.(the ones salvaged and measured in sampling counts) during the 2005-2006 outmigration.

Table 6-7 Example of how the winter-run Chinook juvenile production estimate, and take levels are calculated using 2001-02 adult escapement data.

2001-2002 Winter-Run Chinook Juvenile Production Estimate (JPE)	
Total Spawner escapement (Carcass Survey)	7,572
Number of females (64.4% Total)	4,876
Less 1% pre-spawn mortality	4,828
Eggs (4,700 eggs/female)	22,689,740
Less 0.5% due to high temp	113,449
Viable eggs	22,576,291
Survival egg to smolt (14.75%)	3,330,003
Survival smolts to Delta (56%)	1,864,802
Livingston Stone Hatchery release	252,684
Yellow light(1% natural + 0.5 hatchery)	19,911
Red Light (2% natural + 1% Hatchery)	39,823

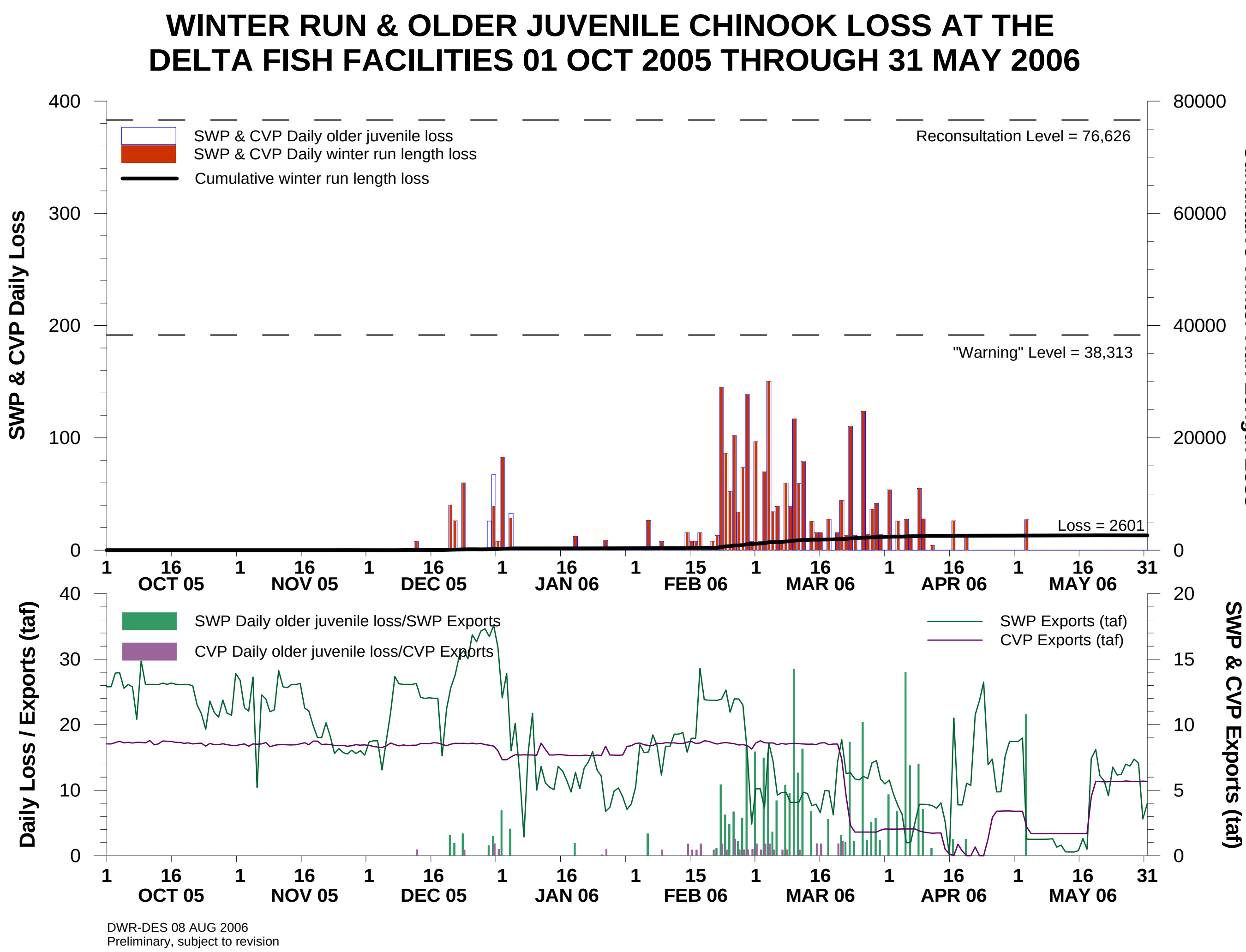


Figure 6-24 Winter-run and older juvenile Chinook loss at Delta fish facilities, October 2005-May 2006.

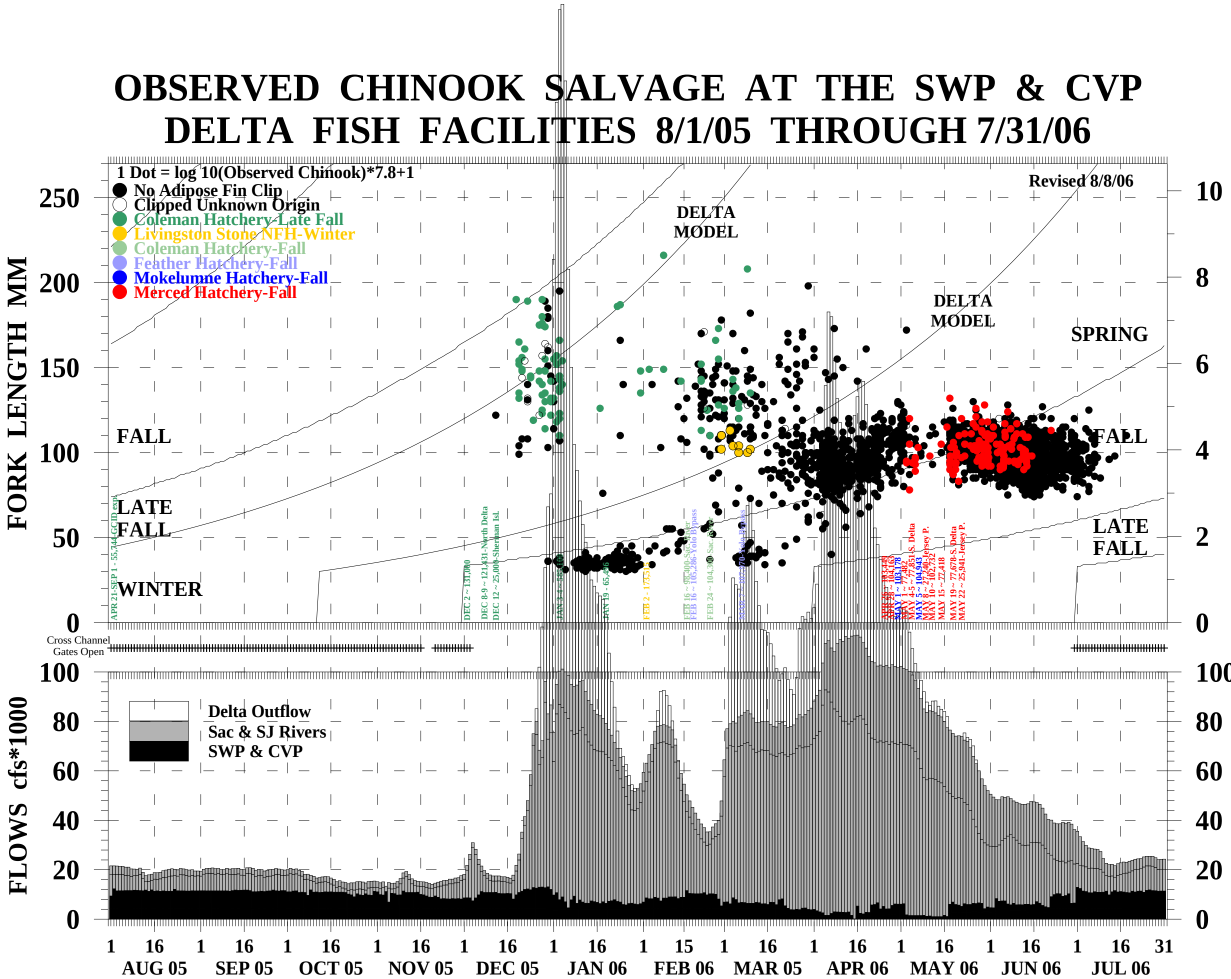


Figure 6-25 Observed Chinook salvage at the SWP and CVP delta fish facilities, 8/1/05 – 7/31/06.

Changes in the Delta Ecosystem and Potential Effects on Winter-Run, Spring-Run and Fall/Late-Fall-Run Chinook Salmon

Changes in estuarine hydrodynamics have adversely affected a variety of organisms at all trophic levels, from phytoplankton and zooplankton to the young life stages of many fish species (Jassby et al. 1995; Arthur et al. 1996; Bennett and Moyle 1996). Ecological processes in the Delta have also been affected by interactions among native and introduced species (Bennett and Moyle 1996; Kimmerer and Orsi 1996), the various effects of water management on Delta water quality and quantity (Arthur et al. 1996), and land use practices within the watershed (Simenstad et al. 1999). Cumulatively, these changes may have diminished the suitability of the Delta as a juvenile salmon rearing habitat and may have reduced the survival of young salmon migrating through the Delta to the Pacific Ocean. Population level effects of changes in the Delta are complex and have not been quantified.

As juvenile salmon from the Sacramento basin migrate through the Delta toward the Pacific Ocean, they encounter numerous junctions in the river and Delta channels (both natural and human-made). Two such junctions are located near Walnut Grove at the Delta Cross Channel (DCC) (a man-made channel with an operable gate at the entrance) and Georgiana Slough (a natural channel). Both channels carry water from the Sacramento River into the central Delta. The relatively high-quality Sacramento River water flows into the central Delta, mixes with water from the east-side tributaries (Mokelumne, Cosumnes and Calaveras Rivers) and the San Joaquin River. This mixture, which much of the time is predominantly Sacramento River water, flows westward through the estuary or is pumped from the Delta water in-Delta water users or for use south of the Delta.

Significant amounts of flow and many juvenile salmon from the Sacramento River enter the DCC (when the gates are open) and Georgiana Slough. Mortality of juvenile salmon entering the central Delta is higher than for those continuing downstream in the Sacramento River. This difference in mortality could be caused by a combination of factors: the longer migration route through the central Delta to the western Delta, exposure to higher water temperatures, higher predation rates, exposure to seasonal agricultural diversions, water quality impairments due to agricultural and municipal discharges, and a more complex channel configuration making it more difficult for salmon to successfully megrate to the western Delta and the ocean.

Water is drawn from the central Delta through lower Old River and Middle River to the export pumps when combined CVP/SWP pumping exceeds the flow of the San Joaquin River water down the upper reach of Old River and Middle Rivers. This situation likely increases the risk of juvenile salmon migrating to the south Delta and perhaps being entrained at the SWP and CVP facilities. This condition can be changed either by reducing exports or increasing Delta inflows or the use of physical barriers and gates. Decreasing exports to eliminate net upstream flows (or, if net flows are downstream, cause an increase in positive downstream flows) may reduce the chances of migrating juvenile salmonids moving up lower Old River towards the CVP/SWP diversions. Tidal flows, which are substantially greater than net flows, play an important role in salmon migrations.

Juvenile salmon, steelhead and other species of fish in the south Delta are directly entrained into the SWP and CVP export water diversion facilities (Table 6-8, Table 6-9, Table 6-10,Figure 6-26, Figure 6-27). Many juvenile salmon die from predation in Clifton Court Forebay before they reach the SWP fish screens to be salvaged (80 percent mortality currently used in loss calculations based on Gringas 1997) and approved by the fishery agencies. Loss at the SWP is thought to vary inversely with the pumping rate because when water is drawn through Clifton Court Forebay faster, salmon are not exposed to predation for as long (Buell 2003). At the CVP pumping facilities the loss rate through the facility for Chinook is about 33 percent.

Salmon from the San Joaquin Basin, and those migrating from the Sacramento River or east Delta tributaries through the central Delta are more directly exposed to altered channel flows due to exports and to entrainment because their main migration route to the ocean puts them in proximity to these diversions. Some juvenile salmon migrating down the main stem Sacramento River past Georgiana Slough may travel through Three-Mile Slough or around Sherman Island and end up in the southern Delta. There is a lack of understanding about how or why salmon and steelhead from the north Delta end up at the diversions in the south Delta, particularly regarding the influence of the SWP and CVP export pumping. Nevertheless it is clear that once juvenile salmon are in the vicinity of the pumps, they are more likely to be drawn into the diversion facilities with the water being diverted. By reducing the pumping rate, entrainment of fish, and therefore loss (loss = number of fish salvaged multiplied by prescreen loss from predation, louver efficiency, and survival through the salvage process to release) of these fish may be reduced. If reservoir releases are not reduced simultaneously, the net flow patterns in Delta channels are changed to the benefit of emigrating salmonids and other fish. The relative magnitude and significance of these factors on direct and indirect mortality of juvenile salmon, however, has not been quantified.

Table 6-8 Total Chinook salmon salvage (all sizes combined) by year at the SWP and CVP salvage facilities (Source: DFG fish salvage database).

Year	SWP	CVP	Total
1981	101,605	74,864	176,469
1982	278,419	220,161	498,580
1983	68,942	212,375	281,317
1984	145,041	202,331	347,372
1985	140,713	137,086	277,799
1986	435,233	752,039	1,187,272
1987	177,880	92,721	270,601
1988	151,908	54,385	206,293
1989	106,259	42,937	149,196
1990	35,296	6,107	41,403
1991	39,170	31,226	70,396
1992	22,193	41,685	63,878

Year	SWP	CVP	Total
1993	8,647	20,502	29,149
1994	3,478	12,211	15,689
1995	19,164	64,398	83,562
1996	14,728	39,918	54,646
1997	11,853	53,833	65,686
1998	3,956	167,770	171,726
1999	50,811	132,886	183,697
2000	45,613	78,214	123,827
2001	28,327	29,479	57,806
2002	6,348	15,573	21,921
2003	17,339	15,977	33,336
2004	12,393	24,110	36,503
2005	13,050	25,625	38,675
2006	8,611	34,923	43,534
2007	833	3,709	4,542

Table 6-9 Average Chinook salmon salvage (all sizes and marks combined) by facility 1981 - 1992.

Month	SWP	CVP
Jan	2,889	1,564
Feb	5,989	47,227
Mar	7,679	8,241
Apr	40,552	33,983
May	56,327	55,146
Jun	21,863	15,929
Jul	496	2,105
Aug	232	233
Sep	33	0
Oct	1,474	4,814
Nov	2,181	4,133
Dec	9,682	3,365

Table 6-10 Average Chinook salmon salvage (all sizes and marks combined) by facility, 1993 - 2007.

Month	SWP	CVP
Jan	1,439	4,389
Feb	1,000	7,726
Mar	1,597	5,194
Apr	6,008	12,126
May	4,910	12,749
Jun	1,921	6,197
Jul	65	246
Aug	30	18
Sep	145	108
Oct	40	56
Nov	29	116
Dec	300	403

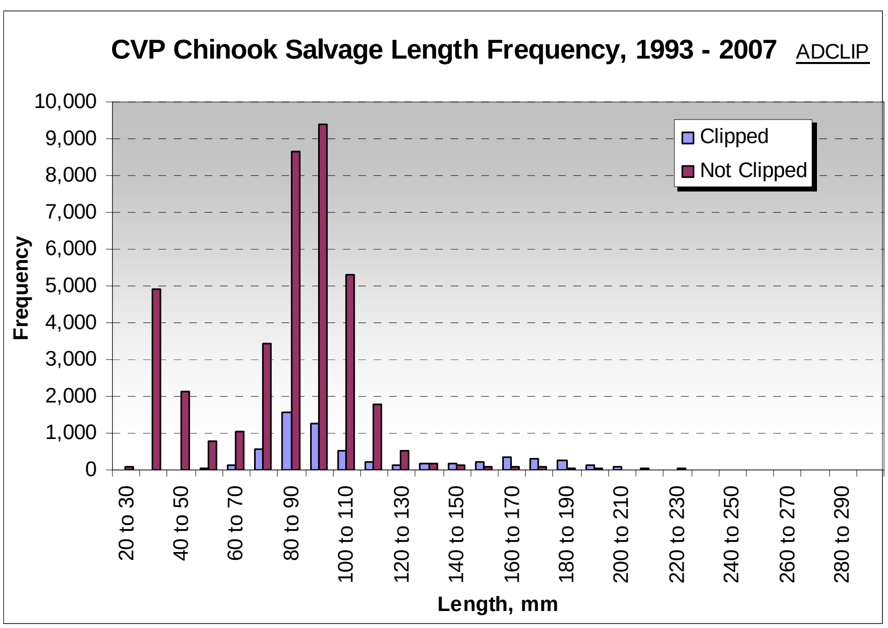


Figure 6-26 Length frequency distribution of Chinook salvaged at the CVP.

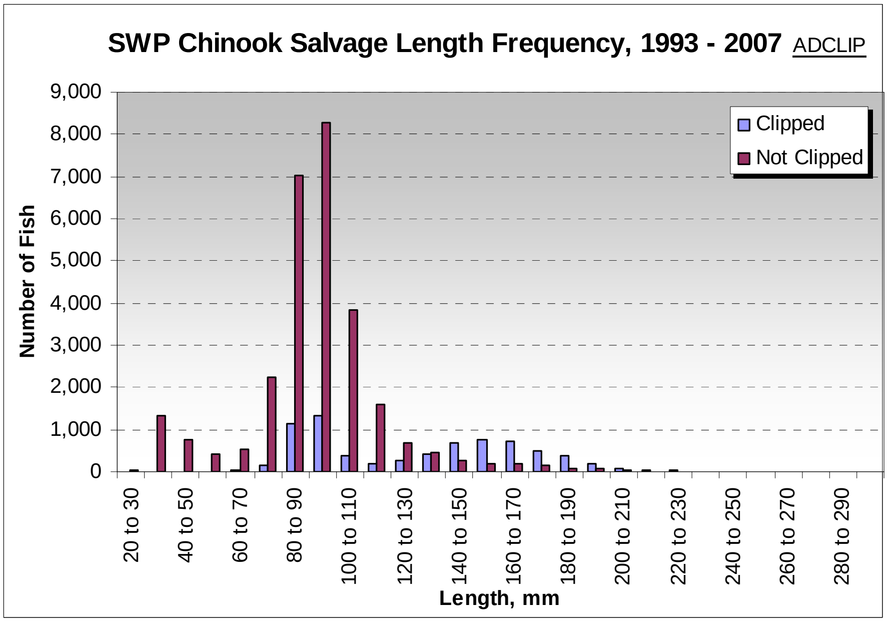


Figure 6-27 Length frequency distribution for Chinook salvaged at SWP.

Past Chinook salmon expanded loss density (fish lost per cfs of water pumped) for winter-run and spring-run are shown in Figure 6-28 through Figure 6-31 for the Tracy Fish Salvage Facilities (CVP) and the Skinner Fish Salvage Facilities (SWP).

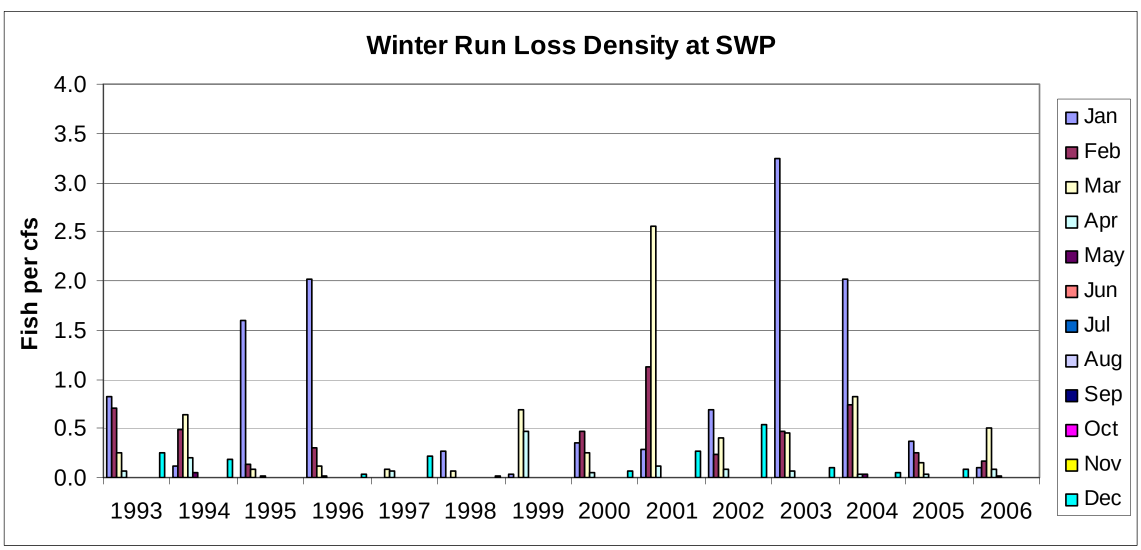


Figure 6-28 Winter run loss per cfs at the SWP, 1993 – 2006.

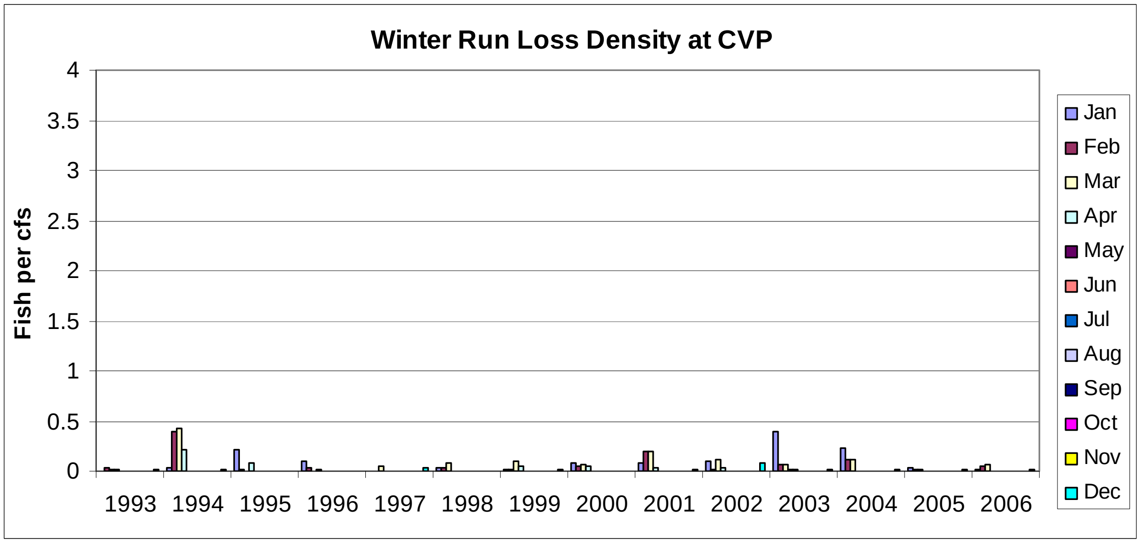


Figure 6-29 Winer run loss per cfs at the CVP, 1993 – 2006.

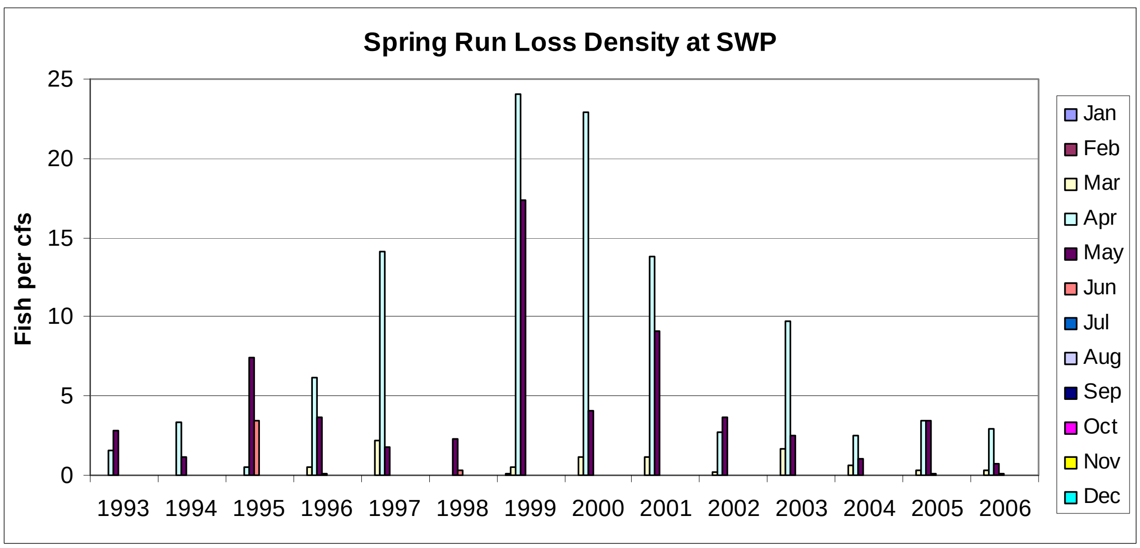


Figure 6-30 Spring run loss density (fish per cfs) at the SWP.

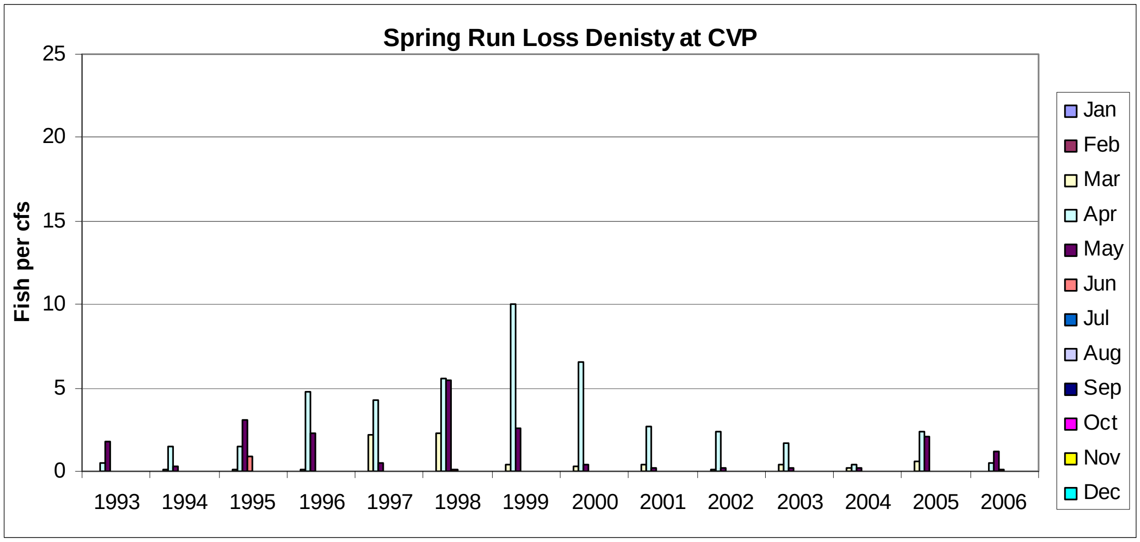


Figure 6-31 Spring run loss density (fish per cfs) at the CVP.

Although the number of fish entrained by the SWP and CVP appear large or of concern, the number is generally relatively small compared to number of outmigrating smolts or the overall population. In most years, the entrainment of fish by the SWP and CVP is limited to very small percent (i.e. less than 2 percent for winter-run) of the outmigrating smolts.Indirect In-Delta Effects on Salmon.

Indirect In-Delta Effects on Chinook Salmon SWP/CVP

Delta water project effects on rearing and migrating juvenile Chinook salmon are both direct (based on observations of salvaged fish at the fish salvage facilities) and indirect (mortality in the Delta that is related to export operations). The entrainment rate (direct loss) of juvenile salmon at the facilities is an incomplete measure of water project impact to juvenile salmon, because it does not include indirect mortality in the Delta.

There are indirect effects on salmon caused by natural and human alterations that increase the route through the central Delta to the western Delta, higher water temperatures, higher predation, and impairments due to agricultural and municipal discharges.

FWS CWT studies have been used to assess survival rates of juvenile Chinook migrating through the Delta relative to those remaining in the Sacramento River (Kjelson et al. 1982, Newman and Rice 1997, Brandes and McLain 2001). Results of these studies suggest survival rates are higher for fish that remain in the Sacramento River, although they do not provide quantitative information regarding what proportion of emigrants remain in the main river, compared to fish that enter the central Delta through the DCC and Georgiana Slough. Many potential influencing factors have been suggested as indirect effects to salmon survival that may occur when salmon move into the central and/or south Delta from the Sacramento River. Most of these have not been explicitly studied, but the available information is discussed below.

Length of Migration Route and Residence Time in the Delta

The length of time Chinook juvenile salmon spend in the lower rivers and the Delta varies depending on the outflow, time of year the salmon emigrate, and the developmental stage of the fish (Kjelson et al. 1982). Residence times tend to be shorter during periods of high flow relative to periods of low flow, and tend to be longer for fry than for smolts. A proportion of the Chinook salmon production enters the Delta as fry or fingerlings rather than as smolts (DFG 1998). Extending Delta residence time for any juvenile salmon likely increases their susceptibility to the cumulative effects of mortality factors within the Delta but also decreases susceptibility to mortality once they enter the ocean because they are larger.

Much attention has been given to the lower river migration route of salmon produced in the Sacramento watershed (Kjelson et al. 1982; Stevens and Miller 1983; Brandes and McLain 2001). At issue is the migration route via Georgiana Slough (about 37 miles to Chipps Island) compared to that in the Sacramento River from Ryde (27 miles to Chipps Island). Tests completed by FWS found survival is higher for late-fall-run Chinook smolts released in the Sacramento River at Ryde versus Georgiana Slough even though the Georgiana Slough route is only 1.4 times longer. Fish emigrating through Georgiana Slough probably have increased residence time in the Delta due to both the longer travel distance and the generally lower flows in the slough. These factors potentially increase the duration of a migrating salmon’s exposure to migration hazards. DCC closures are one of the actions being taken to reduce the likelihood that juvenile Chinook salmon will use an internal Delta route.

The following is an analysis of the relationships between the through-Delta survival of Coleman Hatchery late-fall-run Chinook smolts, Delta export losses of these fish in the fall and winter, and Delta hydrologic variables.

FWS has conducted these experiments using late-fall-run smolts since 1993. The purpose of the experiments is to determine what factors in the Delta affect yearling Chinook survival. One factor hypothesized to affect survival is emigration route. Based on previous results for fall-run salmon (Brandes and McLain 2001) FWS hypothesized yearlings emigrating through the interior Delta survive at a lower level than juveniles emigrating through the main stem Sacramento River (Brandes and McLain 2001). The juveniles can enter the interior Delta through Georgiana Slough or the DCC when it is open. Since FWS does not have measurements of gear efficiency for its Chipps Island trawl, and gear efficiency is assumed to vary from experiment to experiment, the survival estimates are considered indices of relative survival, not absolute numbers of survivors. To overcome this limitation, FWS uses the ratio of the survival indices of paired releases in the interior Delta and the main stem Sacramento River at Ryde. Evaluating the relative interior Delta survival cancels out differences in gear efficiency.

Models generated using the data from CWT’ed juvenile salmon support the conclusion that closure of the DCC gates will improve survival for smolts originating from the Sacramento Basin and emigrating through the Delta. The greatest mortality for smolts between Sacramento and Chipps Island was in the central Delta, and survival could be improved if the gates were closed (Kjelson et al. 1989). However, survival for salmon smolts released in the Sacramento River upstream of the DCC and Georgiana Slough are generally higher than those for releases made at downstream, mainstem locations (e.g. Ryde) or into the interior delta (Delta Action 8 Workshop, Brown and Kimmerer 2006). This trend suggests that experimental smolt releases intended to evaluate through delta survival may not be representative for naturally salmon outmigrating either because relatively few fish actually enter the interior delta or because smolt releases into Georgiana Slough are subject to uncontrolled experimental artifacts (e.g. shock effect, disorientation) which negatively bias observed survival rates.

In a generalized linear model that estimates the effects of various parameters on salmon smolt survival through the Delta, Newman and Rice (1997) found that mortality was higher for smolts released in the interior Delta relative to those released on the main stem Sacramento River. They also found lower survival for releases on the Sacramento River associated with the DCC gate being open. Using paired release data, Newman (2000) found that the DCC gate being open had a negative effect on the survival of smolts migrating through the Delta and was confirmed using Baysian and general linear modeling (Newman and Remington 2000).

The analyses to date appear to support the conclusion that closing the DCC gates will improve the survival of smolts originating from the Sacramento basin and migrating through the Delta. However, a recent particle tracking study (Kimmerer and Nobriga 2008) shows that DCC closure results in substantial compensatory increases in the proportion of Sacramento River water flowing into Georgiana Slough, Threemile Slough, and at the confluence of the Sacramento and San Joaquin Rivers. This result suggests that DCC closure may have less influence on the potential for central Delta fish mortality than previously supposed.

Radio-tracking studies of large juvenile salmon in the Delta (Vogel 2003) showed that localized currents created by the DCC operations and flood and ebb tide cycles greatly affected how radio-tagged Chinook moved into or past the DCC and Georgianna Slough. Chinook migration rates were generally slower than the ambient water velocities. Chinook were documented moving downstream past the DCC during outgoing tides and then moving back upstream and into the DCC with the incoming tide. When the DCC gates were closed, Chinook movement into Georgianna Slough was unexpectedly high, probably due to fish positions in the water column in combination with physical and hydrodynamic conditions at the flow split. Radio-tagged smolts moved large distances (miles) back and forth with the incoming and outgoing tides. Flow conditions at channel splits were a principal factor affecting the routes used by migrating salmon. Hydroacoustic tracking and trawling (Horn 2003, Herbold and Pierce 2003) showed that juvenile Chinook in the vicinity of the DCC were most actively moving at night and that they tend to go with the highest velocity flows. Water flow down through the DCC is much greater during the incoming tidal cycles than on the outgoing tides. These results suggest that during periods of high juvenile salmonid abundance in the vicinity of the DCC, closing the gates during the incoming tidal flows at night could reduce juvenile salmon movement into the central Delta through the DCC but may also increase movement into Georgianna Slough.

The survival indices and estimated losses of juvenile Chinook at the Delta fish facilities for all Georgiana Slough and Ryde releases since 1993 are illustrated in Figure 6-32. A unique symbol is used to highlight each paired experiment. In every paired experiment, the survival index of the Ryde release was higher than the Georgiana Slough release. Evaluating the Georgiana Slough and Ryde data separately, the Georgiana Slough releases all have low survival over a wide range of losses, and the Ryde releases all have low losses over a wide range of survival indices. Survival indices and losses for each of the Georgiana Slough and Ryde releases were not strongly correlated.

Delta hydrology is another factor hypothesized to affect juvenile Chinook survival, although hydrology should not be viewed independently from effects of migration route. The relative interior Delta survival of Coleman late-fall juveniles was plotted against Delta exports, Sacramento River flow, QWEST, and export to inflow ratio. The explanatory (hydrologic) variables are average conditions for 17 days from the day of release. This value was selected by FWS based on previously collected data on the average travel time from the release sites to Chipps Island. The combined CVP and SWP expanded losses from salvage for each of the Georgiana Slough and Ryde releases are also plotted against the same four hydrologic variables. A linear regression was calculated.

Regression and correlation analyses of these data (1993-98) indicate that the survival of smolts released into Georgiana Slough is increased as exports are reduced, relative to the survival of salmon released simultaneously at Ryde (Figure 6-33). These findings are the basis for reducing exports to further protect juvenile salmon migrating through the Delta. There was also a trend of increased loss of Georgiana Slough releases with increased exports, but it was not statistically significant (Figure 6-34).

Relationships between relative survival (Figure 6-35) or late-fall-run Chinook salvage at the Delta export facilities (Figure 6-36) and Sacramento River flow were not statistically significant. QWEST was also a poor predictor of both relative survival (Figure 6-37) and losses to the export facilities (Figure 6-38).

This data demonstrate that there may be relationships between certain factors and take of salmon. The data do not demonstrate, however, that the take affects the abundance of salmon.

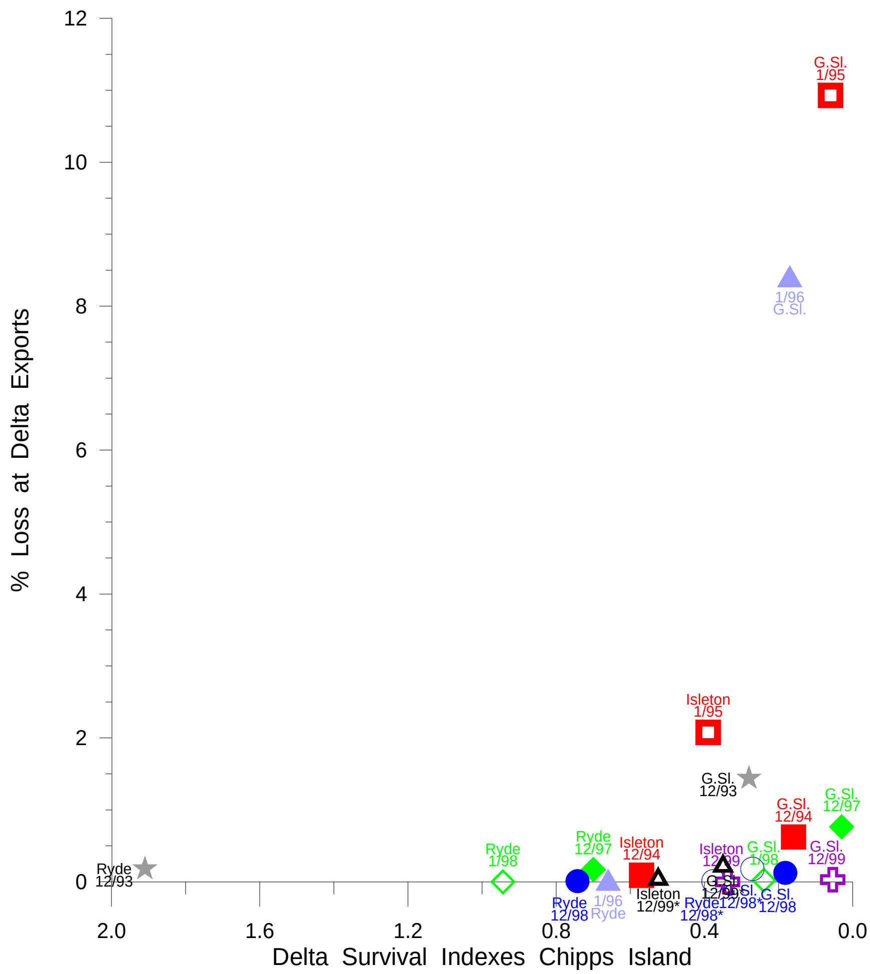


Figure 6-32 Scatterplot of Delta survival indices for Coleman Hatchery late-fall-run Chinook salmon from paired release experiments in the Sacramento River and Georgiana Slough v. percentage of the release group salvaged at the CVP and SWP Delta facilities.

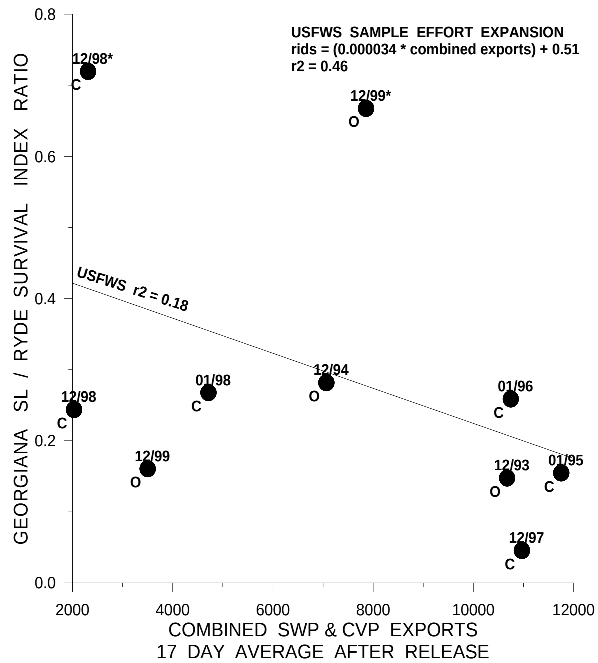


Figure 6-33 Relationship between Delta exports and the Georgiana Slough to Ryde survival index ratio. The export variable is combined average CVP and SWP exports for 17 days after release.

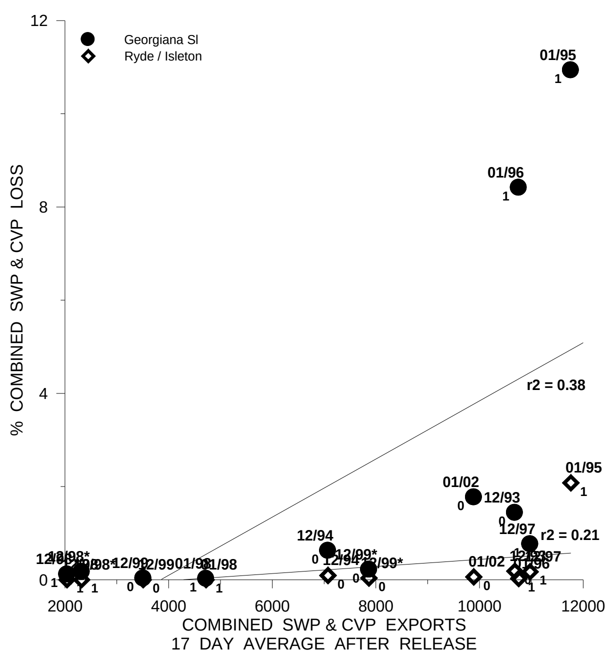


Figure 6-34 Relationship between Delta exports and percentage of late-fall-run CWT Chinook salmon Delta release groups salvaged at the CVP and SWP Delta facilities. The export variable is combined average CVP and SWP exports for 17 days after release.

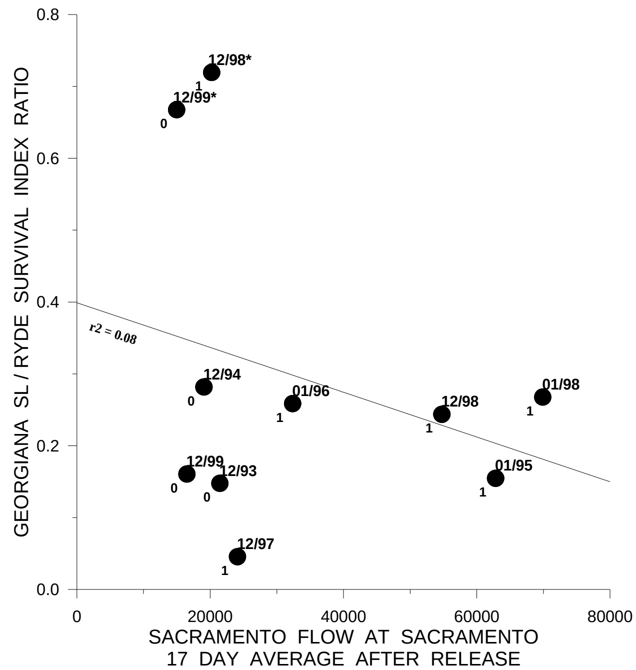


Figure 6-35 Relationship between Sacramento River flow and the Georgiana Slough to Ryde survival index ratio. The flow variable is average Sacramento River flow at Sacramento for 17 days after release.

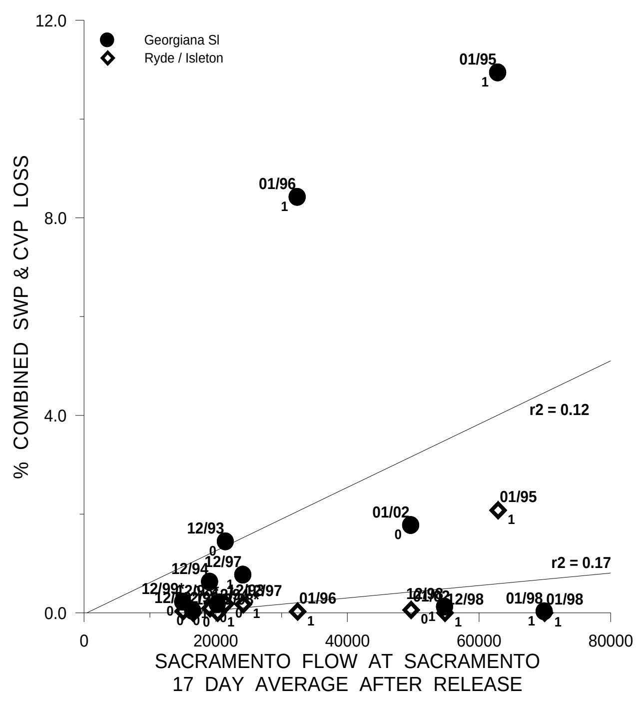


Figure 6-36 Relationship between Sacramento River flow and the percentage of late-fall-run CWT Chinook salmon Delta release groups salvaged at the CVP and SWP Delta facilities. The flow variable is average Sacramento River flow at Sacramento for 17 days after release. Georgiana Slough and Ryde releases are plotted separately.

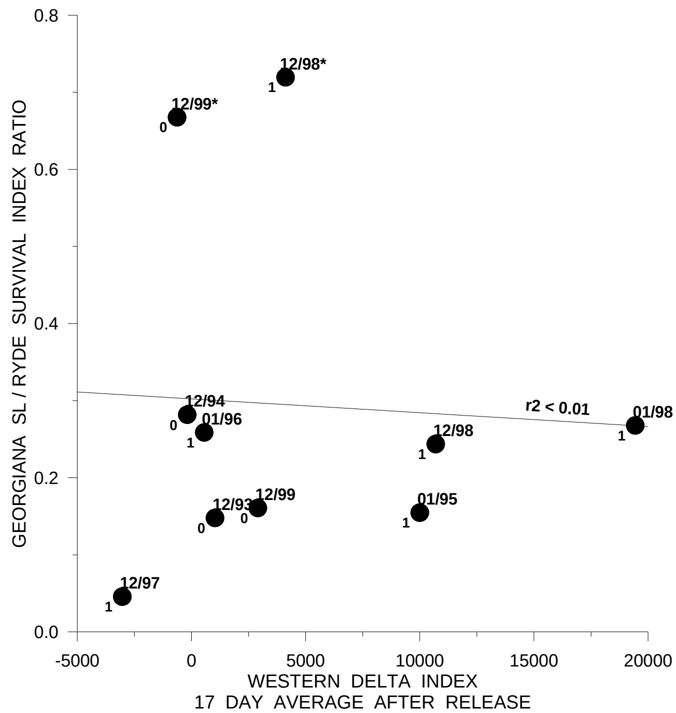


Figure 6-37 Relationship between QWEST flow and the Georgiana Slough to Ryde survival index ratio. The flow variable is average QWEST flow for 17 days after release.

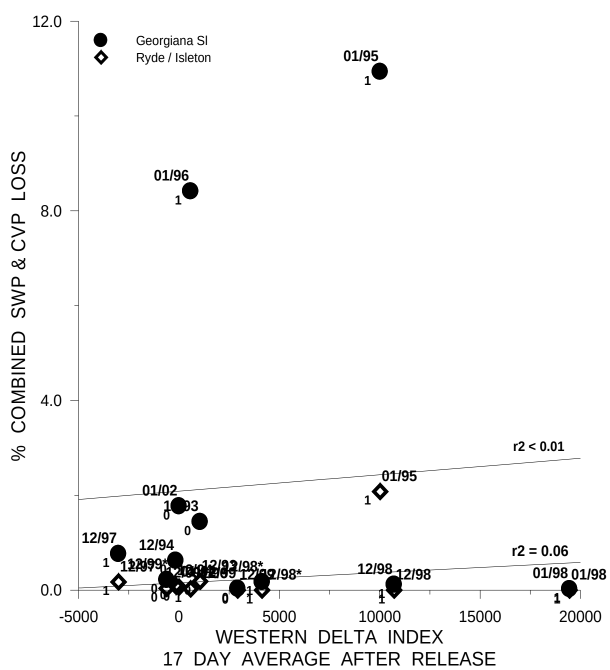


Figure 6-38 Relationship between QWEST flow and the percentage of late-fall-run CWT Chinook salmon Delta release groups salvaged at the CVP and SWP Delta facilities. The flow variable is average QWESTflow for 17 days after release.

There was no evidence of decreased relative survival with increased export to inflow ratio (Figure 6-39). The relationship between the export to inflow ratio and the percentage of late-fall-run yearlings salvaged was highly insignificant (Figure 6-40), providing no evidence that entrainment is the primary mechanism for reduced relative survival. Newman and Rice (1997), and more recent work by Newman (2000), suggests that reducing export pumping will increase the survival for smolts migrating through the lower Sacramento River in the Delta. Newman and Rice's updated 1997 extended quasi-likelihood model (Ken Newman, personal communication) provides some evidence that increasing the percent of Delta inflow diverted (export to inflow (E/I) ratio) reduces the survival of groups of salmon migrating down the Sacramento River, but the effect was slight and not statistically significant. In Newman's extended quasi-likelihood model using paired data, there was a significant export effect on survival (approximate *P* value of 0.02 for a one-sided test) (Newman 2000).

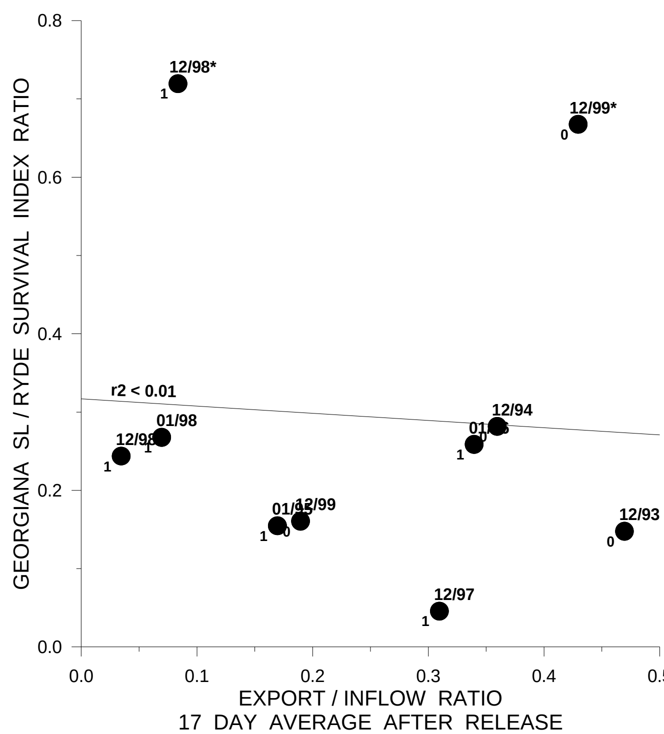


Figure 6-39 Relationship between Export/Inflow ratio and the Georgiana Slough to Ryde survival index ratio. The flow variable is average Export/Inflow ratio for 17 days after release.

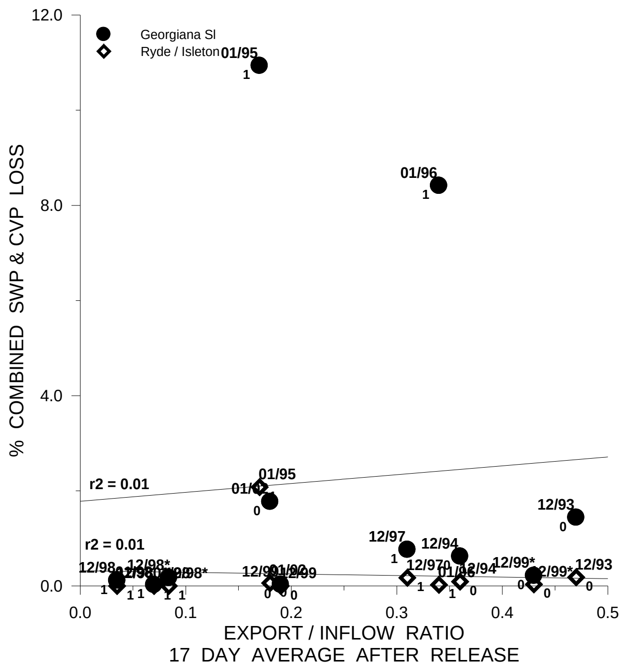


Figure 6-40 Relationship between Export/Inflow ratio and the percentage of late-fall-run CWT Chinook salmon Delta release groups salvaged at the CVP and SWP Delta facilities. The flow variable is average Export/Inflow ratio for 17 days after release.

In summary, no significant linear relationships were found between the Georgiana Slough-Ryde survival ratios for the Coleman late-fall-run releases, or the losses of these fish at the Delta export facilities, and commonly used Delta hydrologic variables. Although not statistically significant, relative interior Delta survival was high and losses of both Georgiana Slough and Ryde release groups were low during one of the two low-export experiments. At high exports, relative interior Delta survival was generally lower, with relatively high losses of Georgiana Slough release groups on two occasions. The data are not sufficient to provide the information necessary to quantify the benefit of export reductions to the Chinook population, due to the lack of information on the proportion of yearling emigrants using the DCC or Georgiana Slough routes. The relatively high degree of statistical uncertainty in most of the current modeled salmon mortality-Delta export relationships precludes highly confident conclusions whether or not exports are consistently and significantly impacting overall juvenile salmon mortality that ultimately affect population dynamics of fishery and spawner recruitment. The data are difficult to use for quantitative guidance in computing a take level or for suggesting a best mitigation measure. The middle poartion of the data sets are the most uncertain, while the extreme ends of the data relationships suggest with a higher degree of certainty that in years with higher fish abundance there is higher take at the pumps and very high export:inflow ratios result in higher take.

FWS Delta experiments were not designed to test the effects of Delta operations on fish released by hatchery personnel upstream of the Delta. However, releases of Coleman Hatchery late-fall-run yearlings in the upper Sacramento River have occurred coincident with the Delta experiments. These were not paired releases, but they were made within a week of the Delta experiments. A comparison of the direct losses of fish released in the upper Sacramento River, and in the Delta is illustrated in Figure 6-41. The losses of the upper Sacramento releases are all very small (less than 2 percent) even though the releases encompass a wide range of hydrologic conditions. In addition, the loss estimates for fish released upstream of the Delta are very similar to those calculated for the Ryde releases and most of the Georgiana Slough releases.

The survival indices of the upper Sacramento River releases may be helpful in the evaluation of effects on the population. This evaluation should be repeated when FWS completes the calculations of the upper Sacramento River releases' survival indices.

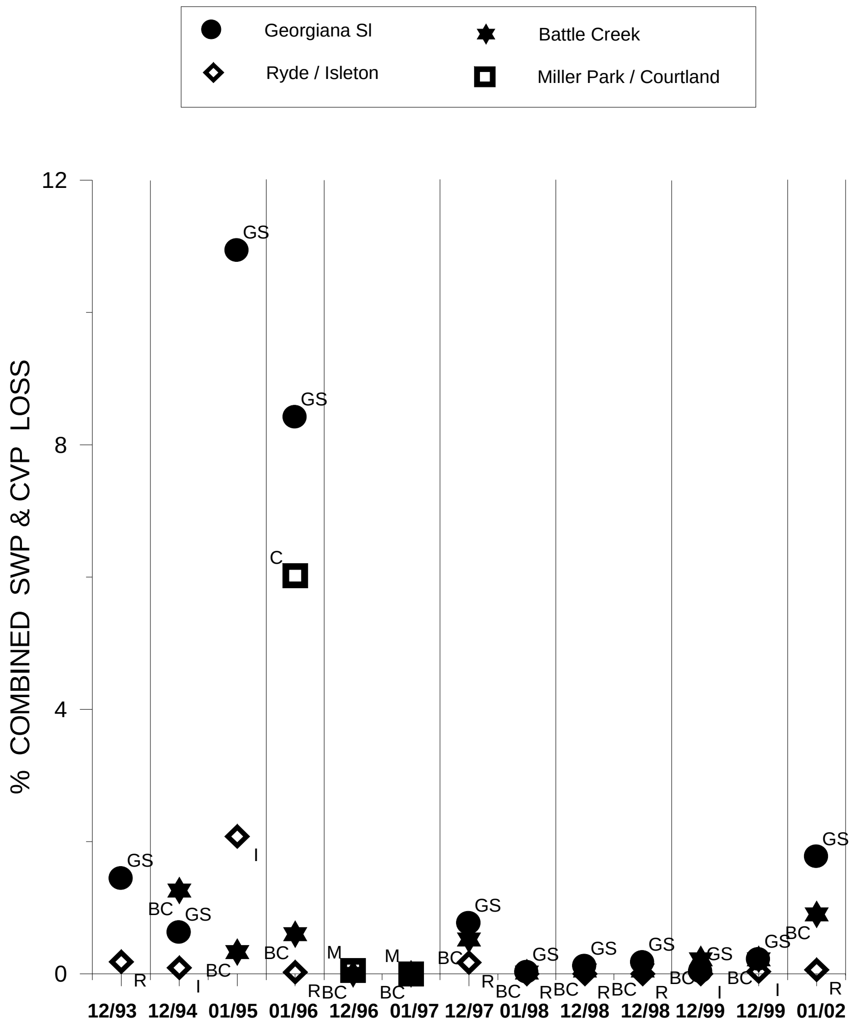


Figure 6-41 The percentage of late-fall-run CWT Chinook salmon Sacramento River and Delta release groups salvaged at the CVP and SWP Delta facilities grouped by release date.

Altered Flow Patterns in Delta Channels

Flow in the Delta results from a combination of river-derived flow and tidal movement. The relative magnitudes of river and tidal flow depend on location and river flow, with greater tidal dominance toward the west and at lower river inflows. The presence of channel barriers at specific locations has a major influence in flow dynamics. Tidal flows, because of the complex geometry of the Delta, can produce net flows independent of river flow and cause extensive mixing. During high-flow periods, water flows into the Delta from Valley streams. During low-flow periods, flow in the San Joaquin River is lower than export flows in the southern Delta, so water is released from reservoirs to provide for export and to meet salinity and flow standards in the Delta.

Particle tracking models, using data from direct measurement of river or channel velocities and volume transport at various Delta locations, have given us our most recent view of net flow in Delta channels. The general trend of model results seems to be that particles released in the Delta will move generally in the direction of river flow but the distribution of particles spreads extensively due to tidal dispersion. SWP, CVP and Delta island agricultural diversions impose a risk that the particle will be lost, as a result of entrainment at the diversions, from the system. This risk increases with greater diversion flow, initial proximity of the particle to the diversion, and duration of the model run.

Tidal flow measurements allow calculation of tidally averaged net flows. Results indicate that tidal effects are important in net transport, and that net flow to the pumping plants is not greatly affected by the direction of net flow in the western (lower) San Joaquin River.

With respect to fish movement, relatively passive life stages as Delta smelt larvae should move largely under the influence of river flow with an increasing behavioral component of motion as the fish develop. Larger, strong-swimming salmon smolts are more capable of moving independently but may still be affected to some degree by river flow. Particle tracking model results are not being used for the salmonid effects analysis.

Altered Salinity in the Delta

Increasing salinity westward through the estuary may provide one of many guidance cues to emigrating juvenile salmon (DFG 1998). Salinity levels in the central and south Delta are sometimes increased above ambient conditions by agricultural return waters from the south Delta and San Joaquin River. Salmon emigrating from the Sacramento River may move into the interior and south Delta in response to the elevated salinity levels. Agricultural return water increases salinity but has a different chemical composition than ocean water so does not likely attract salmon (Oltmann 1998).

Contaminants

The role of potential contaminant-related effects on salmon survival in the Delta is unknown (DFG 1998). Elevated selenium levels in the estuary may affect salmon growth and survival. The EPA is pursuing reductions in selenium loadings from Bay Area oil refineries, and the San Francisco Regional Water Quality Control Board has recommended an additional 30 percent reduction in selenium levels to adequately protect the Bay's beneficial uses. Nonpoint sources (including urban and agricultural runoff) contribute to elevated levels of polychlorinated biphenyls (PCBs) and chlorinated pesticides, which have been found in the stomach contents of juvenile salmon from the Bay, the Delta, and from hatcheries (NMFS 1997, as cited in DFG 1998). Collier (2002) found that juvenile Chinook salmon in Puget Sound estuaries were contaminated with sediment-associated contaminants such as PCBs. He found a reduced immune response affecting fitness in these fish. These contaminants may also affect lower-level food-web organisms eaten by juvenile salmon, or bioaccumulate in higher trophic level organisms like the salmon themselves.

During periods of low flow and high residence time of water through the Stockton deep-water ship channel, high oxygen demand from algae concentrations can deplete dissolved oxygen to lethal levels. This can result in a barrier to upstream and downstream migrating salmon and steelhead and could kill fish present in the area of low-dissolved oxygen.

Food Supply Limitations

Food limitation and changes in the Delta's invertebrate species composition have been suggested as factors contributing to abundance declines and/or lack of recovery of estuarine-dependent species such as Delta smelt and striped bass (Bennett and Moyle 1996; Kimmerer et al. 2000). There is no direct evidence of food limitation for salmon in the Delta or lower estuary (DFG 1998). However, there is evidence that some habitats (like nonnatal tributaries and Yolo Bypass) may provide relatively better feeding and rearing opportunities for juvenile Chinook than the channelized Sacramento River (Moore 1997; Sommer et al. 2001b). Improved feeding conditions contribute to faster growth rates for fish using these habitats. Faster growth may yield at least a slight survival advantage, but the current evidence is insufficient to demonstrate this effect with statistical significance (Sommer et al. 2001b).

Predation and Competition

Predation is an important ecosystem process that helps to structure and maintain fish communities. Predation effects are very difficult to discern in nature because they are typically nonlinear and density-dependent (Bax 1999). Even without human intervention, natural predation rates are affected by spatio-temporal overlap of predators and prey, activity and metabolic needs of predators and prey at different temperatures, efficiency of different types of predators at capturing different prey, and the relative availability of appropriate prey types. Every Central Valley and Pacific Ocean predator's diet includes prey items other than salmon. Anthropogenic changes to ecosystems can alter these predator-prey dynamics, resulting in artificially elevated predation rates (Pickard et al. 1982a; Gingras 1997). Perhaps the most significant example of altered predation rates on Chinook salmon is human predation through harvest, which is discussed in the next section. Excepting direct human harvest, there are three factors that could affect predation dynamics on juvenile salmon in the project area. These are changes in the species composition and diversity of potential salmon predators through exotic species introductions, changes in the abundance of potential salmon predators (both of these may or may not be coupled to habitat alteration), and the placement of large structures in the migratory pathways of the salmon.

Striped bass and largemouth bass were introduced into the system and although they have coexisted with Chinook salmon, the Delta ecosystem has changed and altered this relationship. Chinook may be more sensitive to predation by these species now than in the past.

Changes in the species composition of predators can cause fish declines. Many potential salmon predators have been introduced to Central Valley waterways, particularly during the latter part of the 1800s and the early part of the 1900s (Dill and Cordone 1997). These included piscivorous fishes like striped bass, largemouth bass, crappies, and white catfish. Channel catfish is another common Delta-resident piscivore that seems to have become established considerably later, during the 1940s. All of these fish were establishing Central Valley populations during a time spring-run Chinook were declining for a variety of reasons. This makes it difficult to determine whether one or more of these predatory fishes significantly affected juvenile salmon survival rates.

There have been substantial changes in the abundance of several potential Chinook salmon predators over the past 20 to 30 years. These changes could have altered the predation pressure on salmon, but the data needed to determine this have not been collected. A few examples of changes in potential predator abundance are discussed below.

The striped bass is the largest piscivorous fish in the Bay-Delta. Its abundance has declined considerably since at least the early 1970s (Kimmerer et al. 2000). Both striped bass and spring-run and winter-run Chinook were much more abundant during the 1960s (DFG 1998) when comprehensive diet studies of striped bass in the Delta were last reported on. During fall and winter 1963-1964, when spring-run yearlings and juvenile winter-run would have been migrating through the Delta, Chinook salmon only accounted for 0 percent, 1 percent, and 0 percent of the stomach content volume of juvenile, subadult, and adult striped bass respectively (Stevens 1961). During spring and summer 1964, Chinook salmon accounted for up to 25 percent of the stomach content volume of subadult striped bass in the lower San Joaquin River, although most values were less than 10 percent. Presumably most of these spring and summer prey were fall-run since they dominate the juvenile salmon catch during that time of year. These results do not suggest striped bass had a major predation impact on spring-run Chinook during the year studied, though a year is not adequate to draw firm conclusions. Despite lower population levels, striped bass are suspected of having significant predation effects on Chinook salmon near diversion structures (see below).

Although striped bass abundance has decreased considerably, the abundance of other potential Chinook salmon predators may have increased. Nobriga and Chotkowski (2000) reported that the abundance of virtually all centrarchid fishes in the Delta, including juvenile salmon predators like largemouth bass and crappies, had increased since the latter 1970s, probably as a result of the proliferation of Brazilian water weed, *Egeria densa*. The increase in largemouth bass abundance is further corroborated by DFG fishing tournament data (Lee 2000). Predation by centrarchids such as largemouth bass and bluegill on salmon is probably minor because centrarchids are active at higher temperatures than those preferred by salmon so the two species are not likely present in the same areas at the same time.

Surveys at the Farallon Islands also indicate populations of pinnipeds (seals and sea lions) have increased substantially since the early 1970s (Sydeman and Allen 1999). High concentrations of seals and sea lions at the relatively narrow Golden Gate could impact the abundance of returning adult salmon. However, the extent to which marine mammals target the salmon populations over other prey types has not been studied thoroughly.

Predatory fish are known to aggregate around structures placed in the water, where they maximize their foraging efficiency by using shadows, turbulence, and boundary edges. Examples include dams, bridges, diversions, piers, and wharves (Stevens 1961, Vogel et al. 1988, Garcia 1989, Decoto 1978, all as cited in DFG 1998).

In the past, salmon predation losses to Sacramento pikeminnow predation at RBDD were sometimes high, particularly after large releases of juvenile Chinook from Coleman Hatchery. Currently, predation mortality on juvenile salmonids at RBDD is probably not elevated above the background in-river predation rate (DFG 1998). All spring-run juvenile emigrants should pass RBDD during the gates-out period based on average run timing at RBDD (FWS 1998, as cited in DFG 1998). Winter-run juveniles also should pass primarily during gates out periods. During the gates-out operation (September 15 through May 14) fish passage conditions are run-of-the-river and most of the adverse effects associated with the diversion dam have been eliminated. The structure in the river may congregate predators somewhat but salmonids will not be flushed through gates and likely disoriented as happens when the gates are closed. Gates-out operations are also important in preventing the large aggregations of Sacramento pikeminnow and striped bass that once occurred at RBDD.

The GCID diversion near Hamilton City is another one of the largest irrigation diversions on the Sacramento River (DFG 1998). Predation at this diversion is likely most intense in the spring when Sacramento pikeminnow and striped bass are migrating upstream, juvenile Chinook are migrating downstream, and irrigation demands are high. Predation may be significant in the oxbow and bypass system (DFG 1998), but this was not substantiated during 2 years of study in the GCID oxbow (Cramer et al. 1992). The GCID facility is an atypical oxbow with cooler temperatures and higher flows than most.

Predation in Clifton Court Forebay (CCF) has also been identified as a substantial problem for juvenile Chinook. Between October 1976 and November 1993, DFG conducted 10 mark and recapture experiments in CCF to estimate prescreen loss (which includes predation) of fishes entrained to the forebay (Gingras 1997). Eight of these experiments involved hatchery-reared juvenile Chinook salmon. Prescreen loss (PSL) rates for juvenile fall-run Chinook ranged from 63 percent to 99 percent, and for late-fall-run smolts they ranged from 78 percent to 99 percent. These studies were used to establish the standard prescreen loss figures used today. PSL of juvenile Chinook was inversely proportional to export rate, and striped bass predation was implicated as the primary cause of the losses. Although a variety of potential sampling biases confound the PSL estimates, the results suggest salmon losses are indeed high at the times of year when the studies were conducted. Studies being completed by DWR seek to determine prescreen loss rates for steelhead.

Predation studies have also been conducted at the release sites for fish salvaged from the SWP and CVP Delta pumping facilities (Orsi 1967, Pickard et al. 1982, as cited in DFG 1998). Orsi (1967) studied predation at the old surface release sites, which are no longer in use. Pickard et al. (1982a) studied predation at the currently used subsurface release pipes. Striped bass and Sacramento pikeminnow were the primary predators at these sites. They were more abundant and had more fish remains in their guts at release sites than at nearby control sites. However, Pickard et al. (1982a) did not report the prey species composition found in the predator stomachs. The current release sites release fish in deeper water where tidal currents distribute fish over 7 miles.

DFG conducted predator sampling at the Suisun Marsh Salinity Control Gates (SMSCG) from 1987 through 1993 and concluded the striped bass population increased substantially in the vicinity of this structure (DWR 1997). However, the sampling during 1987 through 1992 did not include a control site to measure background predation potential. During the 1993 study, a control site was added 2 miles upstream. Results from the 1993 study showed no significant differences in catch of predatory fishes between the control site and sampling sites at the SMSCG.

An analysis of the Suisun Marsh Monitoring database indicated few juvenile Chinook salmon (of any race) occur in Suisun Marsh (only 257 were captured by beach seine and otter trawl between 1979 and 1997). This suggests that even if striped bass have increased in abundance at SMSCG, they may not pose a predation problem for the winter-run or spring-run population as a whole. This hypothesis is supported by diet data from striped bass and Sacramento pikeminnow collected near the SMSCG. Only three Chinook salmon were found during 7 years of diet studies (Heidi Rooks, personal communication, 1999). Dominant striped bass prey were fishes associated with substrate, such as three-spine stickleback, prickly sculpin, and gobies (DWR 1997). Dominant pikeminnow prey types were gobies and smaller pikeminnows. Adult Chinook are too large to be consumed by any predatory fishes that inhabit the Delta. Pinnipeds seasonally occur in areas of the Delta to prey on immigrating salmonids.

Ocean Conditions and Harvest

The loss of inland salmonid habitat in the Central Valley to human development has resulted in substantial ecological effects to salmonids (Fisher 1994; Yoshiyama et al. 1998). Ocean sport and commercial fisheries harvest large numbers of adult salmon. Central Valley salmon populations are managed to maintain a fairly consistent level of spawner escapement of 122,000 to 180,000 fall-run Chinook salmon in the Sacramento River watershed (Figure 6-43). The ocean fishery is largely supported by hatchery-reared fall-run Chinook salmon. A large hatchery system is operated to allow these levels of harvest. Harvest may be the single most important source of salmon mortality, but all the hatchery fish probably would not be reared and released if there were no ocean harvest. During 1994 an estimated 109 coded-wire tagged winter-run were harvested in the ocean troll fishery off the California coast while escapement in the Sacramento River was estimated at only 144 fish (Table 5-11). Major changes in ocean harvest regulations were made in 1995, due to ESA concerns for winter-run Chinook. Harvest levels on Central Valley stocks have been lower since 1995. Strong year-classes like 1988 and 1995 were so heavily fished that their reproductive potential was never realized. The 2000 Central Valley fall-run Chinook spawning escapement of 478,000 was the highest recorded since 1953 when an escapement of 478,000 also occurred. The high escapement in 2000 was probably due to above-average precipitation during freshwater residency and good ocean conditions combined. The high escapement in 2000 was exceeded in 2001 when an estimated escapement of 599,158 occurred and again in 2002 with an escapement of 850,000. The reason for the high escapement in 2001 was probably because most of the Chinook were concentrated north of the open commercial fishing area and thus were missed by the commercial fisheries. The commercial harvest in 2001 of 179,600 Chinook was the second lowest harvest since 1966. The Central Valley Index of abundance (commercial landings + escapement) in 2001 was 806,000 Chinook, which was actually lower than the forecasted production based on prior year 2-year-old returns. The Central Valley harvest index in 2001 of 27 percent (percent of production harvested) was the lowest ever recorded. The next lowest harvest index was 51 percent in 1985 (PFMC 2002). This illustrates the substantial effect of ocean harvest on Chinook escapement. Restrictions on ocean harvest to protect southern Oregon and northern California coho salmon, Klamath Chinook, and

Central Valley winter-run and spring-run played a role in the recent high escapements and contributed to the recent increases in winter-run and spring-run escapement to the Central Valley.

Returns of several West Coast Chinook and coho salmon stocks were lower than expected in 2007. In addition, low jack returns in 2007 for some stocks suggest that 2008 returns will be at least as low. Central Valley fall run Chinook escapement was estimated to have been less than 25 percent of predicted returns and below the escapement goal of 122,000 – 180,000 for the first time since the early 1990’s and continuing a declining trend since the recent peak abundance in 2002. For the spring and summer of 2005 (the ocean-entry year for 2004 brood fall Chinook and 2003 brood coho), two approaches to estimating ocean suitability for juvenile salmon both indicated very poor conditions for salmon entering the ocean, indicating poor returns for coho in 2006 and age 3 fall Chinook in 2007. Coast-wide observations showed that 2005 was an unusual year for the northern California Current, with delayed onset of upwelling, high surface temperatures, and very low zooplankton biomass. These poor ocean conditions provide a plausible explanation for the low returns of Central Valley fall Chinook in 2007 and coho in 2006 and 2007. Consistent with Central Valley fall Chinook record low jack return in 2007, the ocean indicators would predict very low fall Chinook adult returns in 2008 (Varanasi and Bartoo, 2008).

MacFarlane et al (2008) report on the Wells Ocean Productivity Index (WOPI), a composite index of 13 oceanographic variables and indices, weighted heavily by sea level height, sea surface temperature, upwelling index, and surface wind stress, has been used to accurately predict zooplankton, juvenile shortbelly rockfish, and common murre production along the California coast, and is thus a valid indicator of ocean productivity. Index values for the spring-summer of 2005 and 2006 were low, indicating poor conditions for growth and survival (Figure 6-42). In fact, only the El Niño years (1982-83, 1992-93, 1999) had lower WOPI values. The WOPI assesses conditions on a local scale for California, but has tracked another index, the Northern Oscillation Index (NOI), which is based on the strength of the North Pacific high pressure cell and describes a broader region of the North Pacific Ocean. In 2005 and 2006, the WOPI decoupled from the NOI, suggesting local conditions on the California coast were worse than for the larger North Pacific region. The WOPI also predicts low Chinook returns for 2008.

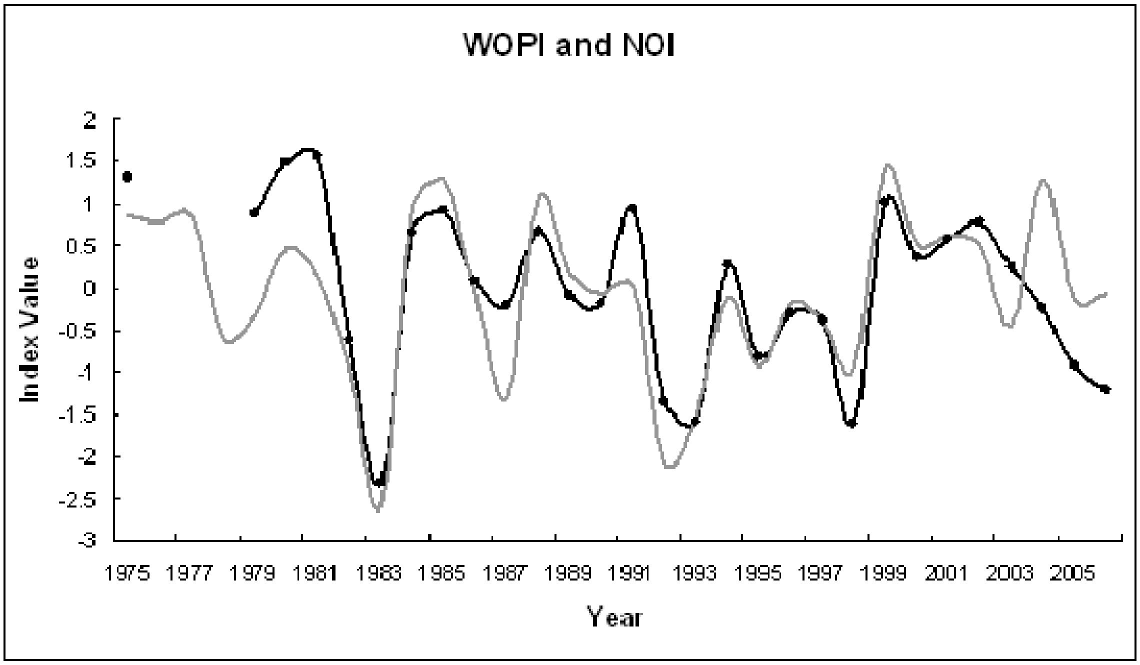


Figure 6-42 The Wells Ocean Productivity Index (WOPI, black line) and the Northern Oscillation Index (NOI, grey line) between 1975 and 2006. Values derived for March-August. Note the close fit between the larger-scale NOI, which represents the strength of the North Pacific high pressure cell, and local-scale WOPI, except for recent years (2004-2006), suggesting a change in local conditions. Low values indicate conditions for lower biological productivity. Source: MacFafrlane et al (2008)

The percentage of Central Valley salmon harvested in ocean fisheries has averaged 60 percent since 1970 (Figure 6-43), and has exceeded 70 percent several times. The average number of Central Valley Chinook landed in ocean fisheries between 1970 and 2006 was 430,000 fish per year (all races combined). Survival rates of young salmon are very low, meaning a large number must enter the ocean to support an average annual fishery of 430,000 fish. Beamish and Neville (1999) reported that smolt to adult survival rates for Fraser River (British Columbia) Chinook ranged from about 0.2 percent to about 6.8 percent, with an average during good ocean conditions of 4.8 percent. If the average Chinook smolt to adult survival is 4.2 percent and the pumps take 2 percent of winter-run, this take would equate to 67 adults out of a winter-run escapement of 7,000, a 0.96 percent reduction in number of adults.

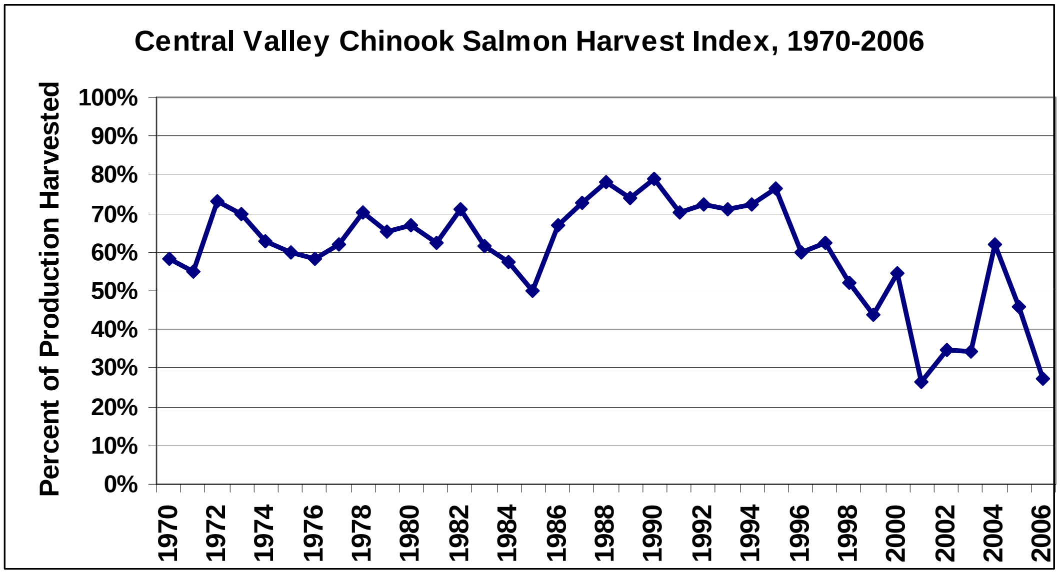


Figure 6-43 Central Valley fall-run Chinook salmon Ocean Harvest Index, 1970–2006.

Assuming Central Valley smolt to adult survival rates also average 4.8 percent, 9.2 million Central Valley smolts would have to enter the ocean every year to support the average ocean fishery. Production of fall-run Chinook at Central Valley hatcheries exceeds 9.2 million smolts, and may more than support the entire ocean fishery. This number is actually higher than the total number of young salmon salvaged at both the SWP and CVP facilities (about 7 million or 230,000 per year) during the 30-year period 1970 through 1999. Salvage does not account for indirect losses attributable to SWP/CVP project operations, which may be substantial and are estimated to be five times the direct losses. Nonetheless, this suggests that on average, indirect losses from Delta operations would have to be more than 30 times higher than the number salvaged to equal the adult-equivalent mortality contributed by the ocean fisheries, assuming 4.8 percent smolt to adult survival. Considering the SWP/CVP projects are exporting a high portion of the total freshwater outflow, this suggests that salmon are finding their way out of the system and not being diverted at the facilities in direct proportion to the diversion rate. Both the ocean harvest and Delta salvage are managed to protect the ESA-listed races.

Recent advances in the scientific understanding of interdecadal changes in oceanographic conditions on marine fisheries were outlined in Chapter 4. The abundance of pink, chum, and sockeye salmon appears to fluctuate out of phase with Chinook stocks to the south (Beamish and Bouillon 1993, as cited in Bakun 1999; Beamish and Neville 1999). Beamish and Neville (1999) found Chinook smolt survival rates to adulthood in the Strait of Georgia (Fraser River stocks) declined from 4.8 percent prior to abrupt changes in local oceanographic conditions during the latter 1970s, to 0.7 percent after the oceanographic changes. As a consequence, adult Chinook returns to the Fraser River system decreased to about 25 percent of 1970s levels even though approximately twice as many smolts were entering the Strait during the 1980s. The specific reasons for decreased smolt survival rates were unclear, but the authors suggested that decreased coastal precipitation and resultant decreased river discharge, increased temperatures in the strait and an increased tendency for spring plankton blooms to precede the peak smolt immigration into the strait were likely contributing factors. In addition, aggregations of opportunistic predators like spiny dogfish, may have contributed to lower hatchery smolt survival rates due to the increasing density of young fish added into the Strait of Georgia by hatcheries.

No dramatic change in Central Valley salmon abundance occurred during the latter 1970s (Figure 6-44), like the one observed in Fraser River stocks. In fact, Central Valley salmon abundance was remarkably consistent during the 1970s. However, the variation in abundance of Central Valley Chinook increased dramatically beginning in 1983. Since 1983, Central Valley salmon abundance has varied by a factor of three during two periods of 5 years or less.

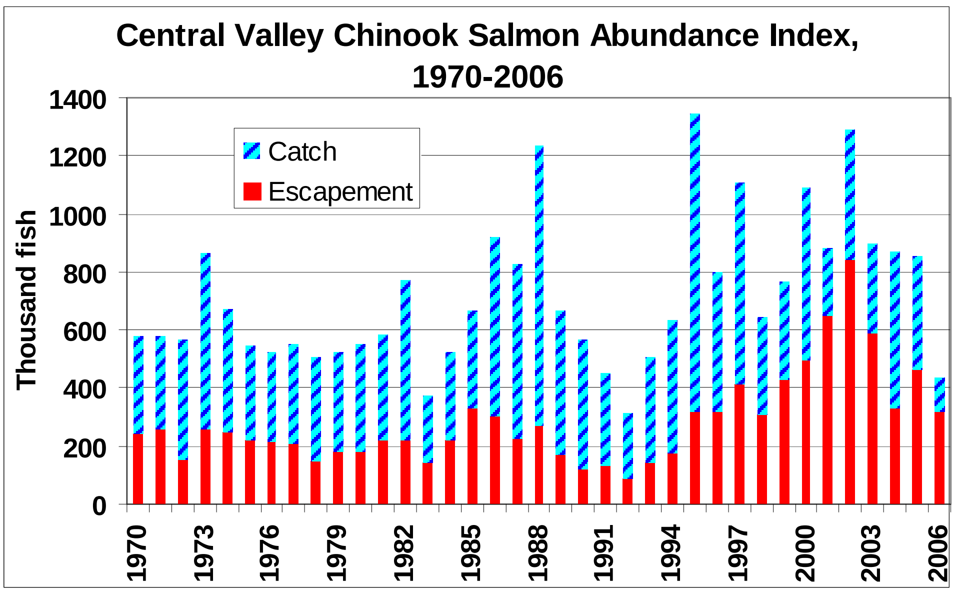


Figure 6-44 Central Valley Chinook salmon (all races) abundance index, 1970–2006 (PSFMC data).

All Central Valley Chinook salmon stocks have overlapping ocean distributions (DFG 1998). This may provide the opportunity for occasional overharvest of a rare stock like winter or spring-run, relative to the abundant target stock, fall-run Chinook salmon. This situation has occurred occasionally in the past. The brood year 1976 Feather River Hatchery spring-run was fished at levels about five to 13 times higher than the background rate on coded wire tagged fall-run Chinook by both the recreational and commercial fisheries for several years (Figure 6-45) This may also have happened to a lesser degree with the brood year 1983 spring-run from FRH. For whatever reason, these year classes remained particularly susceptible to the ocean fisheries for the duration of their ocean residency. Current ocean and freshwater fishing regulations are designed to avoid open fishing in areas where winter-run and spring-run are concentrated. Estimated harvest of winter-run Chinook salmon coded-wire tagged release groups are shown in Table 6-11.

Table 6-11 Winter-run Chinook estimated harvest of code-wire tagged release groups (expanded from tag recoveries) by harvest location (data from RMIS database).

Winter run recoveries (estimated) from RMIS database, 4/15/2003

Sum of estimated_number	run_year											
recovery_location_name	1980	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Grand Total
AMER.R. TO COLUSA									8	17		25
BATTLE CREEK												
BIG LAG.-CENTERV.BEA									4			4
BROOKINGS SPORT 6									3			3
C.VIZCAINO-NAVARR.HD	6									8		14
CARQUINEZ TO AMER. R									14			14
COLEMAN NFH												
COLUSA TO RBDD										67		67
COOS BAY SPORT 5											2	2
COOS BAY TROLL 5									4		4	8
FORT ROSS-PIGEON PT	24	5	55	8	4	18		8	25			147
GSPTS YEO PT								3				3
NEWPORT SPORT 4										2		2
NEWPORT TROLL 4										3		3
NTR 02W-118							6					6
NWTR 026-000											7	7
PIGEON PT.-POINT SUR	7	7	34	5	5	19			86	22	34	218
PIGEON PT-CA/MEX.BOR									8			8
POINT SUR-CA/MEX.BOR			20	9	5	10			3	14	8	68
PT.ARENA-PT.REYES										7	15	22
PT.REYES-PIGEON PT.										18	27	45
PT.SN.PEDRO-PIGN.PT.										4	8	12
SACRA.R, ABO FEATHER												
Grand Total	37	13	109	22	13	47	6	11	154	162	105	679
Escapement	1,142	349	144	1,159	1,001	836	2,930	3,288	1,352	7,572	7,337	27,110
# CWT fish released 2 years prior	9,988	10,866	27,383	17,034	41,412	48,154	4,553	20,846	147,393	30,433	162,198	530,653
Estimated % of cwt released fish recovered	0.37%	0.12%	0.40%	0.13%	0.03%	0.10%	0.13%	0.05%	0.10%	0.53%	0.06%	0.13%

In addition to occasional effects to particular year-classes, ocean fishing may affect the age structure of Central Valley spring-run Chinook. A DFG (1998) analysis using CWT spring-run from the Feather River Hatchery estimated harvest rates were 18 percent to 22 percent for age-3 fish, 57 percent to 85 percent for age-4 fish, and 97 percent to 100 percent for age-5 fish. Since length tends to be correlated with age, and fecundity is correlated with length (DFG 1998), the effect of ocean fishing on the age structure of the population has effects on population fecundity.

Recent papers have reemphasized the ecological importance of salmon carcasses to stream productivity (Bilby et al. 1996, 1998; Gresh et al. 2000). As mentioned in the preceding chapter on steelhead, the substantial declines in mass transport of marine-derived nutrients to streams due to overall salmonid declines may also affect growth and survival of juvenile salmonids (Bilby et al. 1996, 1998). Levels of ocean harvest that attempt to maximize production from a minimum of adults may exacerbate nutrient deficiencies (Gresh et al. 2000).

In addition to ocean harvest, legal and illegal inland fishing for spring-run salmon undoubtedly occurs at fish ladders and other areas where adult fish are concentrated, such as pools below dams or other obstructions (DFG 1998). Mill, Deer, and Butte Creeks, as well as other tributaries with spring-run populations, are particularly vulnerable to poaching during the summer holding months because of the long period in which adults occupy relatively confined areas. The significance of illegal freshwater fishing to the spring-run salmon adult population, however, is unknown. The increased law enforcement programs have reduced poaching. The Central Valley angler survey was restarted during 2007 and should yield valuable harvest data.

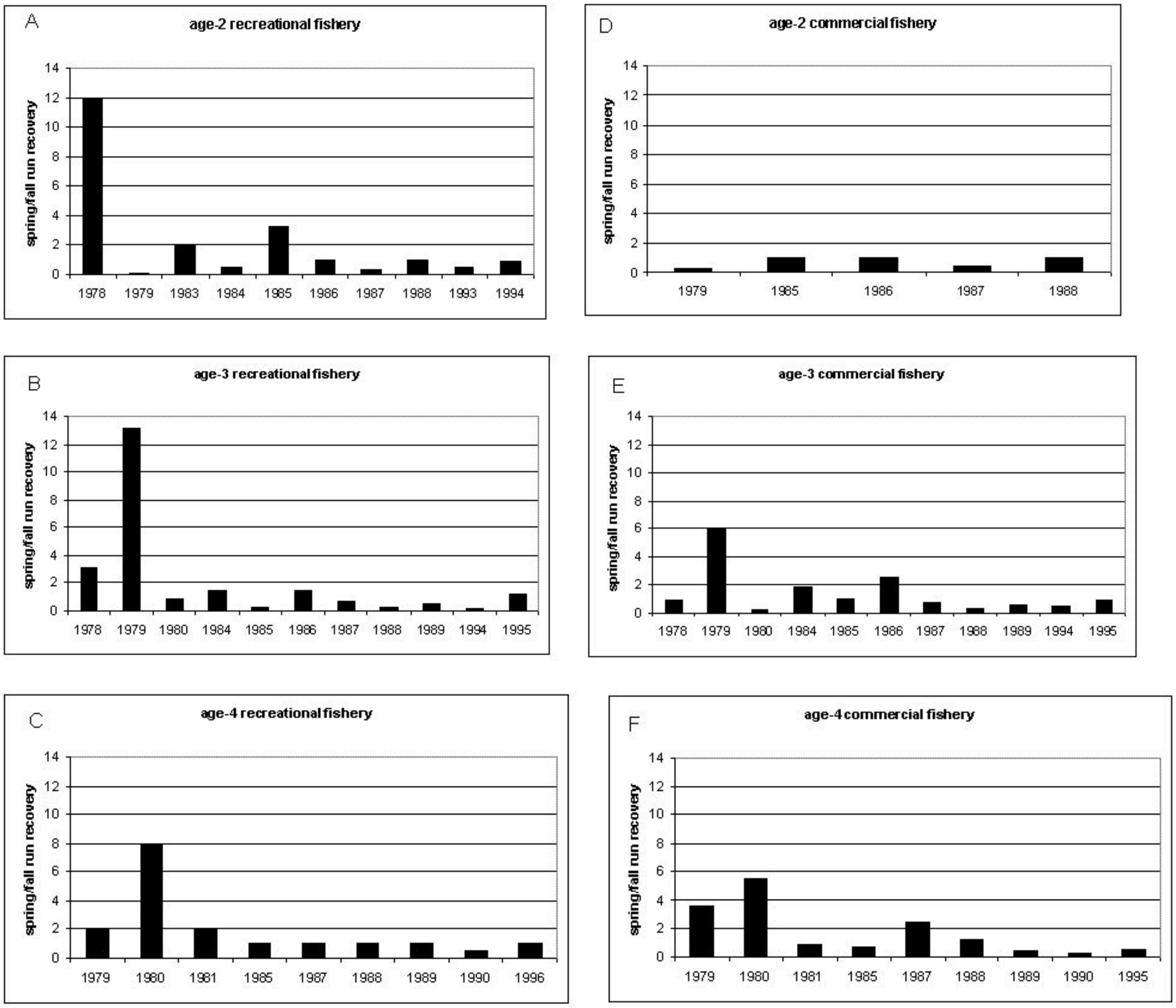


Figure 6-45 Coded-wire tag recovery rate of Feather River Hatchery spring-run Chinook salmon relative to the coded-wire tag recovery rate of Central Valley fall-run Chinook salmon. Data were taken from DFG (1998), and are presented individually for recreational and commercial fisheries for age-2, age-3, and age-4 fish. Values greater than one indicates fishing pressure above the level sustained by the fall-run.

Hatchery Influence

Central Valley Chinook salmon runs are heavily supplemented by hatcheries to mitigate for the loss of habitat when dams were built. Table 6-12 lists salmon hatcheries operating in the Central Valley and their yearly production goals. When all hatcheries reach their production goals, over 34 million Chinook smolts are released into the system. This large number of smolts in the common ocean environment may result in competition with wild fish in times of limited food resources. Chinook and coho salmon are also produced in the Trinity River hatchery and released in the Trinity River. NMFS now requires HGMP plans to address effects of hatchery operations on listed species. HGMPs are being developed at Nimbus, Feather River, Coleman, and Trinity River Hatcheries under separate ESA constultation processes.

Table 6-12 Production data for Central Valley hatchery produced Chinook salmon.

Hatchery	River	Chinook Runs	Yearly Production Goal
Coleman NFH	Battle Creek	Fall, late-fall, winter	13,200,000 smolts
Livingston Stone	Sacramento	winter	
Feather River	Feather	Fall, spring	~14,000,000 smolts
Nimbus	American	Fall	4,000,000 smolts
Mokelumne River	Mokelumne	Fall	2,500,000 post smolt
Merced River	Merced	Fall	960,000 smolts
Total			34,660,000
Source: DFG and NMFS 2001.			

The percentage of the Central Valley fall-run Chinook adult escapement taken at hatcheries has shown a gradual increase since 1952 (Figure 6-46). Hatcheries have likely helped to maintain Chinook populations at a level allowing a harvestable surplus (not in 2008 though). However, hatcheries may have reduced genetic fitness in some populations, especially the more depressed runs, by increasing hybridization between different runs. Fish have been transferred between watersheds resulting in various genetic effects. Livingston Stone Hatchery produces winter-run Chinook and has assisted in the recent population increases for winter-run.

A majority of hatchery releases are trucked to downstream release locations and in all except Coleman and Livingston Stone hatcheries are trucked to San Pablo Bay. The downstream releases increase survival of the hatchery stocks but also increase the proportion of hatchery relative to wild survival and increase straying. Recent CWT data shows that a good portion of the Chinook in spring-run streams like Clear Creek and Mill Creek are of hatchery origin (NOAA Fisheries 2003). A recent review of hatchery practices (DFG and NOAA fisheries 2001) recommended reducing the practice of using downstream releases and instead releasing fish in the river of origin. This practice would reduce the survival of hatchery fish, but could also reduce the in-river survival of wild fish when the carrying capacity of the habitat is surpassed resulting in intraspecific competition. Currently the proportion of hatchery versus wild fish contributing to fisheries and to the escapement is unknown. Barnett-Johnson et al (2007) examined otoliths of hatchery and wild fish from the California coastal fishery and estimated that the contribution of wild fish was only 10 percent plus or minus 6 percent, indicating hatchery supplementation may be playing a larger role in supporting the central California coastal fishery than previously assumed. A program to mark 25 percent of fall-run Chinook salmon released was begun in the 2007 release year. This program should substantially improve hatchery effects evaluation capabilities.

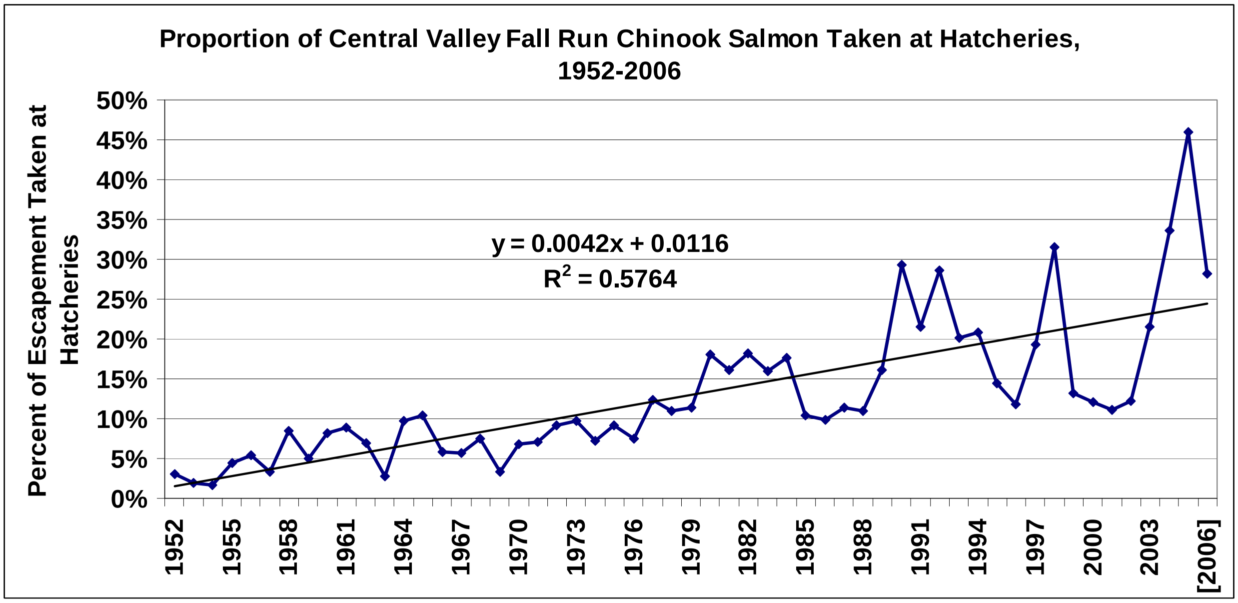


Figure 6-46 Percent of Central Valley fall-run Chinook escapement taken at hatcheries 1952–2006.

Feather River Hatchery-Genetics, Competition for Spawning, and Rearing Habitat

Historically, the adult spring-run salmon immigration into the upper rivers and tributaries extended from mid-March through the end of July with the peak in late May and early June (DFG 1998). Spawning started in mid-August, peaked in early September, and ceased in late September. The peaks of spawning between spring- and fall-run salmon were almost 2 months apart, and more than 30 days separated the end of spring-run spawning and the onset of fall-run spawning at Baird Hatchery at the end of the 1800s.

Although hydraulic mining and dams initially fostered intermixing of Chinook races in the Sacramento River system, hatchery practices have contributed as well (DFG 1998; NOAA fisheries 1998). The Feather River Hatchery (FRH) was built by DWR at the request of DFG to mitigate for the loss of habitat upstream of Oroville Dam. The hatchery was dedicated on October 1, 1967, and is operated by DFG. During the 5-year period prior to the opening of the hatchery (1962 through 1966) all adult salmon were trapped and transported above the site of Oroville Dam. During 1968 and 1969 spring-run salmon were allowed to enter the hatchery as soon as they arrived. The result was greater than 50 percent mortality, because warm water temperatures resulted in an inability to hold adults during the summer months until they were ready for spawning. As a result, since 1970 hatchery policy has been to exclude spring-run salmon entry until the onset of spawning, (August through October, generally early September to October 1). This practice has resulted in the inability of the hatchery operators to clearly identify spring-run based on their adult upstream migration timing, thereby increasing the likelihood of genetic introgression of spring-run and fall-run Chinook stocks.

Coded-wire-tag analysis provided verification of the intermixing of fall and spring runs. Twenty-two percent of juveniles tagged as fall-run subsequently spawned as spring-run, and 295 juveniles tagged as spring-run subsequently spawned as fall-run (Brown and Greene 1994). Preliminary genetic characterization results from the IEP Central Valley Salmonid Genetics Project provided additional evidence of intermixing. University of California geneticists presented preliminary work on Feather River spring-run genetic characterization at the 1999 Salmon Symposium in Bodega Bay. They had access to samples from FRH spring-run, late-summer-season in-river carcass surveys and a limited number of samples from spring-season in-river angler surveys. They found no genetic difference between the Feather River fall and spring runs. The two groups were genetically similar and homogenous. They were most similar to Central Valley fall-runs, and were not genetically similar to spring-run from Mill, Deer, or Butte Creeks.

In 1994, the FRH fish ladder was kept open between May 16 and June 6 to assess the current numbers of Chinook that exhibited spring-run adult migration timing. Prior to June 6, only one fish had entered the hatchery. On June 6, 31 fish entered the hatchery and the ladder was closed (DFG 1998). The implication is that few fish exhibiting the “typical” spring-run salmon adult migration timing ascended the Feather River during 1994. Alternatively, many spring-run adults may have been holding, or not moving, during the period the gates were open. When the ladder was reopened on September 6, 1994, 3,641 spring-run Chinook entered the hatchery.

FRH spring-run have been documented as straying throughout the Central Valley for many years and have intermixed with wild-spawned spring-run and fall-run Chinook in the upper Sacramento River, although the extent of hybridization has not been determined (DFG 1998). In 1982, early returning CWT Chinook were observed at RBDD and subsequently identified as FRH fall-run from the 1980 brood year. Now it is commonplace at RBDD to intercept fish tagged as fall-run during the spring-run migration period (mid-March through the end of July) (Figure 5–6). This intermixed life history pattern was evident when FRH fish were used in an attempt to reestablish spring-run in Clear Creek. More than 523,000 FRH spring-run fry were planted at the base of Whiskeytown Dam during the 3-year period 1991–1993 (DFG 1998). Some of the fish were CWT’ed. Since 1993, snorkeling surveys have been performed during the adult spring-run holding period to determine if the plants were successful. Three unmarked salmon were observed during the spring-run adult holding period in 1993 and two in 1995. However, 23 CWT adults returned between 1993 and 1995 during the adult fall-run spawning migration.

DFG (1998) questioned the viability and genetic integrity of the Butte Creek spring-run because of the potential for intermixing with Feather River salmon. Butte Creek has several different sources of introduced water, including West Branch Feather River water, main stem Feather River water, and Sacramento River water. As a consequence, it is possible that some spring-run salmon in Butte Creek could be strays from the Feather River. Despite the mixing of Feather River water into Butte Creek, DFG (1998) suggested the relative numbers of adult spring-run entering Butte Creek and FRH, for the period 1964 to 1991 did not show a strong relationship, suggesting they are generally independent. In support of this information, Banks et al. (2000) published genetic characterization research results and determined spring-run from Deer and Mill Creeks are more closely related to Central Valley fall-run populations than Butte Creek spring-run. This result would not be expected if Butte Creek spring-run were hybridized with

FRH spring-run because FRH spring-run are known to be hybridized with FRH fall-run. More recently, Hedgecock et al. (2002) reexamined Feather River fall hatchery, spring hatchery and spring wild. Field biologists have found a spring-run phenotype in the Feather River. Hedgecock et al. (2002) found that spring hatchery and spring wild form a genetically distinct population that is different from the fall-run, although the Feather River spring-run population is still more closely related to fall-run than to either Mill or Deer Creeks spring-run populations. In conclusion, Hedgecock et al. (2002) found two distinct populations in the Feather River, one of which exhibits a spring-run phenotype. The Feather River spring-run population is not closely related to Mill and Deer Creeks spring-run and may be, therefore a spring-run in the Sacramento Valley may be poly-phyletic.

The Banks et al. (2000) genetic results are surprising, however, because the escapement estimates for Butte Creek and Feather River spring-run are strongly correlated over more recent years (1987 through 1998), (Spearman $R = 0.83\text{-}0.86$, $p < 0.001$). (The variability in the R-value is due to separate tests of FRH spring-run escapement versus the smallest and largest available Butte Creek escapement estimates.) In contrast, the spring-run escapement estimates for Deer and Mill Creeks, which Banks et al. (2000) found were not genetically different from each other, are not significantly correlated for the 1987 through 1998 period (Spearman $r = 0.27$, $p = 0.40$).

FRH spring-run fry and juveniles were released into Butte Creek in 1983, 1984, and 1985, Brood Years 1982, 1983, and 1984 respectively. Only BY 1983 releases affected resultant year-classes, showing large increases in BY 1986 and BY 1989. There was a significant reduction in adult returns for BY 1992, but BY 1995 was the largest observed (7,500 adults) since 1960, and BY 1998 was higher still (20,259 adults). Since 1995 there have been over 500,000 Butte Creek spring-run tagged and released. While the inland recoveries have been limited, all of the tags recovered within the spring-run population have been from spring-run tagged and released in Butte Creek. One tagged fish was recovered in the Feather River, but no Feather River or other origin fish have been found among the Butte Creek spring-run (DFG 2003).

During the 1977 drought, adult spring-run were trucked from RBDD to Mill, Deer, and Butte Creeks (DFG 1998). No appreciable effect was seen in the subsequent year class (1980) on Butte or Mill Creeks. However there was an apparent single year (1980) increase in the Deer Creek population.

The Yuba River was planted with surplus FRH spring-run in 1980 (15,925), 1983 (106,600), and 1985 (96,800) (DFG 1998). Influence of these three introductions on subsequent adult spring-run returns cannot be determined since escapement surveys were not conducted. In 1984, Antelope Creek was planted with 302,733 FRH spring-run juveniles. In 1985, the creek was planted with another 205,000 juveniles. There is no persistent spring-run population in Antelope Creek, so the effect of hatchery supplementation in this drainage is irrelevant.

The effects of introgression and planting are poorly understood. In the case of the Feather River, Sommer et al. (2001a) found evidence that hatchery operations have had major population effects. Sommers et al. (2001a) examined factors responsible for a long- term shift in the spawning distribution of Chinook salmon toward the low-flow channel of the Feather River. While they found statistical evidence that flow and escapement may affect the distribution of spawning salmon, they concluded that hatchery operations probably account for much of the change. One hypothesis was introgression with spring-run causes the fall-run population to spawn as far upstream as possible, similar to the historical spring-run life history pattern. Another possibility was that a shift in the stocking location of young salmon to the estuary resulted in higher survival rates and an increased proportion of hatchery fish in the population. Hatchery fish would tend to spawn closer to the hatchery in the low-flow channel. In support of the latter hypothesis, there has been a significant increase in the number of fish entering FRH since 1968 (Ted Sommer, DWR unpublished data). A shift in spawning distribution to the heavily-used low-flow channel is expected to result in exceptional spawning superimposition and egg mortality for any spring-run that may be present.

Disease and Parasites

Chinook salmon are susceptible to numerous diseases during different phases of their life cycle. Disease problems are often amplified under crowded hatchery conditions and by warm water. See DFG (1998) for a detailed discussion of Central Valley salmonid diseases.

In-stream Habitat

Dam operations generally store water runoff during winter and spring to be released for instream flows, water delivery, and water quality during late spring, summer and fall. Historical high flows in regulated rivers have been dampened for flood control and water storage. Moderate flows have been extended throughout much of the year to provide appropriate instream flows for fish, water quality in the Delta, and water for pumping in the Delta. The long-term effect of the lack of high flows is the simplification of instream habitat. High channel-forming flows maintain high-quality spawning habitat and riparian floodplain conditions. High flows mobilize spawning-sized gravels from streambanks and incorporate them into the active channel. Low flows that typically occurred in late summer and fall do not occur because of the dampening effect of dam operations. High flows are not as high as occurred under natural conditions but the duration of high flows is longer because flood control operations spread them out over time. The longer duration of moderately high flows may be sufficient enough to wash quality spawning gravel out of riffles and deposit it in deeper water where it is unavailable for spawning but not high enough to mobilize new gravel supplies from the gravel bars, banks, and floodplain. It is anticipated that riffles downstream of dams will continue to degrade as floodflows move gravel downstream without replenishment from upstream areas. The presence of dams has eliminated upstream sources of bedload and woody debris, increasing the importance of streamside sources. Programs are in place to replace gravel recruitment lost due to the presence of dams.

Levees and bank protection projects have been constructed along the lower reaches of many Central Valley rivers, limiting the potential for rivers to meander and reducing seasonal floodplain inundation. Many streambanks near developed areas have been riprapped to cut down on natural channel adjustments and streambank erosion. Natural streambanks generally provide higher quality habitat to salmonids than riprapped banks. In addition, when banks are riprapped riparian vegetation is eliminated in the riprapped portion, eliminating overhanging vegetation and future woody debris sources.

Large woody debris provides valuable habitat to salmonids. Woody debris has been removed from some rivers because it is perceived as a hazard to swimmers and boaters and impedes navigation. The habitat loss cumulatively from lack of woody debris recruitment, woody debris removal, and riprapping could be a significant factor in the the decline of some Central Valley salmon populations. The likelihood that this would reduce the survival of the current Chinook or steelhead populations is unknown.

Factors that May Influence Abundance and Distribution of Coho Salmon

A number of interrelated factors affect coho abundance and distribution in the Trinity River. These include water temperature, water flow, habitat suitability, habitat availability, hatcheries, predation, competition, disease, ocean conditions, and harvest. Current CVP operations affect primarily water temperature, water flow, and habitat suitability in the Trinity River. Water temperature suitability criteria for coho salmon are shown in Table 6-13.

Table 6-13 Water temperature suitability criteria for Coho salmon life stages from DFG 2002a.

Life Stage	Suitable Range, degrees F	Reference or Citation
Migrating adult	44.6 – 59	Reiser and Bjornn 1979
Spawning adult	39.2 – 48.2	Bjornn and Reiser 1991
Rearing juvenile	35 = lower lethal 78.8 - 83.8 = upper lethal 53.6 – 57.2 = optimum 48 – 59.9 = optimum 63.7 – 64.9 = maximum weekly average temperature 62.1=maximum weekly average and 64.4=maximum weekly maximum temperature	Bjornn and Reiser 1991; Flosi et al 1998; Ambrose et al 1996; Ambrose and Hines 1997, 1998; Hines and Ambrose ND; Welsh et al. 2001
Eggs and fry	39.2 – 51.8 39.2 – 55.4 = optimum 32 – 62.6	Davidson and Hutchinson 1938; Bjornn and Reiser 1991; PFMC 1999

Juvenile coho salmon in the Trinity River spend up to a full year in freshwater before migrating to the ocean. Their habitat preferences change throughout the year and are highly influenced by water temperature. During the warmer summer months when coho are most actively feeding and growing, they spend more time closer to main channel habitats. Coho tend to use slower water than steelhead or Chinook salmon. Coho juveniles are more oriented to submerged objects such as woody debris while Chinook and steelhead tend to select habitats in the summer based largely on water movement and velocities, although the species are often intermixed in the same habitat. Juvenile coho tend to use the same habitats as pikeminnows, a possible reason that coho are not present in Central Valley watersheds. Juvenile coho would be highly vulnerable to predation from larger pikeminnows during warm-water periods. Pikeminnow do not occur in SONCC coho streams. When the water cools in the fall, juvenile coho move further into backwater areas or into off-channel areas and beaver ponds if available. There is often no water velocity in the areas inhabited by coho during the winter. These same off-channel habitats are often dry or unsuitable during summer because temperatures get too high.

Lewiston Dam blocks access to 109 miles of upstream habitat (U.S. Department of the Interior 2000). Trinity River Hatchery produces coho salmon with a production goal of 500,000 yearlings to mitigate for the upstream habitat loss. Habitat in the Trinity River has changed since flow regulation with the encroachment of riparian vegetation restricting channel movement and limiting fry rearing habitat (Trush et al 2000). According to the Trinity River Restoration Plan, higher peak flows are needed to restore attributes of a more alluvial river such as alternate bar features and more off-channel habitats. These are projected in the restoration plan to provide better rearing habitat for coho salmon than the dense riparian vegetation currently present. A number of restoration actions have been completed. A new flow schecule has provided higher spring releases to geomorphically maintain habitat. Physical habitat manipulations have been implemented providing better juvenile rearing in selected sites along the river.

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Chapter 7 Basic Biology and Life History of Delta Smelt and Factors that May Influence Delta Smelt Distribution and Abundance

This chapter provides information on the basic biology, life history, and status of delta smelt, as well as a description of the potential factors that may affect delta smelt and critical habitat in the action area. There has been a long-term decline of delta smelt, with an especially sharp downturn after 1999 as delta smelt other pelagic fish species jointly suffered what has become known as the Pelagic Organism Decline.

The term "Pelagic Organism Decline" (POD) denotes the sudden, overlapping and striking declines of San Francisco Bay-Delta Estuary pelagic fishes since about 2000. The POD species include delta smelt, longfin smelt, threadfin shad, and (young-of-year) striped bass. Recent abundance indices for the POD species have included record lows for delta smelt and young-of-year striped bass, and near-record lows for longfin smelt and threadfin shad. Although abundance improved for each species during the wet 2006, levels for all four species have remained near record lows since 2004.

Factors affecting delta smelt fall into four general categories: (1) prior fish abundance or "stock-recruit effects", including low-abundance adult effects that may reduce juvenile production; (2) habitat, including physical and chemical variables, disease, and localized toxic algal blooms that affect survival and reproduction; (3) top-down effects, including predation, entrainment, and other processes that cause juvenile and adult mortality; (4) bottom-up effects, including food web interactions that affect growth, reproduction, and, indirectly, survival.

The POD has been the subject of an intensive analytical effort by the Interagency Ecological Program (IEP) since the POD was recognized in 2005. The POD investigation has greatly improved our understanding of the ecology of pelagic fishes in the estuary, especially delta smelt. While the mechanisms responsible for long-term and POD-era declines of the species probably vary by species, it appears very unlikely that they are independent of one another. Rather, the decline appears to be the result of multiple interacting causes, including some that are related to water project operations and others that are not.

General Biology

The delta smelt is a slender-bodied fish typically reaching 60-70 mm standard length (SL), with a maximum size of about 120 mm SL. Delta smelt is endemic to the upper San Francisco Estuary, primarily the Delta and Suisun Bay (Moyle et al. 1992). Delta smelt is generally associated with the low salinity zone locally indexed by X2, which is the location of the 2 psu isohaline measured near the bottom of the water column (Jassby et al. 1995). It typically has an annual life cycle though a small percentage (< 10 percent) of the population can live to and possibly reproduce at age-two (Brown and Kimmerer 2001). On average, ripe females produce about 1,900 eggs, but fecundity can range from about 1,200 to about 2,600 eggs per female (Moyle et al. 1992). Moyle et al. (1992) considered delta smelt fecundity to be "relatively low", but based on Figure 2a in Winemiller and Rose (1992), delta smelt fecundity is actually fairly high for a fish its size. Delta smelt move into tidal freshwater habitats to spawn in late winter through spring. Most spawning occurs in the Delta, but some also occurs in Suisun Marsh and the Napa River (DFG unpublished). An optimal spawning temperature "window" of about 12 ºC -18 ºC (59 ºF - 64.4 ºF) has recently been reported (Bridges unpublished; Bennett unpublished). After hatching, larvae are dispersed throughout low salinity habitats, generally moving into Suisun Bay, Montezuma Slough, and the lower Sacramento River below Rio Vista as they mature (Grimaldo et al. 1998; Sweetnam 1999). Delta smelt are zooplanktivorous throughout their lives, feeding mainly on copepods, cladocerans, and amphipods with which they co-occur (Moyle et al. 1992; Lott 1998; Nobriga 2002). In the larger picture of fish life history strategies, delta smelt best fit the "opportunistic strategy" of Winemiller and Rose (1992). Opportunistic fishes are characterized as placing "a premium on early maturation, frequent reproduction over an extended spawning season, rapid larval growth, and rapid population turnover rates", and "maintain dense populations in marginal habitats (e.g. ecotones, constantly changing habitats) (Winemiller and Rose 1992)."

Legal Status

The delta smelt was listed as threatened under both the Federal Endangered Species Act and the California Endangered Species Act in 1993. The species was recently proposed for re-listing as endangered under the Federal Endangered Species Act.

Distribution, Population Dynamics, and Baseline Conditions

Distribution

Delta smelt spend most of their lives rearing in low salinity habitats of the northern estuary (Moyle et al. 1992; Sweetnam and Stevens 1993). Delta smelt can temporarily tolerate salinities as high as 19 parts per trillion (ppt) (Swanson et al. 2000) and have been collected in the field at salinities as high as 18 ppt (Baxter et al. 1999). However, most delta smelt are collected at much lower salinities- typically in the range of about 0.2 – 5.0 ppt (Sweetnam and Stevens 1993; Feyrer et al. 2007). The geographical position of these low salinity habitats varies principally as a function of freshwater flow into the estuary. Therefore, the delta smelt population's center of mass has on average been located in the western Delta during years of low freshwater flow and in Suisun Bay during years of high freshwater flow. This relationship between flow and distribution is particularly strong during the larval period (Figure 7-1), but persists throughout the first year of life (Sweetnam and Stevens 1993).

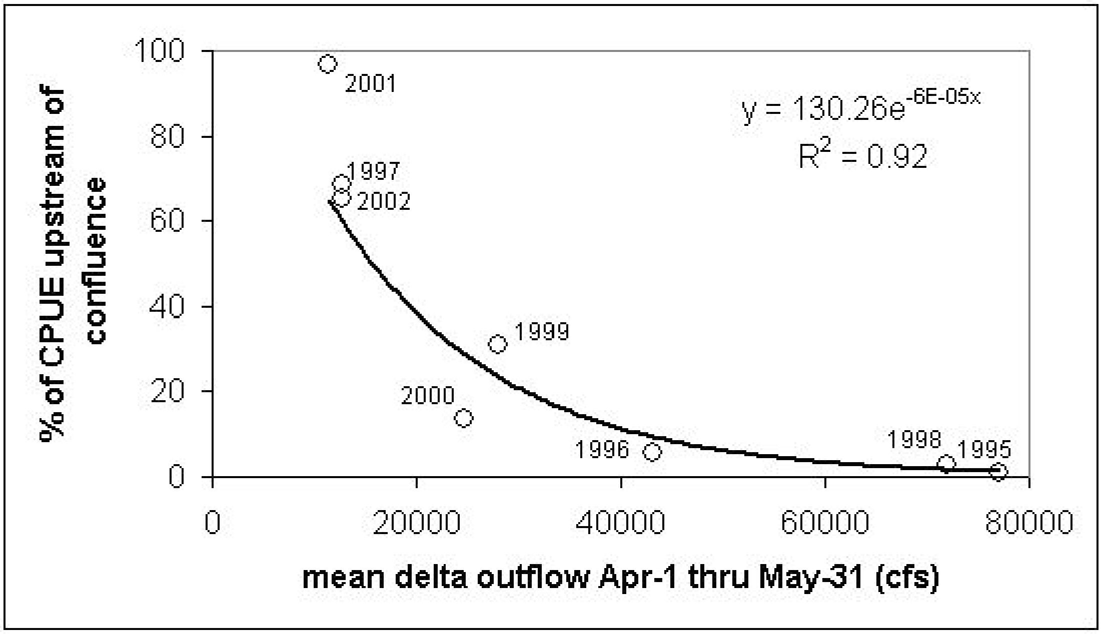

Figure 7-1 (x-axis is DAYFLOW; y-axis is first 20-mm Survey following VAMP).

Currently, the approximate spatial position of low salinity habitat in the estuary is indexed by X2, defined as the distance in km from the Golden Gate to the location of 2 psu salinity near the bottom of the water column (Jassby et al. 1995). The longitudinal position of X2 during spring and/or early summer, which varies as a function of freshwater flow into the estuary, has been correlated with abundance or survival indices of numerous estuarine taxa (Jassby et al. 1995) including delta smelt (Kimmerer 2002). Both late larval (Bennett et al. 2002) and juvenile (Aasen 1999) delta smelt are thought to actively maintain positions in low salinity habitats by using swimming behaviors timed to tidal and diel cues.

Natural History

Spawning

Adult delta smelt spawn during the late winter and spring months, with most spawning occurring during April through mid-May (Moyle 2002). Spawning occurs in sloughs and shallow edge areas in the delta and Sacramento River above Rio Vista, especially, in recent years, in the Cache Slough/ Sacramento Deepwater Ship Channel complex. Spawning has also been historically recorded in Suisun Marsh and the Napa River (Moyle 2002). Most spawning occurs at temperatures between 7—15°C, although it may occur at temperatures up to 22°C (Moyle 2002). Fecundity (59—70 mm SL females) ranges from 1200 to 2600 eggs (Moyle et al. 1992). Most adults do not survive to spawn a second season, but a few (<5%) do (Moyle 2002 and references therein). Large (90—110 mm SL) two-year-old females may contribute disproportionately to the egg supply (Moyle 2002 and references therein).

Larval Growth and Downstream Transport

Larval smelt hatch after 9-13 days at 14.8—16.5°C, and feeding begins 4—5 days later(Mager 1996). Early larvae are demersal and are not strongly subject to net water flows until after swim-up and fin development is complete several weeks later. Larvae enter the water column at about

14—18 mm TL and become fully subject to passive transport with water currents (Moyle 2002). At this point, they are very weak swimmers and are moved in the direction of the prevailing net flow of water. Those outside the zone of entrainment surrounding the CVP and SWP export facilities that survive predation and other dangers are transported downstream to the low salinity zone.

Juvenile Rearing

As described by Moyle:

> In general delta smelt prefer to rear in or just above the region of the estuary where fresh water and brackish water mix and hydrodynamics are complex as a result of the meeting of tidal and riverine currents. This region is typically in Suisun Bay. During the 1987—1992 drought, the smelt were concentrated in deep areas in the lower Sacramento River around Decker Island, where the bottom salinity hovered around 2 ppt much of the year (Herbold 1994), apparently because the salt water-fresh water mixing zone was located in this region. However, smelt may also be common in this region during nondrought years, a finding that suggests they are attracted to favorable hydraulic conditions that allow them to maintain position. (Moyle 2002)

Delta smelt grow rapidly during the summer, especially once they reach 30 mm, a size at which a variety of planktonic prey become available, and reach 40—50 mm FL by early August (Moyle 2002). Juvenile-stage prey include copepods, cladocerans, amphipods, and insect larvae (Moyle 2002). They reach adult size (55—70 mm SL) by early fall (Moyle 2002). At that size, they may also consume larger zooplankton.

Upstream Migration

Movement upstream begins in September and October as a “gradual, diffuse migration” toward spawning areas (Moyle 2002). Adult smelt may take several months to reach spawning sites. Recent evidence suggests that more rapid upstream movement is keyed to “first flush” pulses of turbid water through the estuary at the onset of winter rains (Grimaldo et al. in review).

Population Abundance Trends

The DFG Fall Midwater Trawl Survey (FMWT) provides the best long-term index of relative abundance of maturing adult delta smelt (Moyle et al. 1992; Sweetnam 1999). It has been conducted each September-December since 1967 (except 1974 and 1979). The DFG Summer Townet Survey (TNS), which has been conducted since 1959 (except 1966-68), provides an index of juvenile delta smelt abundance during June-July. These surveys do not at present support statistically respectable population abundance estimates, though substantial progress has recently been made (Newman, in review; Newman, in prep.). However, they are generally accepted to provide a respectable basis for evaluating interannual trends.

The TNS indices have ranged from a low of 0.3 in 2005 to a high of 62.5 in 1978 (Figure 7-2). The FMWT indices have ranged from a low of 27 in 2005 to 1,653 in 1970 (Figure 7-3). Although peak high and low values have varied in time, the TNS and FMWT indices show similar time series of delta smelt relative abundance (Sweetnam 1999; Figures 7-2 and 7-3).

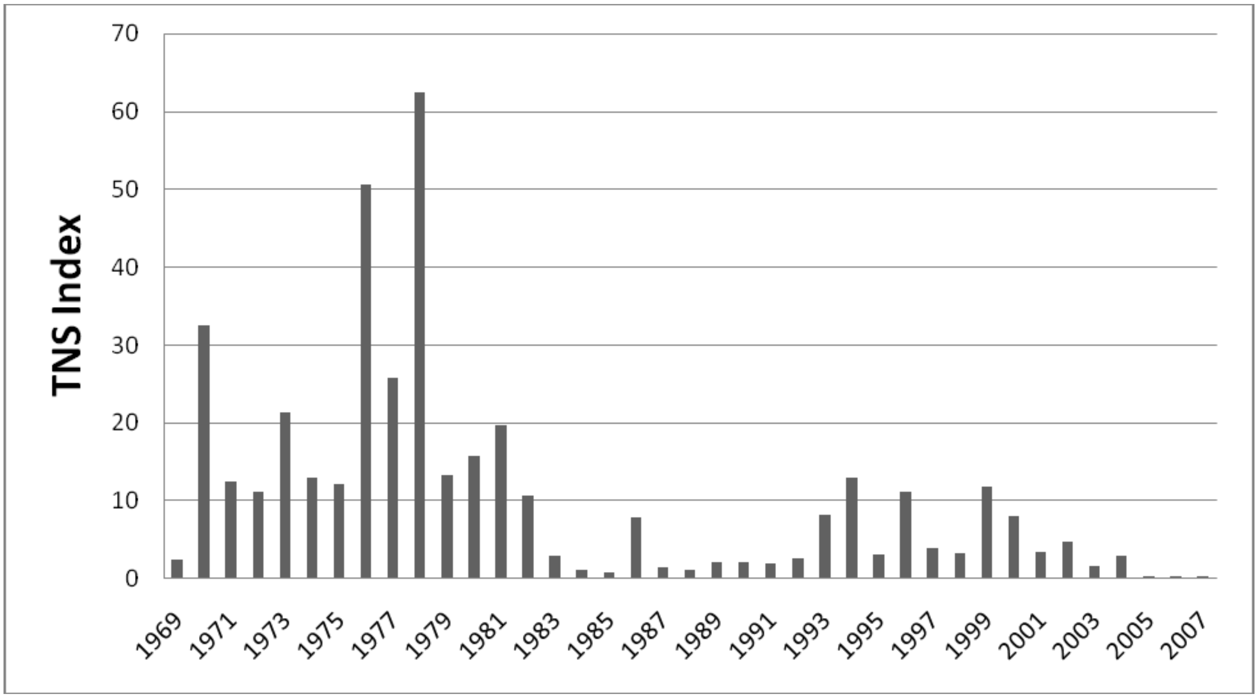

Figure 7-2 IEP TNS indices 1969-2007.

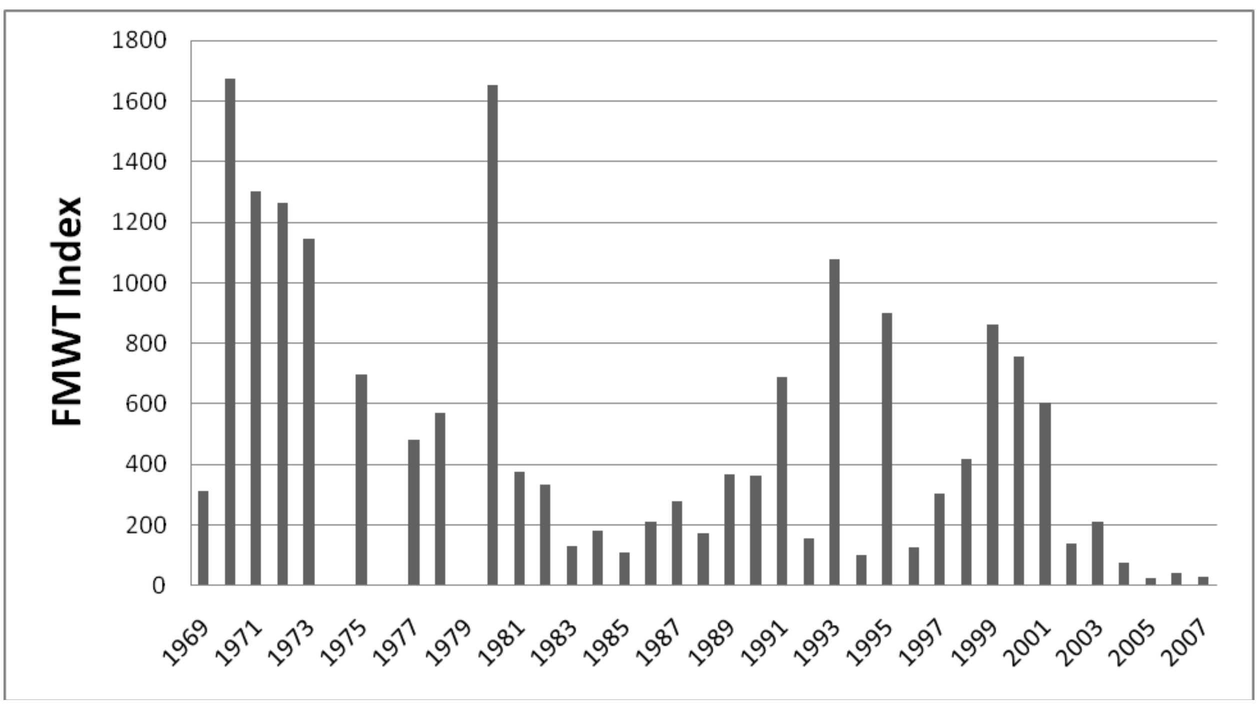

Figure 7-3 IEP FMWT indices 1969-2007.

From 1969-81, mean delta smelt TNS and FMWT indices were 22.5 and 894 respectively. Both indices suggest the delta smelt population declined abruptly in the early 1980s (Moyle et al. 1992). From 1982-1992, mean delta smelt TNS and FMWT indices dropped to 3.2 and 272 respectively. The population has rebounded somewhat in the mid-1990s (Sweetnam 1999); mean TNS and FMWT indices were 7.1 and 529 during 1993-2002. However, delta smelt numbers have trended precipitously downward since about 1999, as delta smelt and, later, other pelagic fish species jointly suffered what has become known as the Pelagic Organism Decline (Sommer et al. 2007).

The Pelagic Organism Decline

The term "Pelagic Organism Decline" (POD) denotes the sudden, overlapping declines of San Francisco Estuary pelagic fishes since about 2002 (Sommer et al. 2006). The POD species include delta smelt, longfin smelt, threadfin shad, and (age-0) striped bass, which together account for the bulk of the pelagic fish biomass in the upper Estuary. The year 2002 is often reckoned as the start of the POD because of the striking declines of three of the four POD species between 2001 and 2002; however, statistical review of the data (e.g. Manly and Chotkowski 2006) has revealed that for delta smelt, at least, the POD downtrend really began earlier. The POD declines became clearly evident against the high background variability in these species in early 2005, when analysis of the third consecutive year of extremely low numbers in these species made them statistically clear.

Post-2001 abundance indices for the POD species have included record lows for delta smelt and age-0 striped bass, and near-record lows for longfin smelt and threadfin shad. Abundance improved for each species during 2006, have remained relatively poor since 2002 for all four species. Low abundance levels have been especially remarkable in that winter and spring river flows into the estuary have been moderate or very wet (2006) during recent years. Moderate to wet conditions have historically usually been associated with at least modest recruitment of most pelagic fish species. Longfin smelt (discussed at length in a Technical Assistance appendix to this Biological Assessment) is perhaps the best example of this point as the species shows a very strong relationship with delta outflow. The introduction of the overbite clam (*Corbula amurensis*) in 1986 and associated changes in the food web reduced the magnitude of the response of longfin smelt without altering its slope (Kimmerer 2002). Specifically, the grazing effects from *Corbula* are thought to have resulted in a substantial decline in phytoplankton and calanoid copepods, the primary prey of early life stages of pelagic fishes. As a consequence, comparable levels of flow did not generate the expected levels of fish biomass (as indexed by abundance) after 1986. During the POD years, the abundance indices for longfin smelt deviated substantially from both the pre-and post-*Corbula* relationships with outflow. The situation is similar for young-of-the-year striped bass, which has a historical abundance association with outflow that was also altered by *Corbula*, whereas the recent abundance indices were well below expected levels based on outflow. Hence, it appears that the response of these pelagic fishes to environmental conditions has fundamentally changed since the POD (Sommer et al. 2007).

Because of its many management implications, the POD has been the subject of an intensive analytical effort by the Interagency Ecological Program since the POD was recognized in 2005. The POD investigation has greatly improved our understanding of the ecology of pelagic fishes in the Estuary, especially delta smelt. Revisions to this chapter and in the formulation of the delta smelt effects analysis largely reflect changes in our understanding of delta smelt biology that have emerged from the POD investigation. While mechanisms responsible for POD-era declines of the species probably vary by species, it appears very unlikely that they are independent of one another. Consequently, some of the discussion in the remainder of this chapter involves species other than delta smelt. This chapter borrows heavily from the text of the 2007 POD Synthesis Report (IEP 2008).

Factors That May Influence the Abundance and Distribution of Delta Smelt

Numerous factors are hypothesized to have influenced historical population dynamics of delta smelt (Bennett and Moyle 1996). Some of these factors (e.g., climatic influences on the physical environment) are thought to exert strong, consistent influences, while others are thought to exert more subtle influences (e.g., factors affecting growth rates), or to be important only under certain conditions (e.g., entrainment losses). Historically, the evidence brought to bear on most mechanistic hypotheses has been based on statistical correlations of abundance and/or survival with environmental variables (see Sweetnam and Stevens 1993; Brown and Kimmerer 2001).

For organization we will use the four categories described in the simple conceptual model presented in the POD 2007 Synthesis Report (POD Team, 2008) and in Sommer et al. (2007). Where the POD Team used the model to describe possible mechanisms by which a combination of long-term and recent changes to the ecosystem could produce the observed pelagic fish declines, we use it simply to organize mechanisms that affect abundance and distribution. The conceptual model is rooted in classical food web and fisheries ecology and contains four major components: (1) prior fish abundance, including low-abundance effects that may reduce juvenile production (e.g. stock-recruit effects); (2) habitat, including physical and chemical variables, disease, and localized toxic algal blooms that affect survival and reproduction; (3) top-down effects, including predation, entrainment, and other processes that cause juvenile and adult mortality; (4) bottom-up effects, including food web interactions that affect growth, reproduction, and, indirectly, survival.

Prior Abundance

The relationship between numbers of spawning fish and the numbers of young subsequently recruiting to the adult population is known as a stock-recruit relationship. Stock-recruit relationships have been described for many species and are a central part of the management of commercially and recreationally fished species (Myers et al. 1995). Different forms of stock recruit relationships are possible, including density-independent, density-dependent, and density vague types. The latter refers to situations where there is not a statistically demonstrable stock recruit relationship observable in available data. In any form of a stock-recruit model, there is a point at which low adult stock will result in low juvenile abundance and subsequent low recruitment to future adult stocks even under favorable environmental conditions while the stock ‘rebuilds’ itself.

Moyle et al. (1992) and Sweetnam and Stevens (1993) both reported that number of delta smelt spawners (indexed by the FMWT) was a poor predictor of subsequent recruits (indexed by the following year’s TNS). Both linear and nonlinear Beverton-Holt models suggested that only about a quarter of the variance in delta smelt TNS abundance could be explained by the abundance of the adult spawners. This means that over the range of empirical experience most of the variation in delta smelt abundance is due to other causes.

At present, there is an ongoing scientific debate concerning interpretation of within-year dynamics of delta smelt. Both the TNS and FMWT indices suggest similar long-term abundance trends for delta smelt collected in the summer and fall respectively (Figure 7-2 and Figure 7-3). However, when all of the available data are considered together, a nonlinear Beverton-Holt model describes the relationship between the TNS and FMWT data better than a linear model (Bennett unpublished; reproduced in Figure 7-4).

The standard fisheries interpretation of such a relationship is that it indicates a carrying capacity for the population - in this case during late summer of the first year of life. Phrased another way, this relationship suggests that as the number of juveniles produced increases, so does population mortality. Evidence for this density-dependent mortality was presented in Figure 19 of Brown and Kimmerer's (2001). In fisheries science, density-dependence is the mechanism allowing stocks to be sustainably fished. A correlation of abundance and mortality means there is "surplus production" that can be harvested without negatively affecting a population's viability.

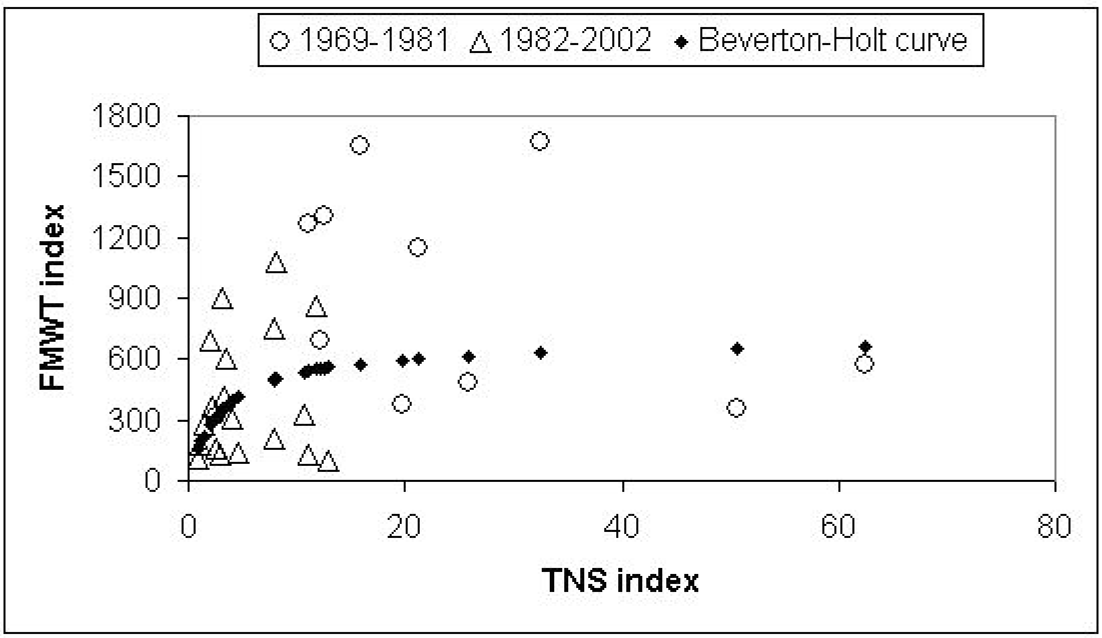

Figure 7-4 (Beverton-Holt curve was fitted to all data even though time periods are shown separately).

The evidence for density-dependent mortality in the delta smelt population has not been universally accepted by delta smelt biologists (Brown and Kimmerer 2001; EET 2007 unpublished). One reason for this skepticism is that it may not be appropriate to pool all years of data. In Figure 7-4, the data points from the pre-decline period (1969-1981) almost all occur outside of the range of the post-decline (1982-2002) data points. Therefore, an alternative explanation of the TNS-MWT relationship is possible - the non-linearity may reflect two different relationships from two time periods with different delta smelt carrying capacities. This latter relationship suggests that summer abundance is not and has never been a statistically significant predictor of fall abundance. As stated above, which (if either) of these interpretations is correct remains a subject of debate.

One possible problem with analyses using the TNS index is that it is not considered as robust an abundance index as the FMWT (Miller 2000). However, the TNS indices are correlated with two unpublished versions of a larval abundance index derived from the DFG 20-mm Delta Smelt Survey, which has been conducted each spring-summer since 1995 (Figure 7-5). This provides support for the density-dependent mortality hypothesis because it suggests the Townet Survey reflects the large differences in young-of-year (YOY) delta smelt abundance that underlie the density-dependent mortality hypothesis.

From a stock-recruit perspective, the present low abundance of delta smelt is of particular concern. The current population is an order of magnitude smaller than at any time previously in the record (Figure 7-6). The delta smelt stock-recruit relationship appears to be density vague over the entire period that data is available (Bennett 2005), meaning there is no clear relationship between the adult spawning population and the number of adult recruits expected in the following year, as measured by the Fall Midwater Trawl. There was also a historically weak statistical association between summer abundance (as measured by the Summer Townet Survey) and abundance a few months later during the Fall Midwater Trawl Survey, suggesting that delta smelt year-class strength was often set during late summer. However, Feyrer et al. (2007) found that the abundance of pre-adult delta smelt during fall was a statistically significant predictor of juvenile delta smelt abundance the following summer, for the time period 1987-2005. Similarly, delta smelt summer abundance is a statistically significant predictor of fall abundance. These relationships are particularly strong for the period 2000-2006 (Figure 7-7). The strong relationship in summer to fall survival since 2000 (Figure 7-7) suggests that the primary factors affecting juvenile survival recently changed and shifted to earlier in the life cycle, or that the stock has declined to such a low level that prior abundance is now the primary factor controlling abundance. These observations strongly suggest that recent population trends are outside the historical realm of variability and resilience shown by these species, particularly delta smelt.

Scientific debate also continues regarding the meaning of statistically significant autocorrelation in the TNS and FMWT time series. Autocorrelation means that index values within the time series are dependent in part on values that preceded them. Both sets of indices show significant autocorrelation at lag two years, meaning that successive index values are correlated with index values from two years prior. Bennett (unpublished) hypothesized the lag two-year autocorrelation was evidence for a reproductive contribution of age-two spawners, but this interpretation has not thus far been backed by strong empirical evidence. The contribution of age-two spawners to delta smelt population dynamics is currently under investigation (Brown and Kimmerer 2002).

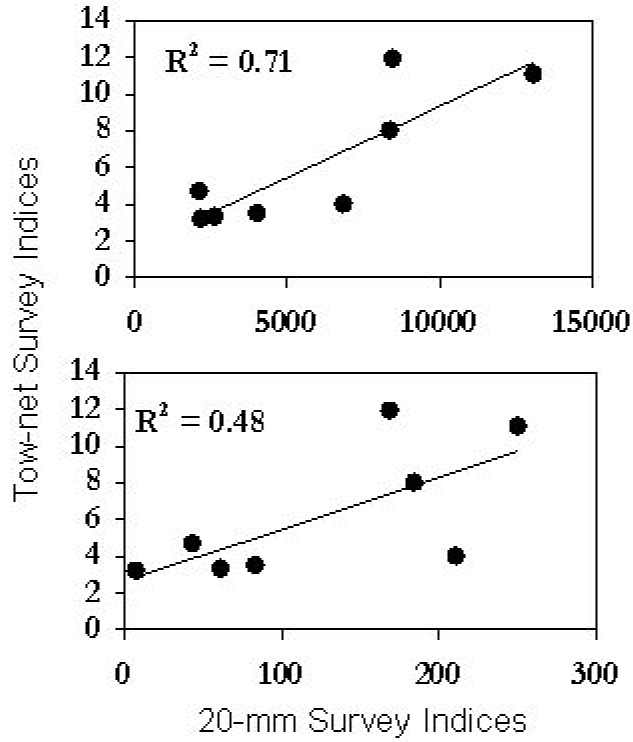

Figure 7-5 Relationships between 20-mm Survey indices and TNS indices, 1995-2002.

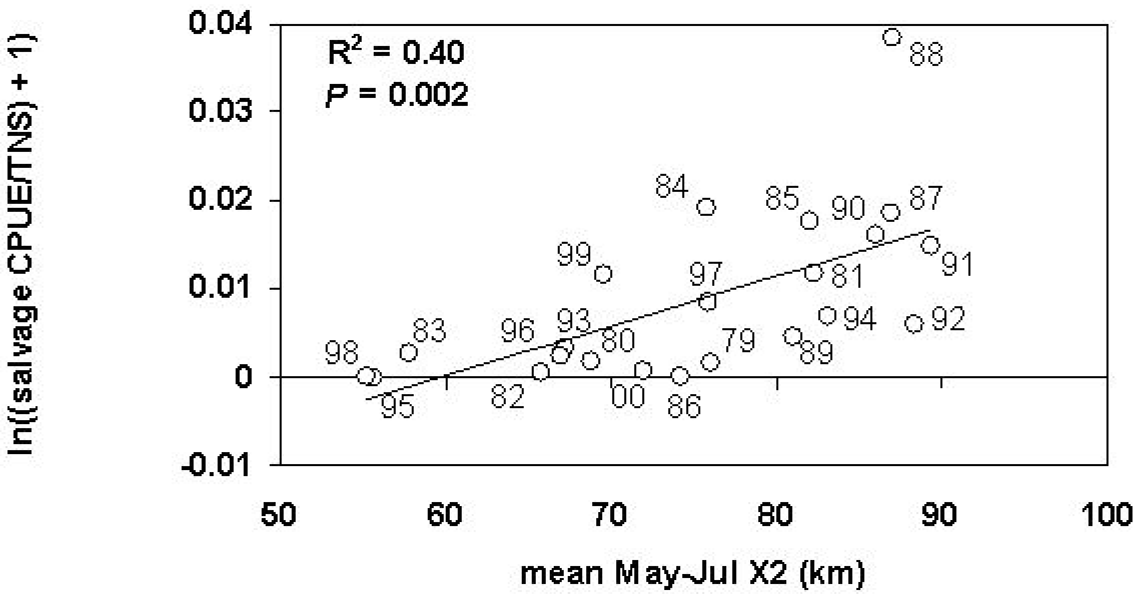

Figure 7-6 Water operations impacts to the delta smelt population.

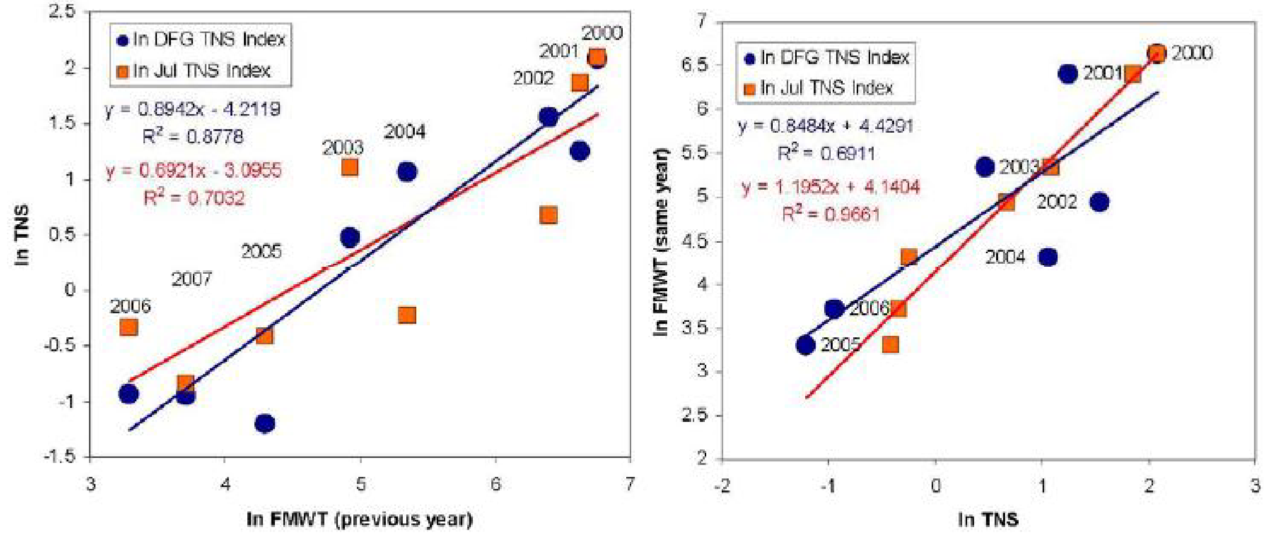

Figure 7-7 Relationships between juvenile and adult lifestages of delta smelt since 2000.
NOTE: The Townet Survey is a measure of summer juvenile abundance. The Fall Midwater Trawl is a measure of fall pre-spawning adult abundance. The blue circles represent the data from the full Townet Survey which begins in June and ends when the average fork length of striped bass reaches 38 mm. The red squares represent data from July only. Regression equations and coefficients are given in blue font for the full Townet Survey data and in red font for the July Townet Survey data.

Reclamation and DWR (1994) were concerned about autocorrelation resulting in spurious conclusions about environmental influences on delta smelt population dynamics. Statistically speaking, autocorrelation in a time series or in the residuals from a correlative analysis of the time series and an explanatory variable can complicate interpretation because a variable may happen to covary with, but not actually influence the underlying process resulting in the autocorrelation. Recent statistical analyses have mitigated for this by using residuals from various stock-recruit relationships (Brown and Kimmerer 2001) and by testing regression residuals for significant autocorrelation.

Habitat

Aquatic habitats are the suites of physical, chemical, and biological factors that species occupy (Hayes et al. 1996). The maintenance of appropriate habitat quality is essential to the long-term health of aquatic resources (Rose 2000; Peterson 2003). A key point is that habitat suitability affects most or all other factors affecting abundance and/or distribution. This is because changes in pelagic habitat, to take an example, affect not only affect delta smelt and other pelagic fishes but also their predators and prey.

Habitat for delta smelt is open water, largely away from shorelines and vegetated inshore areas. This includes large embayments such as Suisun Bay and the deeper areas of many of the larger channels in the Delta. More specifically, delta smelt habitat is water with suitable values for a variety of physical-chemical properties, especially including salinity, turbidity, and temperature, suitably low levels of contaminants, and suitably high levels of prey production to support growth. Thus, delta smelt habitat suitability in the estuary can be strongly influenced by variation in freshwater flow (Jassby et al. 1995; Bennett and Moyle 1996; Kimmerer 2004). Several of the POD fishes, including delta smelt, use a variety of tidally assisted swimming behaviors to maintain themselves within open-water areas where water quality and food resources are favorable (Bennett et al. 2002). The four POD fishes also distribute themselves at different values of salinity within the estuarine salinity gradient (Dege and Brown 2004), so at any point in time, salinity is a major factor affecting their geographic distributions.

Physical Habitat

We will focus exclusively on pelagic habitat because there has been little work done to date to develop the specific qualities of other habitat types, such as flooded islands or shallow sloughs, that might be either important requirements for delta smelt or detrimental to their success. The spawning season is the only period during which delta smelt might use littoral habitats or vegetated inshore areas, especially those in freshwater areas of the delta. However, while something is known about the spawning substrate preferences of the osmerid clade that includes delta smelt, and about delta smelt from lab studies by Lindberg and Baskerville-Bridges (summarized in Wang 2007), we still do not know what substrates or habitats are actually used for spawning by wild delta smelt, nor what non-pelagic habitats are occupied by larval delta smelt before they move into the pelagic realm. We still rely on pelagic-zone trawling to quantify the distribution of adult delta smelt during the spawning season and by larval and juvenile delta smelt later in the year. By contrast, the role of physico-chemical properties of openwater habitat has been relatively intensively studied in recent years as a result of the POD. These properties are now known to be important determinants of pelagic habitat use by delta smelt.

Changes in delta smelt habitat quality in the San Francisco Estuary can be indexed by changes in X2. The abundance of many local taxa has tended to increase in years when flows into the estuary are high and the 2 psu isohaline is pushed seaward (Jassby et al. 1995), implying that over the range of historical experience the quantity or suitability of estuarine habitat increases when outflows are high.

Currently, X2 (which is controlled by both climate and water operations) is a strong predictor of the delta smelt TNS index but curiously, the slope of the X2-TNS relationship switched sign about the time of the delta smelt decline in the early 1980s (Kimmerer 2002). During 1959-81, TNS indices were highest in years of low freshwater flow. In contrast, during 1982-2000, TNS indices were usually among the lowest recorded during years of low freshwater flow. Throughout 1959-2000, TNS indices have been comparable during years of high freshwater flow. The reason(s) for this change in the relationship of young delta smelt abundance to low spring flow conditions beginning in the early 1980s is unknown.

The number of days during spring that water temperature remained between 15 ºC and 20 ºC (59ºF to 68ºF), with a density-dependence term to correct for the saturating TNS-FMWT relationship (described below), predicts FMWT indices fairly well ($r^2 \approx 0.70$; $p < 0.05$; Bennett unpublished presentation at the 2003 CALFED Science Conference). The spring temperature "window" is thought to influence delta smelt abundance by influencing reproductive success - a longer period of optimal water temperatures during spring increases the number of spawning events and cohorts produced. More cohorts translate into a higher probability for a strong year class. Summer water temperatures have also been shown to be an important predictor of delta smelt occurrence based on multi-decadal analyses of the TNS data (Nobriga et al. 2008). Water temperatures in the Delta and estuary are primarily affected by air temperatures and cannot be controlled by CVP/SWP operations because water storage facilities are too far away from the Delta. Therefore, Delta water operations cannot manage water temperatures to enhance conditions for delta smelt spawning or rearing in a manner analogous to strategies used for salmonid fishes in Delta tributaries.

The number of days X2 is in Suisun Bay during spring also is weakly positively correlated with the FMWT indices (Brown and Kimmerer 2001). Hypotheses regarding potential mechanisms underlying X2-abundance relationships have been described previously (Moyle et al. 1992; Jassby et al. 1995; Bennett and Moyle 1996; Kimmerer 2002). However, it is probable that X2 position covaries with the number of days spawning temperatures remain optimal during spring, so both of these correlations may reflect the same phenomenon.

Based on a 36-year record of concurrent midwater trawl and water quality sampling, there has been a long-term decline in fall habitat environmental quality for delta smelt (Feyrer et al. 2007). The long-term environmental quality declines for delta smelt are defined by a lowered probability of occurrence in samples based on changes in specific conductance and Secchi depth. Notably, delta smelt environmental quality declined recently coinciding with the POD (Figure 7-8). The greatest changes in environmental quality occurred in Suisun Bay and the San Joaquin River upstream of Three Mile Slough and southern Delta (Figure 7-9). There is evidence that these habitat changes have had population-level consequences for delta smelt. The inclusion of specific conductance and Secchi depth in the delta smelt stock-recruit relationship described above improved the fit of the model, suggesting adult numbers and their habitat conditions exert important influences on recruitment.

The importance of salinity in this study was not surprising, given the relationships of population abundance indices with X2 for many species. Fall salinity has been relatively high during the POD years, with X2 positioned further upstream, despite moderate to high outflow conditions during the previous winter and spring of most years. Recent increases in fall salinity could be due to a variety of anthropogenic factors although the relative importance of different changes have not yet been fully assessed. Initial results from 2007 POD studies have identified increased duration in the closure of the Delta Cross Channel, operations of salinity gates in Suisun Marsh, and changes in export/inflow ratios (i.e. Delta exports/reservoir releases) as contributing factors. There appeared to be a curious anomaly in the salinity distribution of delta smelt collected during the September 2007 FMWT survey. All seven delta smelt collected during this survey were captured at statistically significant higher salinities than what would be expected based upon the relationship generated by Feyrer et al. (2007). There could be any number of reasons why this occurred, including the substantial Microcystis bloom which occurred further downstream than normal and may have affected the distribution of other organisms.

The importance of Secchi depth (a measure of water clarity or, conversely, turbidity) in the longterm changes in pelagic fish environmental quality (Feyrer et al. 2007) was more surprising. Unlike salinity, interannual variation in water clarity in the Delta is not primarily a function of flow variation (Jassby et al. 2002). The primary hypotheses to explain the increasing water clarity are (1) reduced sediment supply due to dams in the watershed (Wright and Schoellhamer 2004), (2) sediment washout from very high inflows during the 1982-1983 El Nino (Jassby et al. 2005), and (3) biological filtering by submerged aquatic vegetation (Brown and Michniuk 2007;

Dave Schoellhamer, USGS, unpublished data). In lakes, high densities of Egeria densa and similar plants can mechanically filter suspended sediments from the water column (Scheffer 1999). Vegetation has also been shown to facilitate sedimentation in marshes and estuaries (Yang 1998; Braskerud 2001; Pasternack and Brush 2001; Leonard et al. 2002). The mechanisms causing the negative associations between water clarity and delta smelt occurrence are unknown, but based on research in other systems (e.g. Gregory and Levings 1998), Nobriga et al. (2005) hypothesized that higher water clarity increased predation risk for delta smelt, young striped bass, and other fishes typically associated with turbid water.

Regional Changes in Habitat

Initial results from a POD-funded study indicate that *E. densa*, an introduced species, is continuing to spread by expansion of existing patches and invasion of new areas (Erin Hestir et al., UC Davis, unpublished data). Areal coverage of *E. densa* increased more than 10 percent per year from 2004 to 2006. Light penetration and water velocity are the factors likely controlling its distribution in the Delta and salinity likely limits its penetration into the estuary (Hauenstein and Ramirez 1986). In clear water, E. densa can grow to depths of 6 m (Anderson and Hoshovsky 2000). If Delta clearing continues, it seems likely that E. densa will spread into progressively deeper water.

Trends in environmental quality for delta smelt differ during the summer period. Specific conductance, Secchi depth, and water temperature all significantly predict delta smelt occurrence in summer, suggesting they all interact to affect delta smelt distribution (Nobriga et al. in press). However, none of the water quality variables were correlated with delta smelt abundance (as indexed by the Summer Townet Survey) at the scale of the entire estuary (Nobriga et al. 2008). Based on these habitat variables, Nobriga et al. (in press) identified three distinct geographic regions that had similar long-term trends in the probability of delta smelt occurrence. The primary habitat region was centered on the confluence of the Sacramento and San Joaquin rivers near Sherman Island; delta smelt relative abundance was typically highest in the confluence region throughout the study period. There were two marginal habitat regions, one centered on Suisun Bay where specific conductance was highest and delta smelt relative abundance varied with specific conductance. The third region was centered on the San Joaquin River and the southern Delta. The San Joaquin River region had the warmest water temperatures and the highest water clarity. Water clarity increased strongly in this region during 1970-2004. In the San Joaquin River region, delta smelt relative abundance was correlated with water clarity; catches declined rapidly to zero from 1970-1978 and remained consistently near zero thereafter. These results support the hypothesis that basic water quality parameters are predictors of summer delta smelt relative abundance, but only at regional spatial scales. These regional differences are likely due to variability in habitat rather than differences in delta smelt responses. Water management operations are targeted on keeping the lower Sacramento and San Joaquin rivers fresh for water exports so the range in salinity is probably smaller than the range in turbidity. In the Suisun Bay region, there is a wider range of salinities relative to the other regions, so a response to that variable is possible.

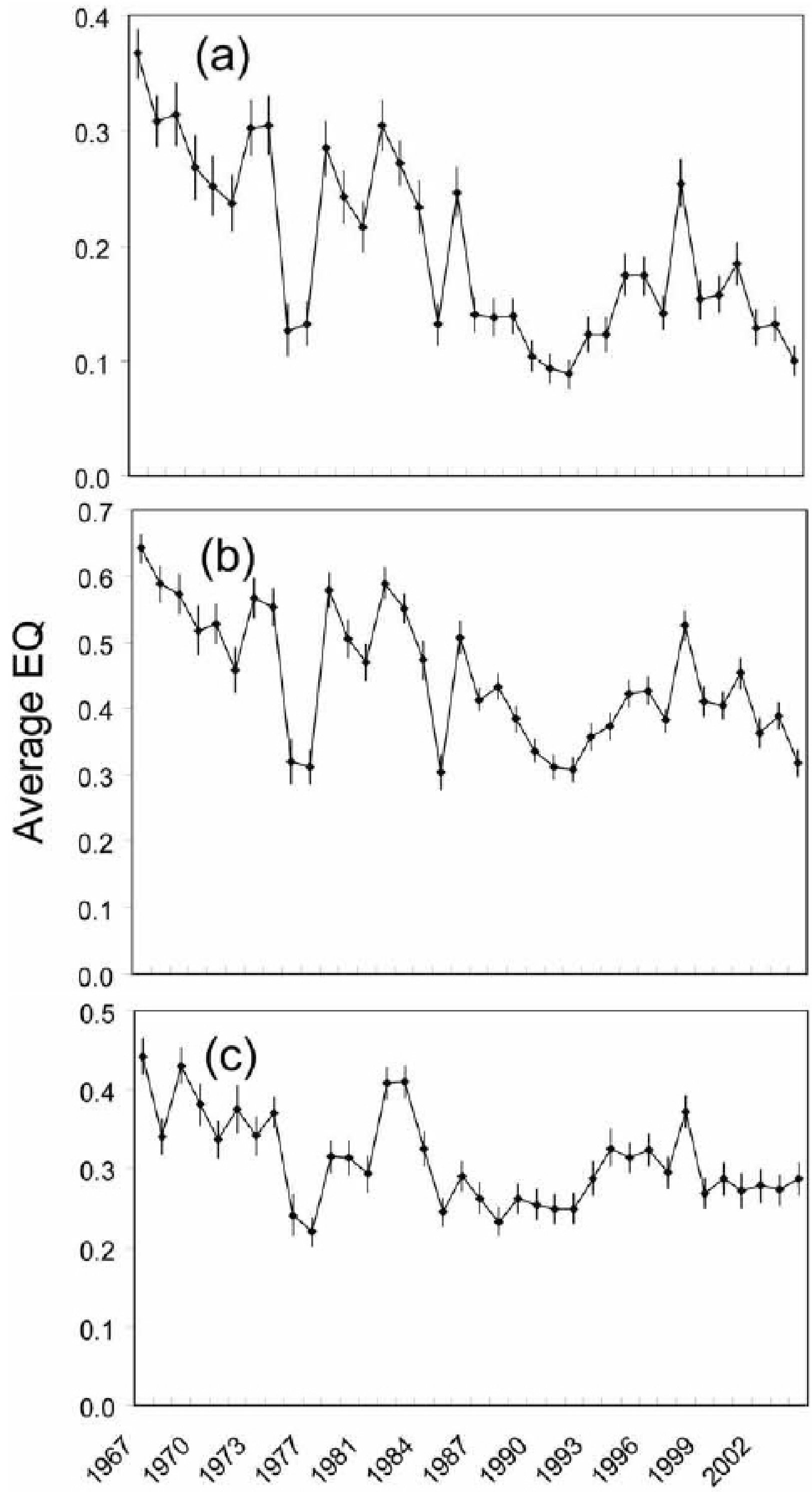

Figure 7-8 Annual values (± 2 standard errors) of environmental quality (EQ) for (a) delta smelt, (b) threadfin shad, (c) striped bass in San Francisco Estuary, based on data from the Fall Midwater Trawl (from Feyrer et al. 2007).

NOTE: EQ is the probability of capturing the species in a sample based on values of specific conductance and Secchi depth for delta smelt and striped bass and based on values of water temperature and specific conductance for threadfin shad.

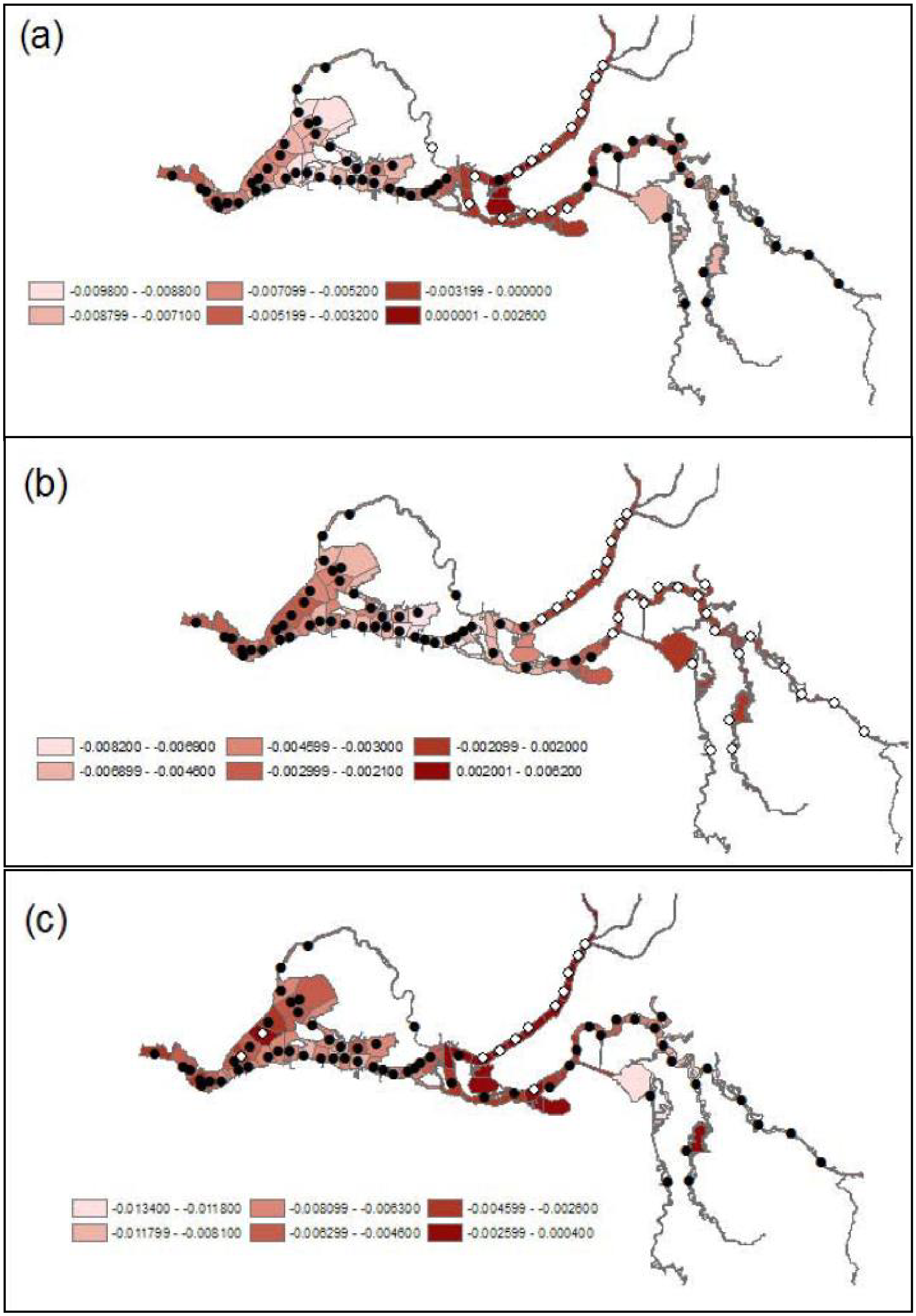

Figure 7-9 Spatial distribution of long-term trends in annual EQ for (a) delta smelt, (b) threadfin shad, (c) striped bass in San Francisco Estuary shown for the region bordered downstream at Carquinez Strait.

NOTE: Color shading represents the coefficient for the year term for individual linear regressions of EQ versus year for each station. Lighter shading represents a more negative slope. Open circles and filled circles represent stations with non-significant (P > 0.05) or significant regressions (P < 0.05), respectively (from Feyrer et al. 2007).

Contaminants and Disease

In addition to habitat changes from salinity, turbidity and invasive aquatic vegetation such as E. densa, contaminants can change ecosystem functions and productivity through numerous pathways. The trends in contaminant loadings and their ecosystem effects are not well understood. We are currently evaluating direct and indirect toxic effects on the POD fishes of both man-made contaminants and natural toxins associated with blooms of M. aeruginosa (a cyanobacterium or blue-green alga). The main indirect contaminant effect we are investigating is inhibition of prey production.

Although a number of contaminant issues were first investigated during the POD years, concern over contaminants in the Delta is not new. There are long standing concerns related to mercury and selenium in the watershed, Delta, and Bay (Linville et al. 2002; Davis et al. 2003). Phytoplankton growth rate may occasionally be inhibited by high concentrations of herbicides (Edmunds et al. 1999). New evidence indicates that phytoplankton growth rate may at times be inhibited by ammonium concentrations in and upstream of Suisun Bay (Wilkerson et al. 2006, Dugdale et al. 2007, Dugdale et al unpublished). Toxicity to invertebrates has been noted in water and sediments from the Delta and associated watersheds (e.g., Kuivila and Foe 1995; Giddings 2000; Werner et al. 2000 and unpublished; Weston et al. 2004). Undiluted drainwater from agricultural drains in the San Joaquin River watershed can be acutely toxic (quickly lethal) to fish and have chronic effects on growth (Saiki et al. 1992). Evidence for mortality of young striped bass due to discharge of agricultural drainage water containing rice herbicides into the Sacramento River (Bailey et al. 1994) led to new regulations for discharge of these waters. Bioassays using caged fish have revealed DNA strand breakage associated with runoff events in the watershed and Delta (Whitehead et al. 2004). Kuivila and Moon (2004) found that peak densities of larval and juvenile delta smelt sometimes coincided in time and space with elevated concentrations of dissolved pesticides in the spring. These periods of co-occurrence lasted for up to 2-3 weeks, but concentrations of individual pesticides were low and much less than would be expected to cause acute mortality. However, the effects of exposure to the complex mixtures of pesticides actually present are unknown.

The POD investigators initiated several studies beginning in 2005 to address the possible role of contaminants and disease in the declines of Delta fish and other aquatic species. Their primary study consists of twice-monthly monitoring of ambient water toxicity at fifteen sites in the Delta and Suisun Bay. In 2005 and 2006, standard bioassays using the amphipod Hyalella azteca had low (<5%) frequency of occurrence of toxicity (Werner et al. unpublished data). However, preliminary results from 2007, a dry year, suggest the incidence of toxic events was higher than in wetter previous years. Parallel testing with the addition of piperonyl butoxide, an enzyme inhibitor, indicated that both organophosphate and pyrethroid pesticides may have contributed to the observed 2007 toxicity. Most of the tests that were positive for H. azteca toxicity have come from water samples from the lower Sacramento River. Pyrethroids are of particular interest because use of these insecticides has increased (Ameg et al. 2005, Oros and Werner 2005) as use of some organophosphate insecticides has declined. Toxicity of sediment-bound pyrethroids to macroinvertebrates has also been observed in watersheds upstream of the Delta (Weston et al. 2004, 2005).

Larval delta smelt bioassays were conducted simultaneously with a subset of the invertebrate bioassays. The water samples for these tests were collected from six sites within the Delta during May-August of 2006 and 2007. Results from 2006 indicate that delta smelt is highly sensitive to high levels of ammonia, low turbidity, and low salinity. There is some preliminary indication that reduced survival under low salinity conditions may be due to disease organisms (Werner, unpublished data). No significant mortality of larval delta smelt was found in the 2006 bioassays (Werner 2006), but there were two instances of significant mortality in June and July of 2007 (Werner, unpublished). In both cases, the water samples were collected from sites along the Sacramento River and had relatively low turbidity and salinity and moderate levels of ammonia. It is also important to note that no significant *H. azteca* mortality was seen in these water samples. While the H. azteca tests are very useful for detecting biologically relevant levels of water column toxicity, interpretation of the H. azteca test results with respect to fish should proceed with great caution. The relevance of the bioassay results to field conditions remains to be determined.

POD investigators have also monitored blooms of the toxic cyanobacterium *Microcystis aeruginosa*. Large blooms of *M. aeruginosa* were first noted in the Delta in 1999 (Lehman et al. 2005). Further studies (Lehman et al. in prep.) suggest that microcystins, the toxic chemicals associated with the algae, probably do not reach concentrations directly toxic to fishes, but during blooms, the microcystin concentrations may be high enough to impair invertebrates, which could influence prey availability for fishes. The *M. aeruginosa* blooms peak in the freshwaters of the central Delta during the summer at warm temperatures (20-25 °C; Lehman et al. in prep). Delta smelt and longfin smelt are generally not present in this region of the Delta during summer (Nobriga et al. 2008; Rosenfield and Baxter 2007) so *M. aeruginosa* toxicity is not likely a factor in their recent decline. However, in the low flow conditions of 2007, blooms of this cyanobacterium spread far downstream to the west Delta and beyond during summer (Lehman, unpublished data), so toxicity may have been a much broader issue than in other years.

The POD investigations into potential contaminant effects also include the use of biomarkers that have been used previously to evaluate toxic effects on POD fishes (Bennett et al. 1995; Bennett 2005). The results to date have been mixed. Histopathological and viral evaluation of young longfin smelt collected in 2006 indicated no histological abnormalities associated with toxic exposure or disease (Foott et al. 2006). There was also no evidence of viral infections or high parasite loads. Similarly, young threadfin shad showed no histological evidence of contaminant effects or of viral infections (Foott et al. 2006). Parasites were noted in threadfin shad gills at a high frequency but the infections were not considered severe. Thus, both longfin smelt and threadfin shad were considered healthy in 2006. Adult delta smelt collected from the Delta during winter 2005 also were considered healthy, showing little histopathological evidence for starvation or disease (Teh et al. unpublished). However, there was some evidence of low frequency endocrine disruption. In 2005, 9 of 144 (6 percent) of adult delta smelt males were intersex, having immature oocytes in their testes (Teh et al. unpublished).

In contrast, preliminary histopathological analyses have found evidence of significant disease in other species and for POD species collected from other areas of the estuary. Massive intestinal infections with an unidentified myxosporean were found in yellowfin goby *Acanthogobius flavimanus* collected from Suisun Marsh (Baxa et al. in prep.). Severe viral infection was found in inland silverside *Menidia beryllina* and juvenile delta smelt collected from Suisun Bay during summer 2005 (Baxa et al. in prep.). Lastly, preliminary evidence suggests that contaminants and disease may impair striped bass. Ostrach et al. (in prep.) found high occurrence and severity of parasitic infections, inflammatory conditions, and muscle degeneration in young striped bass collected in 2005; levels were lower in 2006. Several biomarkers of contaminant exposure including P450 activity (i.e., detoxification enzymes in liver), acetylcholinesterase activity (i.e., enzyme activity in brain), and vitellogenin induction (i.e., presence of egg yolk protein in blood of males) were also reported from striped bass collected in 2006 (Ostrach et al. in prep.).

Effects of Habitat Change on the Food Web

Much of the previous discussion about how physical conditions and water quality affect delta smelt and other fishes is also relevant to other aquatic organisms including plankton and the benthos. It is important to keep in mind that river flows influence estuarine salinity gradients and water residence times. The residence time of water affects both habitat suitability for benthos and the transport of pelagic plankton. High tributary flow leads to lower residence time of water in the Delta (days), which generally results in lower plankton biomass (Kimmerer 2004), but also lower cumulative entrainment effects in the Delta (Kimmerer and Nobriga 2008). In contrast, higher residence times (a month or more), which result from low tributary flows, may result in higher plankton biomass. This can increase food availability for planktivorous fishes; however, much of this production may be lost (exported from the Delta) as a result of CVP/SWP and local agricultural water diversions under low flow conditions. Under extreme low flow conditions, long water residence times may also promote high biological oxygen demand when abundant phytoplankton die and decompose (Lehman et al. 2004; Jassby and Van Nieuwenhuyse 2006). Recent particle tracking modeling results for the Delta show that residence times in the southern Delta are highly variable, depending on Delta inflow, CVP/SWP exports, and particle release location (Kimmerer and Nobriga, 2008). Very high inflow leads to short residence time. The longest residence times occur in the San Joaquin River near Stockton under conditions of low Delta inflow and low CVP/SWP export rates.

Salinity variation can have a major effect on the benthos, which occupy relatively “fixed” geographical positions along the gradient of the estuary. While the distributions of the benthos can undergo seasonal and annual shifts, benthic organisms cannot adjust their locations as quickly as the more mobile pelagic community. Analyses of long-term benthic data for four regions of the upper San Francisco estuary indicate that two major factors control community composition: exotic species invasions, and salinity (Peterson et al. in prep). Specifically, the invasion of the overbite clam *Corbula amurensis* in the late 1980s resulted in a fundamental shift in the benthic community; however; the center of distribution of *C. amurensis* and other benthic species varies with flow and the resulting salinity regime. So at any particular location in the estuary, the benthic community can change substantially from year to year as a result of environmental variation and species invasions (Figure 7-10). These changes in the benthic assemblage can have major effects on food availability to pelagic organisms, including delta smelt.

Climate Change

There are several reasons we expect future climate change might have negative long-term influences on pelagic habitat suitability for the POD fishes, including delta smelt. First, there has been a trend toward more Sierra Nevada precipitation falling as rain earlier in the year (Roos 1987, 1991; Knowles and Cayan 2002, 2004). This increases the likelihood of winter floods and may have other effects on the hydrographs of Central Valley rivers and Delta salinity. Altered hydrographs interfere with pelagic fish reproduction, which is usually tied to historical runoff patterns (Moyle 2002). Second, sea level is rising (IPPC 2001). Sea level rise will increase salinity intrusion farther upstream into the Delta unless sufficient freshwater resources are available to repel the seawater. This will shift fish distributions upstream and possibly further reduce habitat area for some species. Third, climate change models project warmer temperatures in central California (Dettinger 2005). As stated above, water temperatures may have a strong influence on POD fish distributions, and there have been long-term regional increases in temperature (Jassby 2008). Summer water temperatures throughout the upper estuary are fairly high for delta smelt. Mean July water temperatures in the upper estuary are typically 21-24C (Nobriga et al. in press) and the lethal temperature limit for delta smelt is reported to be 25C (Swanson et al. 2000), though entrainment of juvenile delta smelt in spring 2007 continued until central Delta temperatures approached 28C. Thus, if climate change were to result in summer temperatures in the Delta substantially exceeding current levels, the geographical extent of suitable habitat for delta smelt during those months could be reduced in some years.

The potential effects of several projected climate change scenarios presented in Appendix R are discussed in Chapter 13. The scenarios are based on a common assumption that sea level will rise by about 1 foot by 2030 and that tidal range will increase by 10% over the same period. The scenarios include extremes of two variables, temperature and precipitation, such that the four scenarios describe a rectangle in temperature-precipitation space that contains most of the climate change projections reviewed in the Appendix.

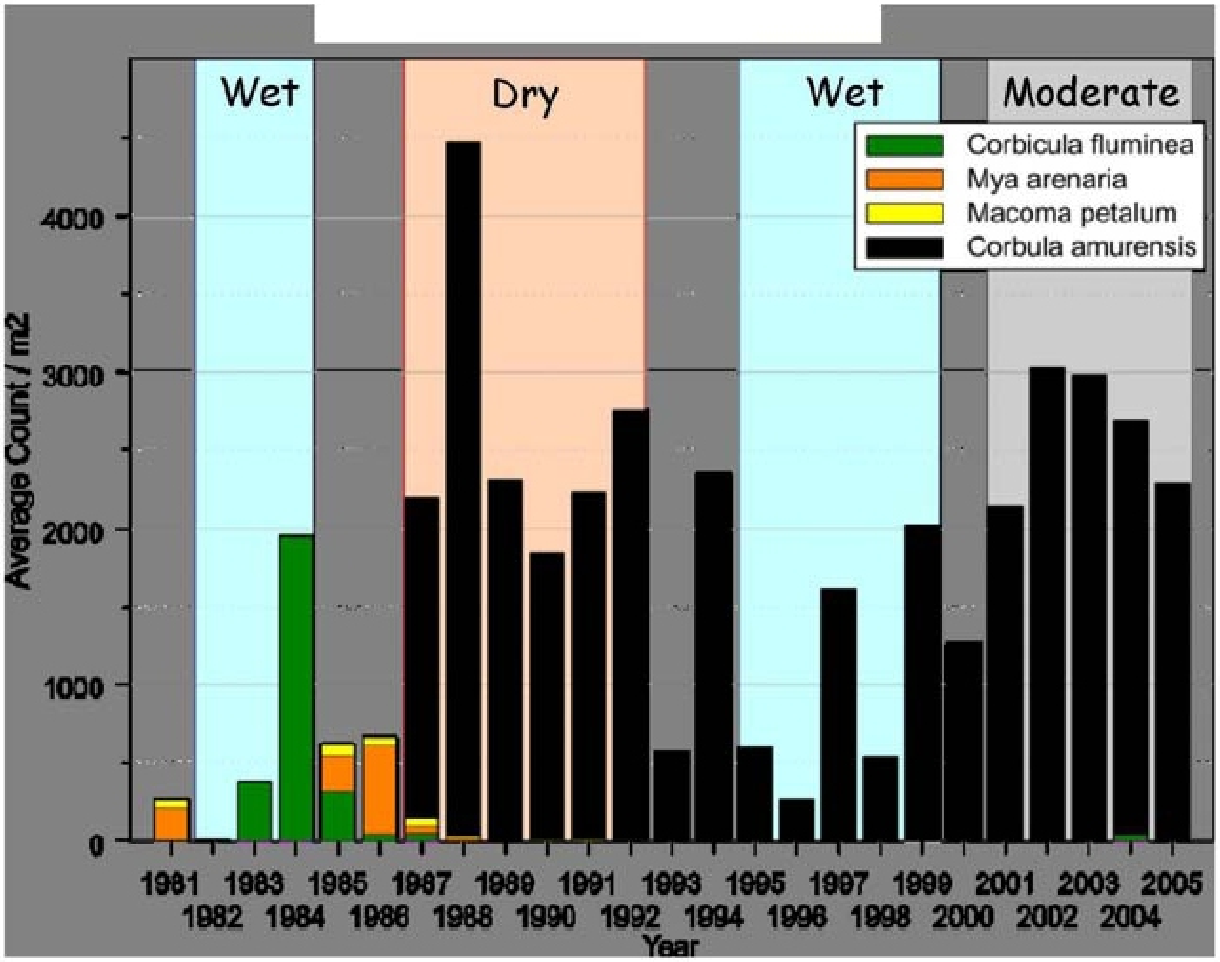

Figure 7-10 Changes in abundance of bivalves in Grizzly Bay from 1981 to 2005 (IEP 2005; Peterson et al. In prep).
NOTE: Salinity is highest during dry years, lowest during wet years and intermediate during moderate years. Water year classifications are explained in detail at: http://cdec.water.ca.gov/cgi-progs/iodir/WSI.

Top-Down Effects

The two most prominent top-down influences on delta smelt and other pelagic fishes are entrainment into various water diversions and predation by piscivorous fishes. Major water diversions in the delta include the SWP and CVP export facilities, power plants, and agricultural diversions. The CVP and SWP water export operations include upstream reservoirs, the DCC, the SMSCG, the North Bay Aqueduct facilities (NBA), the Contra Costa Canal facilities (CCC), CCF, the Banks Pumping Plant/Skinner Fish Facilities (hereafter SWP), the South Delta Temporary Barriers (SDTB) and the Jones Pumping Plant/Fish Collection Facilities (hereafter CVP). The description and operation of these facilities was covered in the “Project Description” section of this Biological Assessment and will not be repeated here.

Water export operations occur primarily at SWP and CVP, with far smaller amounts of water diverted at NBA and CCC. Because of their size, and because of evidence implicating water project operations as contributing causes of the POD, the discussion of them below borrows heavily from the POD analysis.

As described in Chapter 2, the NBA diversions have fish screens designed to FWS criteria for delta smelt protection. In addition, a delta smelt monitoring program occurs each spring in the sloughs near NBA. Until 2005, larval delta smelt sampling was conducted in the vicinity of the NBA. It was discontinued with the consent of FWS because of very low larval smelt occurrence. Because the FWS deems these NBA measures to be adequately protective of delta smelt, the NBA will not be considered further.

Water is also temporarily diverted by two power plants located in the western Delta at Antioch and Pittsburgh. Nonconsumptive water use may reach 3200 cfs during full operation of both plants, which might be enough to create a substantial entrainment risk for fishes residing in the vicinity (Matica and Sommer, in prep.). Studies in the late 1970s indicated that losses of pelagic fishes during such operations can be very high. In recent years these plants have not been operated frequently, and several generating units are now retired. Use of the plants appears to be restricted to supplying power only during periods of extreme demand. They are discussed in more detail below.

Entrainment

Because large volumes of water are drawn from the estuary, water exports and inadvertent fish entrainment at the SWP and CVP export facilities are among the best-studied top-down effects in the San Francisco Estuary (Sommer et al. 2007). The export facilities are known to entrain most species of fish inhabiting the delta (Brown et al. 1996), and are of particular concern in dry years, when the distributions of young striped bass, delta smelt, and longfin smelt shift upstream, closer to the diversions (Stevens et al. 1985; Sommer et al. 1997). As an indication of the magnitude of the effects, approximately 110 million fish were salvaged at the SWP screens and returned to the Delta over a 15-year period (Brown et al. 1996). However, this number greatly underestimates the actual number of fish entrained. It does not include losses at the CVP. Even for the SWP alone, it does not account for mortality of fish in CCF and the waterways leading to the diversion facilities, larvae less than 20 mm FL not efficiently collected by the fish screens, and losses of fish larger than 20 mm FL that because of other inefficiencies are not guided into the salvage tanks by the louver system.

One piece of evidence that export diversions played a role in the POD is the substantial increases in winter CVP and SWP salvage that occurred contemporaneously with recent declines in delta smelt and other POD species (Grimaldo et al. in review). Increased winter entrainment of delta smelt, longfin smelt and threadfin shad represents a loss of pre-spawning adults and all their potential progeny (Sommer et al. 2007). Note that winter salvage levels subsequently decreased to very low levels for all POD species during the winters of 2005-2006 and 2006-2007, possibly due to the very low numbers of fish that appear to remain in the estuary.

In trying to evaluate the mechanism(s) for increased winter-time salvage, POD studies by USGS made three key observations (IEP 2005). First, there was an increase in exports during winter as compared to previous years, mostly attributable to the SWP (Figure 7-11). Second, the proportion of tributary inflows shifted. Specifically, San Joaquin River inflow decreased as a fraction of total inflow around 2000, while Sacramento River increased (Figure 7-12). Finally, there was an increase in the duration of the operation of barriers placed into south Delta channels during some months. These changes may have contributed to a shift in Delta hydrodynamics that increased fish entrainment.

These observations led to a hypothesis that the hydrodynamic change could be indexed using net flows through Old and Middle rivers, which integrate changes in inflow, exports, and barrier operations (Arthur et al. 1996; Monsen et al. 2007). Net or residual flow refers to the calculated flow when the effects of the tide are mathematically removed. An initial analysis revealed that there was a significant inverse relationship between net Old and Middle rivers flow and winter salvage of delta smelt at the SWP and CVP (P. Smith, unpublished). These analyses were subsequently updated and extended to other pelagic fishes (Figure 7-13, L. Grimaldo, in review). The general pattern is that POD species salvage is low when Old and Middle river flows are positive.

The hydrologic and statistical analyses suggest a reasonable mechanism by which winter entrainment increased during the POD years; however, the direct population-level effects of increased entrainment are less clear. As part of the POD investigation, Manly and Chotkowki (IEP 2005; Manly and Chotkowski 2006) used log-linear modeling to evaluate environmental factors that may have affected long-term trends in the Fall Midwater Trawl abundance index of delta smelt. They found that monthly or semi-monthly measures of exports or Old and Middle rivers flow had a statistically significant effect on delta smelt abundance; however, individually they explained a small portion (no more than a few percent) of the variability in the fall abundance index of delta smelt across the entire survey area and time period. Hence, there are other factors that dominate the relationship between exports and delta smelt fall abundance in these analyses. Several of these other factors, including habitat, food web characteristics, and toxic chemical effects are discussed elsewhere in this chapter. Among them, habitat alone is clearly affected by water project operations. Consequently, X2 is examined as an index of habitat location and quality in the delta smelt effects portion of Chapter 13. Similarly, Kimmerer et al. (2001) estimated that entrainment losses of young striped bass were sometimes very high (up to 99 percent), but they did not find evidence that entrainment losses were a major driver of long-term striped bass population dynamics. Kimmerer (2008) addressed delta smelt entrainment by means of particle tracking, and estimated historical entrainment rates for larvae and juvenile delta smelt to be as high as 40%; however, he concluded that larger effects occurring later in the year had more leverage over FMWT delta smelt numbers.

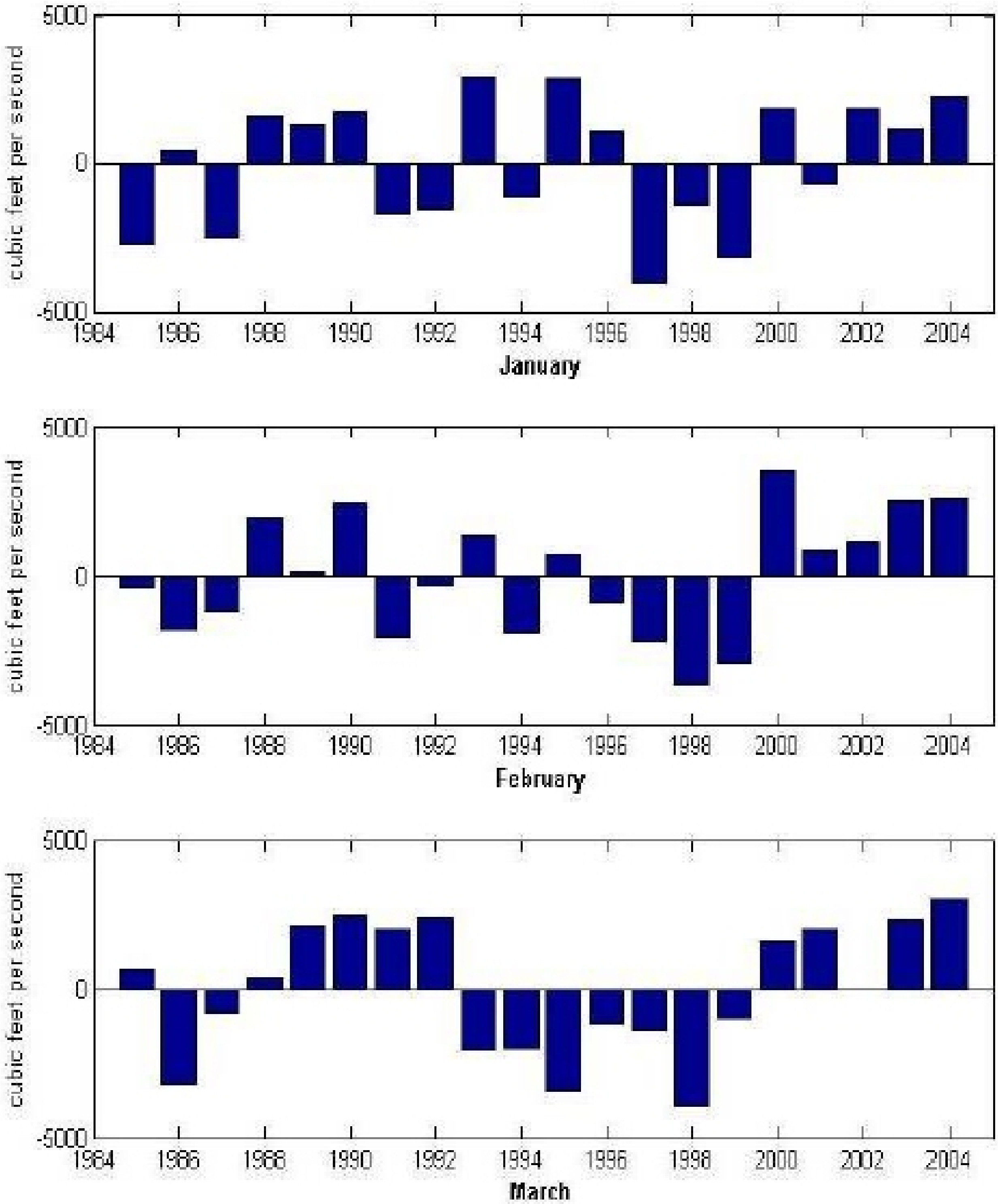

Figure 7-11 Deviations from average exports (cubic feet per second) in January, February, and March exports from 1984 to 2004 (IEP 2005; Simi et al., U.S. Geological Survey, unpublished data).

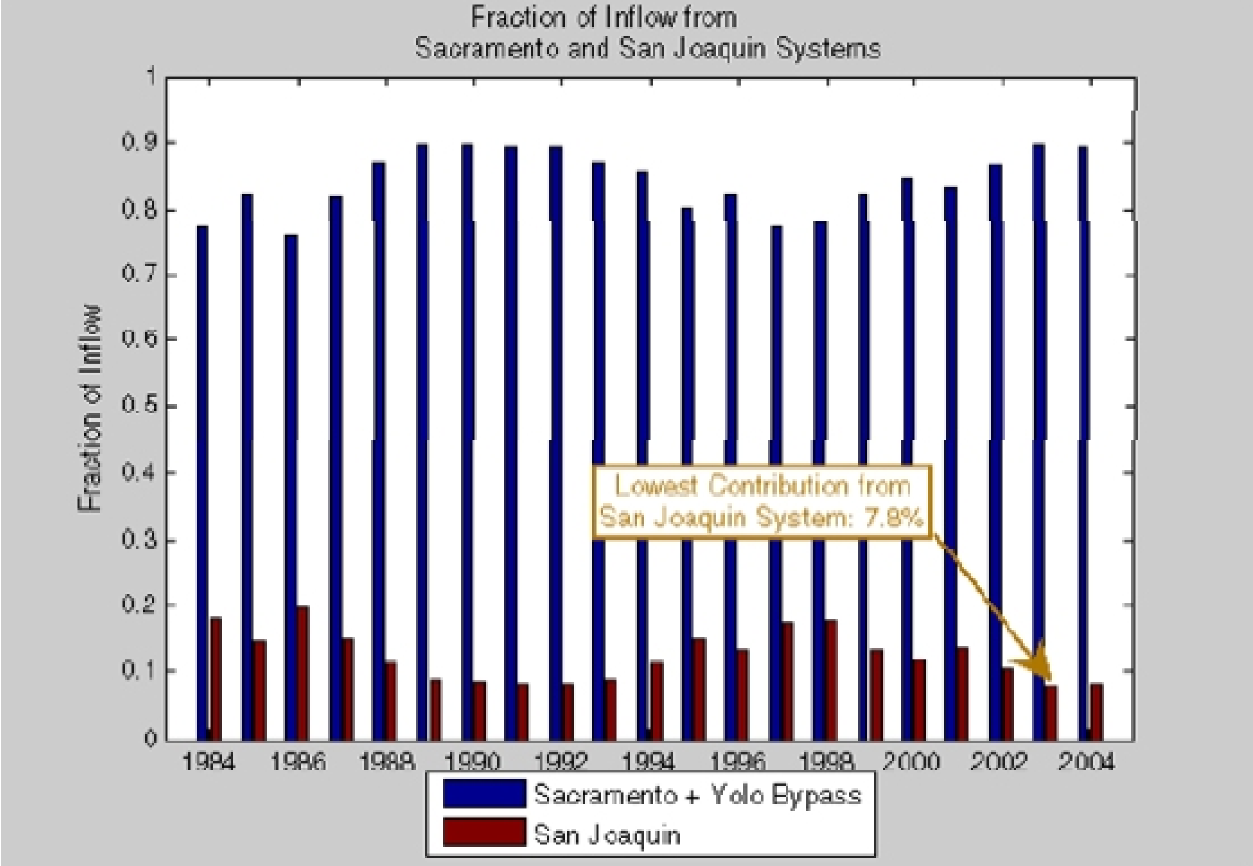

Figure 7-12 Proportion of Delta inflow coming from the San Joaquin River and the Sacramento River, including Yolo Bypass from 1984 to 2004 (IEP 2005; Simi et al., U.S. Geological Survey, unpublished data).

These results do not mean, however, that direct export effects can be dismissed as a contributing cause of the POD. There are two aspects of entrainment that explicitly were not addressed by Manly and Chotkowski (2006) and are not well understood: (1) the possibility that selective entrainment among a heterogeneous population of prespawning adults could produce consequences that do not become manifest until the following year (discussed in the next paragraph), and (2) larval entrainment. Very little is known about historical larval entrainment because larvae are not sampled effectively at the fish screening facilities. To address this shortcoming, Kimmerer and Nobriga (in press) coupled a particle tracking modeling with survey results to estimate larval entrainment. Kimmerer (in press) used data from several Interagency Ecological Program (IEP) monitoring programs to estimate entrainment of delta smelt. These approaches suggest that larval delta smelt entrainment losses could exceed 50 percent of the population under some low flow and high export conditions depending on spawning distribution. Although not necessarily a realistic operational scenario, the effect of larval entrainment could be significant. Because there are few reliable larval entrainment data, it is not possible to directly address the question of how important these losses were historically.

It has been proposed that losses of larger females and their larvae may have a disproportionate effect on the delta smelt population (B. Bennett, unpublished data). Bennett (unpublished data) proposes that larger females spawn earlier in the season and produce more eggs, which are of better quality, and survivability, as has been noted for Atlantic cod and other commercially harvested species (Marteinsdottir and Steinarsson 1998; Swain et al. 2007). As a consequence, winter and early spring exports, which have continually increased as described above (Figure 7-14), could have an important effect on reproductive success of early spawning female delta smelt. Bennett hypothesizes that the observed reduction in the mean size of adult delta smelt in the early 1990s (Sweetnam 1999) is a result of selective losses of earlier spawning adults and their larvae, thereby selecting for later spawned offspring (that have less time to reach maturity). Under this hypothesis, the most important result of the loss of early spawning females would manifest itself in the year following the loss, and would therefore not necessarily be detected by analyses relating fall abundance indices to same-year (or same-water year) predictors. This hypothesis is presently being evaluated by Bennett’s laboratory using otolith methods.

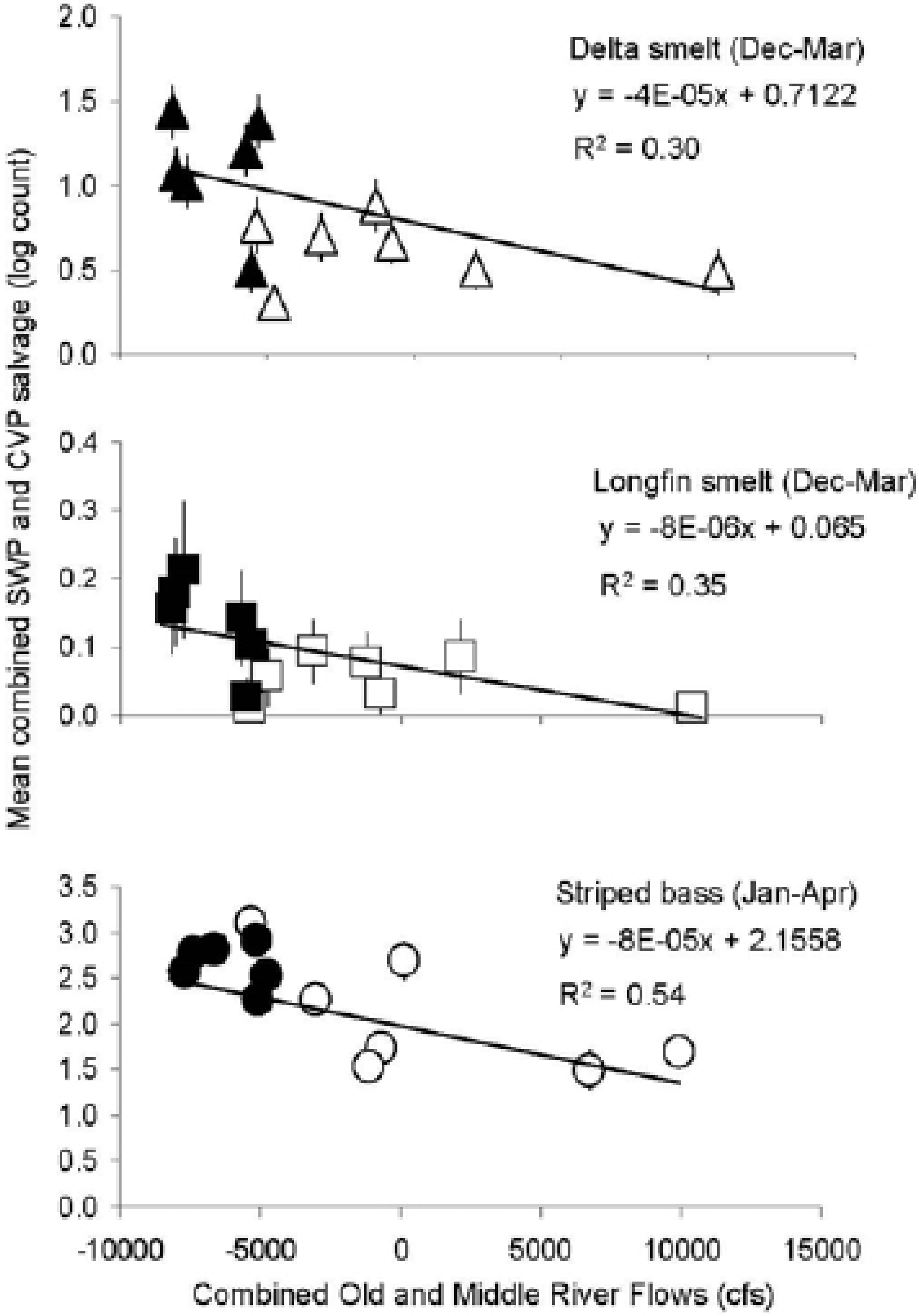

Figure 7-13 Relationship of mean combined salvage of delta smelt, longfin smelt, and striped bass at the State Water Project (SWP) and Central Valley Project (CVP) to combined Old and Middle rivers (OMR) flow (cubic feet per second).
NOTE: Open symbols denote pre-POD years (1993-1999) and filled symbols represent post-POD years (2000-2005) (Grimaldo et al. In prep).

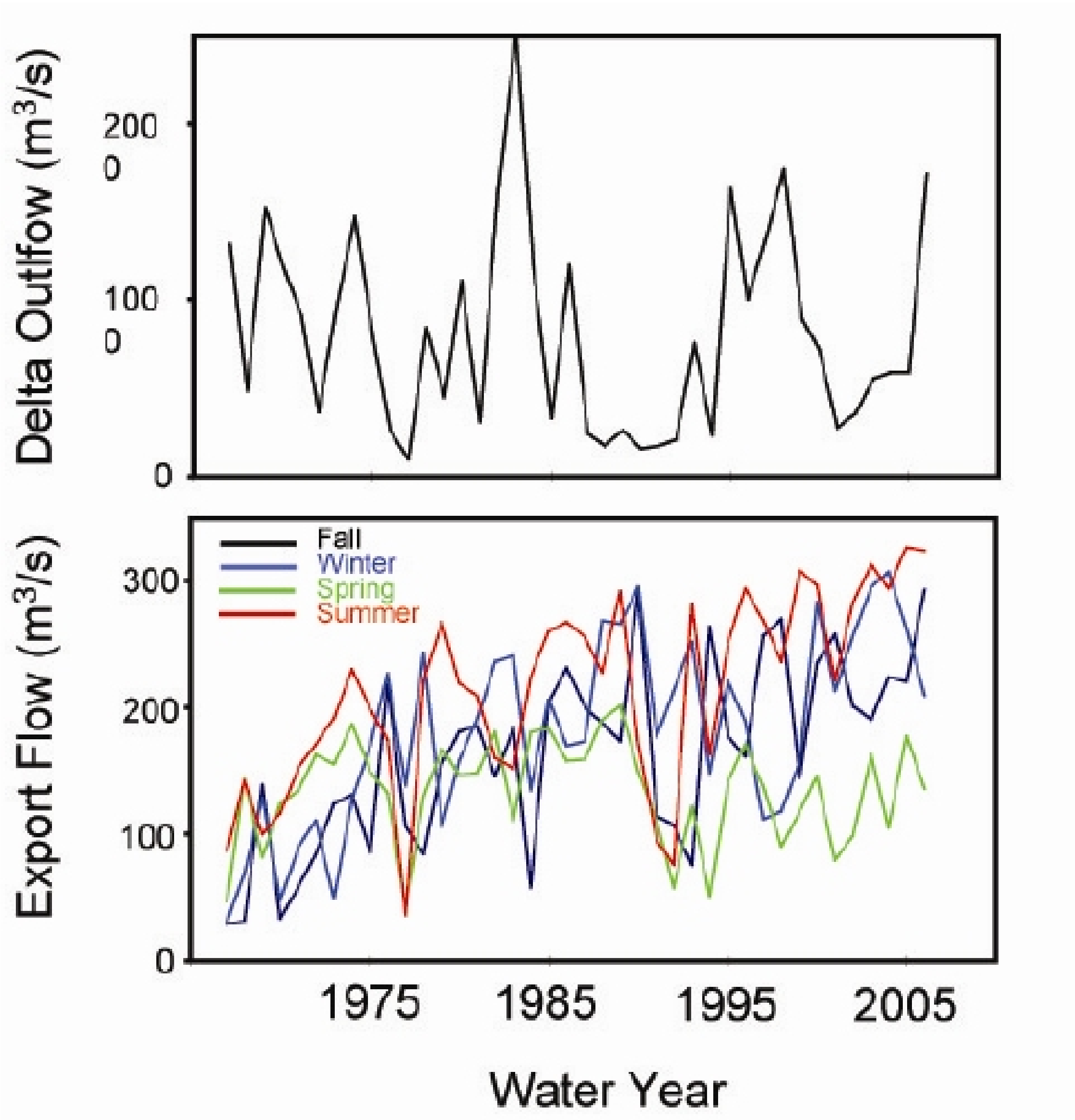

Figure 7-14 Delta outflow (m3/s) averaged over water years (top) and export flow (m3/s) averaged over seasons (bottom).
NOTE: Water years begin on 1 October of the previous calendar year. Seasons are in 3-month increments starting in October. Export flows are the sum of diversions to the Federal Central Valley Project and State Water Project pumping plants. The outflow and export data are from DWR (http://iep.water.ca.gov/dayflow) (from Sommer et al. 2007).

The CVP and SWP export operations are most likely to impact adult delta smelt during their upstream spawning migration between December and April. A significant negative correlation between November-February delta smelt salvage and the residuals from a FMWT index at year one vs. FMWT index at year two stock-recruit relationship is evidence for an influence of adult entrainment on delta smelt population dynamics (Brown and Kimmerer 2001). Delta smelt spawn over a wide area (much of the delta and some areas downstream). In some years a fairly large proportion of the population seems to spawn in or be rapidly transported to the central and southern delta. Presumably, entrainment vulnerability is higher during those years. Unfortunately, it is not currently known what cues decisions about where to spawn.

The CVP and SWP water operations are not thought to have any impact on delta smelt eggs because they remain attached to substrates. Shortly after hatching, larvae are vulnerable to entrainment at all points of diversion, but, as mentioned earlier, are not counted in SWP or CVP fish salvage operations. Juvenile delta smelt also are vulnerable to entrainment and are counted in salvage operations once they reach 20-25 mm in length. Most juvenile salvage occurs from April-July with a peak in May-June (Nobriga et al. 2001).

Salvage of delta smelt population has historically been greatest in drier years when a high proportion of YOY rear in the delta (Moyle et al. 1992; Reclamation and DWR 1994; Sommer et al. 1997; and Figure 7-6). In recent years however, salvage also has been high in moderately wet conditions (Nobriga et al. 2000; 2001; Grimaldo et al., in prep.; springs of 1996, 1999, and 2000) even though a large fraction of the population was downstream of the Sacramento-San Joaquin River confluence. Nobriga et al. (2000; 2001) attributed recent high wet year salvage to a change in operations for the VAMP that began in 1996. The VAMP provides a San Joaquin River pulse flow from mid-April to mid-May each year that probably improves rearing conditions for delta smelt larvae and also slows the entrainment of fish rearing in the delta. The high salvage events may have resulted from smelt that historically would have been entrained as larvae and therefore not counted at the fish salvage facilities growing to a salvageable size before being entrained. However, a more recent analysis summarized in Figure 7-6 provides an alternative explanation. delta smelt salvage in 1996, 1999, and 2000 was not outside of the expected historical range when three factors are taken into account, (1) delta smelt distribution as indexed by X2 position, (2) delta smelt abundance as indexed by the TNS, and (3) the amount of water exported. Therefore, it is uncertain that operations changes for VAMP have influenced delta smelt salvage dynamics as strongly as suggested by Nobriga et al. (2000). Nonetheless, it is likely that actual entrainment has decreased since the initiation of the VAMP because of the improved transport flows it provides. In addition, “assets” from CALFED’s Environmental Water Account (EWA) are often used during this time of year to further reduce delta smelt entrainment. Although the population level benefits of these actions are unknown, they appear to have been successful at keeping delta smelt salvage under the limits set by FWS (1993) (Brown and Kimmerer 2002).

Another possible effect on delta smelt entrainment is the South Delta Temporary Barriers (SDTB). The SDTB are put in place during spring and removed again each fall (see Chapter 2 - “Project Description” of this Biological Assessment for more detail). Computer simulations have shown that placement of the barriers changes south delta hydrodynamics, increasing central delta flows toward the export facilities (DWR 2000). When delta smelt occur in areas influenced by the barriers, entrainment losses might increase.

Predation Effects

Predator-prey dynamics in the San Francisco Estuary are poorly understood, but are currently receiving considerable research attention by the IEP as part of the POD investigation. Studies during the early 1960s found delta smelt were an occasional prey fish for striped bass, black crappie and white catfish (Turner and Kelley 1966). This, coupled with the substantial decline in striped bass abundance has been taken as evidence that delta smelt are not very vulnerable to predation (Sweetnam and Stevens 1993). In recent years, it has become clear that the prey choices of piscivorous fishes switch as the relative abundances of species in the prey field change (Buckel et al. 1999). Even in the 1960s, delta smelt was rare relative to the dominant prey fishes of striped bass (age-zero striped bass and threadfin shad) (Turner and Kelley 1966). Therefore, there should have been no expectation that delta smelt would be commonly found in stomach contents samples. Because delta smelt are still rare relative to currently common prey fishes, the same holds true today (Nobriga et al. 2003). Because of the limitations of using stomach samples, IEP researchers are attempting to model potential impacts of striped bass on delta smelt using bioenergetics and individual-based approaches.

Bennett and Moyle (1996) proposed that inland silverside may be impacting delta smelt through predation (on delta smelt eggs and/or larvae) and competition (for copepod prey). This hypothesis is supported by recent statistical analyses showing negative correlations between inland silverside abundance and delta smelt TNS indices, and two indices of egg and/or larval survival (Brown and Kimmerer 2001). The hypothesis also is consistent with the analysis by Kimmerer (2002) showing a change in the sign of the delta smelt X2-TNS relationship (described above) because inland silversides began to increase in abundance about the same time the relationship changed sign (Brown and Kimmerer 2001). It should be noted however that since the early 1980s, there also have been increases in other potential larval fish predators such as coded wire tagged Chinook salmon smolts released in the Delta for survival experiments (Brandes and McLain 2001) and centrarchid fishes (Nobriga and Chotkowski 2000). In addition, striped bass appear to have switched to piscivorous feeding habits at smaller sizes than they historically did following severe declines in the abundance of mysid shrimp (Feyrer et al. in press). We suspect that CWT salmon and centrarchid abundance, as well as the striped bass diet switch have covaried with the increase in inland silverside abundance and the declines in phytoplankton and zooplankton abundance mentioned above.

One hypothesis arising from the POD investigation holds that predation effects on delta smelt and other POD species have increased in all water year types as a result of increased populations of pelagic and inshore piscivores. In the pelagic habitat, age-1 and age-2 striped bass appear to have declined more slowly than age-0 striped bass (compare Figure 7-6 with Figure 7-15 and DFG unpublished data). Adult striped bass abundance increased in the latter 1990s (Figure 7-16) so high striped bass predation pressure on smaller pelagic fishes in recent years is probable. Further, largemouth bass abundance has increased in the Delta over the past few decades (Brown and Michniuk 2007). While largemouth bass are not pelagic, their presence at the boundary between the littoral and pelagic zones makes it probable that they do opportunistically consume pelagic fishes. Analyses of fish salvage data show this increase occurred somewhat abruptly in the early 1990s and has been sustained since (Figure 7-17). The increase in salvage of largemouth bass occurred during the time period when *E. densa*, an introduced aquatic macrophyte was expanding its range in the Delta (Brown and Michniuk 2007). The habitat provided by beds of *E. densa* provide good habitat for largemouth bass and other species of centrarchids. Thus, the increased abundance of this introduced predator was likely caused by an increase in an introduced plant, which provided favorable habitat. The areal coverage of *E. densa* in the Delta continued to expand by more than 10 percent per year from 2004 to 2006, by infesting a greater portion of channels and invasion of new habitat (E. Hestir et al., U.C. Davis, unpublished data). This suggests that populations of largemouth bass and other species using submerged aquatic vegetation will continue to increase. Although none of the IEP surveys adequately tracks largemouth bass population trends, the Delta has become the top sport fishing destination in North American for largemouth bass, which illustrates the recent success of this species. Each year, lucrative fishing tournaments are held in the Delta to take advantage of the large number of trophy-sized bass in the region. Largemouth bass have a much more limited distribution in the estuary than striped bass, but a higher per capita impact on small fishes (Nobriga and Feyrer 2007). Increases in largemouth bass may have had a particularly important effect on threadfin shad and striped bass, whose earlier life stages occur in littoral habitat (Grimaldo et al. 2004; Nobriga and Feyrer 2007).

A change in predation pressure may, in part, be an effect of interactions between biotic and abiotic conditions. Natural, co-evolved piscivore-prey systems typically have an abiotic production phase and a biotic reduction phase each year (e.g., Rodriguez and Lewis 1994). Changing the magnitudes and durations of these cycles greatly alters their outcomes (e.g., Meffe 1984). Generally, the relative stability of the physical environment affects the length of time each phase dominates and thus, the importance of each. Biotic interactions like predation will have stronger community-structuring influence in physically stable systems (e.g., lakes). Historically in the estuary, the period of winter-spring high flow was the abiotic production phase, when most species reproduced. The biotic reduction phase probably encompassed the low-flow periods in summer-fall. Multi-year wet cycles probably increased (and still do) the overall ‘abiotic-ness’ of the estuary, allowing populations to increase. Drought cycles likely increased the estuary’s ‘biotic-ness’ (e.g., Livingston et al. 1997), with low reproductive output and increased effect of predation on population abundance. Our managed system has reduced flow variation much of the time and in some locations more than others. This has probably affected the magnitudes and durations of abiotic and biotic phases (e.g., Nobriga et al. 2005). In other words, reduced flow variability in the estuary may have exacerbated predation effects. However, there is no clear evidence that such changes have been abrupt enough to account for the POD.

Agricultural Diversions

There are 2,209 agricultural diversions in the Delta and an additional 366 diversions in Suisun Marsh used for enhancement of waterfowl habitat (Herren and Kawasaki 2001). The vast majority of these diversions do not have fish screens to protect fish from entrainment. It has been recognized for many years that delta smelt are entrained in these diversions (Hallock and Van Woert 1959; Pickard et al. 1982). In the early 1980s delta smelt were the most abundant fish entrained in the Roaring River diversion in Suisun Marsh (Pickard et al. 1982), so it is possible the waterfowl diversions are detrimental. However, delta smelt may not be especially vulnerable to Delta agricultural diversions for several reasons. First, adult delta smelt move into the Delta to spawn during winter-early spring when agricultural diversion operations are at a minimum. Second, larval delta smelt occur transiently in most of the Delta. Third, Nobriga et al. (2002; in press) examined delta smelt entrainment at an agricultural diversion in Horseshoe Bend during July 2000 and 2001, when much of the YOY population was rearing within one tidal excursion of the diversion. Delta smelt entrainment was low compared to density estimates from the DFG 20 mm Delta Smelt Survey. Low entrainment was attributed to (1) offshore distribution of delta smelt, and (2) the extremely small hydrodynamic influence of the diversion relative to the channel it was in. Because Delta agricultural diversions are typically close to shore and probably take small amounts of water relative to what is in the channels they draw water from, delta smelt vulnerability may be low despite their modest swimming ability and their poor performance near simulated fish screens in laboratory settings (Swanson et al. 1998; 2002). It should be noted however that DWR screened five agricultural diversions around Sherman Island, an area consistently used by delta smelt of all life stages.

Antioch and Pittsburgh Power Plants

Mirant, an independent power company, operates two power generation facilities within the range of delta smelt: Contra Costa Power Plant and Pittsburg Power Plant. Contra Costa Power Plant is about six miles east of the confluence of the Sacramento and San Joaquin rivers. Pittsburg Power Plant is on the south shore of Suisun Bay, in the town of Pittsburg. Each power plant has seven generating units that rely on diverted water for condenser cooling. Cooling water is diverted at a rate as high as about 1,500 cfs for the Contra Costa plant and 1,600 cfs for the Pittsburg plant, forming a thermal plume as it is discharged back into the estuary. Pumping rates are often significantly lower under normal operation. Potential impacts of the power plants fall into two categories - direct and indirect. Previous data on direct and indirect impacts of the power plants were summarized by Reclamation and DWR (1994). However, robust data analyses of population level effects of power plant operation on delta smelt and other fishes have not been performed. Briefly, the direct impact of the power plants comes from the removal of fish during diversion operations. Indirect effects stem from water temperature increases when the cooling water is returned to the estuary. Intakes at all units at both power plants employ a screening system to remove debris, but the screens allow entrainment of fish smaller than about 38 mm and impingement of larger fish.

In recent years, the plants have been operated only on a standby basis when regional power consumption is not high. However, although they may not be routinely operated, the plants are most likely to be called into use during the summer, at a time when delta smelt are potentially close to the intake and discharge points, and thus vulnerable to entrainment and other adverse effects.

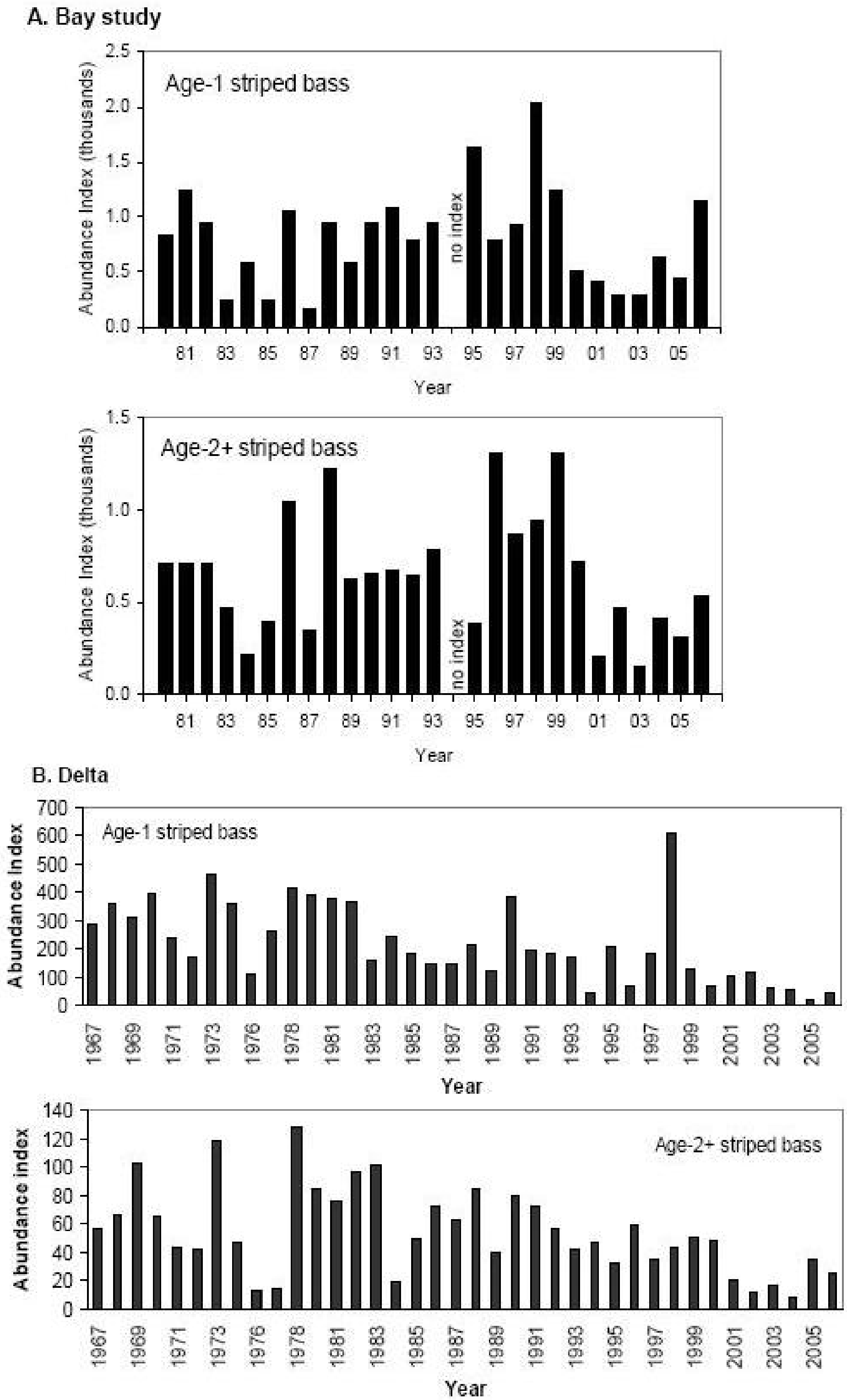

Figure 7-15 Abundance of age-1 and age-2+ striped bass in midwater trawls in A) San Francisco Bay based on the California Department of Fish and Game Bay study (Bay Study) and B) in the Delta from the Fall Midwater Trawl.

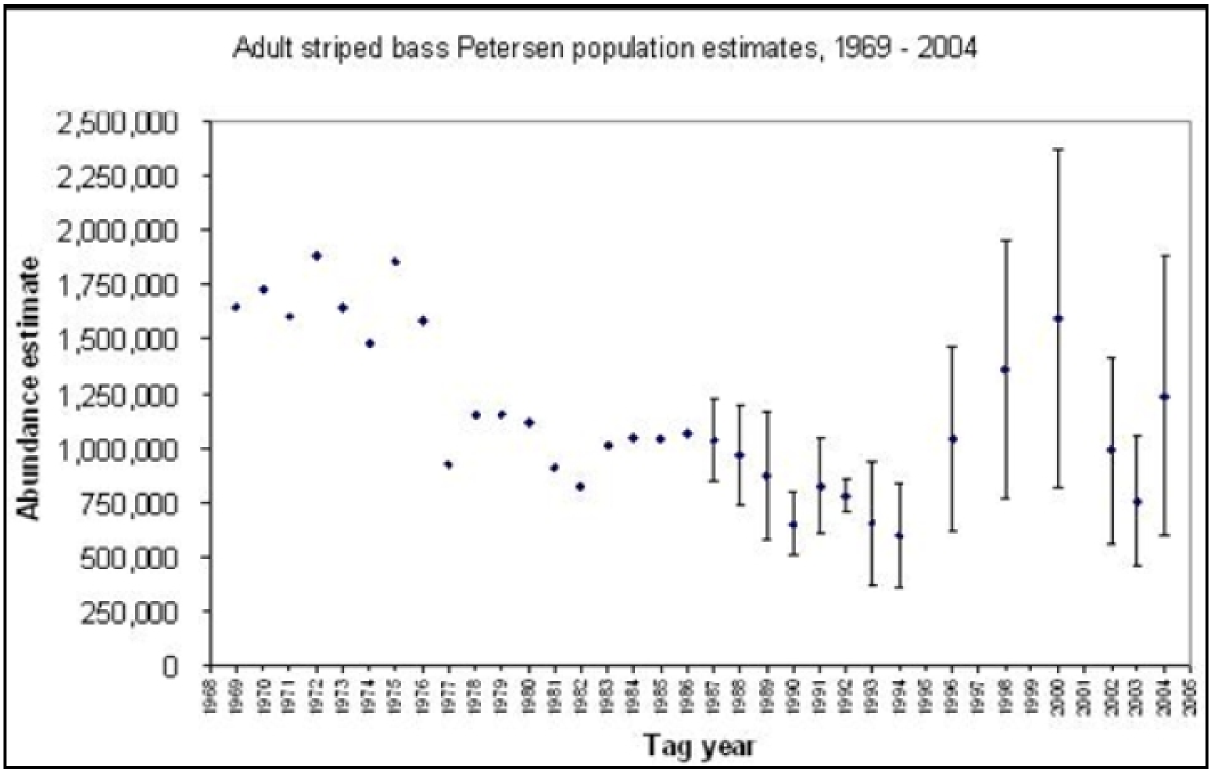

Figure 7-16 Peterson population estimates of the abundance of adult (3+) striped bass < 460 mm total length from 1969 to 2004.
NOTE: Error bars represent 95% confidence intervals (DFG, unpublished data). Confidence intervals are not shown previous to 1987. Striped bass were only tagged during even years from 1994 to 2002, so no estimates are available for odd years during that period.

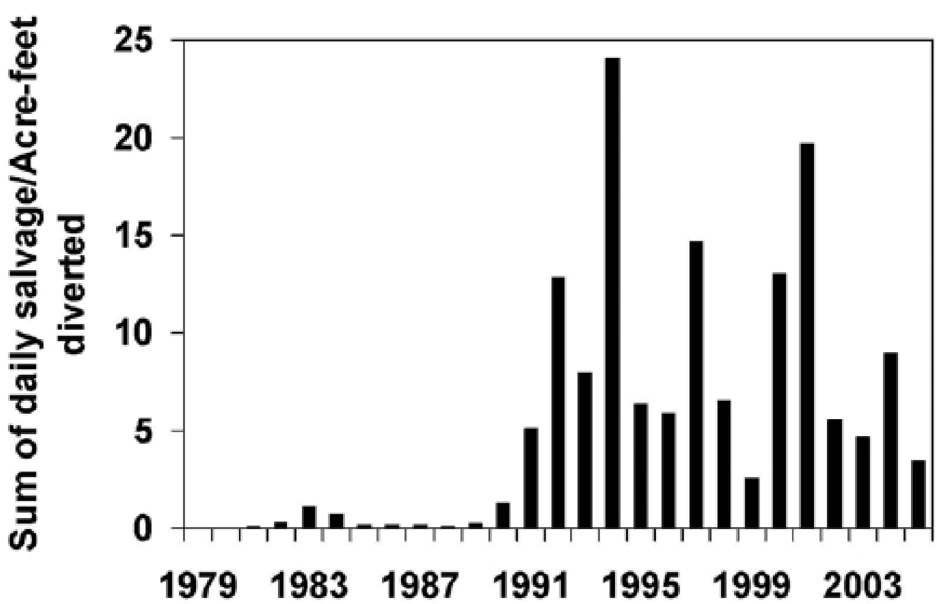

Figure 7-17 Annual salvage density (fish per acre foot) of largemouth bass at the CVP and SWP combined from 1979 to 2005 (DFG, unpublished data).

Bottom-Up Effects

The quality and availability of food may have important effects on the abundance and distribution of delta smelt. Historical food quality and availability have varied substantially, largely because of the history of exotic species introduction into the Estuary. In this section information developed by the IEP and others on the delta smelt and its trophic support is presented. Because a large part of this discussion has evolved only in the last few years as a result of the POD investigation, this account borrows heavily from the POD work (Baxter et al. 2008).

Interconnected Recent Changes in Plankton and Benthos

Estuaries are commonly characterized as highly-productive nursery areas for a suite of organisms. Nixon (1988) noted that there actually is a broad continuum of primary productivity levels in different estuaries, which in turn affects fish production and abundance. Compared to other estuaries, pelagic primary productivity in the upper San Francisco estuary is poor and a low fish yield is expected (Figure 7-18). Moreover, there has been a significant long-term decline in phytoplankton biomass (chlorophyll a) and primary productivity to very low levels in the Suisun Bay region and the lower Delta (Jassby et al 2002). Hence, low and declining primary productivity in the estuary is likely a principal cause for the long-term pattern of relatively low and declining biomass of pelagic fishes.

A major reason for the long-term phytoplankton reduction in the upper estuary is filter-feeding by the overbite clam (*Corbula amurensis*), which became abundant by the late 1980s (Kimmerer 2002). The overbite clam was first reported from San Francisco Estuary in 1986 and it was well established by 1987 (Carlton et al. 1990). Prior to the overbite clam invasion, there were periods of relatively low clam biomass in the upper estuary because the Asiatic freshwater clam (*Corbicula fluminea*) colonized Suisun Bay during high flow periods and the native marine clam *Mya arenaria* (also known as *Macoma balthica*) colonized Suisun Bay during prolonged (> 14 month) low flow periods (Nichols et al. 1990). Thus, there were periods of relatively low clam grazing rates while one species was dying back and the other was colonizing. The overbite clam invasion changed this formerly dynamic clam assemblage because the overbite clam, which is tolerant of a wide range of salinity, is now always the dominant clam species in the brackish water regions of the estuary and its grazing influence extends into the Delta (Kimmerer and Orsi 1996; Jassby et al. 2002) beyond the clam's typical range, presumably due to tidal dispersion of phytoplankton-depleted water.

According to recent research, shifts in nutrient concentrations may also contribute to the phytoplankton reduction as well as to changes in algal species composition in the San Francisco Estuary. While phytoplankton production in the San Francisco Estuary is generally considered light limited and nutrient concentrations exceed production limiting levels, nutrients may affect production during times when light conditions are more favorable and also affect species composition. Dugdale et al (2007) and Wilkerson et al (2006) found that high ammonium concentrations prevented the formation of diatom blooms but stimulated flagellate blooms in the Delta and lower estuary. Ammonium concentrations in the Delta and Suisun Bay have significantly increased over the last few decades due to increased loading from sewage treatment plants (Jassby, in press, Mueller-Solger, in prep.). Van Nieuwenhuyse (2007), on the other hand, found that a rapid reduction in wastewater total phosphorus loads in the mid-1990s coincided with a similarly rapid drop in phytoplankton biomass at three stations in the Delta.

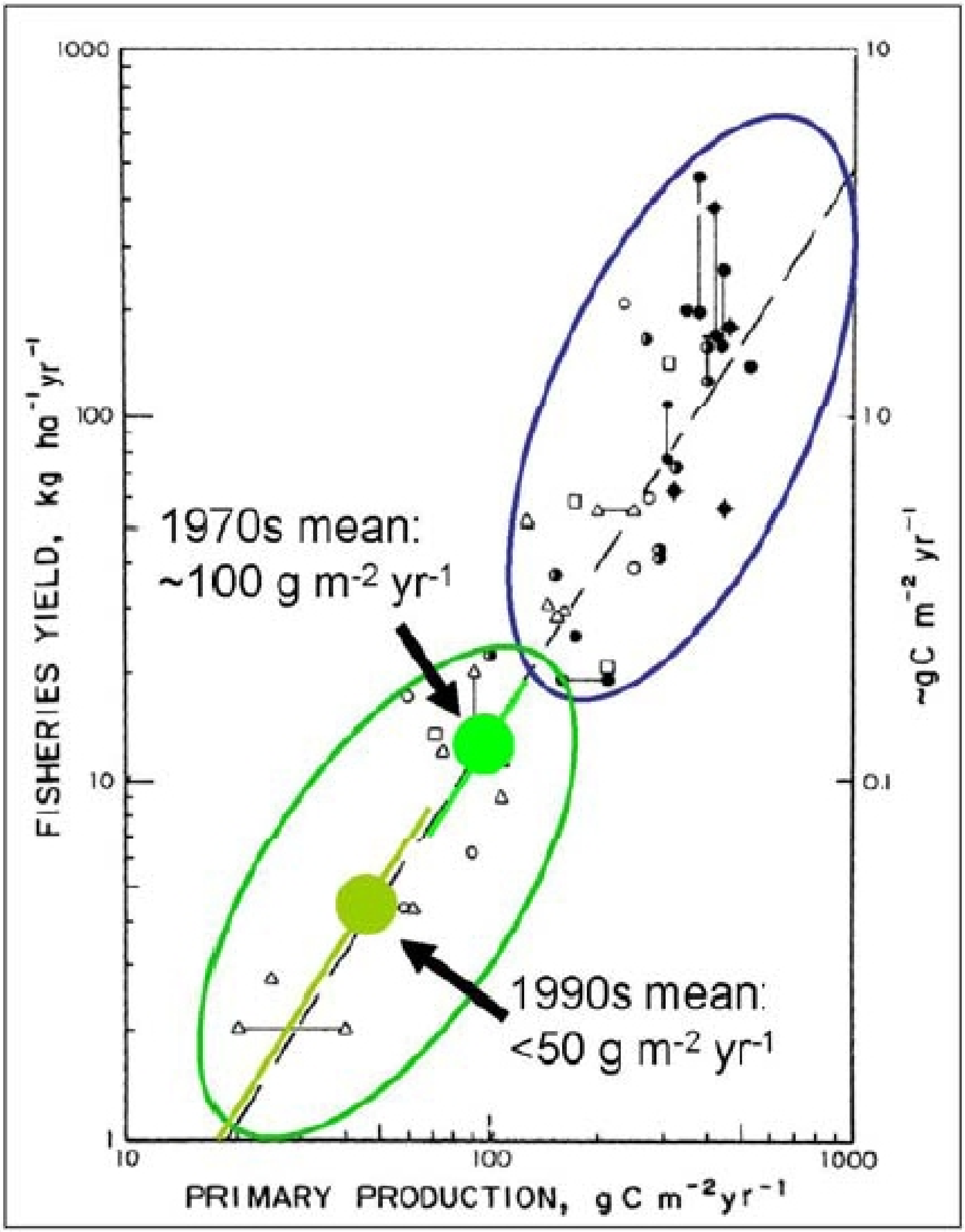

Figure 7-18 Mean value and range in primary production in Suisun Bay and the Delta in the 1970s and 1990s plotted on the relationship of fishery yield to primary production from other estuaries around the world (modified from Nixon 1988, using data provided by Alan Jassby, U.C. Davis and James Cloern, U.S. Geological Survey).

Starting in the late 1980s, a series of major changes was observed in the estuarine food web that negatively influenced pelagic fish (including delta smelt) production. Major step-declines were observed in the abundance of phytoplankton (Alpine and Cloern 1992) and the copepod Eurytemora affinis due to grazing by the clam (Kimmerer et al. 1994). Northern anchovy abandoned the estuary's low salinity zone coincident with the overbite clam invasion, presumably because the sharp decline in planktonic food items made occupation of low-salinity waters unprofitable for this marine fish (Kimmerer 2006). There was also a major step-decline in mysid shrimp in 1987-1988, presumably due to competition with the clam for phytoplankton (Orsi and Mecum 1996). The mysid shrimp had been an extremely important food item for larger fishes like longfin smelt and juvenile striped bass; its decline resulted in substantial changes in the diet composition of these and other fishes (Feyrer et al. 2003). As described above, the population responses of longfin smelt and juvenile striped bass to winter-spring outflows changed after the overbite clam invasion. Longfin smelt relative abundance was lower per unit outflow post-clam (Kimmerer 2002b). Young striped bass relative abundance stopped responding to outflow altogether (Sommer et al. 2007). One hypothesis to explain these changes in fish population dynamics is that lower prey abundance reduced the system carrying capacity (Kimmerer et al. 2000; Sommer et al. 2007).

Several recent studies have shown that pelagic consumer production is limited by low phytoplankton productivity in the San Francisco Estuary (Sobczak et al. 2002, 2004; Mueller-Solger et al. 2002). However, in contrast to the substantial long-term declines in phytoplankton biomass and productivity (Jassby et al. 2002), phytoplankton trends for the most recent decade (1996-2005) are actually positive in the Delta and neutral in Suisun Bay (Jassby, in press). While this does not support the hypothesis that changes in phytoplankton quantity are responsible for the recent declines of delta smelt and other pelagic fishes, phytoplankton may nevertheless play a role via changes in species composition, as will be discussed in the food quality section below.

A notable finding for the POD is that *Pseudodiaptomus forbesi*, a calanoid copepod that has replaced *Eurytemora affinis* as the most common delta smelt prey during summer, continued to decline in the Suisun Marsh and confluence regions from 1995 to 2004, while its numbers increased in the southern Delta (Figure 7-19; Kimmerer et al. in prep., Mueller-Solger et al. in prep.). Although substantial uncertainties about mechanisms remain, this trend may be related to increasing recruitment failure and mortality in Suisun Bay and the western Delta due to competition and predation by the overbite clam, contaminant exposures, and entrainment of source populations in the Delta (Durand et al. in prep., Mueller-Solger et al. 2006). For example, overbite clam abundance and distribution in the Suisun Bay and the western Delta during 2001-2004 was greater than during the 1995-1999 wet period, but similar to abundance indices and distribution patterns during the 1987-1992 drought (IEP 2005, Peterson et al. in prep.). Further, in the two most recent years (2005 and especially 2006), *P. forbesi* has started to rebound substantially in the western Delta (Figure 7-20, Mueller-Solger et al. in prep., Jassby et al. in prep.).

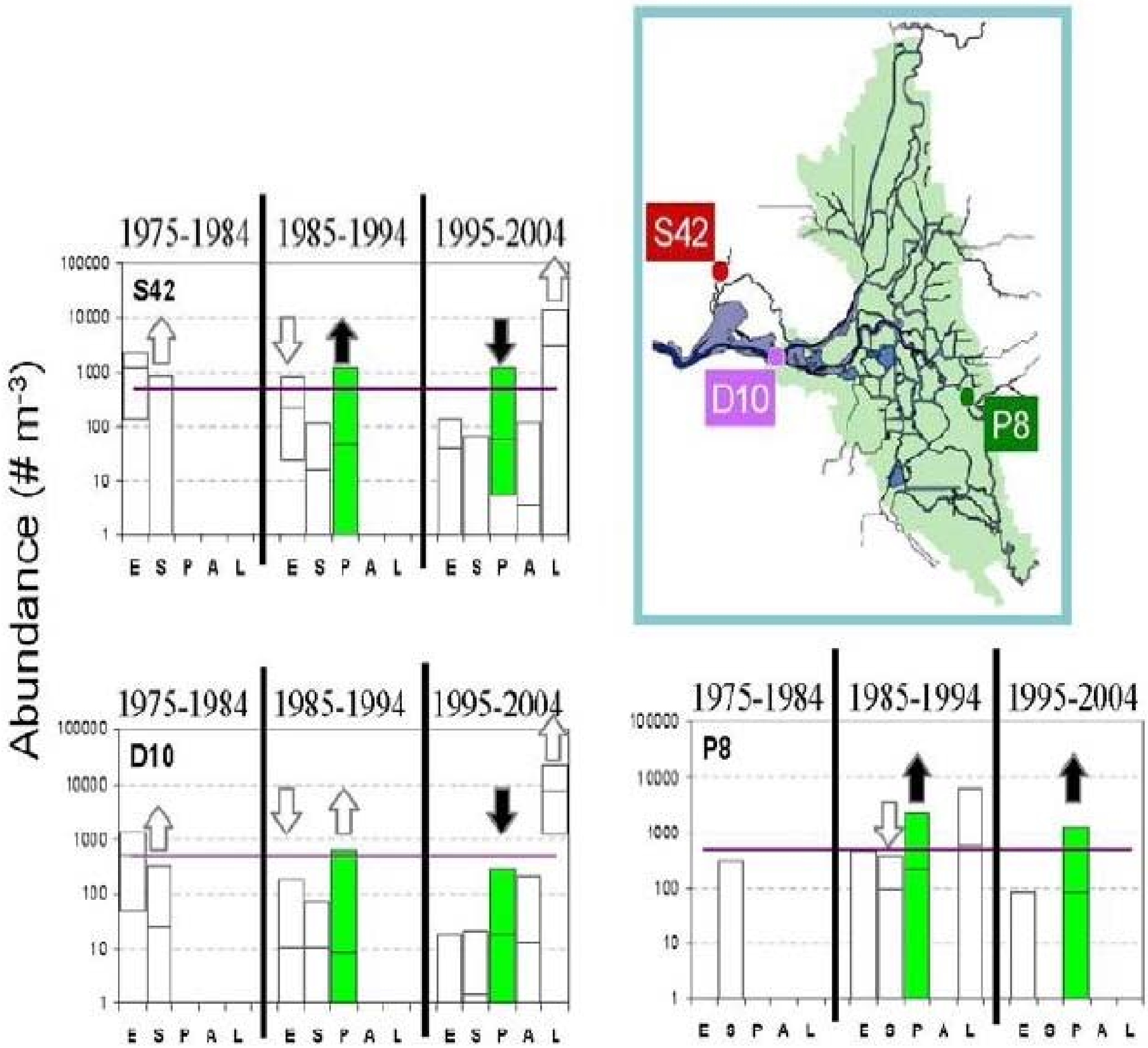

Figure 7-19 Changes in abundance of Pseudodiaptomus forbesi and other copepods at the confluence of the Sacramento and San Joaquin rivers (D10), Suisun Marsh (S42), and the southern Delta (P8) during three decades from 1975-2004.
NOTE: Arrows indicate the direction of statistically significant trends within decades. E: Eurytemora affinis; S: Sinocalanus doerri; P: Pseudodiaptomus forbesi; A: Acartiella sinensis; L: Limnoithona sp. Site codes correspond to designations used in the California Department of Fish and Game zooplankton survey.

There is also interest in a more recent invader, the cyclopoid copepod *Limnoithona tetraspina*, which significantly increased in the Suisun Bay region beginning in the mid-1990s. It is now the most abundant copepod species in the low-salinity zone (Bouley and Kimmerer 2006). It has been hypothesized that *L. tetraspina* is an inferior food for pelagic fishes including delta smelt because of its small size, generally sedentary behavior, and ability to detect and avoid predators (Bouley and Kimmerer 2006). Experimental studies addressing this issue are ongoing (Sullivan et al., unpublished). *Acartiella sinensis*, a calanoid copepod species that invaded at the same time as L. tetraspina, also reached considerable densities in Suisun Bay and the western Delta over the last decade. Its suitability as food for pelagic fish species remains unclear, but is also being investigated (Sullivan et al., unpublished).

Preliminary information from studies on pelagic fish growth, condition and histology provide additional evidence for food limitation in pelagic fishes in the estuary (IEP 2005). In 1999 and 2004, residual delta smelt growth was low from the Sacramento-San Joaquin confluence through Suisun Bay relative to other parts of the system. Delta smelt collected in 2005 from the Sacramento-San Joaquin confluence and Suisun Bay also had high incidence of liver glycogen depletion, a possible indicator of food limitation. Similarly, during 2003 and 2004 striped bass condition factor decreased in a seaward direction from the Delta through Suisun Bay.

Thus far, there is little evidence that the unusually poor growth rates, health, and condition of fishes from Suisun Bay and western Delta are due directly to the effects of toxic contaminants or other adverse chemical or physical habitat conditions. Therefore, our working hypothesis is that the poor fish growth and condition in the upper estuary are due to food limitation. Note, however that contaminant episodes may be contributing to poor phytoplankton growth (Dugdale et al. 2007) and invertebrate mortality (Werner unpublished data), which could exacerbate food limitation. If fishes are food limited in Suisun Bay and west Delta during larval and/or juvenile development, then we would expect greater cumulative predation mortality, higher disease incidence, and consequently low abundance indices at later times.

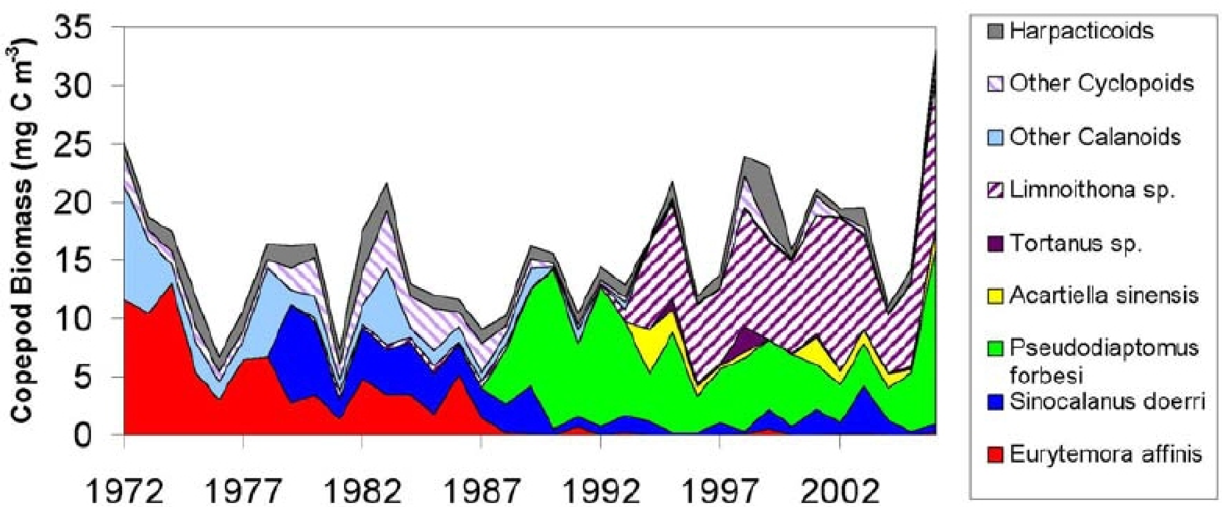

Figure 7-20 Biomass of copepods in summer delta smelt habitat as defined by salinity and turbidity.

Fish Co-Occurrence with Food

The above patterns in fish food have generally been described at rather broad scales. Recently, interest has focused on determining patterns of co-occurrence of fish predators, particularly delta smelt, and their zooplankton prey. The assumption is that predators should co-occur with their prey. This idea was first explored by Nobriga (2002) who showed that delta smelt larvae with food in their guts typically co-occurred with higher calanoid copepod densities than larvae with empty guts. Recently, Kimmerer (in press), Miller and Mongan (unpublished data), and Mueller-Solger (unpublished data) used similar approaches to look at potential co-occurrence of delta smelt and their prey and its effects on survival. Kimmerer (in press) showed that there was a positive relationship between delta smelt survival from summer to fall and zooplankton biomass in the low-salinity region of the estuary (Figure 7-21). Miller and Mongan (unpublished data) have concluded that April and July co-occurrence is a strong predictor of juvenile delta smelt survival. Mueller-Solger (unpublished data) defined delta smelt habitat based on the environmental quality results of Nobriga et al. (in press) and prey spectrum more broadly (as all copepods) compared to Miller and Mongan (unpublished data) and found no long-term decline in the total biomass of copepods potentially available for consumption by delta smelt in midsummer, although species composition has changed considerably (Figure 7-20).

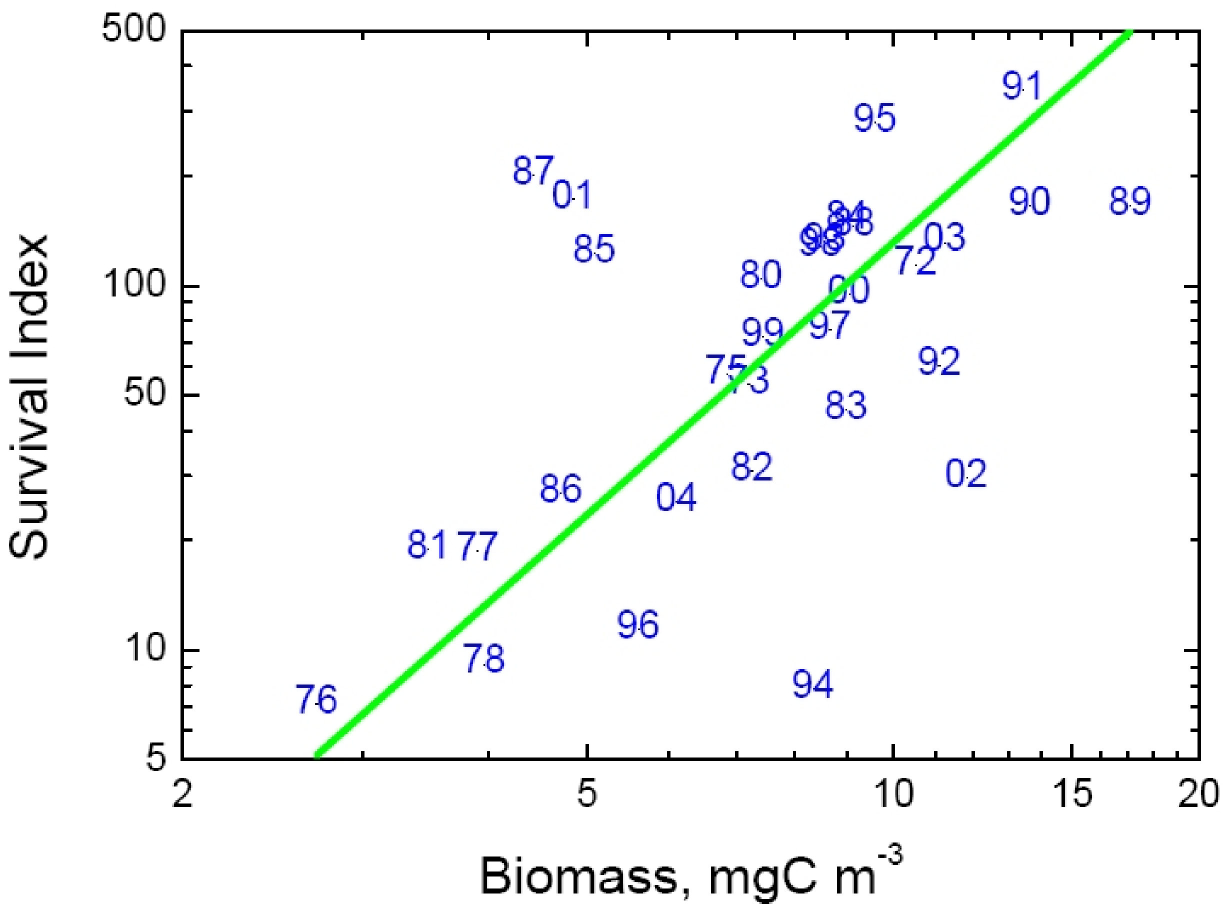

Figure 7-21 Summer to fall survival index of delta smelt in relation to zooplankton biomass in the low salinity zone (0.15 – 2.09 psu) of the estuary.
NOTE: The survival index is the log ratio of the Fall Midwater Trawl index to the Summer Townet Survey index. The line is the geometric mean regression for log(10) -transformed data, y = 2.48x – 0.36. The correlation coefficient for the log-transformed data is 0.58 with a 95% confidence interval of (0.26, 0.78) (Kimmerer, in press).

There are two shortcomings of co-occurrence analyses like those described above. First, it is difficult to characterize fish prey suitability. For instance, *E. affinis* and *P. forbesi* are generally believed to be "preferred" prey items for delta smelt (Nobriga 2002; Miller and Mongan unpublished). However, diet data show that delta smelt will actually feed on a wide variety of prey (Lott 1998; S. SlaterDFG, unpublished;Figure 7-22). Thus, the question of prey co-occurrence involves questions of prey catchability (e.g., Meng and Orsi 1991) and profitability (energy per item consumed and nutritional quality of individual prey items). For example, *L. tetraspina* has a large biomass in the system but individual *L. tetraspina* are smaller and possibly more evasive than the larger calanoid copepods. The energy needed by an individual delta smelt to harvest a similar biomass of *L. tetraspina* compared to the energy needed to harvest a larger species could be very different, as suggested by optimal foraging theory (e.g., Stephens and Krebs 1986). Another major limitation of co-occurrence analyses is that IEP sampling programs sample fish and zooplankton at larger spatial and temporal scales than those at which predator-prey interactions occur. Both fish and copepods are likely to be patchy and the long tows required to collect sufficient numbers of organisms for counting would homogenize such patch structure. Moreover, it is unlikely that the (monthly or even twice monthly) "snapshot" of fish and prey co-occurrence in specific locations or even small regions provided by the IEP surveys is representative of feeding conditions actually experienced by fish on an hourly or daily basis.

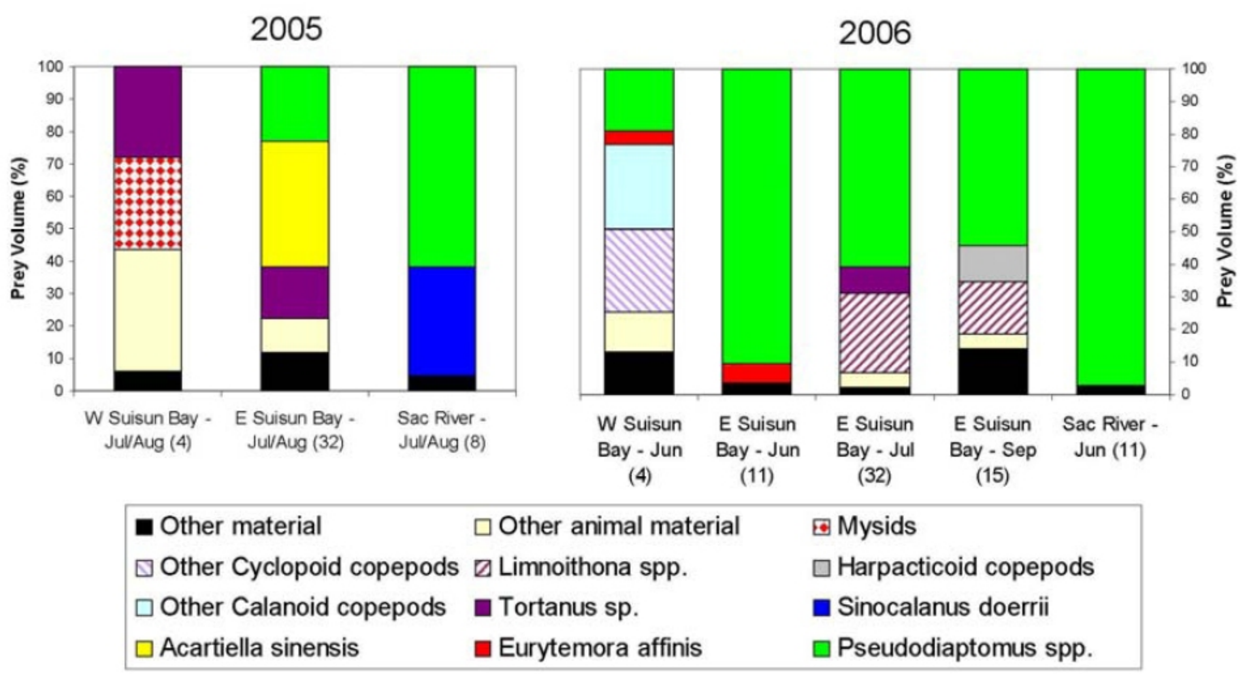

Figure 7-22 Prey volume in guts of delta smelt collected during summer 2005 and 2006.
Note: Sample size appears in parentheses (Steve Slater, California Department of Fish and Game, unpublished data).

The weight of evidence strongly supports bottom-up food limitation as a factor influencing longterm fish trends in the upper estuary. However, the bottom-up hypothesis is unlikely as a single mechanism for the recent pelagic organism declines. Specifically, it is unclear why there has been a substantial recent decline in some Suisun Bay and western Delta calanoid copepod species, but not in phytoplankton chlorophyll a concentration. Also, calanoid copepod densities (especially *P. forbesi*) rebounded substantially in 2006 (Mueller-Solger, unpublished data) while the POD fish abundance indices (especially for delta smelt) remained low. Second, recent *C. amurensis* levels are not unprecedented; they are similar to those found during the 1987-92 drought years, so it is unclear if and why benthic grazing would have a greater effect on the Suisun Bay food web during the POD years than during the earlier drought years. Finally, it is possible that the hypothesis that the San Francisco Estuary is driven by phytoplankton production rather than through detrital pathways (Sobczak et al. 2002, 2004; Mueller-Solger et al. 2002) may have been accepted too strictly. Many zooplankton are omnivorous and can consume microbes utilizing dissolved and particulate organic carbon. This has recently been demonstrated for several zooplankton species in the San Francisco Estuary (Gifford et al. 2007 and references therein). Thus, shifts in availability of phytoplankton and microbial food resources for zooplankton might favor different species. It is possible that a better understanding of shifts in phytoplankton and zooplankton community composition and perhaps related changes in the microbial food web in the Suisun Bay region could explain these apparent inconsistencies.

Food Quality

Studies on food quality have been relatively limited in the San Francisco Estuary, with even less information on long-term trends. However, food quality may be another limiting factor for pelagic zooplankton and their fish predators, including delta smelt.

At the base of the pelagic food web, food quality for consumers is determined by the relative contributions of different phytoplankton and microbial species and detritus to the overall organic particle pool available to primary consumers. For example, diatoms and cryptophytes are thought to be of good food quality for zooplankton, while the nutritional value of cyanobacteria such as *Microcystis aeruginosa* can be very low (Brett and Müller-Navarra 1997), particularly for toxic varieties (Rohrlack et al. 2005). Lehman (1996, 2000) showed shifts in phytoplankton species composition in the San Francisco Estuary from diatom dominated to more flagellate dominated communities. Mueller-Solger et al. (2006) found that in recent years, diatoms were most abundant in the southern San Joaquin River region of the Delta, and Lehman (2007) found greater diatom and green algal contributions upstream and greater flagellate biomass downstream along the San Joaquin River. To date, the *M. aeruginosa* blooms have occurred most intensively in the central Delta, thus POD species that utilize the central Delta such as threadfin shad, striped bass, and the poorly monitored centrarchid populations (largemouth bass and sunfish) would be most likely to suffer any direct adverse effects of these blooms.

In 2007, the *M. aeruginosa* bloom year was the worst on record in the Delta (P. Lehman, in prep.). The highest cell densities were observed near Antioch, i.e. considerably west of the previous center of distribution, and may thus have affected invertebrates and fishes in the confluence and Suisun Bay regions of the upper estuary. In general, phytoplankton carbon rather than the much more abundant detrital carbon are thought to fuel the food web in the San Francisco Estuary (Mueller-Solger et al. 2002; Sobczak et al. 2002, 2004); however, that does not mean the detrital pathways are not significant because many zooplankton are omnivorous and capable of utilizing both pathways. For example, Rollwagen- Bollens and Penry (2003) observed that while heterotrophic ciliates and flagellates were the dominant prey of *Acartia* spp. in the bays of the San Francisco Estuary, diatoms and autotrophic ciliates and flagellates also formed an important part of their diet during phytoplankton blooms. Calanoid copepod and cladoceran growth and egg production may often be limited by low levels of phytoplankton biomass. This appears to be true even for omnivorous calanoids such as *Acartia* spp. Kimmerer et al (2005) found a significant relationship between *Acartia* spp. egg production and chlorophyll a concentration in the San Francisco Estuary, suggesting that *Acartia* spp. likely also derived a large part of carbon and energy from phytoplankton. Bouley and Kimmerer (2006), on the other hand, reported that egg production rates of the cyclopoid copepod *L. tetraspina* were unrelated to chlorophyll a concentrations in the low salinity region of the San Francisco Estuary. *L. tetraspina* digestion rates were highest for ciliates, perhaps suggesting a greater importance of the detrital carbon pathway for this species.

In a study focusing on the nutrition and food quality of the calanoid copepods *Eurytemora affinis* and *Pseudodiaptomus forbesi*, Mueller-Solger et al (2006) found evidence for "trophic upgrading" of essential fatty acids by *Eurytemora* and *Pseudodiaptomus*, confirming their importance as high-quality food for fish. They also found that *E. affinis* gained the greatest nutritional benefits from varied food sources present in small tidal sloughs in Suisun Marsh. *P. forbesi*, on the other hand, thrived on riverine phytoplankton in the southern Delta, especially diatoms. Diatoms are likely also an important food source for other calanoid copepod species. The relative decrease in diatom contributions to the phytoplankton community in the central Delta and Suisun Bay (Lehman 1996, 2000) is thus a concern and may help explain the declines in *P. forbesi* and other calanoid copepods in these areas.

Mueller-Solger et al. (2006) concluded that areas rich in high-quality phytoplankton and other nutritious food sources such as the southern Delta and small tidal marsh sloughs may be critical "source areas" for important fish prey organisms such as *P. forbesi* and *E. affinis*. This is consistent with results by Durand et al. (unpublished data) who showed that transport from upstream was essential for maintaining the *Pseudodiaptomus* population in Suisun Bay. It is possible that the increase in *Pseudodiaptomus* densities in the western Delta in 2006 could be related to greater San Joaquin River flows during this wet year, which may have reduced entrainment of *Pseudodiaptomus* source populations in the Delta.

As noted in earlier sections, the dichotomy between phytoplankton and detrital/microbial energy pathways supporting zooplankton has probably been applied more stringently than is appropriate. Both are likely important, with the balance between them in specific areas of the estuary likely having affects on the success of particular zooplankton species. Additional research into the detrital pathway might be useful in understanding the factors controlling zooplankton populations, which are critical food resources for pelagic fishes.

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Chapter 8 Basic Biology and Life History of Green Sturgeon & Factors that May Influence Green Sturgeon Distribution and Abundance

In 2006 the Southern Distinct Population Segment (DPS) of North American green sturgeon (green sturgeon) were listed as threatened under provisions of ESA. The Southern DPS includes green sturgeon that spawning and living in the Sacramento River, Sacramento-San Joaquin Delta and the San Francisco Bay Estuary. The spawning migrations and spawning by green sturgeon in the upper Sacramento River mainstem have been well documented over the last 15 years. In addition, it has been surmised that spawning by green sturgeon may taken place at one time in the lower San Joaquin River. However, specific empirical estimates of abundance are not available for green sturgeon throughout the action area. There are several factors which affect green sturgeon populations including: fish passage, low flows, entrainment, loss of historical habitat, warm water temperatures, contaminants, and illegal harvest. As long-lived, late maturing fish that spawn periodically, green sturgeon are particularly susceptible to threats from overfishing. Green sturgeon are regularly caught in the sport, commercial, and tribal fisheries, particularly in Oregon and Washington commercial fisheries.

Although spawning and migration patterns for the green sturgeon have been well documented in recent years, designation of critical habitat and a recovery plan has not yet been developed for green sturgeon. A principle threat to green sturgeon is the reduction of spawning areas as the result of impassible barriers, primarily Keswick Dam on the Sacramento River and Orville Dam on the Feather River, that block access to historic spawning habitat for several anadromous species. Physical conditions in the Sacramento River and Delta vary substantially from year to year and these factors could drastically affect green sturgeon spawning success, dispersal patterns, and vulnerability to salvage.

There have also been substantial changes in water project operations in the decades since the CVP and SWP were built. These include a variety of actions implemented to protect listed salmonids as well as delta smelt. Concerted efforts have been made to reduce the effects of the projects on all fish. The seasonal timing of export pumping has been changed to weight summer pumping more heavily in order to reduce export pumping when listed salmon, steelhead and delta smelt are in the estuary. Delta Cross Channel (DCC) gate operations are also restricted in spring to protect juvenile salmon migrating downstream. CVP and SWP operations are managed to limit impacts on listed species during migration periods. Coincidently, many of the protective actions for the listed species also benefit the green sturgeon such as increased flows and temperature management and fish screen implementation. Finally, Reclamation is currently working closely with NMFS to develop specific project operation criteria for the Red Bluff Diversion Dam (RBDD) to protect green sturgeon.

Listing Status

On April 7, 2006, NOAA’s National Marine Fisheries Service (NMFS) issued a final rule listing the Southern distinct population segment (DPS) of North American green sturgeon (*Acipenser medirostris*) (green sturgeon) as a threatened species, which took effect on June 6, 2006 (71 FR

17757). Green sturgeon is a Class 1 (qualifying as threatened under the California ESA) Species of Special Concern in California (DFG 2003). Included in the listing is the green sturgeon population that spawns in the Sacramento River and live in the Sacramento River, the Sacramento-San Joaquin Delta, and the San Francisco Bay Estuary. This threatened determination was based on the reduction of potential spawning habitat, the severe threats to the single remaining spawning population, the inability to alleviate these threats with the conservation measures in place, and the decrease in observed numbers of juvenile Southern DPS green sturgeon collected in the past two decades compared to those collected historically (NMFS 2006).

Initially, available data did not indicate declining populations within the northern DPS, but due to uncertainty about the status and threats to these populations, NMFS placed the northern DPS on the Species of Concern List (70 FR 17386). After a status review was completed in 2002 (Adams et al. 2002), NMFS determined that the northern and southern DPSs of the North American green sturgeon did not warrant listing as threatened or endangered (68 FR 4433) but should be listed as a Species of Concern because of uncertainties about population structure and status (69 FR 19975). The “not warranted” determination was challenged on April 7, 2003. NMFS updated their status review on February 22, 2005, and determined that the southern DPS should be listed as threatened under the Federal Endangered Species Act (Biological Review Team 2005; 71 FR 17757).

Critical Habitat

Critical habitat has not been designated for the Southern DPS of green sturgeon.

Recovery Goals

A recovery plan has not been developed for green sturgeon and recovery planning efforts for this species are not yet underway. Green sturgeon were considered in the 1995 Sacramento-San Joaquin Delta Native Fishes Recovery Plan (USFWS 1996). This plan identifies a primary restoration (recovery) objective of a minimum population of 1,000 fish over 1 meter (39 inches) total length each year, including 500 females over 1.3 meters (51 inches) total length (minimum size at maturity), during the spawning period (presumably March-July) when spawners are present in the estuary and the Sacramento River.

Biology and Life History

Description

Sturgeon are among the largest and most ancient of bony fishes. They are placed, along with paddlefishes and numerous fossil groups, in the infraclass Chondrostei, which also contains the ancestors of all other bony fishes. The sturgeon themselves are not ancestral to modern bony fishes but are a highly specialized and successful offshoot of ancestral chondrosteans, retaining such ancestral features as a heterocercal tail, fin structure, jaw structure, spiral valve intestine, and spiracle. They have a cartilaginous skeleton and possess a few large ossified plates, called scutes, instead of scales. Sturgeon are highly adapted for preying on benthic organisms (e.g., clams, shrimp, etc.), which they detect with a row of extremely sensitive barbells on the underside of their snouts. They protrude their extraordinarily long and flexible “lips” to suck up food. Sturgeon are confined to temperate waters of the Northern Hemisphere. Of 25 extant species, only two live in California, the green sturgeon and the white sturgeon (*A. transmontanus*). (Moyle 2002)

Green sturgeon are similar in appearance to the sympatric white sturgeon, except the barbells are closer to the mouth than the tip of the long, narrow snout (Figure 8-1). The dorsal row of scutes numbers 8-11, lateral rows, 23-30, and bottom rows, 7-10; there is one large scute behind the dorsal fin as well as behind the anal fin (both lacking in white sturgeon). The scutes also tend to be sharper and more pointed than in white sturgeon. The dorsal fin has 33-36 rays, the anal fin, 22-28. The body color is olive green with an olivaceous stripe on each side; the scutes are paler than the body (Moyle 2002).

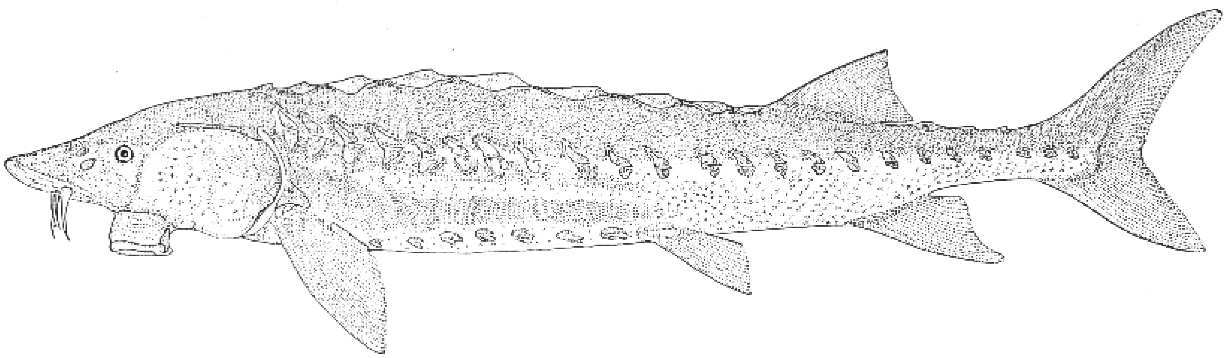


Figure 8-1. Image of Green Sturgeon.

As anadromous fish, sturgeon rely on riverine, estuarine, and marine habitats in the course of their long life. The ecology and life history of green sturgeon have received little study, evidently because of the generally low abundance, limited spawning distribution, and low commercial and sport fishing value of the species (Moyle 2002; Adams et al. 2002).

Green sturgeon is the most marine species of sturgeon, coming into rivers mainly to spawn (Moyle 2002). The majority of a green sturgeon’s life is spent in the ocean following a one to three year freshwater rearing period (Nakamoto et al. 1995). Adult green sturgeon return to freshwater for spawning at around age 15 or older, with additional spawning migrations at two to four year intervals up to age 30-40 (Moyle 2002; Erickson and Webb 2007; VanEenennaam 2002; Cech et al. 2000). Green sturgeon life history could be divided into three phases: 1) freshwater juveniles (<3 years old); 2) coastal migrants; and 3) adults (FWS 1995).

Sturgeon live a long time (40-50 years), delay maturation to large sizes (125 cm total length), and spawn multiple times over their lifespan. This life history strategy has proven to be successful in the face of normal environmental variation in the large river habitats where spawning occurs. The sturgeon’s long lifespan, repeat spawning in multiple years, and high fecundity allows them persist through periodic droughts and environmental catastrophes. The high fecundity that comes with large size allows them to produce large numbers of offspring when suitable spawning conditions occur and compensate for years of poor reproductive and juvenile rearing conditions. Adult green sturgeon do not spawn every year and only a fraction of the population enters freshwater where they might be at risk of a catastrophic event in any year (Beamesderfer et al. 2007).

Size, Age and Maturation

Size, age, and maturation data are limited for the southern DPS but may be similar to that of the northern DPS. For the Klamath River green sturgeon, an average length of 1.0 m is attained in 10 years, 1.5 m by age 15, and 2.0 m by 25 years of age (FWS 1993; Van Eenennaam 2006). The largest reported green sturgeon weighed about 159 kg and was 2.1 m in length (FWS 1993). The largest green sturgeon have been aged at 42 years, but this is probably an underestimate, and maximum ages of 60-70 years or more are likely (Moyle 2002). Newly hatched green sturgeon are typically between 8-19 mm in length and juveniles range between 2-150 cm (Emmett et al. 1991).

Adult green sturgeon are believed to spawn every three to five years and reach sexual maturity at an age of 15 to 17 years (Tracy 1990; Erickson and Webb 2007; Webb and Erickson 2007). Male and female green sturgeon differ in age-at-maturity and size-at-age. Adult males range between 139 and 199 cm in length, and can mature as young as 15 years, but tend to live shorter lives (30 years max) (VanEenennaam et al. 2006). Adult females are typically between 157 and 199 cm in length, mature as early as age 17 and can live up to 40 years (Cech et al. 2000). In the highly productive ocean environment, green sturgeon grow at a rate of approximately seven centimeters per year until they reach maturity (Moyle 2002). Average size-at-age can vary between sub-populations (Adams et al. 2002).

Migration and Spawning

In the southern DPS, adult green sturgeon begin their upstream spawning migrations into the San Francisco Bay in March and reach Knights Landing on the Sacramento River during April (Heublein et al. 2006). Based on the distribution of sturgeon eggs, larvae, and juveniles in the Sacramento River, DFG (2002) indicated that green sturgeon spawn in late spring and early summer above Hamilton City, possibly up to Keswick Dam (Brown 2007). Peak spawning is believed to occur between April and June.

Preferred spawning habitats are thought to be deep, cool pools with turbulent water and large cobble (DFG 2002; Moyle 2002; Adams et al. 2002). Preferred spawning substrate is likely large cobble, but it can range from clean sand to bedrock (Moyle 2002). Eggs are broadcast and externally fertilized in relatively fast water and probably in depths greater than 3 m (Moyle 2002). Female green sturgeon produce 59,000-242,000 eggs, about 4.34 millimeters (mm) in diameter (Van Eenennaam et al. 2001, 2006). Though the number of eggs produced is relatively low compared to other sturgeon species, green sturgeon egg size is large (4.3 mm in diameter; Cech et al. 2000).

Green sturgeon were most often found at depths greater than 5m (16.4 feet) with low or no currents during summer and autumn months (Erickson et al. 2002). Recent acoustic tagging studies on the Rogue River (Erickson et al. 2002) found that adult green sturgeon held for as much as six months in deep (>5 m [16.4 feet]), low gradient reaches or off-channel sloughs or coves of the river during summer months when water temperatures were between 59-73˚F. When ambient temperatures in the river decrease in autumn and early winter (<50˚F), and flows increase, fish moved downstream into the ocean.

Egg Incubation and Rearing

Eggs are deposited at sites where they adhere to and between large rock substrate. The large size of green sturgeon eggs relative to other sturgeon indicates that female green sturgeon invest a greater amount of their reproductive energy resources into maternal yolk for nourishment of the embryo, which results in larger larvae (Van Eenennaam et al. 2001). The reserve of maternal yolk and larger larvae could provide an advantage in larval feeding and survival (Van Eenennaam et al. 2001). Compared with other acipenserids, green sturgeon larvae appear more robust and easier to rear (Van Eenennaam et al. 2001).

Both spawning areas and migratory corridors comprise rearing habitat for juvenile green sturgeon. Young green sturgeon appear to rear for the first one to two months in the Sacramento River between Keswick Dam and Hamilton City (DFG 2002). Rearing habitat condition and function may be affected by variation in annual and seasonal flow and temperature characteristics (70 FR 17386). Van Eenennaam et al. (2005) concluded from laboratory studies that temperatures 63–64°F may be the upper limit of the thermal optima for green sturgeon embryos. Temperatures of 73–79°F affected cleavage and gastrulation of green sturgeon embryos and all died before hatching (Van Eenennaam et al. 2005). Growth studies on younger juvenile green sturgeon determined that cyclical 66-75°F water temperature was optimal (Allen et al. 2006).

Hatchling green sturgeon embryos seek nearby cover, and remain under rocks (Deng et al. 2002). After about 6 to 9 days fish develop into larvae and initiate exogenous foraging up- and downstream on the bottom (Deng et al. 2002; Kynard et al. 2005). After a day or so, larvae initiate a downstream dispersion migration that lasts about 12 days (peak, 5 days). All young movement and foraging during the migration period is nocturnal (Cech et al. 2000; Kynard et al. 2005). Length at 10 days is 19 to 29 mm (mean 24 mm) (Deng et al. 2002). At an age of 15 to 21 days, green sturgeon are 30 mm or greater in length (Deng et al. 2002). Larval green sturgeon are regularly captured during this dispersal stage at about two weeks of age (24-34 mm fork length) in rotary screw traps at Red Bluff Diversion Dam (DFG 2002; FWS 2002), and three weeks old when captured further downstream at the Glen-Colusa facility (DFG, unpublished data; Van Eenennaam et al. 2001).

At the age of 45 days, metamorphosis is complete and green sturgeons are 70 to 80 mm in length (Deng et al. 2002). Post-migrant larvae are benthic, foraging up- and downstream diurnally with a nocturnal activity peak. Foraging larvae select open habitat, not structure habitat, but continue to use cover during the day. A second downstream migration occurs in the fall. Juveniles migrate downstream mostly at night to wintering sites, ceasing migration at temperatures of 45–46°F. During winter, juveniles select low light habitat, likely deep pools with some rock structure. Wintering juveniles forage actively at night between dusk and dawn and are inactive during the day, seeking the darkest available habitat (Kynard et al. 2005). Juveniles grow rapidly, reaching 300 mm in 1 year and over 600 mm within 2-3 years (Nakamoto et al. 1995, FWS 1995). Juveniles spend from 1-4 years in fresh and estuarine waters of the Sacramento-San Joaquin Delta and disperse into salt water at lengths of 300-750 mm (FWS 1995).

Stomach contents from adult and juvenile green sturgeon captured in the Sacramento-San Joaquin Delta point to the importance of habitat that supports shrimp, mollusks, amphipods, and small fish (Radtke 1966; Houston 1988; Moyle et al. 1992). Stomachs of green sturgeon caught in Suisun Bay contained *Corophium* sp. (amphipod), *Cragon franciscorum* (bay shrimp), *Neomysis awatchensis* (Opossum shrimp: synonymous with *Neomysis mercedis*) and annelid worms (Ganssle 1966). Stomachs of green sturgeon caught in San Pablo Bay contained *C. franciscorum*, *Macoma* sp. (clam), *Photis californica* (amphipod), *Corophium* sp., *Synidotea laticauda* (isopod), and unidentified crab and fish (Ganssle 1966). Stomachs of green sturgeons caught in Delta contained *Corophium* sp. and *N. awatchensis* (Radtke 1966). As a result of recent changes in the species composition of macroinvertebrates inhabiting the Bay-Delta estuary, (due to non-native species introductions), the current diet of green sturgeon is likely to differ from that reported in the 1960's.

Ocean Residence

Based on their life history, a large percentage of the adult green sturgeon population inhabit the ocean at any given time (Beamesderfer et al. 2007). Green sturgeon typically stay near shore and avoid depths exceeding 100 m (Erickson and Hightower 2007). Relatively large concentrations of sturgeon occur in the Columbia River estuary, Willapa Bay, and Grays Harbor, with smaller aggregations in the San Francisco estuary and other coastal estuaries (Emmett et al. 1991; Moyle et al. 1992; ODFW 2005a; Israel 2006; Moser and Lindley 2007; Lindley et al. 2008). Adults feed in estuaries during the summer (ODFW 2005a; Moser and Lindley 2007). Annual marine survival rate was estimated at 0.83 for 2004 (Lindley et al. 2008), similar to the survival rate of 0.85 estimated for Klamath River green sturgeon by Beamesderfer and Webb (2002). Little is known about green sturgeon feeding at sea (DFG 2005a).

Population Distribution

North American green sturgeon are composed of two DPSs (Figure 8-2): the northern DPS includes all populations in the Eel River and northward, and the southern DPS includes a single spawning population in the Sacramento River (Adams et al. 2002). The northern DPS includes populations spawning in the Rogue, Klamath, and Umpqua rivers (NMFS 2005). Green sturgeon from the Sacramento River are genetically distinct from their northern counterparts indicating a spawning fidelity to their natal rivers (Israel et al. 2004).

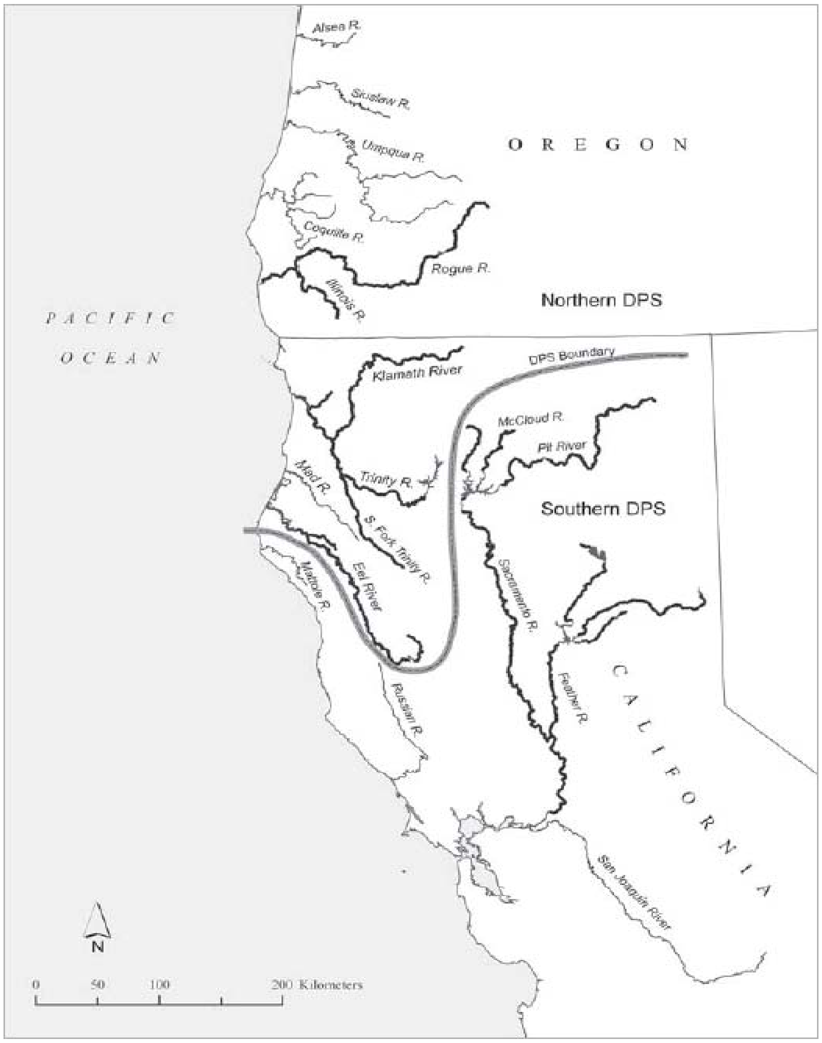


Figure 8-2. Distribution of North American Green Sturgeon of both the Northern and Southern Distinct Population Segments (NMFS 2007).

Sacramento River

Current data and observations document green sturgeon in the Sacramento River as far upstream as Keswick Dam and as far south as the CVP/SWP water export facilities near the southern limit of the Sacramento-San Joaquin Delta.

Spawning in the upper Sacramento River is currently thought to occur from Hamilton City (RM 200) to above Red Bluff Diversion Dam (RM 304). Spawning migrations and spawning by green sturgeon in the upper Sacramento River mainstem have been well documented over the last 15 years (Beamesderfer et al. 2004). Anglers fishing for white sturgeon or salmon commonly report catches of green sturgeon from the Sacramento River at least as far upstream as Hamilton City (Beamesderfer et al. 2004). Eggs, larvae, and post larval green sturgeon are now commonly reported in sampling directed at green sturgeon and other species (Beamesderfer et al. 2004; Brown 2007). Young-of-the-year (yoy) green sturgeon have been observed annually since the late 1980s in fish sampling efforts at Red Bluff Diversion Dam (RBDD) and the Glenn-Colusa

Canal (Beamesderfer et al. 2004). Green sturgeon have not been documented in Sacramento River tributaries other than the Feather River system (Beamesderfer et al. 2004, Moyle 2002).

The upstream extent of historical spawning by green sturgeon in the Sacramento River system is unknown. White sturgeon historically ranged into upper portions of the Sacramento system including the Pit River and a substantial number were trapped in and above Lake Shasta when Shasta Dam was closed in 1944 and successfully reproduced until the early 1960s (Beamesderfer *et al*. 2004). Green sturgeon have not been documented upstream from the Shasta Dam site. According to NMFS (2005), "the BRT considered it possible that the additional habitat behind Shasta Dam in the Pit, McCloud, and Little Sacramento systems would have supported separate populations or at least a single, larger Sacramento River population less vulnerable to catastrophes than one confined to a single mainstem, but the BRT was unable to be specific due to the paucity of historical information" (NMFS 2005).

Green sturgeon currently spawn in the Sacramento mainstem downstream from Keswick and Shasta dams. NMFS concluded that it is unlikely that green sturgeon reproduced in their current spawning area under the historical temperature regime that occurred before the construction of Shasta and Keswick dams (NMFS 2005). NMFS (2005) further concluded: "we have not been able to quantify the reduction of habitat to date, and are uncertain how reduction in spawning habitat has affected the population's viability." However, Shasta Dam operations now maintain relatively favorable temperature conditions in the upper Sacramento River while pre-development patterns were characterized by very high annual variation with periods of extended drought. The net tradeoff in habitat lost vs. habitat gained is unclear.

Prehistoric distribution of sturgeon in California has been mapped by Gobalet et al. 2004 based on bones at Native American archaeological sites. Data were reported on dozens of sites throughout California and summarized by county. Sturgeon remains were observed in 12 counties, all in the Central Valley. Observations were concentrated at San Francisco Bay and Sacramento-San Joaquin and delta sites (Contra Costa, Alameda, San Francisco, Marin, Napa, San Mateo and Santa Cruz counties). Historical 18th-century accounts report the aboriginal gillnetting and use of tule balsa watercraft for the capture of sturgeon, and fishing weirs were also likely employed on bay tidal flats (Gobalet et al. 2004). Most sturgeon were unidentified species but green sturgeon were specifically identified from Contra Costa and Marin county sites. Sturgeon remains (unidentified species) were also identified from lower Sacramento River counties (Sacramento, Yolo, Colusa, Glenn, and Butte counties). No sturgeon remains were found in samples from the upper Sacramento River although other fish species including salmonids were reported in those areas.

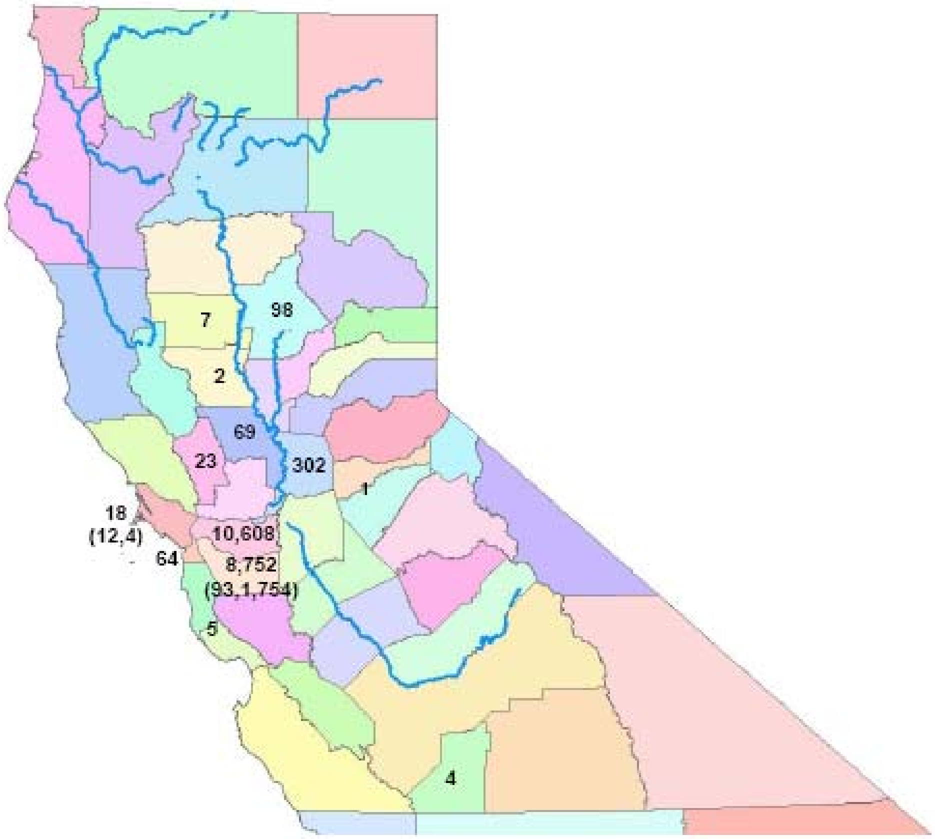


Figure 8-3. Observations of sturgeon remains in the California Native American archaeological sites. (Gobalet et al. 2004). Numbers represent number of sturgeon observations based on skeletal remains. Numbers are typically unidentified sturgeon species. Species-specific identifications are listed in parentheses (green sturgeon, white sturgeon).

Feather River

Historical and recent information confirms that both green and white sturgeons occasionally range into the Feather, Yuba, and Bear rivers but numbers are low (Beamesderfer et al. 2004). Most recently in 2006, a dozen sturgeon were observed to either be captured by anglers or rolling at the surface near the Thermalito Outlet located on the Feather River. Of these, four were able to be positively identified as green sturgeon by DWR biologists (DWR unpublished data, DWR 2007).

It is unknown whether green sturgeon historically spawned in the Feather River either downstream or upstream of Oroville Dam or the Thermolito Afterbay outlet. Unspecific historical reports of green sturgeon spawning in the Feather River (Wang 1986, USFWS 1995, DFG 2002, DWR 2007) have not been corroborated by observations of young fish or significant numbers of adults in focused sampling efforts (Schaffter & Kohlhorst 2002, Niggemyer & Duster 2003, Seesholtz 2003, Beamesderfer et al. 2004). Potential confusion of green and white sturgeon often confounds interpretation of historical records. White sturgeon have been documented in the Feather River system on numerous occasions (Anonymous 1918, Talbitzer 1959, Miller 1972, USFWS 1995, Schaffter and Kohlhorst 2002, Beamesderfer et al. 2004).

Significant habitat on the Lower Feather River, while modified, remains accessible downstream from the Thermolito Afterbay outlet (DWR 2005a). Potential natural and man-made barriers to upstream movements in the Feather River during low flow years might also limit significant movement of Southern DPS green or white sturgeon into the Feather River to wet, high flow water years (Beamesderfer et al. 2004).

San Joaquin River

The current or historical occurrence of green sturgeon in the San Joaquin River has been a source of much speculation. It is unclear whether green sturgeon were historically present, are currently present, or were historically present and have been extirpated from the San Joaquin River (NMFS 2005, Beamesderfer et al. 2007). No adult or juvenile green sturgeon have been documented in the San Joaquin River upstream from the Delta (DFG 2002), although no directed sturgeon studies have ever been undertaken in the San Joaquin River (FWS 1995, DFG 2002, Adams et al. 2002, Beamesderfer et al. 2004, NMFS 2005). Observations of green sturgeon juveniles or unidentified sturgeon larvae in the San Joaquin River has been limited to the Delta where they could easily, and most likely, have originated from the Sacramento River rather than the San Joaquin River (Beamesderfer et al. 2004).

Moyle et al. (1992) surmised that spawning by green sturgeon may have taken place at one time in the lower San Joaquin River. Others have noted the long history of habitat changes in the San Joaquin River basin and assumed historical use by green sturgeon based on the past habitat suitability for spring-run Chinook salmon and steelhead. Sturgeon remains (unidentified species) in deposits at Tulare Lake illustrate that anadromous species were historically capable of reaching the south San Joaquin Valley (Gobalet et al. 2004) but no green or white sturgeon appear to have been trapped behind Friant Dam when it was constructed in the 1940s (DFG 2002). White sturgeon are regularly observed in the San Joaquin River upstream from the Delta (Beamesderfer et al. 2004) and spawning is suspected to occur in wet years (Shaffter, DFG retired, 2004 personal communication). Small fisheries for sturgeon occur in late winter and spring between Mossdale and the Merced River (Kohlhorst 1976, Kohlhorst et al. 1991, Scott 1993, Lewis 1995, Palomares 1995, Keo 1996, Jardine 1998).

Bay-Delta

Green sturgeon juveniles, subadults, and adults are widely distributed in the Sacramento-San Joaquin Delta and estuary areas including San Pablo Bay (Beamesderfer et al. 2004). The Sacramento-San Joaquin Delta serves as a migratory corridor, feeding area, and juvenile rearing area for North American green sturgeon in the southern DPS. Table 8-1 depicts the season occurence of green sturgeon life stages in freshwater habitat throughout the California Central Valley and its neighboring marine environments.

Adults migrate upstream primarily through the western edge of the Delta into the lower Sacramento River between March and June (Adams et al. 2002). Larvae and post-larvae are present in the lower Sacramento River and North Delta between May and October, primarily in June and July (DFG 2002). Juvenile green sturgeon have been captured in the Delta during all months of the year (Borthwick et al. 1999; DFG 2002; BDAT 2007). Catches of 1 and 2 year old Southern DPS green sturgeon on the shoals in the lower San Joaquin River, at the CVP/SWP fish salvage facilities, and in Suisun and San Pablo bays indicate that some fish rear in the estuary for at least 2 years (DFG 2002). Larger juvenile and subadult green sturgeon occur throughout the estuary, possibly temporarily, after spending time in the ocean (DFG 2002; Kelly et al. 2007). Figure 8-4 shows the size distribution of green sturgeon at various life stages observed in sample data from young-of-the-year collected in spring and summer at RBDD in the Sacramento River, juveniles salvaged from CVP/SWP water projects, and subadults sampled by DFG in San Pablo Bay.

Table 8-1. The temporal occurrence of (a) adult, (b) larval and post-larval, (c) juvenile, and (d) coastal migrants of the southern DPS of North American green sturgeon. Locations are specific to the Central Valley of California. Darker shades indicate months of greatest relative abundance.

(a) Adult (≥13 years old for females and ≥9 years old for males)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[1,2,3]Upper Sac. River			Medium	Medium / High	High	High / Medium	Medium	Medium	Medium	Medium	Medium	
[4,8]SF Bay Estuary			Medium	Medium	Medium	Medium	Medium	Medium	Medium			

(b) Larval and post-larval (≤10 months old)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[5]RBDD, Sac River					Medium	High	High	Medium				
[5]GCID, Sac River					Medium	High	High	Medium	Low	Low		

(c) Juvenile (> 10 months old and ≤3 years old)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[6]South Delta*	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
[6]Sac-SJ Delta	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
[5]Sac-SJ Delta				Medium	Medium	Medium	Medium	Medium	Medium	Medium		
[5]Suisun Bay	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

(d) Coastal migrant (3-13 years old for females and 3-9 years old for males)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[3,7]Pacific Coast	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

Source: [1]FWS 2002; [2]Moyle et al. 1992; [3]Adams et al. 2002 and NMFS 2005; [4]Kelley et al. 2006; [5]DFG 2002; [6]Interagency Ecological Program Relational Database, fall midwater trawl green sturgeon captures from 1969 to 2003; [7]Nakamoto et al. 1995; [8]Heublein et al. 2006, * Fish Facility salvage operations

RBDD – Red Bluff Diversion Dam GCID – Glen-Colusa Irrigation District facility

Relative Abundance: ■ =High ■ = Medium ■ = Low

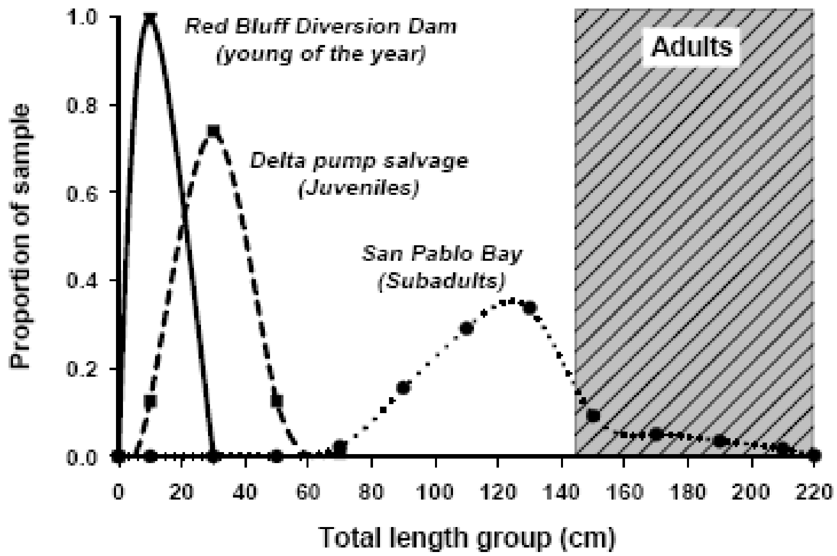


Figure 8-4. Sizes of juvenile green sturgeon measured at CVP/SWP fish salvage facilities, 1968-2001 (DFG 2002), collected in rotary 1994-2000 (FWS 2002), and sampled in semi-annual San Pablo Bay sturgeon stock assessments (DFG 2002). [Figure from Beamesderfer et al. 2007]

Ocean

Green sturgeon from the Southern DPS pass through the San Francisco Bay to the ocean where they commingle with other sturgeon populations (DFG 2002). Green sturgeon are known to range in nearshore marine waters from Mexico to the Bering Sea, with a general tendency to head North after their out-migration from freshwater (NMFS 2005). They are commonly observed in bays and estuaries along the western coast of North America during the late summer (Emmett et al. 1991; Moyle et al. 1992; ODFW 2005a; Israel 2006; Moser and Lindley 2007; Lindley et al. 2008). Both the Northern DPS green sturgeon and Southern DPS green sturgeon occur in large numbers in the Columbia River estuary, Willapa Bay, and Grays Harbor, Washington (NMFS 2005).

Subadult and adult sturgeon tagged in San Pablo Bay oversummer in bays and estuaries along the coast of California, Oregon, and Washington, between Monterey Bay and Willapa Bay, before moving further north in the fall to overwinter north of Vancouver Island. Individual Southern DPS green sturgeon tagged by the DFG in the San Francisco Estuary have been recaptured off Santa Cruz, California; in Winchester Bay on the southern Oregon coast; at the mouth of the Columbia River; and in Gray’s Harbor, Washington (FWS 1993; Moyle 2002). Most tags for Southern DPS green sturgeon tagged in the San Francisco Estuary have been returned from outside that estuary (Moyle 2002).

Lindley et al. (2008) investigated marine migrations of green sturgeon by tagging subadults and adults from northern and southern DPSs with ultrasonic pinger tags. An array of receivers off the coast of California, Oregon, Washington, British Columbia and Alaska tracked their northern and southern migrations. Most tagged sturgeon moved north along the coast in the fall to spend winters north of Vancouver Island and south of southeast Alaska, and returned in the spring to oversummer in California, Oregon and Washington bays and estuaries. Distribution patterns of fish from different tagging locations varied. Green sturgeon from all spawning populations appear to migrate north as far as Brooks Peninsula but vary in the extent of their southerly spring migrations (Lindley et al. 2008). Marine migrations of green sturgeon may include areas as far south as Monterey Bay and as far north as Brooks Peninsula, Vancouver, BC.

Abundance and Trends in the Action Area

Empirical estimates of green sturgeon abundance are not available for any west coast population including the Sacramento River population. Interpretations of available time series of abundance index data for green sturgeon are confounded by small sample sizes, intermittent reporting, fishery-dependent data, lack of directed sampling, subsamples representing only a portion of the population, and potential confusion with white sturgeon (Heppell and Hofmann 2002, Adams et al. 2002). This section summarizes the best available data and identifies qualifications to be considered in its application as a description of the current baseline.

Population Estimates

The most consistent sample data for Sacramento green sturgeon is for subadults captured in San Pablo Bay during periodic white sturgeon assessments since 1948. DFG measured and identified 15,901 sturgeon of both species between 1954 and 1991 (FWS 1996). Catches of subadult and adult North American green sturgeon by the Interagency Ecological Program (IEP) between 1996 and 2004 ranged from one to 212 green sturgeon per year, with the highest catch in 2001 (Samantha Vu, DFG, pers. comm. 2005). Various attempts have been made to infer green sturgeon abundance based on white sturgeon mark-recapture estimates and relative numbers of white and green sturgeon in the catch (FWS 1996, Moyle 2002). However, low catches of green sturgeon preclude estimates or indices of green sturgeon abundance from this data (Schaffter and Kohlhorst 1999, Gingras 2005). It is unclear if the high annual variability in length distributions in these samples (Figure 8-5) reflect variable recruitment and abundance or are an artifact of small sample sizes, pooling of sample years, or variable distribution patterns between freshwater and ocean portions of the population.

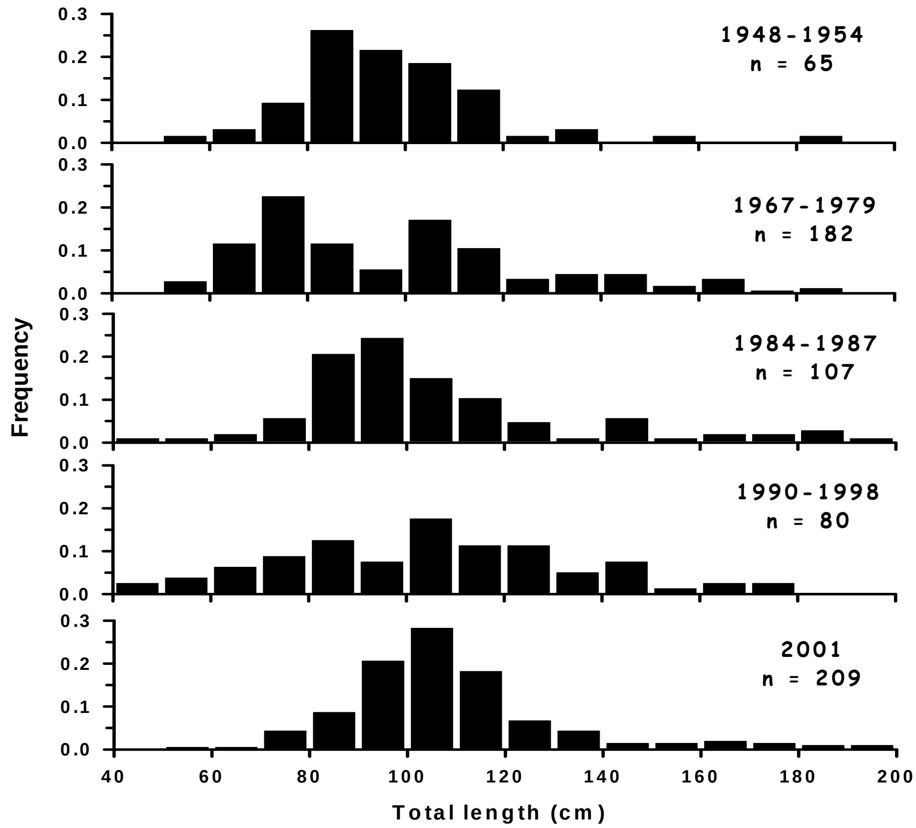


Figure 8-5. Changes in length distribution over time based on trammel net sampling of subadult green sturgeon in San Pablo Bay (DFG 2002). [Figure from Beamesderfer et al. 2007]

Migrant Sampling

Anecdotal information is also available on young-of-the-year green sturgeon from juvenile fish monitoring efforts at RBDD and the Glenn-Colusa Irrigation District pumping facility on the upper Sacramento River. Fish traps have been operated below RBDD and at the Glenn-Colusa Irrigation District (GCID) pumping plant. These facilities report sampling of between zero and 2,068 juvenile green sturgeon per year (Adams et al. 2002) and suggest that at least some green sturgeon reproduction occurred during the 1990s (Beamesderfer 2005).

Approximately 3,000 juvenile green sturgeon have been observed in rotary screw traps operated for juvenile salmon at RBDD from 1994-2000 (Figure 8-6). Annual catches have declined over the period from 1995 through 2000 although the relationship of these catches to actual abundance is unknown. Over 2,000 juvenile green sturgeon have been collected in fyke and rotary screw traps operated at the GCID Diversion from 1986-2003 (Figure 8-7). Operation of the screw trap at the GCID site began in 1991 and has continued year-around with the exception of 1998. Juvenile green sturgeon at the GCID site were consistently larger in average size, but the number captured varied widely (0 to 2,068 per year) with no apparent patterns in abundance between the two sites. Abundance of juveniles peaked during June and July with a slightly earlier peak at the RBDD site (Adams et al. 2002).

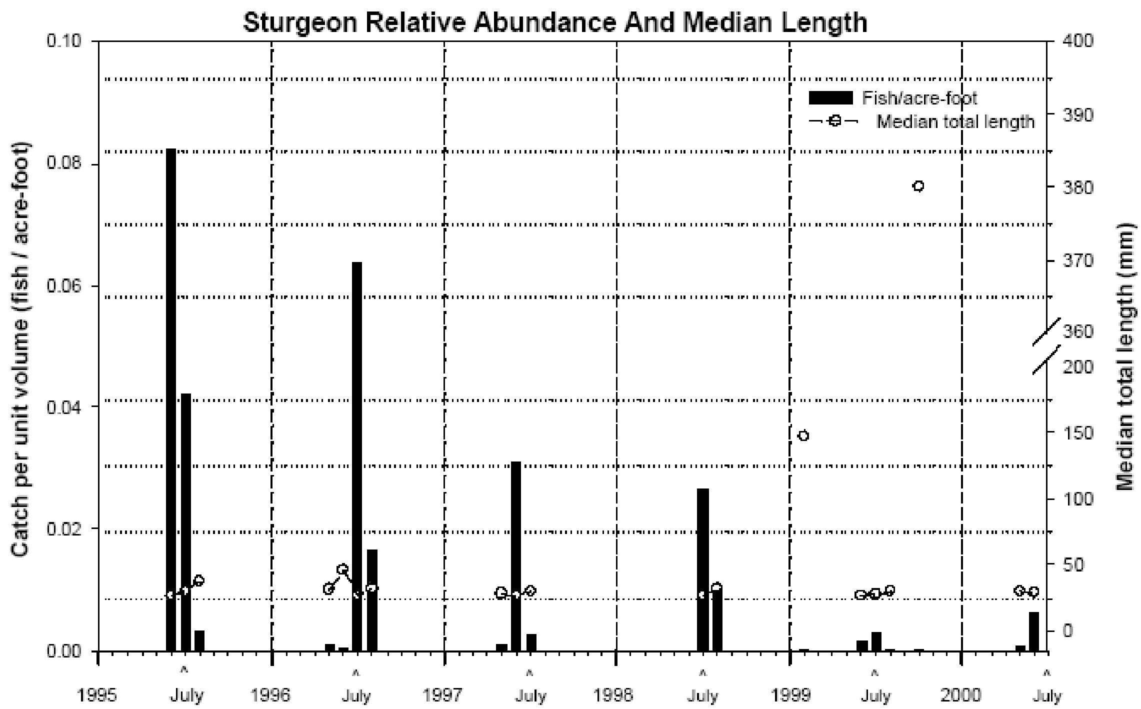


Figure A3. Relative abundance (fish/acre-foot) and median length for juvenile sturgeon (*Acipenser spp.*) captured by rotary-screw traps at Red Bluff Diversion Dam (RK 391), Sacramento River, CA. Data summarized from January 1995 through June 2000. In 1996 and 1997, a total of 124 juvenile sturgeon (*Acipenser spp.*) were grown out and positively identified as green sturgeon (*Acipenser medirostris*).

Figure 8-6. Green sturgeon data sample data from Red Bluff Diversion Dam rotary screw trap monitoring (FWS 2002).

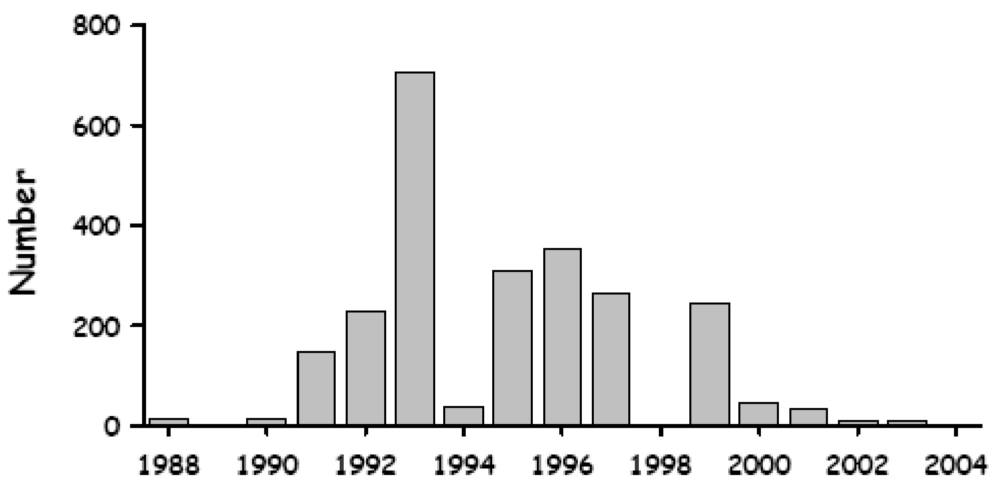


Figure 8-7. Juvenile green sturgeon collected in fyke and rotary screw traps operated at the Glenn-Colusa Irrigation District Diversion from 1986-2003 (Beamesderfer 2005).

Salvage Numbers

Variable numbers of juvenile green sturgeon are observed each year from two south Delta water diversion facilities (DFG 2002). When water is exported through the CVP/SWP export facilities, fish become entrained into the diversion. Since 1957, Reclamation has salvaged fish at the Tracy Fish Collection Facility. DFG's Fish Facilities Unit, in cooperation with DWR, began salvaging fish at the Skinner Delta Fish Protective Facility in 1968. The salvaged fish are trucked daily and released at several sites in the western Delta. Salvage of fish at both facilities is conducted 24 hours a day, seven days a week at regular intervals. Entrained fish are subsampled for species composition and numbers.

Numbers of green sturgeon observed at these fish facilities have declined since the 1980s (Figure 8-8) which contributed to NMFS' decision to list the southern DPS as a threatened species. In the Delta, the average number of green sturgeon salvaged per year at the SWP Skinner Fish Facility was 87 individuals between 1981 and 2000, and 20 individuals from 2001 through 2007 (71 FR 17759). From the CVP Tracy Fish Collection Facility, green sturgeon counts averaged 246 individuals per year between 1981 and 2000, and 53 individuals from 2001 through 2007 (M. Donnellan, unpubl. data). Patterns were similar between total numbers per year and numbers adjusted for water export volumes which increased during the 1970s and 1980s (Figure 8-9).

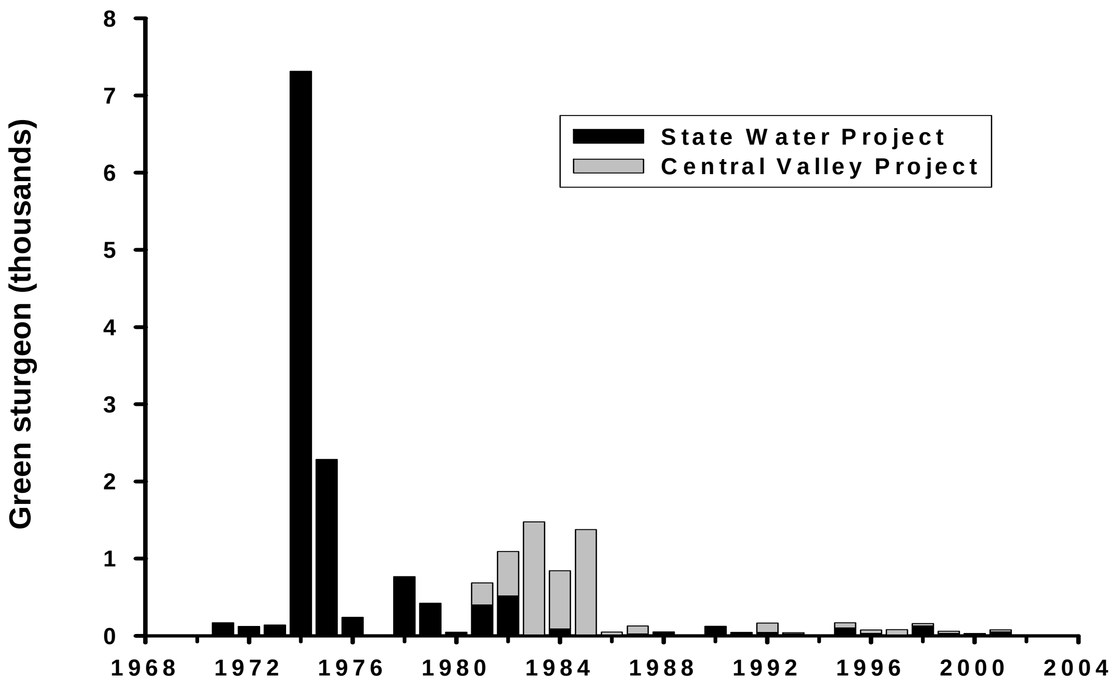


Figure 8-8. Estimated annual salvage of green sturgeon at SWP and CVP fish facilities in the South Sacramento-San Joaquin River delta. Green sturgeon were not counted at the Federal Central Valley Project prior to 1981. (Data from DFG 2004). Figure from Beamesderfer et al. (2007).

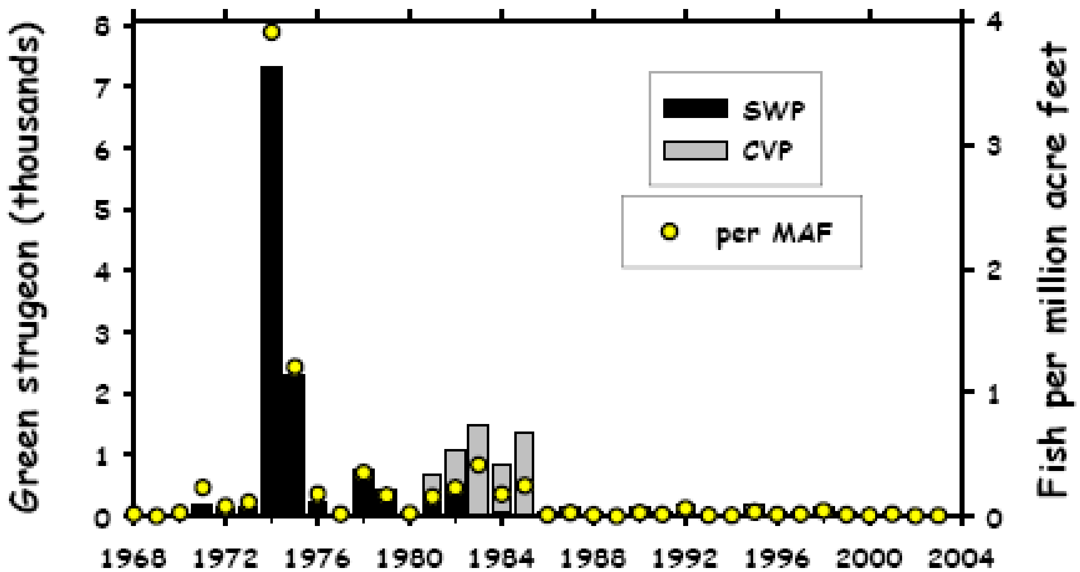


Figure 8-9. Estimated annual salvage of green sturgeon at CVP and SWP fish facilities in the South Sacramento-San Joaquin River Delta (DFG 2002). Prior to 1981, green and white sturgeon were counted together and reported simply as sturgeon at the CVP.

Salvage catches of green sturgeon at the SWP and CVP facilities appears to be primarily juvenile fish approximately 1 to 3 years of age (Figure 8-10). Salvage catches come from the population of juvenile green sturgeon that rear year-round throughout the Delta for several years before dispersing into the ocean. This group of fish may reflect multiple year classes. Green sturgeon are observed in the salvage in all months of the year but are most common in summer and early fall with a peak in August (Figure 8-11).

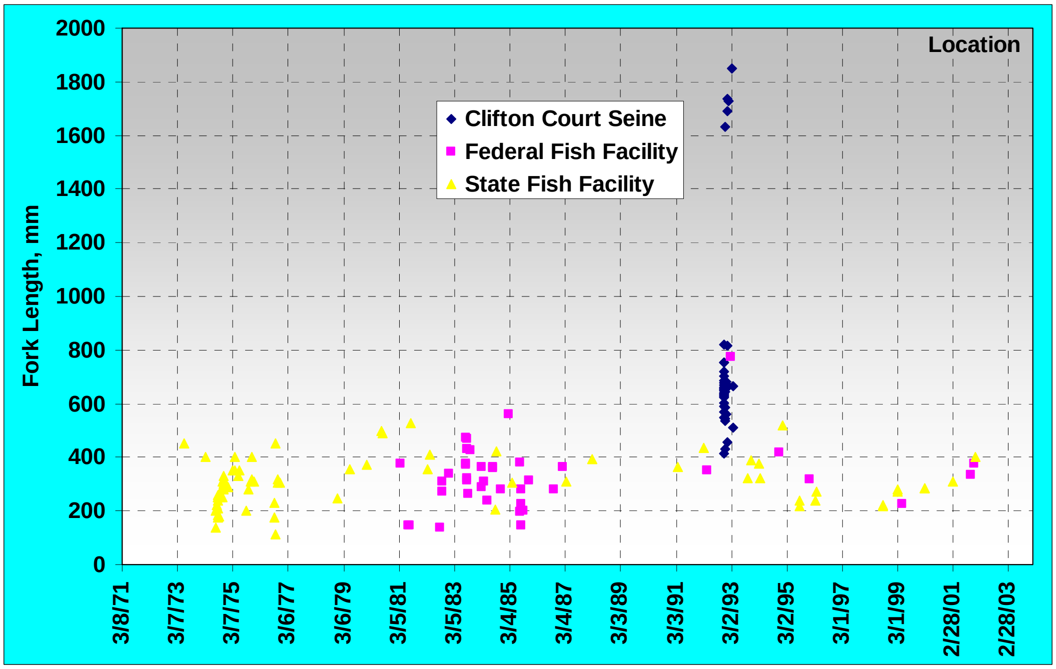


Figure 8-10. Fork lengths of green sturgeon collected at the CVP and SWP fish facilities and by seine in Clifton Court Forebay (data from DFG 2002).

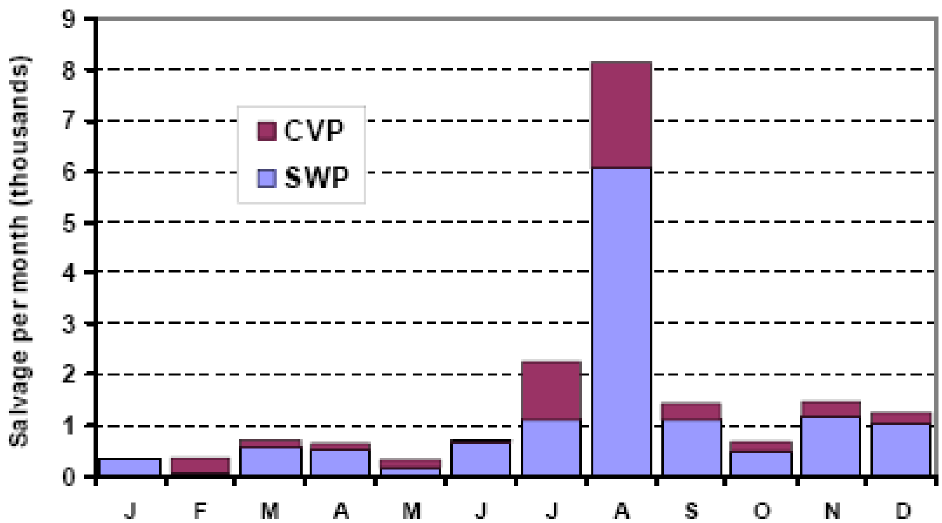


Figure 8-11. Seasonal pattern of juvenile green sturgeon catches at State and Federal fish facilities, 1968-2001 (DFG 2002).

Annual counts of green sturgeon from the SWP and CVP fish facilities are not significantly correlated (Figure 8-12) (Beamesderfer 2005). Data on green sturgeon are available for both facilities from 1981-2005. Only 1 percent of the variability in salvage numbers was correlated between facilities (typically $p<0.10$ or $p<0.05$) (Beamesderfer 2005). In 1983, projected salvage at the CVP was 1,475 and only 1 at the SWP. In 1985, projected salvage at the CVP was 1,374 and only 3 at the SWP (Beamesderfer 2005).

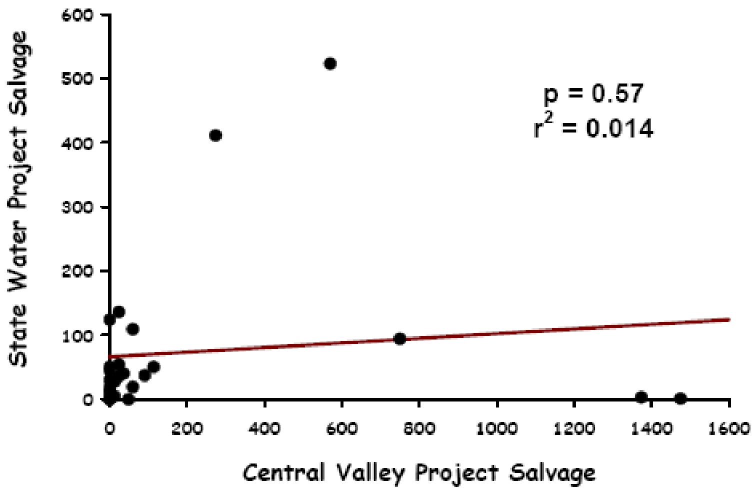


Figure 8-12. Green sturgeon salvage numbers at State and Federal facilities are not statistically correlated (Beamesderfer 2005).

Physical conditions in the Sacramento River and Delta vary substantially from year-to-year and these factors could drastically affect green sturgeon spawning success, dispersal patterns, and vulnerability to salvage. There have also been substantial changes in CVP and SWP water project operations in the decades since the CVP and SWP were built. Changes in SWP and CVP operations, particularly in recent years, include a variety of actions implemented to protect listed salmon (NMFS 2004) as well as delta smelt. Concerted efforts have been made to reduce the effects of projects on fish. The seasonal timing of export pumping has been changed to weight summer pumping more heavily in order to reduce export pumping when listed salmon, steelhead and delta smelt are in the estuary during the late-winter and spring. Delta Cross Channel (DCC) gate operations are also restricted in late-winter and spring to protect juvenile salmon migrating downstream. CVP and SWP water project operations are managed to limit impacts on listed species during migration periods.

Peak catches of both green and white sturgeon prior to 1985 were generally correlated with high Sacramento River flows (Figure 8-13). NMFS (2005) noted the relationships between flow and apparent white sturgeon spawning success and inferred that low flow rates might affect green sturgeon in a similar manner. Declines in green sturgeon salvage numbers since the 1980s corresponded with an eight-year period of low flows (Figure 8-13) when conditions might have been less favorable for sturgeon reproduction. Periodic high flows in the 1990s produced small increases in white sturgeon salvage catches but salvage numbers were much lower than prior to 1985 (Figure 8-13). FWS (1996) in the FWS Recovery Plan for Sacramento/San Joaquin Delta

Native Fishes also reported that juvenile sturgeon are probably more vulnerable to entrainment at the SWP and CVP at low to intermediate flows during those years when river and Delta inflow are normal or below normal.

FWS (1996) reported substantial uncertainty in the interpretation of salvage data for green sturgeon because of poor quality control on both counts and species identification, expansions from small sample sizes, variability in sturgeon dispersal patterns and collection vulnerability in response to complex changes in delta flow dynamics, and changes in configuration and operation over time. Estimated sturgeon salvage numbers are expanded from subsamples and actual numbers of green sturgeon observed are substantially smaller. Historical expansions were based on variable expansion rates (subsample duration) ranging from 15 seconds per two hours when fish numbers were high to 100 percent counting during periods when fish numbers were low. Now, NMFS 2004 required sampling of fish salvage at both the SWP and CVP facilities at intervals of no less than 10 minutes every 2 hours. Green sturgeon salvage estimates reported for years before 1993 may be in error because of uncertainty whether smaller sturgeon were correctly identified (FWS 1996; DFG 2002; DFG 2005b; FWS 2005). Reclamation and DWR recommended that only more recent (from 1993 and later) CVP and SWP salvage data should be used to analyze the effects of water project operations on the green sturgeon and other anadromous fishes (FWS 2005).

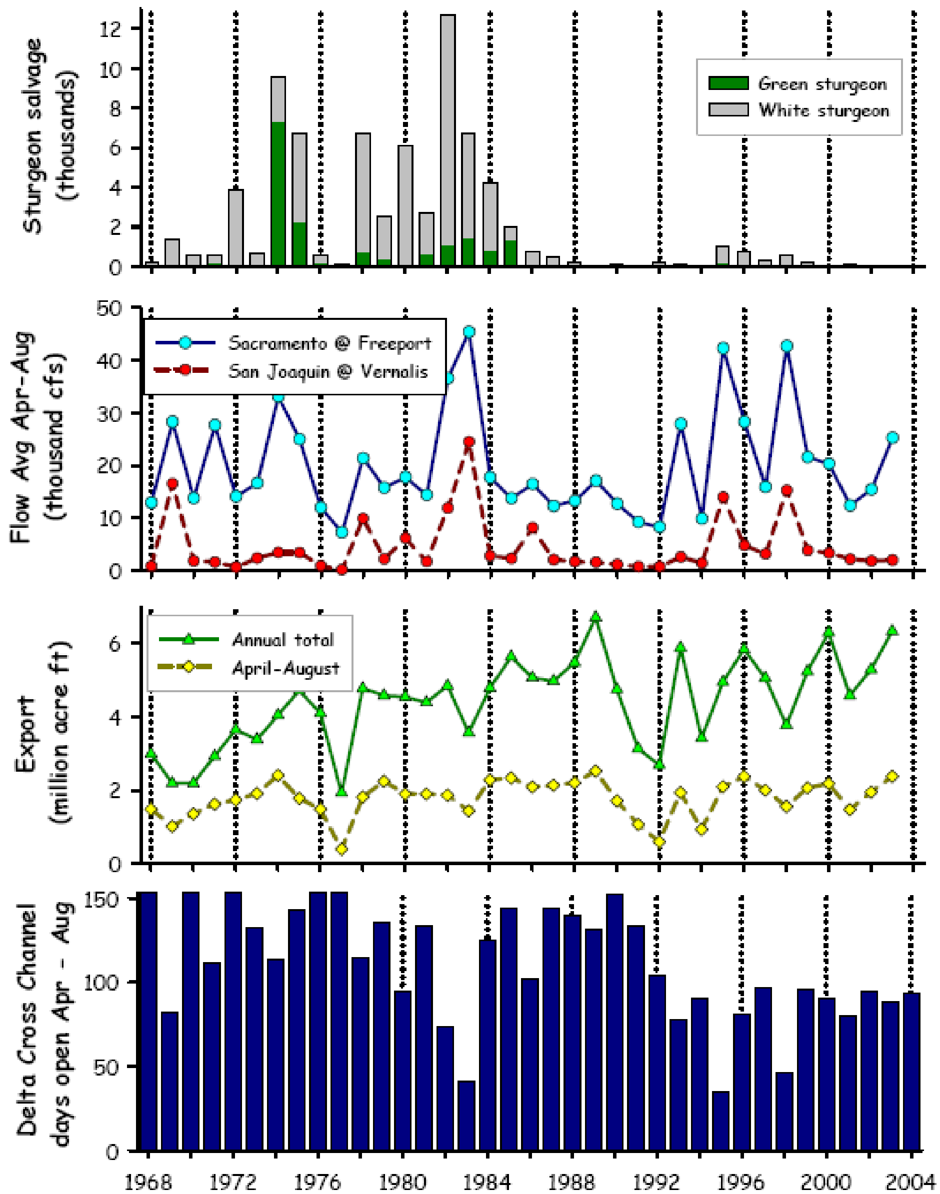


Figure 8-13. Annual patterns in sturgeon salvage, river flow, export volume, and Delta Cross Channel operation, 1968-2004 (Beamesderfer 2005). The April-August period corresponds to the timing of downstream dispersal of juvenile white and green sturgeon from areas of the Sacramento River where they were spawned (Beamesderfer 2005).

Factors that May Influence Abundance and Distribution

NMFS' threatened listing determination of the Southern DPS of green sturgeon was made after consideration of the best available information regarding "loss of historical habitat, the concentration of the spawning population into a single location, the trend in the salvage data, and the cumulative risk from a number of different threats in the Sacramento River and Delta Systems" (71 FR 17758). The following narrative provides a description of potential threats that may have contributed to the decline of green sturgeon in the Southern DPS according to categories identified by NMFS.

Fish Passage

A principal threat to green sturgeon is the reduction of spawning areas as the result of impassible barriers, primarily Keswick Dam on the Sacramento River and Oroville Dam on the Feather River, that block access to historic spawning habitat for anadromous species (Lindley et al. 2004; NMFS 2005). The Feather River is likely to have supported significant spawning habitat for green sturgeon in the Central Valley in the past (DFG 2002). Green sturgeon adults have been observed periodically in the Feather River (FWS 1995; Beamesderfer et al. 2004) and there may be sufficient habitat above Oroville Dam for occupation by sturgeon in the upstream reaches of the Feather River. Sufficient conditions may also be present in the San Joaquin River upstream to Friant Dam, and in the tributaries such as Stanislaus, Tuolumne, and Merced rivers upstream to their respective dams, although it is unknown whether green sturgeon ever used the San Joaquin River and its tributaries for spawning (Beamesderfer et al. 2004).

Potential barriers to adult migration for green sturgeon in the Central Valley include structures such as the RBDD, Sacramento Deep Water Ship Channel locks, Fremont Weir, Sutter Bypass, and DCC gates on the Sacramento River, and Shanghai Bench and Sunset Pumps on the Feather River during low flow periods (70 FR 17386). The RBDD serves as a migration barrier for sturgeon when the gates are closed (FWS 1995). Adult sturgeon can migrate past RBDD when gates are raised between mid-September and mid-May to allow passage for winter-run Chinook salmon and other migratory fish species. However, tagging studies by Heublein et al. (2006) found that, when the gates were closed, a substantial portion of tagged adult green sturgeon failed to use fish ladders at RBDD and were therefore unable to access spawning habitats upstream. A set of locks at the end of the Sacramento River Deep Water Ship Channel at the connection with the Sacramento River "blocks the migration of all fish from the deep water ship channel back to the Sacramento River" (DWR 2003).

Green sturgeon are likely to use the same migratory routes as Chinook salmon. DCC gate closures are required during the winter and early spring months when sturgeon are migrating (February-May), completely blocking migration through the central Delta. Upstream migrating adult Chinook salmon are known to use the DCC as a migratory pathway when the gates are open and Sacramento River water flows into the Mokelumne and San Joaquin rivers (Hallock et al. 1970). It is possible that attraction to this diverted water causes migration delays and straying of green sturgeon, as it does to Chinook salmon, by providing false migration cues (CALFED Science Program 2001; McLaughlin and McLain 2004).

Shasta and Keswick Dams

Reclamation completed Shasta Dam in 1945 and Keswick Dam in 1950. These dams currently block any potential access of sturgeon into the upper Sacramento system. NMFS (2006) concluded that Keswick Dam did block access to assumed historic spawning grounds although the historical upstream extent of green sturgeon distribution is unknown.

Red Bluff Diversion Dam (RBDD)

RBDD was constructed in 1964. RBDD historically blocked migration into a portion of the upper Sacramento River. Green sturgeon are unable to pass upstream from RBDD when the gates are lowered to divert irrigation flows into adjacent canals. Before 1986, the gates were closed year-round. This means that there was a 22-year period when there was complete blockage of spawning habitat above RBDD. After 1993, gates have been open from September 15 through May 14 for passage of winter-run Chinook salmon. The gates of the RBDD are in during the last third of the spawning period of Southern DPS green sturgeon. A draft EIS for RBDD fish passage improvements estimates that closure of the gates results in a 65 percent reduction in green sturgeon blockage to upstream habitat based on adult migration timing (CH2MHill 2002).

Figure 8-14. Historical patterns of gate operations at Red Bluff Diversion Dam.

Optimal spawning temperatures and spawning substrate exist for sturgeon in the Sacramento River well above and well below RBDD. Southern DPS green sturgeon are known to regularly spawn above and below RBDD. Significant natural recruitment of Southern DPS green sturgeon was reported during the 22 year period when the RBDD gates were closed year-round (NMFS 2005) which suggests that at least some some adult green sturgeons attempting to pass through the dam when the gates were closed, were able to spawn successfully downstream.

Following any emergency closure for water delivery purposes prior to May 15 of any year, the 2004 OCAP Biological Opinion (NMFS 2004) prescribed a minimum 5 day gate opening prior to June 15 to benefit upstream migration of Spring-run Chinook salmon. Reclamation implemented this emergency gate closure for the first time in 2007 (Reclamation 2007b).

On May 15, 2007, Reclamation staff discovered 5 to 8 adult Southern DPS green sturgeon dead at or below RBDD (FWS 2007a). A total of 12 dead green sturgeon were subsequently recovered. Several adult sturgeon were actually found stuck under the RBDD gates. A subsequent necropsy determined that at least one was killed by a RBDD gate (FWS 2007b). It is possible that this action, although designed to benefit salmon, may have inadvertently degraded passage and habitat conditions for Southern DPS green sturgeon in proximity to RBDD. Following the first reports of Southern DPS green sturgeon deaths, the salmon migration monitoring operations of the FWS were adjusted and the eleven gate openings were either increased to a 1 foot minimum or to full closure to avoid potential impingement of sturgeon against openings that were too small to provide for their safe downstream passage. Reclamation is only aware of one other Southern DPS green sturgeon carcass being reported in the past 40 years of operation of the RBDD (Reclamation 2007b).

Delta Cross Channel (DCC) Gates Operations

The DCC is a controlled diversion channel located in the northern Delta between the Sacramento River and Snodgrass Slough, a tributary to the Mokelumne River. Reclamation operates the DCC gates to improve the transfer of water from the Sacramento River to the central Delta and export facilities at the Banks and Jones Pumping Plants. To reduce scour in the channels on the downstream side of the DCC gates and to reduce potential flood flows that might occur from diverting water from the Sacramento River into the Mokelumne River system, the radial gates are closed whenever flows in the Sacramento River at Freeport reach 25,000 to 30,000 cfs on a sustained basis. Flows through DCC gates are determined by Sacramento River stage and are not affected by export rates in the south Delta.

The DCC gates can be closed by Reclamation for the protection of fish, provided that water quality is not a concern in the Central or South Delta. From February 1 through May 20, the SWRCB D-1641 requires that the DCC gates remain closed for the protection of emigrating juvenile Chinook salmon in the Sacramento River. An optional gate closure up to 45 days can be requested by the fish agencies during the November through January period and 14 days during the May 21 through June 15 period. The timing and duration of these closures is determined by Reclamation in consultation with FWS, DFG and NMFS.

When the DCC gates are open, juvenile Southern DPS green sturgeon may pass through and enter into the central Delta, which is generally regarded as being lower habitat quality than the western Delta. However, as juvenile green sturgeons are strong swimmers by the time they get into the Delta, and are roaming and feeding about the Delta for one to two years, they possess the ability behaviorally select or avoid habitats within the Delta as desired.

It is possible that water leakage though the DCC gates when closed might serve as a false attractant to green sturgeon adults entering the Delta and moving through the Mokelumne River system from the San Joaquin River side. The DCC gates are closed during the upstream migration period for green sturgeon, thus fish could be blocked by the DCC from entering the mainstem Sacramento River at Walnut Grove.

South Delta Temporary Barriers

The South Delta Temporary Barriers Program (TBP) was initiated in 1991. Its objectives are the short-term improvement of water conditions (water quality and elevation) for the south Delta and agricultural diversions, for the improvement of protection for San Joaquin River salmon, and for the development of data for the design of permanent gates. The program involves the seasonal installation of four barriers—one each on Middle River, Grant Line Canal, and Old River and a fish control barrier at the head of Old River. The barriers are a combination of rock placed into the main channel bed at each location along with overflow weirs and several gated culverts. These barriers are installed in the spring and removed in the fall.

When the barriers are in, Southern DPS green sturgeon within the barriers are trapped in the south Delta, where the habitat is generally regarded as low quality. When the barriers are removed, the Southern DPS green sturgeon are able to migrate out of the south Delta. The TBP continues to be implemented on an annual basis as an interim solution to water levels and circulation until a permanent solution can be implemented.

Suisun Marsh and Salinity Control Gates

DWR operates the Suisun Marsh Salinity Control Gates (SMSCG) to maintain water quality standards set by the SWRCB in D-1641 and the Suisun Marsh Preservation Agreement. The non-operation configuration of the SMSCG from June through August and any period during September through May when the gates are not in operation to meet salinity standards typically consists of the flashboards installed, but the radial gate operation is stopped and held open. Flashboards will be removed if it is determined that salinity conditions at all trigger stations would remain below standards for the remainder of the control season through May 31.

It is possible for young sturgeon to become entrained into Montezuma Slough and Suisun Marsh when the SMSCG is fully operational. Fish may enter Montezuma Slough as they emigrate from the Sacramento River during the fall when the gates are open to draw freshwater into the marsh and then may not be able to move back out when the gates are closed. However, the degree to which movement of green sturgeon is constrained is unknown. In addition, it is possible upstream passage of adults could be influenced as adult green sturgeon may pass through the marsh channels from December through May when their migration into spawning grounds could potentially be delayed. The affects of entrainment on juvenile green sturgeon at RRDS screen intakes is unknown as screening standards for green sturgeon are currently unidentified.

Feather River

Oroville and Thermalito diversion dams currently block any potential sturgeon access into the upper portion of the Feather River. Oroville Dam construction began in 1957 and was completed in 1968. Constructed between 1963 and 1968, the Thermalito Diversion Dam and Pool are located about 4.5 miles downstream from Oroville Dam. NMFS (2006) concluded that Oroville blocked access to assumed historic spawning grounds although the historical upstream extent of green sturgeon distribution is unknown and dams were constructed upstream prior to construction of Oroville Dam.

Other potential natural and man-made passage barriers in the lower Feather River may limit movement of sturgeon into the Feather River during low-flow years (Beamesderfer 2004). Potential barriers include Shanghai Bench (RM 24.5), a natural geologic feature; an artificial rock weir structure at Sunset Pumps (RM 38.5), and Steep Riffle (RM 61), a natural feature. The extent of these sites as a barrier is not well understood since recently collected anecdotal information and data indicates that sturgeon are found upstream of these potential barriers at the

Thermalito Outlet almost yearly (DWR, unpublished data). Under low flow conditions (~2000 cfs), the waterfalls at Shanghai Bench measure approximately 3 - 5 feet in vertical height, stretch across much of the main river channel and exhibit velocities estimated at greater than 3.3 fps (Niggemyer and Duster 2003). The waterfall at Shanghai Bend becomes a riffle at approximately 5100 cfs and may become passable to sturgeon (DWR 2005d). The rock structure at Sunset Pumps exhibits a 2 - 3 foot waterfall and a 4-foot wide slot with water velocities estimated at greater than 5 fps while flows are around 2000 cfs. While it was originally determined that sturgeon likely could not pass this area at low flows (Niggemyer and Duster 2003), recent data from white sturgeon passage studies indicate white sturgeon can pass through velocities up to 8.3 fps (Anderson et al. 2007c). Passage of Sunset Pumps by sturgeon during flows around 10,000 cfs is unlikely as velocities within the slot were estimated at around 10-15 fps (Niggemeyer and Duster 2003). However, it has been estimated that when flows reach about 15,000 cfs, they over-top the rock structure and passage seems likely. Steep Riffle represented the most reasonable passable potential barrier during low-flow and high-flow conditions. Passage determinations at each of the potential migration barriers in the lower Feather River would continue to be speculative without a greater understanding of sturgeon migration patterns and physiologic limitations (DWR 2003). Currently, studies are in place to attempt to gather this information in order to better describe the impacts that sturgeon may face in the Feather River.

Water Diversions

Larval sturgeon are susceptible to entrainment at water diversion facilities, primarily located on the Sacramento River near spawning and juvenile rearing habitat, as a result of their migratory behavior within the water column. Herren and Kawasaki (2001) documented up to 431 diversions from the Sacramento River between Sacramento and Shasta Dam. Entrainment information regarding larval and post-larval individuals of the Southern DPS of green sturgeon is unreliable, as field identification of green sturgeon larvae is difficult. FWS staff are working on identification techniques and are optimistic that green sturgeon greater than 40 mm can be identified in the field (Poytress 2006). Captures reported by GCID are not identified to species, but are assumed to primarily consist of green sturgeon because white sturgeon are known to spawn downstream (Schaffter 1997). Although screens at GCID diversion satisfy both the NMFS and DFG screening criteria for salmonids, the effectiveness of these criteria is unknown for sturgeon. Low numbers of green sturgeon have also been identified and entrained at the Red Bluff Research Pumping Plant (Borthwick et al. 1999).

In the Feather River, there are eight large diversions greater than 10 cfs and approximately 60 small diversions of one to 10 cfs between the Thermalito Afterbay outlet and the confluence with the Sacramento River (FWS 1995). Based on potential entrainment problems of green sturgeon elsewhere in the Central Valley and the presence of multiple screened and unscreened diversions on the Feather River, it is assumed that entrainment at water diversions on the Feather River are a possible threat to juvenile green sturgeon.

Presumably, as green sturgeon juveniles grow, they become less susceptible to entrainment as their capacity to escape diversions improve. The majority of North American green sturgeon captured in the Delta and San Francisco Estuary are between 200 and 500 mm in length (DFG 2002). Herren and Kawasaki (2001) inventoried water diversions in the Delta finding a total of 2,209 diversions of various types, only 0.7 percent of which were screened. The majority of these diversions were between 12 and 24 inches (305 and 710 mm) in diameter, which is not likely a great threat to larger juvenile sturgeon. The largest diversions recorded were those of the CVP and SWP facilities in the southern Delta, which has historical data of captures (DFG 2002).

Entrainment at Unscreened Water Diversions

There are over 2,600 diversions of water in the Sacramento River and Delta. California State law requires all new water diversions to be screened. There is no commercial or scientific data to indicate what the risks are for adult green sturgeon to be entrained at unscreened diversions. However, as green sturgeon are bottom oriented, strong swimmers, and grow rapidly in their first year, Reclamation assumes that green sturgeon are most at risk in their first month or two of life and unscreened diversions in the upper Sacramento River have the greatest potential for entrainment. Most diverters in the upper Sacramento River have pre-CVP water rights and have been diverting water for decades. Approximately 70 percent of all diversions over 250 cubic feet per second (cfs) are now screened. Most of the smaller diversions, particularly the ones in the Delta, are too small to pose a risk to juvenile sturgeons. There is no evidence to indicate that sturgeon are entrained by the operations of the Contra Costa Canal (Reclamation 2006).

Impingement or Entrainment at Screened Diversions of Water

Studies have determined that fish screens operating to delta smelt velocity criteria (0.1 feet per second (fps)), salmon velocity criteria (0.33 fps), or even faster velocities (0.5 fps) were also protective to juvenile Southern DPS green sturgeon (30 mm or larger) (Swanson et al. 2004). Fish screens are not effective with smaller openings in the screen mesh (O'Leary, Personal Communication 2006).

Southern DPS green sturgeon are vulnerable to impingement or entrainment at screened diversions when they are less than 30 mm in length. Larger fish cannot pass through typical fish screen openings, and are also better able to swim and therefore avoid contact. Green sturgeon are larger than 30 mm after 15 to 21 days of age, and in addition they remain hidden in spaces between rocks for their first 10 days after hatching. Therefore green sturgeon are expected to be most vulnerable to impingement and entrainment at screened diversions for only 5 to 11 days. Figure 8-15 shows that half of the green sturgeon caught at the RBDD are greater than 30 mm in length, and Figure 8-16 shows that all of the green sturgeon caught at the GCID are greater than 30 mm in length. As with unscreened diversions discussed above, NMFS 2006 concluded that the potential threat of these diversions is in need of study.

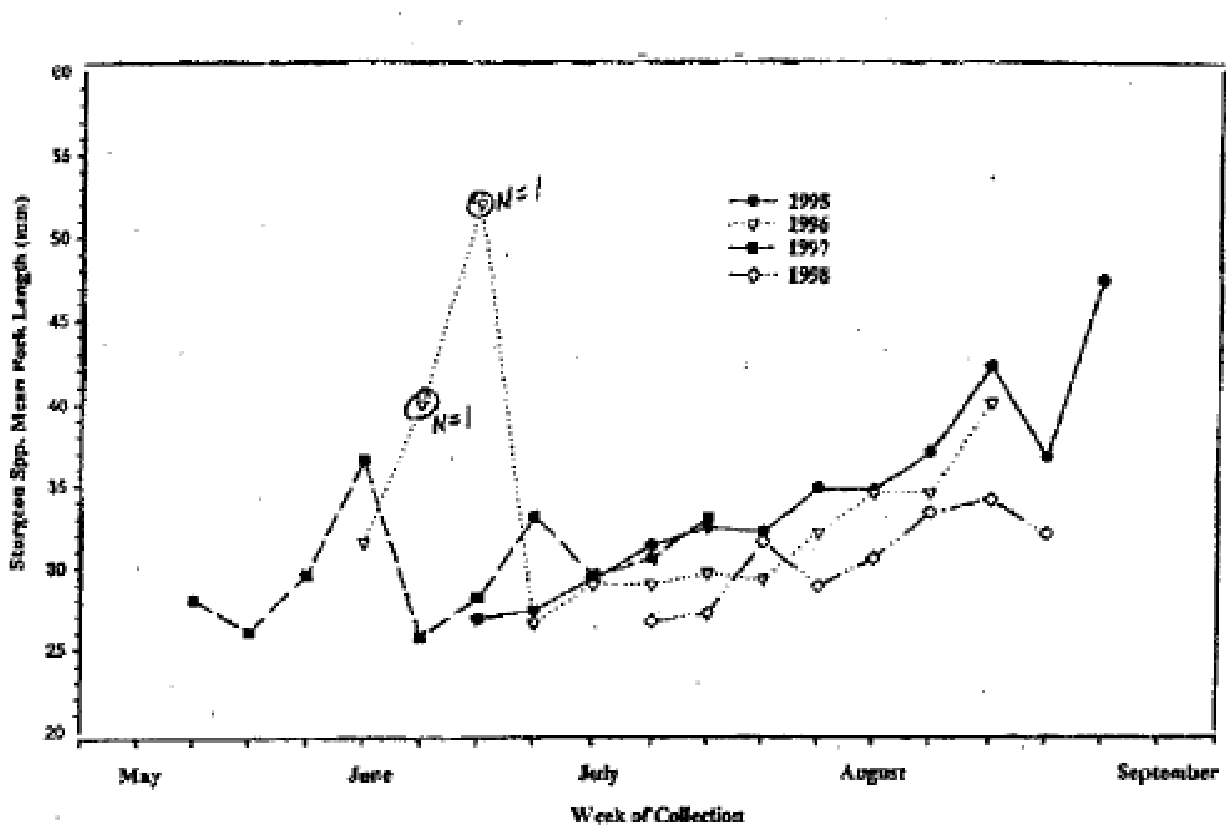


Figure 8-15. Mean fork lengths in mm of green sturgeons captured weekly by rotary screw traps at the Red Bluff Diversion Dam from 1995 to 1998 (DFG 2002).

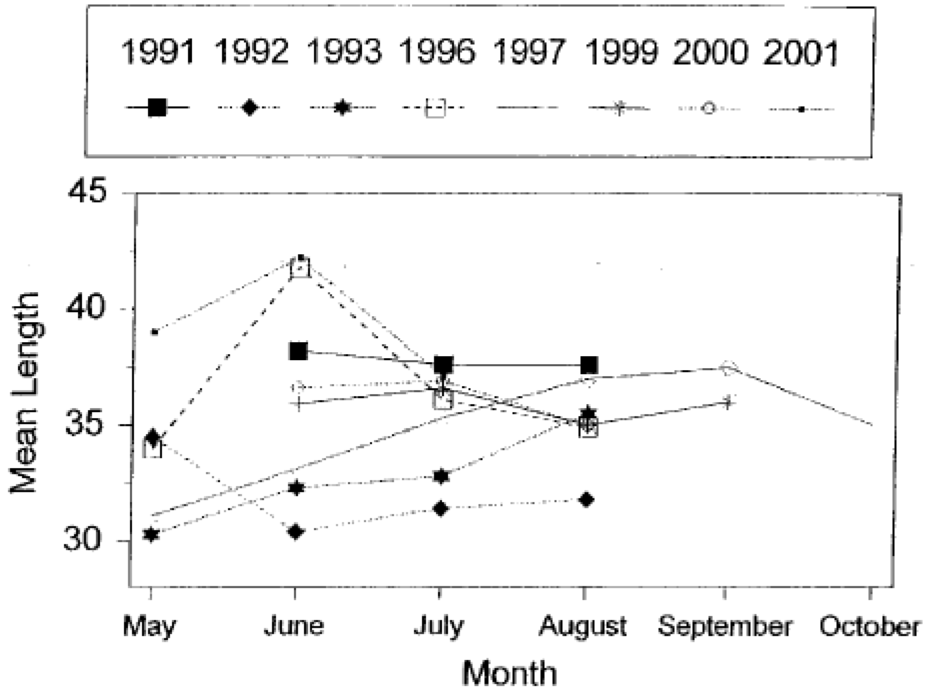


Figure 8-16. Monthly mean lengths in mm of sturgeon caught by the Glenn Colusa Irrigation District rotary screw trap from 1999 to 2001 (DFG 2002).

ACID Diversion Dam

The Anderson Cottonwood Irrigation District (ACID) constructed the Anderson Cottonwood Irrigation District Diversion Dam in 1937. New state of the art fish ladders and screens at ACID's main diversion were installed with funding provided by CALFED via Reclamation (Reclamation and FWS 2004) although ladders were designed for salmon rather than sturgeon passage. No sturgeon passage occurs at ACID when the diversion dam is in place. The availability of favorable spawning and rearing habitat conditions for green sturgeon upstream and downstream from the dam is unknown.

CVP Export Facilities and the Tracy Fish Collection Facility

The Tracy Fish Collection Facility (TFCF), at the intake to the DMC, is designed to intercept fish before they are entrained into the DMC by the Tracy Pumping Plant. Fish are collected and transported by tanker truck to release sites away from the pumps. Adult Southern DPS green sturgeon are rarely observed at the TFCF. In the last 8 years, only one adult (over 2 meters in total length) was found on the TFCF trash rack in spring 2003 (Reclamation 2006b). Adult sturgeon were also periodically reported impinged in the trash racks prior to 2000.

Table 8-2 shows the reliable historic record sturgeon salvage by month, since 1993 when species identifications are considered to be reliable. All other non-sampled fish that enter the facility are collected and transported by tanker truck to downstream Delta release sites.

Table 8-2. Actual salvage of Southern DPS green sturgeon and white sturgeon at the Tracy Fish Collection Facility (Reclamation 2007a). GRN = Southern DPS green sturgeon, WHT = white sturgeon.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	0 grn 0 wht	1 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 2 wht	0 grn 1 wht	0 grn 0 wht	0 grn 3 wht
1994	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	1 grn 0 wht	0 grn 0 wht
1995	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 3 wht	1 grn 8 wht	0 grn 8 wht	0 grn 14wht	0 grn 9 wht	4 grn 4 wht
1996	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht	0 grn 2 wht	0 grn 0 wht	0 grn 1 wht	1 grn 4 wht	0 grn 1 wht	0 grn 2 wht	2 grn 3 wht	0 grn 1 wht	0 grn 1 wht
1997	0 grn 0 wht	0 grn 0 wht	0 grn 4 wht	1 grn 1 wht	1 grn 0 wht	2 grn 1 wht	0 grn 1 wht	0 grn 1 wht	1 grn 2 wht	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht
1998	0 grn 2 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 1 wht	0 grn 6 wht	1 grn 8 wht	1 grn 3 wht	0 grn 0 wht
1999	0 grn 1 wht	0 grn 1 wht	0 grn 1 wht	0 grn 0 wht	1 grn 1 wht	0 grn 1 wht	0 grn 2 wht	0 grn 2 wht	1 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht
2000	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht
2001	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 1 wht	0 grn 0 wht	1 grn 0 wht	0 grn 0 wht	1 grn 0 wht
2002	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht
2003	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht
2004	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht
2005	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	1 grn 0 wht	0 grn 0 wht	0 grn 0 wht
2006	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	1 grn 0 wht	9 grn 0 wht	2 grn 0 wht	3 grn 0 wht	5 grn 1 wht	7 grn 0 wht	1 grn 0 wht
2007	1 grn 0 wht	0 grn 1 wht	0 grn 2 wht	0 grn 1 wht								

State Water Project Export Facilities and Skinner Fish Protection Facility

The Skinner Fish Protection Facility (SFPF) located between Banks and CCF, intercepts fish, which are collected and transported by tanker truck to downstream release sites. This facility uses behavioral barriers to guide targeted fish into holding tanks for subsequent transport by truck to release sites within the Delta. Table 8-3 shows the reliable historic record of SWP sturgeon salvage, by month, between 1993 and 2007. All other non-sampled fish passing through the facility are collected and transported by tanker truck to Delta release sites.

Table 8-3. Actual salvage of Southern DPS green sturgeon and white sturgeon at the Skinner Fish Protection Facility (Reclamation 2007a). GRN = Southern DPS green sturgeon, WHT = white sturgeon.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	3 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	1 grn 0 wht	0 grn 1 wht	2 grn 2 wht	0 grn 0 wht
1994	0 grn 0 wht	1 grn 2 wht	1 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht
1995	2 grn 5 wht	1 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	1 grn 6 wht	3 grn 6 wht	0 grn 2 wht	0 grn 14wht	1 grn 1 wht	0 grn 0 wht
1996	0 grn 31wht	0 grn 5 wht	2 grn 3 wht	0 grn 2 wht	0 grn 0 wht	2 grn 2 wht	0 grn 1 wht	0 grn 2 wht	2 grn 1 wht	0 grn 2 wht	0 grn 5 wht	0 grn 4 wht
1997	0 grn 1 wht	0 grn 0 wht	0 grn 6 wht	1 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht	1 grn 1 wht	0 grn 1 wht	0 grn 1 wht	0 grn 1 wht
1998	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht	4 grn 2 wht	2 grn 2 wht	1 grn 0 wht	0 grn 2 wht	0 grn 1 wht
1999	0 grn 0 wht	2 grn 1 wht	0 grn 1 wht	0 grn 3 wht	0 grn 0 wht	0 grn 0 wht	0 grn 2 wht	0 grn 2 wht	1 grn 1 wht	0 grn 1 wht	0 grn 0 wht	0 grn 0 wht
2000	0 grn 0 wht	3 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht	1 grn 1 wht	1 grn 1 wht
2001	0 grn 0 wht	0 grn 1 wht	1 grn 0 wht	0 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	4 grn 1 wht
2002	0 grn 0 wht	0 grn 0 wht	2 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 1 wht
2003	1 grn 0 wht	1 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	1 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht
2004	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht
2005	2 grn 0 wht	0 grn 0 wht	0 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	2 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht
2006	1 grn 1 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	0 grn 0 wht	1 grn 2 wht	0 grn 1 wht	2 grn 0 wht	0 grn 1 wht	0 grn 1 wht	2 grn 0 wht
2007	0 grn 0 wht	0 grn 1 wht	1 grn 1 wht									

Mirant's Pittsburg and Contra Costa Power Plants

Power plant operations potentially affect fish by entraining and impinging them to the points of cooling water diversion, exposure to chlorine from cleaning processes, and increasing water temperatures with discharged cooling flows. Studies done in 1976 and 1991 (DWR 2005c), which did not report any sturgeon, found greater numbers of some fish species near thermal discharge sites, but no evidence for direct mortality of striped bass and no thermal blockage of migratory species including Chinook salmon, striped bass or American shad. Studies done in 1991 (DWR 2005c), which did not report any sturgeon, were inconclusive as to the effects of chlorination for control of condenser slime. These studies also indicated no entrainment or impingement of green sturgeon.

Low Flows

NMFS 2006 states that "DFG and FWS found a strong correlation between mean daily freshwater outflow (April to July) and white sturgeon year class strength in the Sacramento-San Joaquin Estuary (these studies primarily involve the more abundant white sturgeon; however, the threats to green sturgeon are thought to be similar), indicating that insufficient flow rates are likely to pose a significant threat to green sturgeon."

High temperatures caused by lower flows in rivers and the Delta may have a negative effect on sturgeon populations. DFG (1992) and FWS (1995) found a strong correlation between mean daily temperature (April to July) and white sturgeon year-class strength from the Sacramento River. The Shasta Temperature Control Device began operating in 1997, but storage limitations may limit the ability of Shasta Dam releases to regulate temperatures during drier water years. DFG (1992) and FWS (1995) also found a strong correlation between mean daily freshwater outflow from the Sacramento-San Joaquin watershed and year-class strength in the estuary. It should be noted that flow and temperature are correlated, and the DFG and FWS studies were conducted prior to temperature control device installation on Shasta Dam; therefore, it is difficult to quantify flow effects on juvenile production independent of temperature.

The lack of flow in the San Joaquin River from dam and diversion operations and agricultural return flows contribute to higher temperatures in the mainstem San Joaquin River, offering less water to keep temperatures cool for sturgeon, particularly during late summer and fall. Whether direct or indirect, the effects of flow on green sturgeon are not well understood but likely play an important role in population performance, which is why lows flows are documented as a potential threat in NMFS' 2002 and 2005 status reviews (Adams et al. 2002; NMFS 2005) and the Federal register (70 FR 17386; 71 FR 17757).

Water Temperature

Water temperatures greater than 63ºF can increase mortality of sturgeon eggs and larvae (PSMFC 1992). Moderated stream temperatures in spawning and egg incubation areas are critical as temperatures above 68˚F are lethal to green sturgeon embryos (Cech et al. 2000). Temperatures near RBDD on the Sacramento River historically occur within optimum ranges for sturgeon reproduction; however, temperatures downstream, especially later in the spawning season, were reported to be frequently above 63ºF (USFWS 1995). High temperatures in the Sacramento River from February to June no longer appear to be a concern as temperatures in the upper Sacramento River are actively managed for Sacramento River winter-run Chinook salmon. The Shasta temperature control device installed at Shasta Dam in 1997 appears to maintain cool water conditions below the dam.

As shown on Figure 8-17, a considerable reach of the Sacramento River maintains suitable spawning temperatures for the Southern DPS green sturgeon. From river mile 90 to river mile 160, suboptimal spawning temperatures of 64-68°F occur on average. Optimal spawning temperatures occur from river mile 160 to river mile 302. During the first two-thirds of the spawning season, when the RBDD gates are out, Southern DPS green sturgeon have access to 70 river miles of suboptimal spawning temperatures and 140 river miles of optimal spawning temperatures. During the last one-third of the spawning season, when the RBDD gated are in, Southern DPS green sturgeon have access to 70 river miles of suboptimal spawning temperatures and 78 river miles of optimal spawning temperatures. Note that this description describes the number of available river miles but it is unclear how much actual spawning habitat exists in each portion of the river.

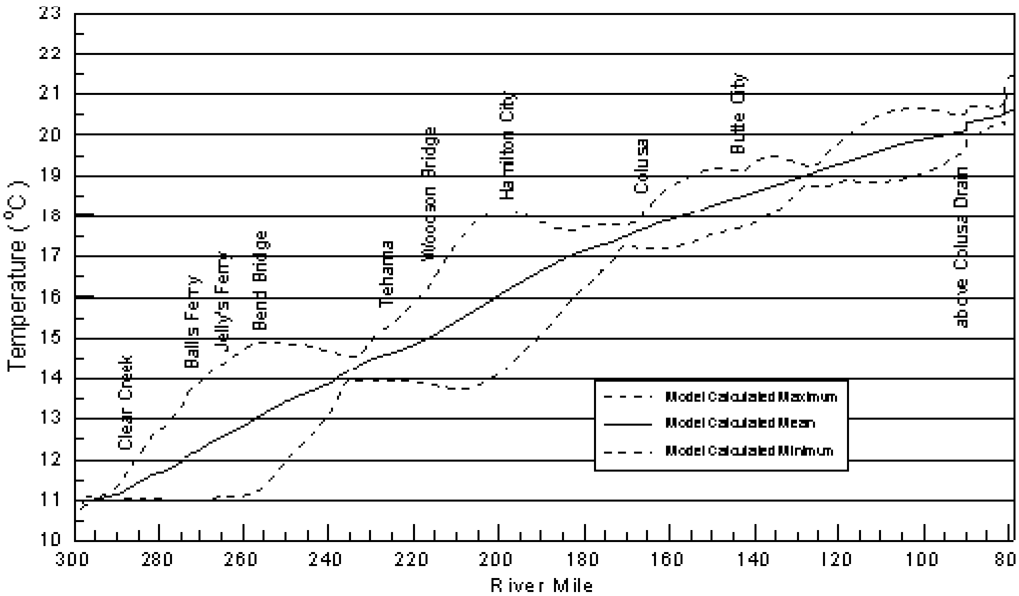


Figure 8-17. Modeled temperatures in the Sacramento River below Keswick Dam (Orlob and King 1997).

NMFS (2006) states that "Elevated water temperature is likely no longer a problem in the Sacramento River with the installation of the Shasta Dam Temperature Control Device in 1997." However, green sturgeon reproduction before 1997, when the Shasta Dam Temperature Control Device was installed, may well have been adversely affected by temperature. There has been a great deal of fishery management emphasis on keeping the Upper Sacramento River cool enough for salmonids eggs (<57°F). For Southern DPS green sturgeon, 57°F is well below their upper limit of optimal temperature for egg development of 63 to 64°F (Van Eenennaam et al. 2005). Therefore, in the Sacramento River, Southern DPS green sturgeons are not limited by a lack of suitable spawning temperatures nor are they likely threatened by drought induced increases in water temperatures.

Water temperatures in the Feather River appear adequate for spawning and egg incubation, contrary to previous concerns that releases of warmed water from Thermalito Afterbay are one reason neither green nor white sturgeon are found in the river in low-flow years (DFG 2002, SWRI 2003). In some years, water temperatures downstream of the Thermalito Outlet are inadequate for spawning and egg incubation, which has been suggested as a reason why green sturgeon are not found in the river during low flow years (DWR 2007). However, post-Oroville Dam water temperatures are cooler than historic river temperatures during the summer months when early life stages are likely to be present in the lower Feather River (DWR 2005a). Prior to the construction of the Oroville Dam, water temperatures in the Feather River at Oroville averaged 65-71°F from June through August for the period of 1958-1968 (CDWR 2004). After Oroville Dam construction, water temperatures in the Feather River at the Thermalito Afterbay averaged 60-65°F from June through August for the period of 1993-2002 (CDWR 2004). In addition, modeling results indicate that under existing conditions, water temperatures several miles downstream of the Thermalito Outlet would average 66ºF or less in 80 percent of all days in July (DWR 2005a).

NMFS states “An effective population of spawning green sturgeon (i.e., a population that is contributing offspring to the next generation) no longer exists in the Feather River and was likely lost due to … thermal barriers associated with the Thermalito Afterbay Facility.” (71 FR 17762). However, Spring-run Chinook salmon regularly hold below and pass upstream of the Thermalito Outlet (CDWR 2005b) suggesting that the outlet of the Thermalito Afterbay does not represent a complete thermal barrier to coldwater species. Similarly, most anecdotal observations of Southern DPS green sturgeon in the Feather River come from the pool below the Thermalito Outlet (DWR 2007). The availability of cold water and deep holding pools further upstream suggests that Southern DPS green sturgeon are selecting the habitat found at the outlet for holding (and possible spawning during some years) rather than avoiding it as a thermal barrier.

Temperatures in the lower San Joaquin River continually exceed preferred temperatures for sturgeon migration and development during spring months. Temperatures at Stevenson on the San Joaquin River near the Merced River confluence on May 31, 2000-2004 (spawning typically occurs during Apr-June) ranged from 77 to 82ºF (California Data Exchange Center, preliminary data). Juvenile sturgeon are exposed to increased water temperatures in the Delta during the late spring and summer due to the loss of riparian shading, and by thermal inputs from municipal, industrial, and agricultural discharges. High water temperatures on the San Joaquin River and in the Delta are likely to deter spawning in these regions.

Contaminants

No specific information is available on contaminant loads or impacts of contaminants on green sturgeon. The difference in distribution of green and white sturgeon (ocean migrants vs. estuarine inhabitants) probably makes green sturgeons less vulnerable than white sturgeon to bioaccumulation of contaminants found in the estuary. NMFS 2006 states that “we conclude that some degree of risk from contaminants probably occurs for green sturgeon.

Environmental stress as a result of poor water quality can lower reproductive success and may account for low productivity rates of green sturgeon (Klimley 2002). High levels of trace elements can also decrease sturgeon early life-stage survival, causing abnormal development and high mortality in yolk-sac fry at concentrations of only a few parts per billion (FWS 1995). Water discharges from Iron Mountain Mine have affected survival of fish downstream of Keswick Dam, and limited availability of dilution flows cause downstream copper and zinc levels to exceed salmonid tolerances. Although the impact of trace elements on green sturgeon production is not completely understood, negative impacts are suspected (71 FR 17763).

Researchers documented a sharp increase in pesticide contamination in the mid-1970s with the increase in use of rice pesticides (FWS 1995). It is thought that pesticide use likely represents a source of risk for green sturgeon because negative effects have been observed in other anadromous Sacramento River species (70 FR 17392).

The Aquatic Pesticide Monitoring Program evaluations, funded by the California State Water Resources Control Board, suggested that potential effects of aquatic herbicides on fish in the Delta are not likely to be significant for most herbicides in use, with worst case scenario modeling and studies conducted over three years showed little indication of short-term and no long-term toxicity of aquatic herbicide applications (Siemering 2005). In addition, according to NMFS 2005, the decline of Southern DPS green sturgeon occurred in 1986, while large scale treatment of the Delta with herbicides to control water hyacinth (*Eichhornia crassipes*) began in 1982 and *Egeria densa* did not commence until 2001.

Little is known about green sturgeon dietary intake. The gut contents of the only green sturgeon recently examined from the Southern DPS revealed that it had been feeding on overbite clams (*Corbula*), a nonnative species known to bioaccumulate selenium (DFG 2002; Linville et al. 2002). Though the extent of accumulation of contaminants in green sturgeon is unknown, bioaccumulation of toxins in white sturgeon is well documented (Feist et al. 2004; Webb et al. 2004) and likely posses a similar threat to green sturgeon.

Dredging

Hydraulic dredging is a common practice to allow commercial and recreational vessel traffic. Such dredging operations can pose risks to bottom oriented fish such as sturgeon. For example, studies by Buell (1992 as cited in NMFS 2007) reported approximately 2,000 white sturgeon entrained in the removal of one million tons of sand from the bottom of the Columbia River at depths of 60-80 feet. In addition, dredging operations can elevate toxics such as ammonia, hydrogen sulfide, and copper (NMFS 2006). Other factors include bathymetry changes and acoustic impacts (NMFS 2006).

Harvest

As long-lived, late maturing fish that spawn periodically, green sturgeon are particularly susceptible to threats from overfishing (Musick 1999). Green sturgeon are regularly caught in the sport, commercial, and tribal fisheries, particularly in Oregon and Washington commercial fisheries (Beamesderfer 2005). With the exception of a Klamath River fishery, green sturgeon are not targeted by fisheries but are caught incidental to harvest of white sturgeon and salmon. Harvest of mixed green sturgeon populations in Oregon and Washington fisheries has steadily declined from a peak of over 8,000 fish per year in 1986 to less than 1,000 fish per year since 2001 (Figure 8-18). This reduction is not due to declining catch-per-effort but is in response to market conditions, regulation changes, and changing fisheries for other species (ODFW 2005b). Limited information suggests no negative or positive population abundance trends in Oregon populations of Southern DPS green sturgeon (ODFW 2005a).

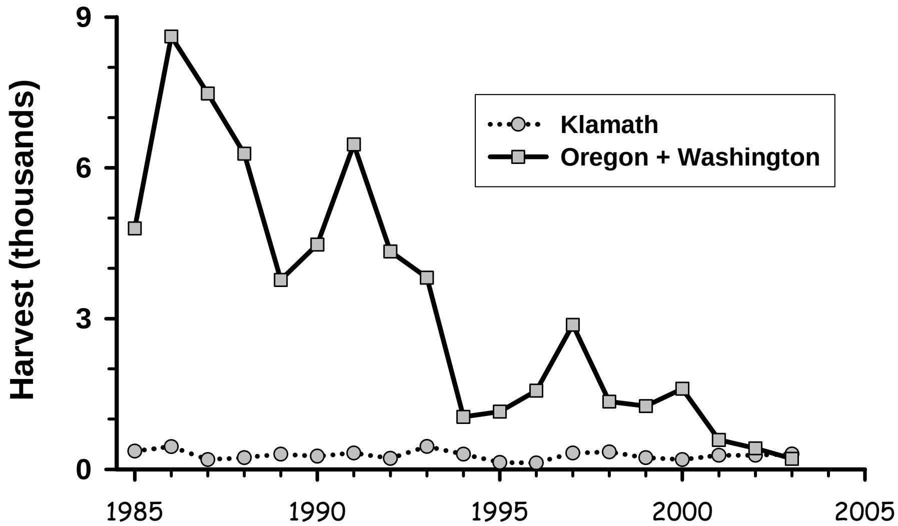


Figure 8-18. Recent annual harvest of green sturgeon (NMFS 2005). Klamath includes Yurok and Hoopa subsistence fishery harvests. The Oregon and Washington total includes sport and commercial fishery harvests from ocean and estuary fisheries including the Columbia River, Willapa Bay, and Greys Harbor. Figure from Beamesderfer et al. (2007).

The largest annual landings occurred in the bays and estuaries of Oregon and Washington (Adams et al. 2002), areas where green sturgeon are known to congregate in the spring and summer (Lindley et al. 2008). Total commercial harvest of green sturgeon in the Columbia River Estuary between 1985-2001 ranged from 240 to 6,000 fish per year (Adams et al. 2002). During this period, Columbia River fisheries harvested over half of the green sturgeon caught in the northern and Southern DPSs. Washington coastal fisheries took approximately 28 percent of the total catch. The bulk of Washington harvest occurred in the Willapa Bay and Grays Harbor areas. About 8 percent of the catch was recorded in California tribal and Oregon sport and commercial fisheries. Harvest numbers in the Klamath River have remained constant, but accounted for a larger percentage of the total catch due to harvest reductions in the Columbia River, Grays Harbor and Willapa Bay fisheries (NMFS 2005).

Green sturgeon are primarily captured incidentally in California by sport fisherman targeting the more desirable white sturgeon, particularly in San Pablo and Suisun Bays (Emmett et al. 1991). New regulations mandate that no green sturgeon can be taken or possessed in California (DFG 2007). If green sturgeon are caught incidentally and released while fishing for white sturgeon, it must be reported to DFG. Sport fishing catch has been reduced through time; however, it is not known if this is a result of reduced abundance, changed fishing regulations, or other factors. DFG (2002) indicates high sturgeon vulnerability to the sport fishery in areas where sturgeon are concentrated, such as the Delta to San Pablo Bay area in late winter and the upper Sacramento River during the spawning migration. Further north, a high proportion of green sturgeon present in the Columbia River, Willapa Bay, and Grays Harbor (as much as 80 percent in the Columbia River) may be from the southern DPS (DFG 2002; Israel 2006; Lindley et al. 2008).

Historical trends in green sturgeon abundance can be at least partly inferred from white sturgeon harvest records (Figure 8-19). Large white sturgeon commercial fisheries developed in San

Francisco Bay and the Columbia and the Fraser rivers during the late 1800s for previously-unexploited white sturgeon populations. Fisheries collapsed within a few years as sturgeon were rapidly harvested at rates far in excess of sustainability (FWS 1993). Protective regulations were enacted following the fishery collapse but populations did not begin to recover for almost 50 years because of the white sturgeon's longevity and delayed maturation. In California, it is unlawful for sturgeon to be taken or possessed for commercial purposes (DFG 2006). Modern harvests have never approached historic levels as fisheries are regulated at more sustainable rates. Green sturgeon were not targeted by excessive white sturgeon fisheries (Beamesderfer 2005, Moyle 2002 and NMFS 2005) but green sturgeon populations were likely depleted as a result of by catch (FWS 1996 and Moyle 2002). Green sturgeon were at least partially buffered from excessive early fisheries by their marine distribution but spawning runs were probably heavily impacted. Like the white sturgeon, green sturgeon probably recovered slowly during the 1900s (Beamesderfer 2005) and gradual recovery is consistent with harvest patterns of green sturgeon in Columbia River fisheries (Figure 8-19).

The longevity of sturgeon is clearly associated with low natural mortality rates beyond the first few years of age. Approximate total annual mortality rates estimated from catch curves for the Klamath River and Columbia River estuary ranged from 8 – 28 percent per year. Total annual rates include both natural and fishing mortalities. The lower rate for Columbia River subadults (8 percent) than for Klamath River adults (19-28 percent) may be due in part to additional fishing mortality during Klamath River spawning migrations although subadults are also subjected to fishing mortality in the Columbia River. These estimates might suggest a natural annual mortality rate of 8 percent or less and fishing mortality rates of 10-20 percent or less on Klamath River adults. These estimates of green sturgeon natural mortality are comparable to those of white sturgeon which typically average 4-16 percent (Beamesderfer 2005).

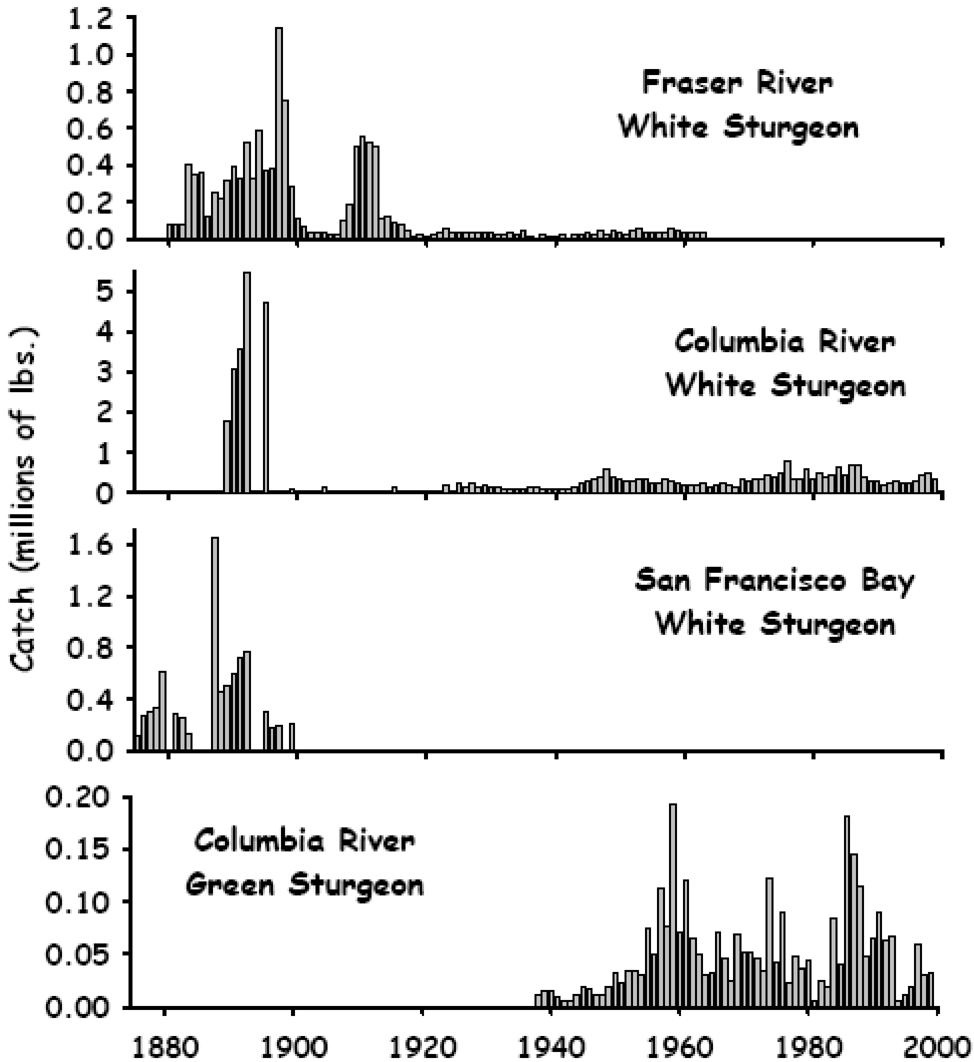


Figure 8-19. Historical yield of white sturgeon in the Fraser River commercial fishery, white sturgeon in the Columbia River commercial and sport fisheries, white sturgeon in San Francisco Bay commercial fisheries and green sturgeon in the Columbia River sport and commercial fisheries (Beamesderfer 2005). Note differences in the scales of the y axes.

Estimates of green sturgeon mortality reflect fishing levels prior to implementation of recent fishery reductions and are uncertain due to untested assumptions of the catch curve estimation method (e.g. constant recruitment and mortality). Fishing mortality rates on Sacramento River green sturgeon are likely to be less than in the Klamath River because there is no terminal fishery on spawners in the Sacramento River. Beamesderfer 2005 estimated white sturgeon exploitation rates in the Sacramento-San Joaquin River Bay-Delta of 1-4 percent per year since a protective slot regulation was implemented for sturgeon in 1990. Green sturgeon exploitation rates within the Sacramento are likely to be less because green sturgeons are less preferred by anglers. Green sturgeon are also subject to incidental fishing mortality in coastal and estuary fisheries of Oregon and Washington.

Illegal harvest of sturgeon is known to occur in the Sacramento River, particularly in areas where sturgeon have become concentrated (e.g., Fremont Weir; M. Marshall, pers comm.), as well as throughout the Bay-Delta. The small population of white sturgeon inhabiting the San Joaquin River experiences heavy fishing pressure, particularly from illegal fishing (FWS 1995). Areas just downstream of Thermalito Afterbay outlet and Cox's Spillway, and several barriers impeding migration, may be areas of high adult mortality from increased fishing effort and illegal harvest. A number of illegal harvest operations for white sturgeon have been discovered in recent years to supply a lucrative caviar market. Green sturgeon caviar is not sought but green sturgeon may be caught incidental to effort targeting white sturgeon. NMFS (2006) states that "DFG has stated that sturgeons are highly vulnerable to fisheries, and the trophy status of large white sturgeon makes sturgeon a high priority for enforcement protection."

Disease and predation

NMFS 2006 states that "we do not believe there is sufficient information to suggest that disease has played an important role in the decline of the Southern DPS." Disease and predation risks are uncertain because little data is available to indicate adverse effects from either of these potential threats. NMFS does, however, acknowledge the potential threat of predation from introduced species such as striped bass (70 FR 17392; 71 FR 17763). More study is needed to determine the magnitude of risk posed by disease and predation in the Southern DPS of green sturgeon.

Little is known about predators of green sturgeon. Smaller fish are undoubtedly taken by various fish and bird predators, although the five lines of sharp, bony scutes along their bodies probably make them less desirable prey than most other species. Predation by pikeminnow, smallmouth bass, and prickly sculpin has been documented for both green and white sturgeon. Sea lions have been observed feeding on adult white sturgeon. Information from the Columbia River suggests that total mortality of green sturgeon is less than for white sturgeon (DFG 2001). NMFS 2006 states that "while predation risk imposed by striped bass on the Southern DPS is uncertain, it likely exists, and additional studies are needed to determine the importance of this threat to the long-term survival of the Southern DPS."

Non-native Invasive Species

Green sturgeon have most likely been impacted by non-native invasive species introductions resulting in changes in trophic interactions in the Delta. Many of the recent introductions of invertebrates have greatly affected the benthic fauna in the Delta. DFG (2002) reviewed many of the recent non-native invasive species introductions and the potential consequences to green sturgeon. Most notable species responsible for altering the trophic system of the Sacramento-San Joaquin Delta include the overbite clam, the Chinese mitten crab, the introduced mysid shrimp *Acanthomysis bowmani*, and another introduced crustaceans, *Gammarus* sp.

Introductions of invasive plant species such as the water hyacinth (*Eichhornia crassipes*) and *Egeria densa* have altered nearshore and shallow water habitat by raising temperatures and inhibiting access to shallow water habitat. *Egeria* forms thick "walls" along the margins of channels in the Delta. This growth prevents juvenile native fish from accessing their preferred shallow water habitat along the channel's edge. Water hyacinth creates dense floating mats that can impede river flows and alter the aquatic environment beneath the mats. Dissolved oxygen levels beneath the mats often drop below sustainable levels for fish due to the increased amount of decaying vegetative matter produced from the overlying mat. Like *Egeria*, water hyacinth is often associated with the margins of the Delta waterways in its initial colonization, but can eventually cover the entire channel if conditions permit. This level of infestation can produce barriers to anadromous fish migrations within the Delta. The introduction and spread of *Egeria* and water hyacinth have created the need for aquatic weed control programs that utilize herbicides targeting these species.

Recent stomach content analysis of white sturgeon from the San Francisco Bay estuary indicates that the invasive overbite clam, Corbula amurensis, may now be a major component of the white sturgeon diet and possibly green sturgeon diets, and unopened clams were often observed throughout the alimentary canal (Kogut 2008). Kogut’s study found that at least 91 percent of clams that passed through sturgeon digestive tracts were alive. Green sturgeon could be affected in a similar manner. This suggests sturgeon are potential vehicles for transport of adult overbite clams and also raise concern about the effect of this invasive clam on sturgeon nutrition and contaminant exposure.

Chapter 9 Modeling and Assumptions

A suite of simulation models were used to analyze effects of proposed Central Valley Project (CVP) and State Water Project (SWP) operations on steelhead, coho salmon, delta smelt, green sturgeon, and winter-run and spring-run Chinook salmon. This chapter presents the modeling tools, study assumptions, sensitivity and uncertainty evaluations, and limitations. In addition, key simulated summary results are included under a range of assumed conditions.

The following simulation models were used to quantify effects:

- Hydrologic- (CalSim-II and CalLite)
- Delta Hydrodynamics - (DSM2)
- Temperature - (Reclamation Temperature, Sacramento Rivers Water Quality Management [SRWQM], and Feather River)
- Salmon Mortality, Population, and Life Cycle - (Reclamation Mortality, SALMOD, and Interactive Object-Oriented Salmon Simulation [IOS])
- Climate Change and Sea Level Rise - (Sensitivity Analysis)
- Sensitivity and Uncertainty - (CalSim-II)

Modeled future assumptions changes in operations expected to affect the CVP and SWP are:

- Limited Environmental Water Account Program
- Lower Yuba River Accord
- Freeport Regional Water Project
- Level of development (full contract/Table A demand in future)
- Sacramento River Water Reliability Project
- American River Flow Management
- New Melones Draft Transitional Operation Plan
- The California Aqueduct (CA) and Delta-Mendota Canal (DMC) Intertie
- South Delta Improvement Project Stage 1 (permanent gates)
- Red Bluff Diversion Dam

The modeling is comprised of studies that represent the following range of conditions:

- Present
- Near Future
- Future
- Future with climate change and sea level rise

The Operations Criteria and Plan (OCAP) Biological Assessment (BA) modeling is defined as the quantitative simulation of the CVP and SWP (within the extent possible, using the best available tools) to identify if a current action or proposed action may affect listed or proposed species, or designated or proposed critical habitat which is protected by the Endangered Species Act (ESA). The following general metrics were identified to prepare this biological assessment:

- River flows
- Reservoir storage
- Sacramento-San Joaquin Delta exports, hydrodynamics, and salinity
- River temperature
- Salmon life cycle and mortality

The objective was to provide the above identified metrics resulting from the CVP and SWP system operations under various hydrologic and assumed conditions (see Studies and Assumptions). Specific metrics used in the evaluation of the biological effects analysis are identified and discussed in Chapter 11: Upstream Effects and Chapter 13: Delta Effects.

Modeling Methods

Model simulations describe water surface storage, conveyance, water quality, temperature, and salmon lifecycle and mortality for the Central Valley and Sacramento-San Joaquin Delta. The suite of simulation models developed and/or applied by Reclamation and DWR include:

- Statewide planning model of water supply, stream flow, and Delta export capability (CalSim-II and CalLite)
- Sacramento-San Joaquin Delta hydrodynamics and particle tracking (DSM2)
- River temperature (Reclamation Temperature, SRWQM, and Feather River Model)
- Salmon mortality (Reclamation Mortality, SALMOD, and IOS)

Specific model methodologies for CalSim-II, DSM2, temperature models, salmon models, climate change and sea level rise, and sensitivity and uncertainty are briefly described in the sections below.

The modeling process for this BA uses a tiered approach where models function independently and are not dynamically linked. After CalSim-II modeling results were complete, they were used as input to the DSM2 model to find hydrodynamic conditions in the Delta. CalSim-II results were also used in temperature models that provide estimates of mean monthly temperatures at a variety of locations and mean daily temperature at select locations along CVP- and SWP-influenced rivers. Modeled temperatures were then compared to thermal criteria for specific life stages in the months when they would be present in the given river as the primary means of assessing potential effects of proposed CVP and SWP operations. These results were used to assess potential effects for proposed CVP and SWP export operations. This process is used to maintain consistency amongst the model results. The models and data flow are graphically shown in Figure 9-1. A list of temporal model characteristics is presented in Table 9-1.

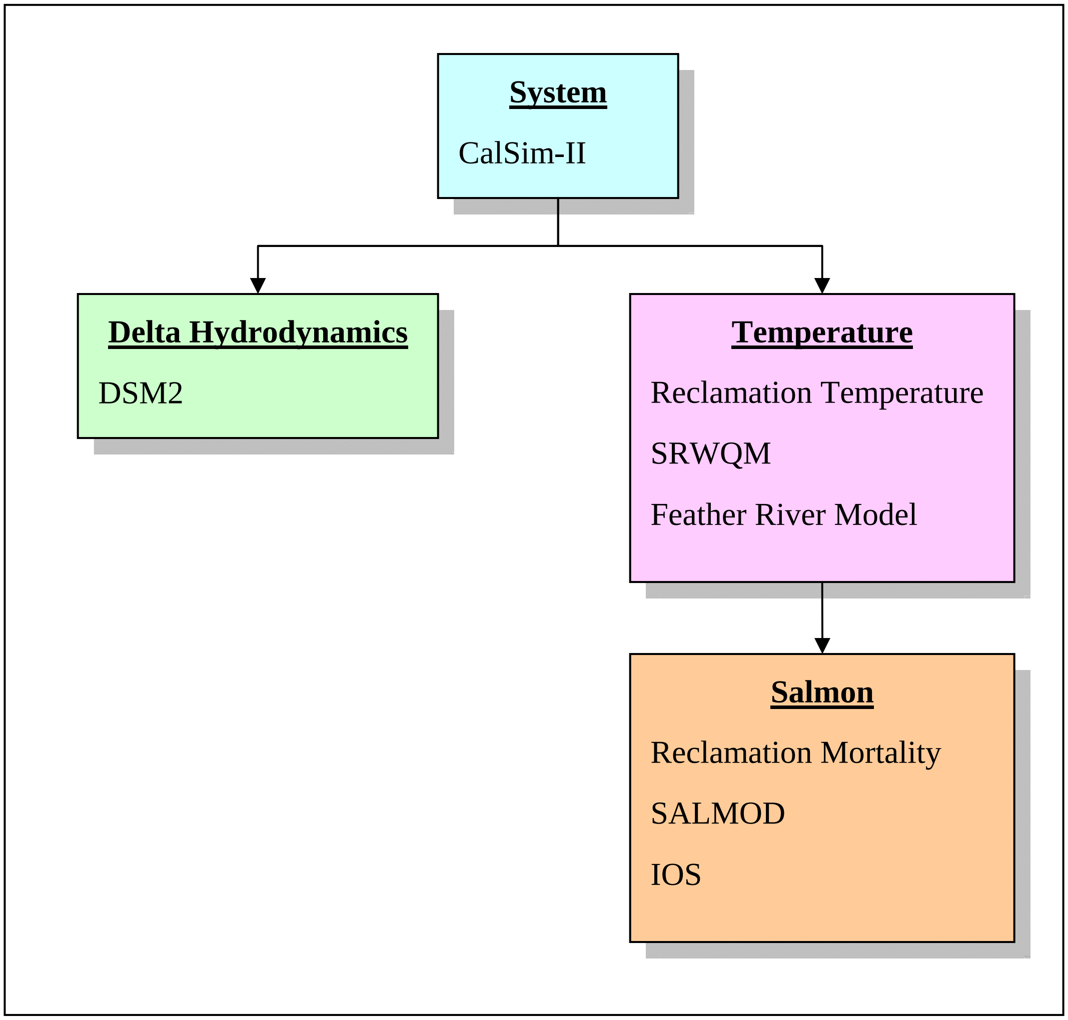


Figure 9-1 OCAP BA Model Information Flow

Table 9-1 Temporal and Simulation Characteristics

Model	Model Time Step	Simulation Period (Water Year)
CalSim-II	Monthly	1922-2003
DSM2	15 minute	1976-1991
Reclamation Temperature	Monthly	1922-2003
SRWQM	6 hour	1922-2003
Feather River Model	1 hour	1922-1994
Reclamation Mortality	Daily	1922-2003
SALMOD	Weekly	1922-2003
IOS	Daily	1923-2002

The simulation results of the OCAP BA are designed for a comparative evaluation because the CalSim-II model uses generalized rules to operate the CVP and SWP systems and the results are a gross estimate that may not reflect how actual operations would occur. Generalizations are also made for various programs based on adaptive management that are too dynamic in nature to codify or capture the wide spectrum of factors used in actual decision making. Results should only be used as a comparative evaluation to reflect how changes in facilities and operations may affect the CVP-SWP system. Biological effects assessing future conditions in the OCAP BA using simulated results were based on comparative evaluations. While models can provide useful insight to complex systems or overcome the deficiencies of incomplete observed data, they are a simplification of the true system or natural processes and yield results with limitations (see Modeling Limitations).

The model appendices (Appendices D, F, H, J, L, N, P, and R) document efforts to demonstrate tangible measures of OCAP BA modeling adequacy, credibility, data quality, model testing, sensitivity, and uncertainty. The results presented (Appendices E, G, I, K, M, O, Q, S, and T) are the product of the best science available at the time this document was prepared. For example, CalSim-II is the SWP-CVP simulation model developed and used by the DWR and the Reclamation. CalSim-II represents the best available planning model for the CVP-SWP system as quoted in the April 9, 2004, Draft Response Plan from the CALFED Science Program Peer Review of CalSim-II:

> *"As the official model of those projects, CalSim-II is the default system model for any inter-regional or statewide analysis of water in the Central Valley…California needs a large-scale relatively versatile inter-regional operations planning model and CalSim-II serves that purpose reasonably well."*

Hydrologic Modeling Methods

The objective of the hydrologic models is to simulate the CVP and SWP project operations with a set of historical hydrology (water-years 1922 to 2003) with existing and assumed future conditions. These results provided the inputs to hydrodynamic and temperature models that assist in the fisheries effects evaluations of alternative CVP/SWP operations. Both the CalSim-II and CalLite models produce monthly results. These results are used to examine the seasonal and water year type (Wet, Above Normal, Below Normal, Dry, and Critical) trends in a comparative manner (as described previously).

CalSim-II

The CalSim model is a water resources simulation planning tool developed jointly by DWR and Reclamation. The CalSim-II model is applied to the SWP, the CVP, and the Sacramento and San Joaquin Delta (Figure 9-2). The model is designed to evaluate the performance of the CVP and SWP systems for: existing or future levels of land development, potential future facilities, current or alternative operational policies and regulatory environments. Key model output includes reservoir storage, instream river flow, water delivery, Delta exports and conditions, biological indicators, and operational and regulatory metrics.

CalSim-II simulates 82 years of hydrology for the region spanning from water year 1922 to water year 2003. The hydrology data is composed of assumed water demands, stream accretions and depletions, stream-groundwater interaction, rim basin inflows, irrigation efficiency, return flows, and non-recoverable losses. The model employs an optimization algorithm to find routing solutions on monthly time step. The movement of water in the system is governed by an internal weighting structure to ensure regulatory and operational priorities. The Sacramento and San Joaquin Delta (Delta) is also represented by DWR’s Artificial Neural Network (ANN), which simulates flow and salinity relationships. Delta flow and electrical conductivity is also reported at key regulatory locations. Details of the level of land development (demands) and hydrology and ANN are discussed in Appendix D.

CalSim-II water deliveries are simulated for water contractors based on a method that estimates the actual forecast allocation process. The North of Delta (NOD) and South of Delta (SOD) deliveries for both the CVP and SWP contractors are determined using a set of rules for governing the allocation of water. CalSim-II uses a water supply and water demand relationship to find delivery quantities given available water, operational constraints and desired reservoir carryover storage volumes. Additional details of the delivery allocation process are available in Appendix D.

CalSim-II simulates a suite of environments to represent the CVP and SWP systems. The regulatory environments consist of the SWRCD D-1485, and the D-1641 (also referred to as the 1995 Water Quality Control Plan “WQCP”). These two environments are necessary for the determination of the CVPIA (b)(2) regulatory environment which implements fish protection actions and is next in the sequence. Following the (b)(2) environment is the conveyance step (formerly known as the Joint Point of Diversion (JPOD)) where water is exported or “wheeled” at the Delta pumping facilities. Next is the Transfers environment. This environment is deactivated and no transfers are dynamically simulated for these studies. However, a post-processed transfer analysis is evaluated. The final regulatory environment is the Environmental Water Account (EWA) or the Limited EWA (the Lower Yuba River Accord transfers are dynamically simulated in the EWA regulatory environment). The following discussion details the CVPIA (b)(2) and the EWA specific for the OCAP BA.

Figure 9-2 General spatial representation of the CalSim-II network

CVPIA 3406 (b)(2) and Environmental Water Account Modeling

CalSim-II dynamically models Central Valley Project Improvement Act (CVPIA) 3406(b)(2) and the Environmental Water Account (EWA). CVPIA 3406(b)(2) accounting procedures in CalSim-II are based on system conditions under operations associated with SWRCB D-1485 and D-1641 regulatory requirements (DWR 2002). Similarly, the operating guidelines for selecting actions and allocating assets under the EWA are based on system conditions under operations associated with a Regulatory Baseline as defined by the CALFED Record of Decision which includes SWRCB D-1641 and CVPIA 3406 (b)(2), among other elements. Given the task of simulating dynamic EWA operations, and the reality of interdependent operational baselines embedded in EWA's Regulatory Baseline, a modeling analysis was developed to dynamically integrate five operational baselines for each water year of the hydrologic sequence.

CVPIA (b)(2)

Consistent with CVPIA, Reclamation manages the CVP to "dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; and to help to meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the Federal Endangered Species Act."

The water allotted under the authorization of CVPIA (b)(2) is dedicated and managed in a manner consistent with processes outlined in Chapter 2 and are generally managed to augment river flows and to limit pumping in the Delta to supplement the requirements of D-1641 and to protect fish species.

To simulate the 3406 (b)(2) accounting, the model uses metrics calculated in the (b)(2) simulation. The metrics measure the flow increases and export decreases from D-1485 to D-1641 WQCP Costs, and from D-1485 to (b)(2), total (b)(2) costs. The following assumptions were used to model the May 2003 3406 (b)(2) Department of the Interior decision.

1. **Allocation of (b)(2) water** is 800,000 acre-feet per year (af/yr), 700,000 af/yr in 40-30-30 Dry Years, and 600,000 af/yr in 40-30-30 Critical years
2. **Upstream flow metrics** are calculated at Clear Creek, Keswick, Nimbus, and Goodwin Reservoirs where (b)(2) water can be used to increase flow for fishery purposes. For OCAP BA modeling purposes, CVPIA (b)(2) accounting of Goodwin releases and volumes are independently determined based on Stanislaus River water availablity and New Melones water allocation estimates. The assumptions used in CalSim-II for taking an upstream action at one of the previously mentioned reservoirs are:
    - **October-January**
        - Clear Creek Releases: Action is on if Trinity Beginning of Month Storage >600,000 af.
        - Keswick Releases: Action is on if Shasta Beginning-of-Month Storage > 1,900,000 af.

- Nimbus Releases: Action is on if Folsom Beginning-of-Month Storage > 300,000 af.
- For all releases, if the 200,000-af target is projected to be violated the model will try to reduce the magnitude of the actions in December and/or January.

- **February-September**
  - Clear Creek Releases: Action is on if Trinity Beginning of Month Storage >600,000 af.
  - Keswick Releases: Action is on if Shasta Beginning-of-Month Storage > 1,900,000 af and if remaining (b)(2) account > projected coming WQCP costs.
  - Nimbus Releases: Action is on if Folsom Beginning-of-Month Storage > 300,000 af and if remaining (b)(2) account > projected coming WQCP costs.

3. **The export metric** is the change in total CVP pumping (Jones + CVP Banks) from the base case (D1485). Assumptions used in CalSim-II for taking a delta action are:
   - **Winter Actions** (December through February) and Pre-Vernalis Adaptive Management Plan (VAMP) (April Shoulder) actions are off.
   - **VAMP Actions**: Always taken and done at a 2:1 ratio (Vernalis flow to CVP pumping ratio) if non-VAMP Vernalis flows are greater than 8,600 cubic feet per second (cfs).
   - **May Shoulder**: Action turned on if the remaining (b)(2) is greater than or equal to the discounted remaining WQCP cost + anticipated Clear Creek cost (25,000 af). DISCOUNT = If the annual WQCP cost > 500,000 af, the difference is subtracted from the remaining WQCP cost.
   - **June Ramping**: Action turned on if the remaining (b)(2) is greater than or equal to the discounted remaining WQCP cost + anticipated Clear Creek cost (20,000 af).
   - **Both May Shoulder and June Ramping** are further restricted to stay within the remaining (b)(2)account – remaining WQCP costs.

Environmental Water Account

The three management agencies (FWS, NMFS, and DFG) and the two project agencies (Reclamation and DWR) share responsibility for implementing and managing the Environmental Water Account (EWA) as described in Chapter 2. The objective of simulating EWA for OCAP BA modeling is to represent the functionality of the program in two ways: as it has been implemented by EWAT during WY2001-2007, referred to as Full EWA and as it is foreseen to be implemented in a limited capacity in coming years, referred to as Limited EWA. The EWA representation that CalSim-II simulates is not a prescription for operations; it is only a representation of the following EWA operating functions:

- Implementing actions at SWP and CVP Delta export facilities
- Assessing debt caused by these actions
- Year-to-year carryover debt was represented for Full EWA, but not for Limited EWA
- Acquiring assets for managing debt

- Storing assets in San Luis, and transferring (or losing) stored assets to the projects as a result of projects' operations to fill San Luis during winter months
- Spending assets to compensate for debt south of the Delta (SOD)
- Tracking and mitigating the effects of debt north of the Delta (NOD) and NOD backed-up water
- Spilling carryover debt to the SWP at San Luis Reservoir was represented for Full EWA, but not for Limited EWA
- Conveyance of assets from NOD to SOD
- Accounting system re-operation effects resulting from EWA operations

For the OCAP BA modeling, action definitions reflect monthly to seasonal aggregate actions implemented by EWAT from WY2001-2007 and in the immediately foreseeable future.

Full EWA

The following actions are simulated in the OCAP BA modeling for Full EWA fishery purposes:

- **Winter-period Export Reduction (December–February):**

  Definition: "Asset spending goal" where a constraint is imposed on total Delta exports that equal 50,000 af less per month relative to the amount of export under the Regulatory Baseline. This is modeled as a monthly action and conceptually represents EWAT implementation of multiple several-day actions during the month.

  Trigger: All years for December and January; also in February if the hydrologic year-type is assessed to be Above Normal and Wet according to the Sacramento 40-30-30 Index.

- **VAMP-period Export Reduction (April 15–May 15):**

  Definition: Reduce exports to a target-restriction level during the VAMP period, regardless of the export level under the Regulatory Baseline; target depends on San Joaquin River flow conditions.

  Trigger: All years. Taking action during the VAMP period has been an EWAT high priority in 2001–2007 and is, therefore, modeled as a high priority.

- **Pre-VAMP "Shoulder-period" Export Reduction (April –April 15):**

  Definition: Extend the target-restriction level applied for VAMP period into the April 1-April 15 period.

  Trigger: It was not simulated to occur based on actions implemented by EWAT from WY2001–2007 and in the foreseeable future.

- **Post-VAMP "Shoulder-period" Export Reduction (May 16–May 31):**

Definition: Extend the target-restriction level applied for VAMP period into the May 16-May 31 period.

Trigger: In any May if collateral exceeds debt at the start of May.

- **June Export Reduction:**

Definition: Steadily relieve the constraint on exports from the target-restriction level of the Post-VAMP period to the June Export-to-Inflow constraint level. Complete this steady relief on constraint during a 7-day period.

Trigger: If the Post-VAMP "Shoulder-period" Export Reduction was implemented and if collateral exceeds debt at the start of June.

The following assets are included in the OCAP BA modeling:

- Allowance for Carryover Debt (Replacing "One-Time Acquisition of Stored-Water Equivalent" defined in the CALFED ROD)
- Water Purchases, North and South of Delta
- 50 percent Gain of SWP Pumping of (b)(2)/ERP Upstream Releases
- 50 percent Dedication of SWP Excess Pumping Capacity (i.e., JPOD)
- July-September Dedicated Export Capacity at Banks (additional 500 cfs capacity)
- Source shifting and dry/wet exchange operations are represented (for the Full EWA simulation, but not the Limited EWA)

The role of these fixed and operational assets in mitigating the effects of EWA actions depends on operational conditions and is ascertained dynamically during the simulation. On the issue of the one-time acquisition of stored-water equivalent, the CALFED ROD specified the acquisition of initial and annual assets dedicated to the EWA, and EWA was to be guaranteed 200 thousand acre-feet (taf) of stored water SOD. This SOD groundwater bank was excluded in the CalSim-II studies for OCAP BA given its absence in actual EWAT operations from WY2001–2007. Since development of this asset has been delayed, EWAT developed a replacement asset (i.e., allowance for carryover debt and subsequent debt spilling) and operational procedures for managing this asset. OCAP BA modeling reflects EWAT guidelines for carrying over and spilling debt in the case of debt situated at SWP San Luis.

The impacts of actions on system operations are assessed in the OCAP BA modeling as EWA debt. Debt is defined as a reduction in project deliveries and/or storage relative to the EWA baseline (i.e., results from Step 5). CalSim-II tracks three general types of EWA debt:

- Deliveries to contractors SOD
- Storage levels SOD
- Storage levels NOD

Occurrence of SOD deliveries, debt, and subsequent failure to immediately pay back this debt, is an indicator that the simulated EWA program's assets are not in balance with the assumed actions. Occurrence of storage debt does not require immediate debt management.

Carried-over SOD storage debt is simulated to be managed through either: (1) direct dedication of assets, or (2) debt spilling. Dedication of assets involves transferring the accumulated purchases and variable assets from EWA San Luis into the projects' shares of San Luis to repay impacts caused by this year's actions and/or carried-over impacts from last year. The second tool, debt spilling, involves elimination of carried-over SOD debt at SWP San Luis assuming that several conditions were met at the end of the previous month (as described by EWAT):

- There was remaining capacity at Banks
- There was surplus water in the Delta that could have been exported
- The sum of end-of-month debt and stored water at SWP San Luis exceeded the sum of storage capacity and the "Article 21 deficit" (Figure 9-3) an Article 21 deficit represents demand minus what was delivered
- There was carried-over debt left to be spilled at SWP San Luis
- There was carried-over debt left to be spilled at SWP San Luis

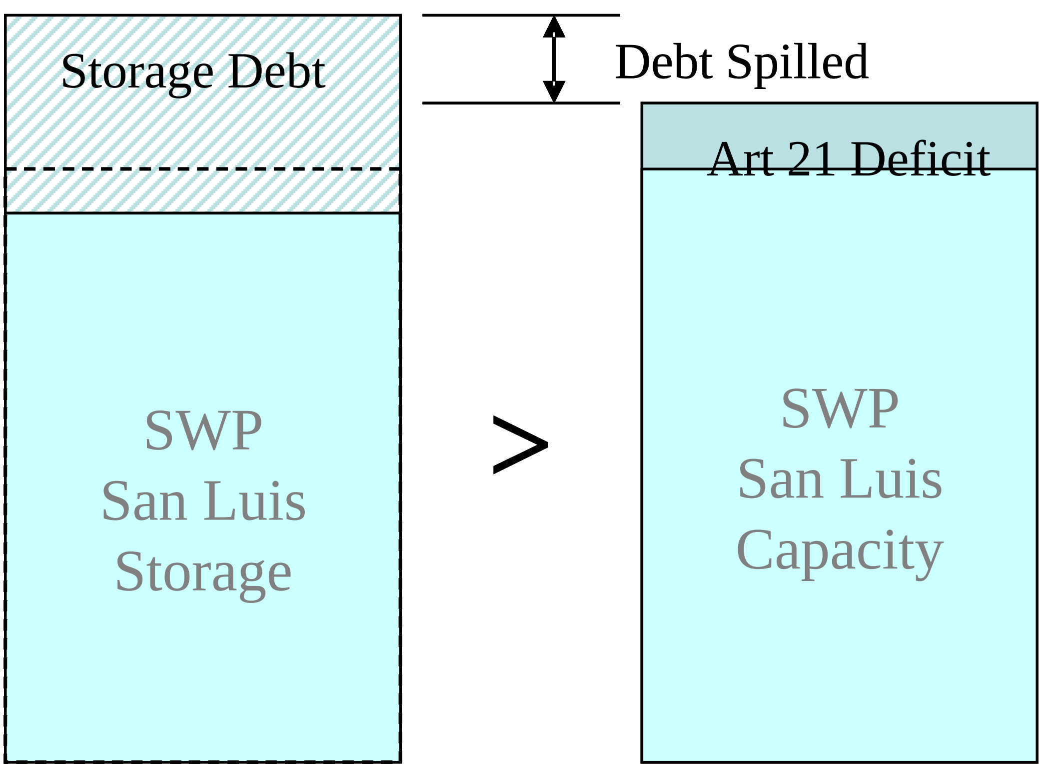


Figure 9-3 Conditions for Spilling Carried-over Debt at SWP San Luis in CalSim-II
Because the Regulatory Baseline cannot exceed SWP San Luis Capacity (i.e., the dashed line in Stack A), then the debt above this capacity line must be carried-over debt. Therefore, this spill tool will only be applicable to erasing carried-over debt and will not affect "new" debt conditions from this year's actions.
Spill amount is limited by the availability of excess capacity at Banks and surplus water in the Delta.

Limited EWA

The following actions are simulated in the OCAP BA modeling for Limited EWA fishery purposes:

- **VAMP-period Export Reduction (April 15–May 15):**

  Definition: Reduce exports to a target-restriction level during the VAMP period, only up to the amount covered by available assets in storage and available assets through Yuba Accord. Otherwise target depends on San Joaquin River flow conditions.

  Trigger: All years. Taking action during the VAMP period has been an EWAT high priority in 2001–2007 and is, therefore, modeled as a high priority.

- **Post-VAMP "Shoulder-period" Export Reduction (May 16–May 31):**

  Definition: Extend the target-restriction level applied for VAMP period into the May 16-May 31 period.

  Trigger: In any May, if assets are remaining after VAMP actions.

The following assets are included in the Limited EWA OCAP BA modeling:

- Water Purchases, Yuba Accord
- 50 percent Gain of SWP Pumping of (b)(2)/ERP Upstream Releases
- 50 percent Dedication of SWP Excess Pumping Capacity (i.e., JPOD) for conveyance of EWA purchase or delta surplus outflow
- July-September Dedicated Export Capacity at Banks for conveyance of EWA purchase or delta surplus outflow (an additional 500 cfs capacity)

CalLite

The CalLite tool is a rapid and interactive screening tool that simulates California's water management system for planning purposes. The CalLite tool is based on CalSim-II's 82 years of hydrologic inputs and logic using a simplified CalSim-II network which simulates, on a monthly time-step, CVP and SWP system conditions. "CalLite simulates the hydrology of the Central Valley, reservoir operations, project operations and delivery allocation decisions, Delta salinity responses to river flow and export changes, and habitat-ecosystem indices." (Munévar et al., 2008). The CalLite tool features:

- Rapid simulation evaluation (approximately 5 minutes depending on the scenario)
- User friendly Graphical User Interface (GUI)
- Flexible selection of policy alternatives or mode of simulation
- Pre-packaged post processing tools for output evaluation and alternative comparisons
- Cross-over of resources with CalSim-II data and logic

The following aspects of the CalLite model highlight areas where the model is coarser than the CalSim-II model to achieve the features listed above. The extent of the CalLite model reaches from northern California's Central Valley south to the Sacramento and San Joaquin Delta where the model terminates at the CVP and SWP Dos Amigos facility. All major CVP and SWP storage and conveyance facilities are included in the CalLite model. For the interim, the San Joaquin River Basin is simulated as a fixed time-series from CalSim-II results, while development is in progress. Differences between the CalSim-II and CalLite model are found in the aggregation of demands and hydrology inputs (accretions and depletions). The model represents "base" regulatory protection measures of SWRCB D-1641, allowing for screening additional policy proposals to augment above the "base" condition.

CalLite focuses on two specific areas which are not simplified "1) aspects governing operation and control of Delta facilities, water quality, channel flows, and ecosystem indicators; and (2) delivery allocation procedures for the CVP and SWP" (Munévar et al., 2008). The Delta is represented in an equivalent level of detail as the CalSim-II model. The CVP and SWP allocation procedures are also enhanced with an embedded module that more closely mimics the allocation forecasting process. In addition, this application has focused on the influence of uncertain hydrologic conditions in the allocation decision-making process.

The purpose of the CalLite tool for the OCAP BA is to screen and evaluate proposed Sacramento-San Joaquin Delta management actions for delta smelt and anadromous fish protection. This tool is well suited to quickly examine the tradeoffs of conflicting objectives for multiple alternatives. "CalLite is not a replacement for existing models, but rather is informed by the data and results of existing models and allows users to explore the future water management actions, improve understanding, and support more stakeholder-involved decision-making." (Munévar et al., 2008). Hence, interactive screening workshops define criteria that are then implemented in the more detailed planning model (CalSim-II) for final simulation. The screening process and selected results of alternative management scenarios requested by USFWS, NMFS and DFG are presented in Appendix V

Delta Hydrodynamic Modeling Methods

The objective of the hydrodynamic model, DSM2, is to simulate the Sacramento-San Joaquin River Delta (Delta) given monthly CVP and SWP project operations from the CalSim-II model results. These results provide flow, velocity, salinity, and particle movement (described below) in the Delta. DSM2 Old and Middle River flow results, an index for Delta fisheries, are used in the determination of the biological effects analysis. These results are also examined in a comparative evaluation because monthly output from the CalSim-II model is used as input to the DSM2 model.

DSM2

The DWR Delta Simulation Model Version 2 (DSM2) was used to simulate the flow, velocity, and particle movement in the Delta (Figure 9-4). DSM2 consists of three one-dimensional modules that simulate the dynamic tidal hydraulics, water quality, and particle movement in a network of riverine channels. The DSM2 modules used for the OCAP-BA were the hydrodynamics module Hydro, and particle tracking module PTM. DSM2 was developed by

DWR in the early 1990's. Since its introduction DSM2 has been used for many projects. It has also been continually improved upon. Some of the most recent enhancements have been:

- Incorporation of a database to control and archive study input parameters,
- Operable gates that allow the model to operate gates in based on a hydrodynamic condition.

DSM2-Hydro is a one dimensional hydrodynamics module that simulates unsteady, open channel flow, along with open water areas, gates and barriers. The Hydro module simulates flow, velocity and water elevations every 15 minutes for a little over 500 channels that represent the Delta channels. The simulated flow, velocity and water elevations are then used to drive the water quality and particle tracking simulations. These hydrodynamic parameters can also be pulled out for individual locations and analyzed. DSM2-PTM is a particle-tracking module that simulates the transport and fate of neutrally buoyant particles in the Delta channels. The module uses velocity and water elevation information from DSM2-Hydro to simulate the movement of virtual particles in the Delta. The movement of particles is tracked on a 15-minute time-step throughout the simulation. If a particle leaves the Delta system by way of an export, diversion, or through any other model boundary, this information is logged for latter analysis and termed the "fate" of the particle. The model grid can also be broken up into groups and the percentage of particles in each group can also be logged and analyzed.

DSM2 models all of the major rivers and waterways in the Sacramento – San Joaquin Delta. The model simulates these rivers and waterways in the Delta starting from the Sacramento River at I Street in the north, and the San Joaquin River at Vernalis in the south, to Benicia Bridge in the west. Major inflows to the model include the Sacramento River, San Joaquin River, Mokelumne River, Cosumnes River, Calaveras River, and Yolo Bypass. Major exports and diversions include Banks Pumping Plant, Jones Pumping Plant, North Bay Pumping Plant, and Contra Costa intake at Old River and Rock Slough. In addition to these inflows and diversions there is also a representation of Delta Island Consumptive Use (DICU), which are the agriculture diversions and return flows throughout the Delta. At the Benicia Bridge is the Martinez stage boundary where a historically based stage is defined every 15 minutes throughout the simulation.

For this effort DSM2-Hydro was used to evaluate the changes in flow and velocity in specific channels and regions of the Delta. DSM2-PTM was used to evaluate the effect of these changes on particle movement in the Delta. Both of the modules were used to evaluate conditions for water-years 1976 through 1991. This period has been traditionally selected because it offers a good mix of water year classifications as well as including an extreme critical year (1977), and extreme wet year (1983).

DSM2-Hydro used monthly operations from the individual CalSim-II simulations as input. The inflow to DSM2-Hydro included the Sacramento River, Yolo Bypass, Mokelumne River, Cosumnes River, Calaveras River and San Joaquin River flows. The exports and diversions included Banks Pumping Plant, Jones Pumping Plant, Contra Costa Water District diversions at Rock Slough and Old River at Highway 4, and North Bay Pumping Plant. Additionally Delta Island Consumptive Use (DICU) was also modeled (Mahadevan 1995). A 15 minute adjusted astronomical tide (Ateljevich 2001a) was used to drive the Martinez tidal boundary.

As described in Appendix F, some pre-processing of monthly CalSim-II flows was needed before DSM2-Hydro could appropriately characterize the system. Since CalSim-II provides monthly flows, and DSM2-Hydro is a 15 minute model some disaggregation and smoothing of data is required to transition from month to month stepwise flows. The Vernalis Adaptive Management Program (VAMP) period was also pre-processed from a monthly average to a daily average in order to include the pulse flows and export cut backs associated with VAMP which typically starts on April 15 and ends May 15.

DSM2 model assumptions can also be modified for Delta Temporary Barriers Project (TBP) and the South Delta Improvements Program (SDIP) Stage 1, permanent gates.

DSM2-PTM used the hydrodynamic information from DSM2-Hydro in order to simulate the movement of particles in the Delta. PTM simulates the movement of neutrally buoyant particles, and so if one can assume that a fish larvae behaves similar to a neutrally buoyant particle then the effects can be evaluated. For this reason, particles were injected every month and then tracked to determine the fate for each month. The particles were counted when they enter the exports, diversions and when they pass Chipps Island in the western Delta. The particles remaining in the Delta are then reported as being in the northern or southern Delta.

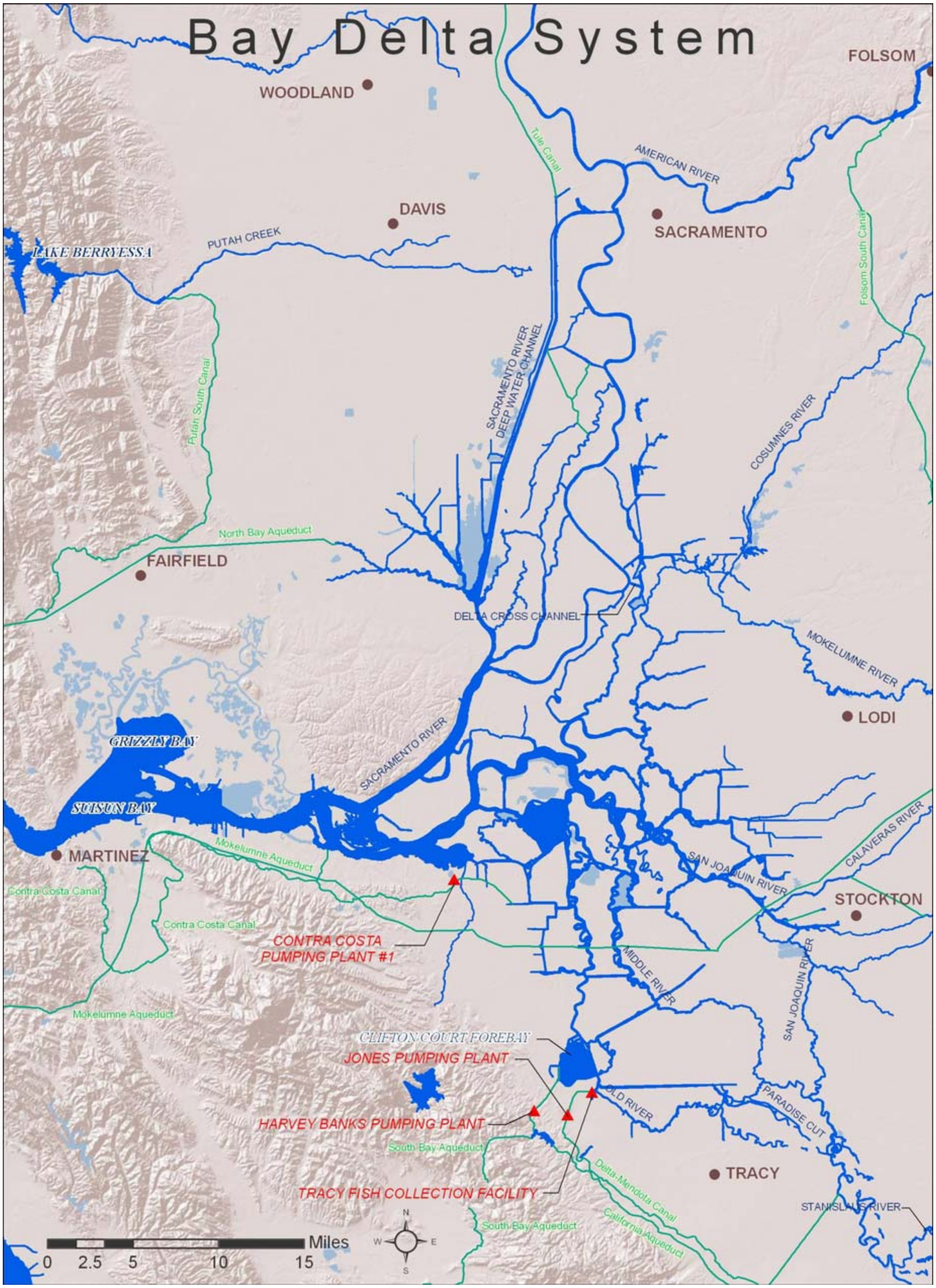


Figure 9-4 General spatial representation of the DSM2 network.

Temperature Modeling Methods

The objective of the temperature models is to assist in the fisheries impact evaluations of the various CVP/SWP operations studies. The Reclamation temperature model was used to estimate temperatures in the Trinity, Sacramento, American, and Stanislaus River systems. In addition, daily temperature simulation was performed on Clear Creek and the upper Sacramento River system using the SRWQM model. Refer to the FERC BO for a temperature evaluation on the Feather River. The joint DWR/Reclamation simulation model CalSim-II provided monthly CVP/SWP project operations input to the temperature model for an 82-year hydrologic period (WY1922-2003). All three temperature model reaches are spatially represented in Figure 9-5 Because of the CalSim-II Model's complex structure, CalSim-II, flow arcs were combined at appropriate nodes to ensure compatibility with the temperature models.

Reclamation Temperature Model

The reservoir temperature models simulate monthly mean vertical temperature profiles and release temperatures for Trinity, Whiskeytown, Shasta, Folsom, New Melones, and Tulloch Reservoirs based on hydrologic and climatic input data. The temperature control devices (TCD) at Shasta, and Folsom Dams can selectively withdraw water from different reservoir levels to provide downstream temperature control. The TCDs are generally operated to conserve cold water for the summer and fall months when river temperatures become critical for fisheries. The models simulate the TCD operations by making upper-level releases in the winter and spring, mid-level releases in the late spring and summer, and low-level releases in the late summer and fall.

Temperature changes in the downstream regulating reservoirs – Lewiston, Keswick, Natomas, and Goodwin – are computed from equilibrium temperature decay equations in the reservoir models, which are similar to the river model equations. The river temperature models output temperatures are listed in Table 9-2.

Table 9-2 Reclamation Temperature Model Key Output Locations

RIVER OR CREEK SYSTEM	LOCATION
TRINITY RIVER	Trinity Dam
	Lewiston Dam
	Douglas City
	North Fork
CLEAR CREEK	Whiskeytown Dam
	Above Igo
	Below Igo
	Mouth

RIVER OR CREEK SYSTEM	LOCATION
AMERICAN RIVER	Folsom Dam
	Nimbus Dam
	Sunrise Bridge
	Cordova Park
	Arden Rapids
	Watt Avenue Bridge
	American River Filtration Plant
	H Street
	16th Street
	Mouth
SACRAMENTO RIVER	Shasta Dam
	Keswick Lake above Spring Creek Tunnel
	Spring Creek Tunnel
	Keswick Dam
	Balls Ferry
	Jellys Ferry
	Bend Bridge
	Red Bluff
	Vina
	Butte City
	Wilkins Slough
	Colusa Basin Drain
	American River
	Freeport
STANISLAUS RIVER	New Melones Dam
	Goodwin Dam
	Tulloch Dam

RIVER OR CREEK SYSTEM	LOCATION
STANISLAUS RIVER	Knights Ferry
	Orange Blossom
	Oakdale
	Riverbank
	McHenry Bridge
	Ripon
	Mouth

The river temperature calculations are based on regulating reservoir release temperatures, river flows, and climatic data. Monthly mean historical air temperatures for the 82-year period and other long-term average climatic data for Trinity, Shasta, Whiskeytown, Redding, Red Bluff, Colusa, Folsom, Sacramento, New Melones, and Stockton were obtained from National Weather Service records and are used to represent climatic conditions for the four river systems. Additional details of the Reclamation Temperature Model are located in Appendix H.

Sacramento River Water Quality Model (SRWQM) Temperature Model

A HEC-5Q model was developed and calibrated for the upper Sacramento River system, including Trinity Dam, Trinity River to Lewiston, Lewiston Dam, Clear Creek Tunnel, Whiskeytown Dam, Spring Creek Tunnel, Shasta Dam, Keswick Dam, Sacramento River from Keswick to Knights Landing, Clear Creek below Whiskeytown, Red Bluff Diversion Dam, Black Butte Dam, and downstream Stony Creek.

The water quality simulation module (HEC-5Q) was developed so that temperature could be readily included as considerations in system planning and management. Using system flows computed by HEC-5, HEC-5Q computes the distribution of temperature in the reservoirs and in stream reaches. HEC-5Q is designed for long-term simulations of flow and temperature using daily average hydrology and 6-hour meteorology. Vertically stratified reservoirs are represented conceptually by a series of one-dimensional horizontal slices or layered volume elements, each characterized by an area, thickness, and volume. The HEC-5Q model simulation approximates diurnal variations in temperature for a 6-hour time step. The model was calibrated for the period of January 1998 through November 2002, using temperature time series field observations at numerous locations in the Trinity River, Clear Creek, and upper Sacramento River.

HEC-5Q is used to evaluate options for coordinating reservoir releases among projects to examine the effects on flow and water temperature at specified locations in the system. The model is used to evaluate instream temperatures at critical locations in a system, and examination of the potential effects of changing reservoir operations or water use patterns on temperature. Reservoirs, such as Shasta Lake, equipped with selective withdrawal structures can be simulated using HEC-5Q to determine operations necessary to meet water quality objectives downstream.

For this analysis, the Temperature Control Device (TCD) algorithm was modified to operate the Shasta Dam spillway, flood control outlets, and TCD gates to meet tailwater temperature targets. Key reporting locations are listed in Table 9-3.

Table 9-3. SRWQM Model Key Output locations

RIVER OR CREEK SYSTEM	LOCATION
Shasta Dam	Tailwater
Lewiston	Fish Hatchery
Spring Creek	Powerhouse
Sacramento River	Below Keswick Dam
	Clear Creek Confluence
	Balls Ferry
	Jellys Ferry
	Bend Bridge
	Red Bluff Diversion Dam
	Tehama
	Woodson Bridge
	Hamilton City
	Butte City
	Colusa
	Above Colusa Basin Drain
Black Butte Dam	Black Butte Dam
Stony Creek	Tehama Colusa Canal

Additional information is available in Appendix H.

Oroville Facilities Water Temperature Modeling

The operations on the Feather River for the Oroville Facilities are currently being covered under a separate Section 7 ESA consultation process for the Federal Energy Regulatory Commission (FERC) relicensing process. The draft NMFS BO is scheduled for release in late May 2008. Oroville Facilities water temperature modeling information is being provided for information purposes only.

Water temperature modeling supporting the Oroville Facilities FERC Relicensing utilized a suite of five models linked through a central database. The five models included reservoir simulations of Oroville Reservoir, the Thermalito Diversion Pool, the Thermalito Forebay, and the Thermalito Afterbay, and a river model of the Feather River between the Thermalito Diversion Dam and the Sacramento River confluence. All models were 1-dimensional models operating on an hourly timestep; the reservoirs were simulated as a series of vertically segregated, one-meter thick layers, the Feather River was simulated as a series of depth-averaged river segments with cross-section data from a calibrated flow-stage model, based on hydrologic and climactic input data. The modeling suite included iteration to meet water temperature objectives at the two Feather River water temperature compliance locations, the Feather River Fish Hatchery (FRFH) and Robinson Riffle. Operations for the water temperature objectives incorporated a range of temperature control actions including: curtailment of pumpback operations, elimination of hydropower peaking operations, removal of shutters on the Hyatt Pumping-Generating Plant intake, increasing the flow in the Low Flow Channel, and making releases through the Oroville Dam river valve. The water temperature modeling suite provided the following data output:

-Water temperatures in 100 river segments on the Feather River between the Thermalito Diversion Dam and the Sacramento River confluence. Several key river segments were used in evaluation, two of which, the FRFH and Robinson Riffle, were used to determine water temperature compliance (see Appendix J for key output locations).

-Reservoir profiles and release temperatures for Oroville Reservoir, the Thermalito Diversion Pool, the Thermalito Forebay, and the Thermalito Afterbay

-Agricultural diversion temperatures at four locations in the Thermalito Afterbay

-Water temperature in the Feather River Fish Hatchery

Hydrologic and climactic input data were based on historical records from the Durham and Nicolaus stations of the California Irrigation Management Information System (CIMIS) and extrapolated out for a 73 year (1922-1994) period of record based on available historical Sacramento Valley data. DWR collected field data for the model calibration and verification from March 28, 2002 through December 30, 2003. Calibration of the model was performed with data from August 11, 2002 to December 30, 2003, including two occurrences of the most critical period for water temperature management, September through October. The model was verified against conditions from the remaining time period of the available data, March 28 through July 15, 2002. It is anticipated that additional model calibration and verification will be included in future modeling efforts for the implementation phase of the Oroville Facilities Relicensing. Additional information about the water temperature model can be found in Appendix J and Appendix K.

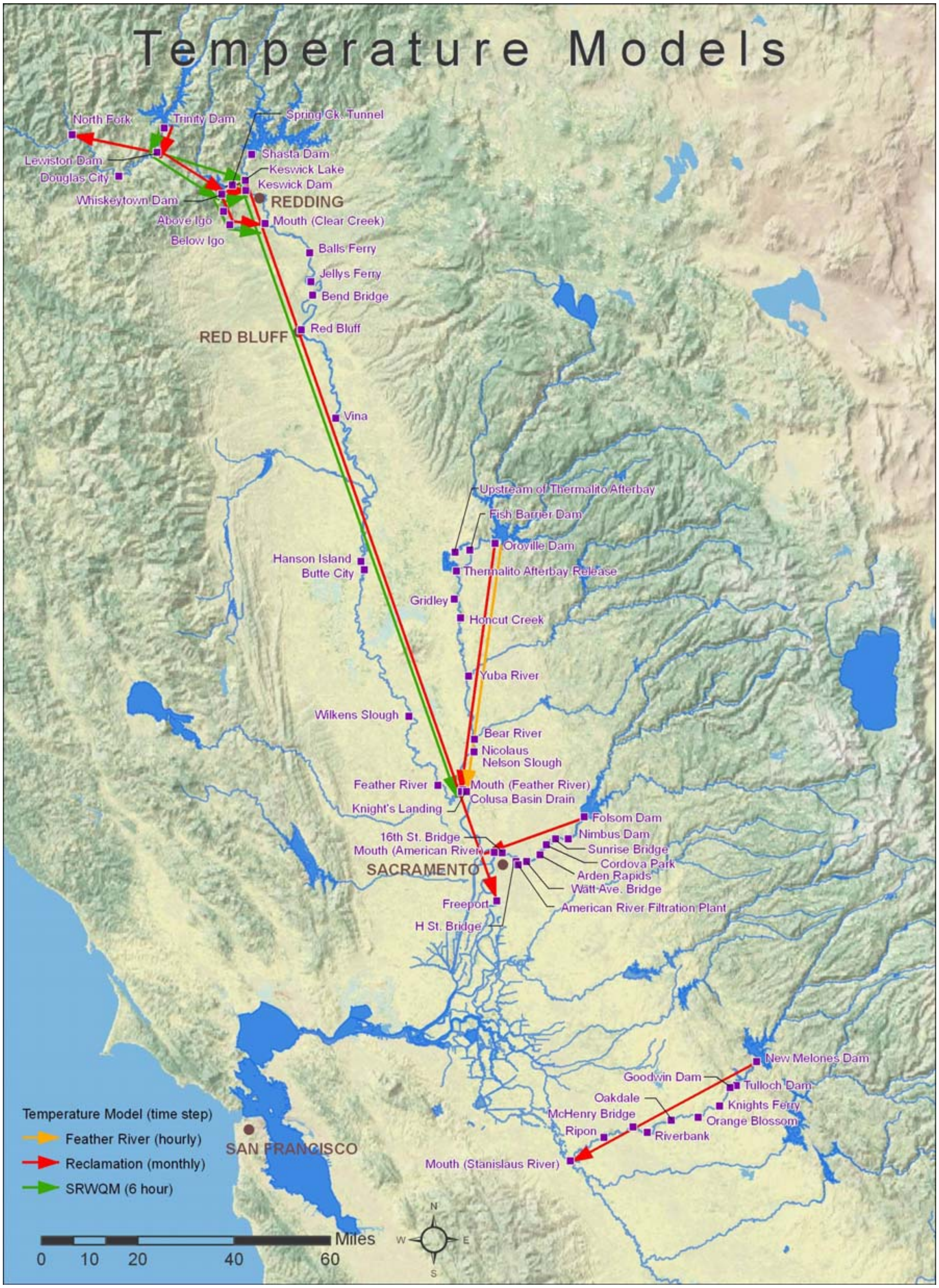


Figure 9-5 General spatial representation of the temperature model networks.

Salmon Mortality and Life Cycle Modeling Methods

The objective of the salmon mortality and life cycle models is to simulate salmon losses and population dynamics. These results quantify the change of salmon loss and population dynamics as compared amongst the model scenarios. The salmon models use simulated temperature results and CVP/SWP operation results from CalSim-II, described above. The three models applied to the OCAP BA are the Reclamation salmon mortality model, SALMOD, and the Interactive Object-Oriented Salmon Simulation (IOS) life cycle model for winter-run salmon. Each of the three salmon models is spatially represented in Figure 9-6.

Reclamation Salmon Mortality Model

The Reclamation salmon mortality model computes salmon spawning losses in the four rivers, Trinity, Sacramento, American, and Stanislaus, based on the Reclamation Temperature Model estimates. The model uses DFG and FWS data on Chinook salmon spawning distribution and timing in the five rivers (Reclamation 1991, Loudermilk 1994, and Reclamation 1994) Temperature-exposure mortality criteria for three life stages (pre-spawned eggs, fertilized eggs, and pre-emergent fry) are used along with the spawning distribution data and output from the river temperature models to compute percents of salmon spawning losses. Temperature units (TU), defined as the difference between river temperatures and 32°F, are calculated daily by the mortality model and used to track life-stage development. Eggs are assumed to hatch upon exposure to 750 TUs following fertilization. Fry are assumed to emerge from the gravel after exposure to 750 TUs following egg hatching into the pre-emergent fry stage. The temperature mortality rates for fertilized eggs, the most sensitive life stage, range from 8 percent in 24 days at 57°F to 100 percent in 7 days at 64°F or above (Reclamation, 1994). Most salmon spawning generally occurs above the North Fork on the Trinity River, above Red Bluff on the Sacramento River main stem for all four Chinook salmon runs, above Watt Avenue on the American River, and above Riverbank on the Stanislaus River. Fall-run salmon spawning usually occurs from mid-October through December, peaking about mid-November. Winter-run salmon usually spawn in the Sacramento River during May-July, and spring-run salmon during August-October. Additional information on the Reclamation mortality model is located in Appendix L.

SALMOD

SALMOD is a computer model that simulates the dynamics of freshwater salmonid populations. SALMOD was applied to this project because the model had been previously used on the upper Sacramento River (from Keswick Dam down to Battle Creek), and because a thorough review and update of model parameters and techniques on the Klamath River enabled a smooth transfer of relevant model parameters to the Sacramento River (Bartholow, 2003). The study area for this analysis covers a 53-mile (85-kilometer) stretch of the Sacramento River from Keswick Dam to just above the RBDD. Keswick Dam forms the current upstream boundary of anadromous fish migration in the Sacramento River, and the RBDD marks the current downstream limit of habitat that has been consistently classified by mesohabitat type and evaluated using the Physical Habitat Simulation System (PHABSIM) and River 2D. The study area terminates at this point because RBDD is operated with gates that can be raised or lowered that alter the inundation pool's hydraulics. This pool has not been modeled for habitat value. SALMOD functions to integrate microhabitat and macrohabitat limitations to a population through time and space. The term “habitat limitations” does not imply that freshwater habitat is the ultimate factor limiting the populations, but that habitat constraints may reduce populations while other factors, such as ocean conditions or fishing pressure, may be the ultimate limiting factor.

SALMOD simulates population dynamics for all four runs of Chinook salmon in the Sacramento River between Keswick Dam and RBDD. SALMOD presupposes egg and fish mortality are directly related to spatially and temporally variable microhabitat and macrohabitat limitations, which themselves are related to the timing and volume of streamflow and other meteorological variables. SALMOD is a spatially explicit model in which habitat quality and carrying capacity are characterized by the hydraulic and thermal properties of individual mesohabitats, which serve as spatial computation units in the model. The model tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of water temperature in a computational unit. Individual cohorts either remain in the computational unit in which they emerged or move, in whole or in part, to nearby units.

Model processes include spawning (with redd superimposition), incubation losses (from either redd scouring or dewatering), growth (including egg maturation), mortality due to water temperature and other causes, and movement (habitat and seasonally induced). SALMOD is organized around physical and environmental events on a weekly basis occurring during a fish’s biological year (also termed a brood year), beginning with adult holding and typically concluding with fish that are physiologically “ready” to begin migration towards the ocean. Input variables, represented as weekly average values, include streamflow, water temperature, and number and distribution of adult spawners. The study area is divided into individual mesohabitats (i.e., pool, riffle, and run) categorized primarily by channel structure and hydraulic geometry, but modified by the distribution of features such as fish cover. Thus, habitat quality in all computational units of a given mesohabitat type changes similarly in response to discharge variation. Habitat type and streamflow determine the available habitat area for a particular life stage for each time step and computational unit. Habitat area (quantified as weighted usable area, or WUA) is computed from flow: microhabitat area functions developed empirically or by using PHABSIM (Milhous et al., 1989) or River 2D for the reach from Keswick Dam to Battle Creek and a two dimensional hydraulic model for Battle Creek to RBDD. Habitat capacity for each life stage is a fixed maximum number of salmon per unit of habitat area available estimated from literature or empirical data. Thus, the maximum number of individuals that can reside in each computational unit is calculated for each time step based on streamflow, habitat type, and available microhabitat. Fish in excess of the habitat’s capacity must move to seek unoccupied habitat elsewhere. Fish from outside the model domain (from tributary production) were also added to the modeled stream as fry and juveniles.

Flow and water temperature time series values were derived from the CalSim-II and HEC-5Q models. Data for each day corresponded to the weekly average conditions for that day forward. Data covered the period 1921 to 2003, a total of 82 water-years. Additional information on the SALMOD model is located in Appendix P.

Interactive Object-Oriented Salmon Simulation (IOS) Winter-Run Life Cycle Model

The IOS Winter-Run Life Cycle model was used to evaluate the influence of different Central Valley water operations on the life cycle of Sacramento River winter-run Chinook salmon over an 80 year period using simulated flow and water temperature inputs. The IOS model was designed to serve as a quantitative framework for estimating the long-term response of Sacramento River Chinook populations to changing environmental conditions (e.g. river discharge, temperature, habitat quality at a reach scale). Life cycle models are well-suited for such evaluations because they integrate survival changes at various life stages, across multiple habitats, and through many years. The IOS model was seeded with 5,000 spawners for the first four years then allowed to cycle through multiple generations during years 1923-2002.

Reach specific, daily (disaggregated CalSim-II) discharge and daily HEC-5Q water temperature provided the basic inputs for model runs. In addition, monthly average Delta conditions (inflow, exports, DCC operations, temperature) were provided by CalSim-II. Other model settings were set specifically for this analysis and at constant values throughout the 80-year run of the IOS model. The use of constant values for parameters with little uncertainty or with lesser management significance is desirable because it simplifies the model and facilitates easier interpretation of results.

The effect of different water operation scenarios on the Sacramento River winter-run Chinook salmon population was evaluated by comparing abundance and survival trends at various life stages among the three runs of the IOS Model. The annual abundance of returning spawners and juveniles out-migrating past RBDD were reported for each model run. Trends in survival through time at various life stages were examined to explain patterns seen in yearly escapement under each water operation scenario. Average differences in winter-run survival between water operation scenarios were translated into average differences in annual escapement to better evaluate the potential impact each water operation scenario has on the winter-run abundance in the Sacramento River. Finally, typical monthly spatial distribution of juvenile salmon during model runs was reported. Additional details of the IOS model are also presented in Appendix N.

Figure 9-6 General spatial representation of the salmon model networks.

Climate Change and Sea Level Rise Sensitivity Analysis Modeling Methods

The approach selected for the climate change analysis is being referred to as “Sensitivity Analysis”, which includes a quantitative analysis of implications for future CVP and SWP operations under a range of potential climates in order to illustrate how the OCAP BA future operational baseline is sensitive to the future climate assumptions. With respect to the OCAP BA, the Sensitivity Analysis is focused on exploring how climate change might affect:

- Operational conditions of interest (e.g., storage, deliveries, flows, reservoir and river water temperature, Delta water levels and salinity),
- Described statistically during long-term, by year-type, or during drought-periods,
- Assessed at a 2030 look-ahead consistent with the consultation horizon.

The chosen approach for incorporating climate change information calls for re-evaluating the OCAP BA future operations baseline given assumptions consistent with different future climates, representing a range of potential future climates. These re-evaluated results are then compared against baseline results represented under “recent” climate. The comparison of results illustrates the sensitivity of the operations condition to the future climate assumption. The re-evaluations will focus on regional climate change defined in terms of monthly temperature and precipitation changes translated into surface water supply changes, and to global climate change defined in terms of sea level rise affecting Delta conditions. CVP and SWP operational policies are not modified to respond to the future climates and sea level rise.

To define a range of future climate possibilities, four projections were selected to encapsulate a reasonable range of projected climate conditions over the study region. The four projections will were selected based on how they collectively represent a range of:

- “lower” to “greater” temperature changes (which correspond to “*less warming*” to “*more warming*” over California),
- combined with a range of “lower” to “greater” precipitation magnitude changes (which correspond to “*drier*” to “*wetter*” conditions).

Projections selection depends on several factors that are study-specific:

- **Factor 1 –** Look-ahead horizon relevant to this study
- **Factor 2 –** Climate metric relevant to the study’s operational questions
- **Factor 3 –** Location representative of the study region
- **Factor 4 –** Projected “Change Range” of Interest, a subjective choice on how much projections spread to represent.

Climate projection selection for the OCAP BA sensitivity analysis then proceeds with a four-step implementation process based on the four selection factor decisions.

- **Step 1**: Survey climate projections data from the Downscaled Climate Projections (DCP) archive spanning the periods of selection factor decision #1, reported at the location of selection factor decision #3.
- **Step 2:** For base and future periods (selection factor decision #1), compute mean annual Temperature (T) and Precipitation (P) conditions for each of the 112 projections surveyed in Step 1. "Mean annual" is the climate metric of selection factor decision #2. Next, compute change in mean annual T and P (ΔT and ΔP, change respectively) from base to future period, by projection, and evaluate the rank-distribution of changes among the projections for each variable. Identify rank-percentile changes for each variable based on selection factor decision #4 (i.e. focusing on 10^{th} and 90^{th} percentile changes for both variables).
- **Step 3**: Switch focus to "projections spread", and evaluate the plot of ΔT versus ΔP. Overlay rank-percentile changes identified for each variable in Step 2. The intersection of the $\Delta T_{10\%\text{-tile}}$ and $\Delta T_{90\%\text{-tile}}$ with $\Delta P_{10\%\text{-tile}}$ and $\Delta P_{90\%\text{-tile}}$ formulates a two-variable "change range of interest."
- **Step 4:** Choose 4 projections having paired projected changes (i.e. {ΔT, ΔP}) that most closely match the four vertices of the two-variable "change range of interest."

CalSim-II hydrology inputs are modified to reflect the 4 projected changes in temperature and precipitation. Sea level rise assumptions are also implemented and evaluated using the DSM2 hydrodynamic model. See Appendix R for additional details.

Sensitivity and Uncertainty

Sensitivity and uncertainty analyses are typical testing procedures used to assess model performance. The tests provide useful information to assist decision makers who are using results from models. The purposes of the two analyses include:

1. Sensitivity Analysis: Identify parameters and input data which have a major impact to the system, and
2. Uncertainty Analysis: Understand the confidence of simulated results.

The CalSim-II sensitivity results are useful in tandem with the uncertainty results to affirm model performance, identify sensitive variables, and understand a likely band of modeled uncertainty. In this evaluation, sensitivity and uncertainty analyses are limited to the CalSim-II model.

These analyses examine a limited perspective of uncertainty and do not evaluate all aspects of uncertainty. Uncertainty of engineered water resources systems is generally categorized as hydrologic, hydraulic, structural, and economic (Mays and Tung, 1992). Ecosystems are an additional category of uncertainty to consider. Cumulative uncertainty or total uncertainty, defined here, is the collective simulated uncertainty due to the application of tiered modeling and to the categories mentioned above. Sensitivity and uncertainty to hydrology, water demands, and Delta compliance standards are addressed in the analysis for CalSim-II. However, a rigorous uncertainty evaluation including tiered modeling, hydraulic, structural, economic, ecosystem, and other drivers was not attempted due to the level of effort required for this type of analysis. The methods, scope and evaluation of the CalSim-II sensitivity and uncertainty analyses are presented in Appendix W. Sensitivity and uncertainty results are presented in Appendix X.

The model results presented below and elsewhere (Chapters 10-13) are generated using models with uncertain information. The uncertainty of absolute results, as models build upon another with the tiered approach, is expected to increase. For example, the CalSim-II representation of the current operational conditions captures seasonal trends, frequencies and magnitudes well but imperfectly (see Appendix U). The uncertainty evaluation and historical comparisons should be considered in the evaluation of all of the simulated results presented in the OCAP BA.

Other Tools

Qualitative or quantitative tools which are, or could be, applied to the CVP and SWP systems but were not used in OCAP BA are also acknowledged. Some tools are in development or contained a component of incompatibility that could not be applied. These tools or processes should be considered for future evaluation when available or made compatible.

In early 2008 the California Department of Fish and Game introduced new conceptual models to better manage species and ecosystem responses. These models were not available for use during the development of this BA, however, they seem promising and should be considered in the future. The following are excerpts from the Delta Restoration Plan Species Life History Models Report (DFG, 2007) summarizing the DRERIP model and process:

> "*Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) will implement adaptive management by incorporating scientific evaluation of restoration actions in light of the current state of knowledge and restoration projects implemented to date. The DRERIP science input process is divided into four phases; (1) process design; (2) the development of species life history models and ecosystem element conceptual models; (3) the development and evaluation of proposed ERP actions; and (4) an analysis of the feasibility and prioritization of the actions.*
>
> *The California Department of Fish and Game, working with the CALFED Science Program and other CALFED agencies, is engaged in the development of a series of conceptual models for the Delta that can inform decision making regarding future conservation and restoration actions. The following provides general guidelines for the preparation of these species models, including how the models will be used, definitions of terms, information that should be included in each model, and a basic outline that should be followed. These guidelines have been amended following beta-testing of the overall Delta Restoration Plan (DRERIP) suite of models in order to facilitate vetting of likely restoration actions.*
>
> *The purpose of these guidelines is to promote consistency between the structure, format, and level of information contained within each species model. The guidelines are also intended to improve the application of the models, including linkages between the species models and related ecosystem element conceptual models being developed separately that describe natural processes, habitats, and stressors acting upon the population dynamics of the component species within the community.*"

> *"The purpose of the species models is to describe the basic biology (life cycle and life history) of several key species, and to articulate explicitly the current state of knowledge regarding factors influencing their reproductive success, growth, and survival—the underlying population dynamics as we understand them. This information will necessarily direct appropriate restoration actions most efficiently, and forms the foundation for adaptive management within the CALFED ERP process. It is critically important that these models address the most appropriate outputs (outcomes) to define particular restoration actions and objectives towards long-term population viability of your particular species. This information includes a comprehensive treatment of the threats facing different lifestages of these species under different seasonal scenarios and conditions."*

> *"The DRERIP conceptual models follow a deterministic paradigm, using the DLO approach: drivers (D), linkages (L), and outcomes (O). **Drivers** are physical, chemical, or biological forces that control the species or system of interest. **Linkages** are cause-and-effect relationships between drivers and outcomes. **Outcomes** are response variables (such as reproductive success, growth, and mortality) that the conceptual model is attempting to explain. In the context of the DRERIP species conceptual models, "ultimate" outcomes reflect population-level responses to drivers."*

Other temperature models were also examined but not used during the development of the OCAP BA. Various water temperature models are available and applied to CVP Rivers and tributaries. These models represent a variety of geographic locations and temporal resolution. The simulation of water temperature in the OCAP BA captures short term variability (e.g. daily time-step) in the Clear Creek, Sacramento, and the Feather Rivers and a coarser time step elsewhere.

Other temperature models applied in the Central Valley include simulation of the American River (Reclamation) and the Stanislaus River (AD and RMA, 2002) at a sub-monthly time-step. However, daily and sub-daily disaggregation assumptions, testing, and verification were not available for these locations using the full 82 year CalSim-II data sets for the American and Stanislaus rivers. Tools simulating real-time temperature operations, such as optimizing cold water pool storage using CalSim-II data, were also not available. Supplemental historical temperature observations were evaluated to overcome these modeling limitations.

The treatment of temperature simulation is unequal amongst the basins presented in the BA. This is due in part to present data availability, inconsistency in model approach between agencies, model complexity, and computation time. For the short term, supplemental historical temperature observations are presented to overcome these modeling limitations (Appendix U). A long-term temperature model development plan including consistent spatial and temporal application for the CVP and SWP systems will be considered for future applications.

Modeling Studies and Assumptions

DWR and Reclamation developed a set of "Common Assumptions" (as part of CALFED Storage Project Investigations) for the purpose of developing an updated CalSim-II study to be used as a basis for comparing project alternatives. From the "Common Assumptions" CalSim-II model, ten CalSim-II studies (and one study from the previous 2004 BA modeling) have been developed to evaluate the effects of changes in future operations for the OCAP BA. The programs evaluated include: Freeport Regional Water Project, California Aqueduct and Delta-Mendota Canal Intertie, level of development (future demands), Yuba River Accord, Full Environmental Water Account (EWA) and Limited EWA, Red Bluff Diversion Dam, American River Flow Management, Sacramento River Reliability, South Delta Improvements Program (SDIP) Stage 1, and climate change and sea level rise.

Study assumptions and refinements have been made since the OCAP BA May 2008 documentation in response to external reviews and requests from the FWS. Study 3a and Study 6.0 now include simulations through the EWA step. CVP and SWP operational refinements have also been applied to Studies 7.0, 7.1, 8.0 and the 9.0 suite to better capture North-of-Delta and South-of-Delta balancing. A full list of model refinements is included in Appendix E.

The study scenarios were formed to capture the past assumptions, present, near-future, future, and future with an alternative climate conditions:

1. **Study 3a –** This study is repeated from the previous OCAP BA 2004 for comparative purposes. It represents a prior condition (a 2001 level of land use development) and simulates through the Environmental Water Account (EWA) simulation step. Study 3a also includes the Trinity Record of Decision (ROD) implementation.
2. **Study 6.0 –** This study represents the previous OCAP BA 2004 assumptions within the new CalSim-II model framework. Conditions for water demands, facilities, and water project-operational policy are duplicated, to the extent possible, to Study 3a. This study corresponds to an “existing” condition (developed to compare to the 2004 OCAP BA Study 3a, with a 2005 level of land use development) and simulates through the EWA step. This study is designed to compare to Study 3a and highlights differences due to model refinement.
3. **Study 6.1 –** This study represents the previous OCAP BA 2004 assumptions also within the new CalSim-II model framework. Conditions for water demands, facilities, and water project-operational policy are duplicated, to the extent possible, to Study 3a, but this is simulated only through the CVPIA (b)(2) step. This study is identical to Study 6.0 in the OCAP BA May 2008 issue and is included to emulate pre-Pelagic Organism Decline (POD) conditions. Study 6.1 is an imperfect representation of the pre-POD and supplemental analysis should be evaluated to compensate for this modeling limitation (discussed in Chapter 13: CVP and SWP Delta Effects). Study 6.1 results are presented in Appendix E.
4. **Study 7.0 –** This study forms the model to compare future proposed operations. Study 7.0 describes existing water demands, facilities, and water project operational policy, to the extent possible. It represents the today condition (a 2005 level of land use development) through the EWA simulation step.
5. **Study 7.1 –** This study represents water demands and policy for existing conditions, current and near-future facilities, and existing and near-future water project operational policy. It corresponds to the today condition (a 2005 level of land use development)

through the Limited EWA simulation step. Study 7.1 should be compared to Study 7.0 to determine the effect of near-future facilities and policies.

6. **Study 8.0 –** This study represents assumed water demands and policy for the future. It represents the future condition (a 2030 level of land use development) through the Limited EWA. Study 8.0 should be compared to Study 7.0 to determine the effect of future facilities and policies.

7. **Study 9.0-9.5 suite –** These studies constitute the future with climate change and sea level rise. It represents a conservative future condition (a 2030 level of land use development) for D-1641 WQCP. Studies 9.1-9.5 are identical to Study 8.0's D-1641 simulation step except:

    a. Climate modified hydrology, and

    b. Sea level rise.

    The sub-suite studies represent the range of temperature and precipitation explored for climate change. The Study 9.0 suite represents future condition as a separate study for sensitivity evaluation.

Compatible comparisons can be made with the following studies:

1. **Study 3a and Study 6.0 –** This comparison identifies the difference between model development/refinement since the OCAP BA 2004 (see Table 9-3 for CalSim-II model revisions). Appendix E presents the comparison between OCAP BA 2004 Study 3a and Study 6.0 CalSim-II results. Note there is no compatible comparison information on 6.1.
2. **Study 7.0 and Study 7.1 –** A comparison between Study 7.0 and Study 7.1 illustrates the change between the "Today" and "Near-Future" conditions. Where the "Near Future" contains the Limited EWA, South Delta Improvement Project Stage 1, Freeport Regional Water Project, and California Aqueduct/Delta Mendota Canal Intertie.
3. **Study 7.0 and Study 8 –** This comparison presents the change between the base model, "Today" and "Future" conditions. The "Future" contains the Limited EWA, the South Delta Improvement Project Stage 1, Freeport Regional Water Project, California Aqueduct/Delta Mendota Canal Intertie, and future water demands.
4. **Study 7.1 and Study 8.0 –** A comparison between Study 7.1, the "Near Future", and Study 8.0, the "Future" highlights the change in future water demands.

Table 9-4 shows the eleven studies developed for OCAP BA and generally how assumptions change. Table 9-5 shows the detailed assumptions of Studies 3a through 9.0. The latter table also illustrates specific operational changes regarding regulatory and operational rules.

Table 9-4 Summary of Assumptions in the OCAP BA Runs

	CVPIA 3406 (b)(2)	Level of Developm ent	EWA	SDIP Stage 1	Freeport	Intertie	Climate and Sea Level Rise
Study 3a Today EWA	May 2003	2001	Full				
Study 6.0 Today EWA	May 2003	2005	Full				
Study 6.1 Today CVPIA (b)(2)	May 2003	2005					
Study 7.0 Today EWA	May 2003	2005	Full				
Study 7.1 Today Limited EWA	May 2003	2005	Limited	X	X	X	
Study 8.0 Future Limited EWA	May 2003	2030	Limited	X	X	X	
Study 9.0 Future D1641 SA Climate Change		2030		X	X	X	No Sea Level Rise
Study 9.1 Future D-1641		2030		X	X	X	1ft Sea Level Rise and 4" amplitude
Study 9.2 Future D-1641		2030		X	X	X	Wetter, Less Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.3 Future D-1641		2030		X	X	X	Wetter, More Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.4 Future D-		2030		X	X	X	Drier, Less Warming

	CVPIA 3406 (b)(2)	Level of Developm ent	EWA	SDIP Stage 1	Freeport	Intertie	Climate and Sea Level Rise
1641							Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.5 D-1641 Future		2030		X	X	X	Drier, More Warming Climate Change with 1ft Sea Level Rise and 4" amplitude

Table 9-5. Assumptions for the Base and Future Studies

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
		OCAP BA 2004 Today CVPIA 3406 (b)(2) with EWA	**Today-OCAP BA 2004 Assumptions in Revised CalSim-II Model - EWA**	**Today-OCAP BA 2004 Assumptions in Revised CalSim-II Model - CVPIA (b)(2) - CONV**	**Today-Existing Conditions, (b)(2), EWA**	**Near Future-Existing Conditions and OCAP BA 2004 Consulted Projects, (b)(2), Limited EWA**	**Future - (b)(2), Limited EWA**	**Future Climate Change-D1641**	**Model Revisions since OCAP BA 2004**
OCAP Base model: Common Assumptions: Common Model Package (Version 8D) *"Same" indicates an assumption from a column to the left*									
Planning horizon		2001	2005[a]	Same	Same	Same	2030[a]	Same	
Period of Simulation		73 years (1922-1994)	82 years (1922-2003)	Same	Same	Same	Same	Same	Extended hydrology timeseries
HYDROLOGY								Inflows are modified based on alternative climate inputs [b]	Revised level of detail in the Yuba and Colusa Basin including rice decomposition operations
Level of development (Land Use)		2001 Level	2005 level	Same	Same	Same	2030 level[c]	Same	
Sacramento Valley (excluding American R.)									
	CVP	Land-use based, limited by contract amounts[d]	Same	Same	Same	Same	CVP Land-use based, Full build out of CVP contract amounts[d]	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	SWP (FRSA)	Land-use based, limited by contract amounts[e]	Same	Same	Same	Same	Same	Same	
	Non-project	Land-use based	Same	Same	Same	Same	Same	Same	
	Federal refuges	Firm Level 2	Same	Same	Recent Historical Firm Level 2 water needs[f]	Same	Firm Level 2 water needs[f]	Same	
American River									
	Water rights	2001[g]	Same	Same	2005[g]	Same	2025[g]	Same	
	CVP (PCWA American River Pump Station)	No project	Same	Same	CVP (PCWA modified)[g]	Same	Same	Same	
San Joaquin River[h]									
	Friant Unit	Regression of Historical Demands	Limited by contract amounts, based on current allocation policy	Same	Same	Same	Same	Same	Developed land-use based demands, water quality calculations, and revised accretions/depletions in the East-Side San Joaquin Valley
	Lower Basin	Fixed Annual Demands	Land-use based, based on district level operations and constraints	Same	Same	Same	Same	Same	
	Stanislaus River	New Melones Interim Operations Plan	Same	Same	Same	Draft Transitional Operations Plan[r]	Same	Same	Initial storage conditions for New Melones Reservoir

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
									were increase d.
South of Delta									
	(CVP/SWP project facilities)	CVP Demand based on contracts amounts[d]	Same	Same	Same	Same	Same	Same	
	Contra Costa Water District	124 TAF/yr annual average	135 TAF/yr annual average CVP contract supply and water rights[i]	Same	Same	Same	195 TAF/yr annual average CVP contract supply and water rights[i]	Same	
	SWP Demand - Table A	Variable 3.1-4.1 MAF/Yr	Same	Same	Variable 3.1-4.2 MAF/Yr [e,j]	Same	Full Table A	Same	Revised SWP delivery logic. Three patterns with Art 56 and more accuratel y defined Table A / Article 21 split modeled
	SWP Demand - North Bay Aqueduct (Table A)	48 TAF/Yr	Same	Same	71 TAF/Yr[u]	Same	Same	Same	
	SWP Demand - Article 21 demand	Up to 134 TAF/month December to March, total of other demands up to 84 TAF/month in all months	Same	Same	Up to 314 TAF/month from December to March, total of demands up to 214 TAF/month in all other months[e,jw]	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Federal refuges	Firm Level 2	Same	Same	Recent Historical Firm Level 2 water needs[f]	Same	Firm Level 2 water needs[f]	Same	
FACILITIES									
Systemwide		Existing facilities[a]	Same	Same	Same	Same	Same	Same	
Sacramento Valley									
	Red Bluff Diversion Dam	No diversion constraint	Same	Same	Diversion Dam operated May 15 - Sept 15 (diversion constraint)	Same	Diversion Dam operated July - August (diversion constraint)	Same	
	Colusa Basin	Existing conveyance and storage facilities	Same	Same	Same	Same	Same	Same	
	Upper American River	No project	Same	Same	PCWA American River pump station[k]	Same	Same	Same	
	Sacramento River Water Reliability	No project	Same	Same	Same	Same	American/Sacramento River Diversions[t]	Same	
	Lower Sacramento River	No project	Same	Same	Same	Freeport Regional Water Project (Full Demand)[l]	Same	Same	
Delta Region									
	SWP Banks Pumping Plant	South Delta Improvements Program Temporary Barriers, 6,680 cfs capacity in all months and an additional 1/3 of Vernalis flow from Dec 15 through	Same	Same	Same	South Delta Improvements Program Permanent Operable Gates (Stage 1). 6,680 cfs capacity in all months and an additional 1/3 of Vernalis flow from Dec	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
		Mar 15[a]				15 through Mar 15 [a]			
	CVP C.W. Bill Jones (Tracy) Pumping Plant	4,200 cfs + deliveries upstream of DMC constriction	Same	Same	Same	4,600 cfs capacity in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie)	Same	Same	
	City of Stockton Delta Water Supply Project (DWSP)	No project	Same	Same	DWSP WTP 0 mgd	Same	DWSP WTP 30 mgd	Same	
	Contra Costa Water District	Existing pump locations	Same	Same	Same	Same	Same[m]	Same	
South of Delta **(CVP/SWP project facilities)**									
	South Bay Aqueduct (SBA)	Existing capacity 300 cfs	Same	Same	SBA Rehabilitation: 430 cfs capacity from junction with California Aqueduct to Alameda County FC&WSD Zone 7 diversion point	Same	Same	Same	
REGULATORY STANDARDS									
Trinity River									
	Minimum flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
		TAF/year)							
	Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF as able)	Same	Same	Same	Same	Same	Same	
Clear Creek									
	Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 USBR Proposal to USFWS and NPS, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
Upper Sacramento River									
	Shasta Lake	NMFS 2004 BiOp: 1.9 MAF end of Sep. storage target in non-critical years	Same	Same	Same	Same	Same	Same	
	Minimum flow below Keswick Dam	Flows for SWRCB WR 90-5 temperature control, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
Feather River									
	Minimum flow below Thermalito Diversion Dam	1983 DWR, DFG Agreement (600 cfs)	Same	Same	Same	2006 Settlement Agreement (700 / 800 cfs)	Same	Same	
	Minimum flow below Thermalito Afterbay outlet	1983 DWR, DFG Agreement (750-1,700 cfs)	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
Yuba River									
	Minimum flow below Daguerre Point Dam	Available Yuba River Data[p]	D-1644 Interim Operations[p]	Same	Yuba Accord Adjusted Data[p]	Same	Same	Same	
American River									
	Minimum flow below Nimbus Dam	SWRCB D-893 (see Operations Criteria), and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	(b)(2) Minimum Instream Flow management[s]	Same	American River Flow Management [s]	Same	
	Minimum Flow at H Street Bridge	SWRCB D-893	Same	Same	Same	Same	Same	Same	
Lower Sacramento River									
	Minimum flow near Rio Vista	SWRCB D-1641	Same	Same	Same	Same	Same	Same	
Mokelumne River									
	Minimum flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100-325 cfs)	Same	Same	Same	Same	Same	Same	
	Minimum flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25-300 cfs)	Same	Same	Same	Same	Same	Same	
Stanislaus River									
	Minimum flow below Goodwin Dam	1987 USBR, DFG agreement, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Minimum dissolved oxygen	SWRCB D-1422	Same	Same	Same	Same	Same	Same	
Merced River									
	Minimum flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180-220 cfs, Nov-Mar), Cowell Agreement	Same	Same	Same	Same	Same	Same	
	Minimum flow at Shaffer Bridge	FERC 2179 (25-100 cfs)	Same	Same	Same	Same	Same	Same	
Tuolumne River									
	Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94-301 TAF/year)	Same	Same	Same	Same	Same	Same	
San Joaquin River									
	Maximum salinity near Vernalis	SWRCB D-1641	Same	Same	Same	Same	Same	Same	
	Minimum flow near Vernalis	SWRCB D-1641, and Vernalis Adaptive Management Plan per San Joaquin River Agreement	Same	Same	Same	Same	Same	Same	
Sacramento River–San Joaquin River Delta									
	Delta Outflow Index (Flow and Salinity)	SWRCB D-1641	Same	Same	Same	Same	Same	Same	Revised Delta ANN (salinity estimation)[v]
	Delta Cross Channel gate operation	SWRCB D-1641	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Delta exports	SWRCB D-1641, USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
OPERATIONS CRITERIA: RIVER-SPECIFIC									
Upper Sacramento River									
	Flow objective for navigation (Wilkins Slough)	3,250 - 5,000 cfs based on CVP water supply condition	Same	Same	Same	Same	Same	Same	
American River									
	Folsom Dam flood control	Variable 400/670 flood control diagram (without outlet modifications)	Same	Same	Same	Same	Same	Same	
	Flow below Nimbus Dam	Discretionary operations criteria corresponding to SWRCB D-893 required minimum flow	Same	Same	(b)(2) Minimum Instream Flow management[s]	Same	American River Flow Management [s]	Same	
	Sacramento Area Water Forum "Replacement" Water	"Replacement" water is not implemented	Same	Same	Same	Same	Same	Same	
Stanislaus River									
	Flow below Goodwin Dam	1997 New Melones Interim Operations Plan	Same	Same	Same	Draft Transitional Operations Plan[r]	Same	Same	
San Joaquin River									
	Flow at Vernalis	D1641	Same	Same	Same	Same	Same[q]	Same	

OPERATIONS CRITERIA: SYSTEMWIDE		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
CVP water allocation									
	CVP Settlement and Exchange	100% (75% in Shasta critical years)	Same	Same	Same	Same	Same	Same	
	CVP refuges	100% (75% in Shasta critical years)	Same	Same	Same	Same	Same	Same	
	CVP agriculture	100%-0% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions)	Same	Same	Same	Same	Same	Same	
	CVP municipal & industrial	100%-50% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions)	Same	Same	Same	Same	Same	Same	
SWP water allocation									
	North of Delta (FRSA)	Contract specific	Same	Same	Same	Same	Same	Same	
	South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
CVP-SWP coordinated operations									
	Sharing of responsibility for in-basin-use	1986 Coordinated Operations Agreement (FRWP EBMUD and 2/3 of the North Bay Aqueduct diversions are considered as Delta Export, 1/3 of the North Bay Aqueduct diversion is considered as in-basin-use)	Same	Same	Same	Same	Same	Same	
	Sharing of surplus flows	1986 Coordinated Operations Agreement	Same	Same	Same	Same	Same	Same	
	Sharing of Export/Inflow Ratio	Equal sharing of export capacity under SWRCB D-1641; use of CVPIA 3406(b)(2) restricts only CVP and/or SWP exports	Same	Same	Same	Same	Same	Same	
	Sharing of export capacity for lesser priority and wheeling related pumping	Cross Valley Canal wheeling (max of 128 TAF/year), CALFED ROD defined Joint Point of Diversion (JPOD)	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
Study assumptions from above apply			**Study 6a**	**Study 7a**	**Study 7a**	**Study 7.1a**	**Study 8a**	**NA**	
CVPIA 3406(b)(2): Per May 2003 Dept. of Interior Decision									
	Allocation	800 TAF, 700 TAF in 40-30-30 dry years, and 600 TAF in 40-30-30 critical years[n]	Same	Same	Same	Same	Same	NA	
Study assumptions from above apply			**Study 6b**	**Study 7b**	**Study 7b**	**Study 7.1b**	**Study 8b**	**NA**	
CALFED Environmental Water Account / Limited Environmental Water Account									
	Actions	Dec-Feb reduce total exports by 50 TAF/mon relative to total exports without EWA; VAMP (Apr 15 - May 16) export restriction on SWP; Post (May 16-31) VAMP export restriction on SWP and potentially on CVP if B2 Post-VAMP action is not taken; Ramping of exports (Jun)	Dec/Jan 50 TAF/mon export reduction, Feb 50 TAF export reduction in Wet/AN years, Feb/Mar 100, 75, or 50 TAF reduction dependent on species habitat conditions; VAMP (Apr 15 - May 16) export restriction on SWP; Pre (Apr 1-14) VAMP export reduction in Dry/Crit years; Post (May 16-31) export restriction; June ramping restriction if PostVAMP action was done. Pre- and Post-VAMP and June actions done if foreseeable October debt at	NA	Same	VAMP (Apr 15 - May 16) 31-day export restriction on SWP; If stored assets and purchases from the Yuba are sufficient, Post (May 16-31) VAMP export restrictions apply to SWP[pq]	Same	NA	The EWA actions, assets, and debt were revised and vetted as part of the Long Term Environmental Water Account EIS/R project

	Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
		San Luis does not exceed 150 TAF.						
Assets	Fixed Water Purchases 250 TAF/yr, 230 TAF/yr in 40-30-30 dry years, 210 TAF/yr in 40-30-30 critical years. The purchases range from 0 TAF in Wet years to approximately 153 TAF in Critical years NOD, and 57 TAF in Critical years to 250 TAF in Wet years SOD. Variable assets include the following: use of 50% of any CVPIA 3406(b)(2) releases pumped by SWP, flexing of Delta E/I Ratio (post-processed from CalSim-II results), additional 500 CFS pumping capacity at Banks in Jul-Sep	Fixed Water Purchases 250 TAF/yr, 230 TAF/yr in 40-30-30 dry years, 210 TAF/yr in 40-30-30 critical years. NOD share of annual purchase target ranges from 90% to 50% based on SWP Ag Allocation as an indicator of conveyance capacity. Variable/operational assets include use of 50% of any CVPIA 3406(b)(2) releases pumped by SWP, additional 500 CFS pumping capacity at Banks in Jul-Sep, source shifting, Semitropic Groundwater Bank, "spill" of San Luis carryover debt, and backed-up stored water from Spring EWA actions.	NA	Same	Purchase of Yuba River stored water under the Lower Yuba River Accord (average of 48 TAF/yr), use of 50% of any CVPIA 3406 (b)(2) releases pumped by SWP, additional 500 CFS pumping capactiy at Banks in Jul-Sep.	Same	NA	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Debt	Delivery debt paid back in full upon assessment; Storage debt paid back over time based on asset/action priorities; SOD and NOD debt carryover is explicitly managed or spilled; NOD debt carryover must be spilled; SOD and NOD asset carryover is allowed	Same	NA	Same	No Carryover Debt	Same	NA	
Post Processing Assumptions									
WATER MANAGEMENT ACTIONS (CALFED)									
Water Transfers									
	Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks Pumping Plant over non-SWP users	Same	NA	Same	Same	Same	NA	
	Phase 8[o]	Evaluate available capacity	Same	NA	Same	Same	Same		
	Refuge Level 4 water	Evaluate available capacity	Same	NA	Same	Same	Same		

	Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II

Notes:

[a] The OCAP BA project description is presented in Chapter 2.

[b]Climate change sensitivity analysis assumptions and documentation are presented in Appendix R.

[c] The Sacramento Valley hydrology used in the CALSIM II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Development of 2030 land-use assumptions are being coordinated with the California Water Plan Update for future models.

[d] CVP contract amounts have been reviewed and updated according to existing and amended contracts as appropriate. Assumptions regarding CVP agricultural and M&I service contracts and Settlement Contract amounts are documented in Table 3A (North of Delta) and 5A (South of Delta) of Appendix D: Delivery Specifications section of the Technical Appendix.

[e] SWP contract amounts have been reviewed and updated as appropriate. Assumptions regarding SWP agricultural and M&I contract amounts are documented in Table 1A (North of Delta) and Table 2A (South of Delta) of Appendix D: Delivery Specifications section.

[f] Water needs for federal refuges have been reviewed and updated as appropriate. Assumptions regarding firm Level 2 refuge water needs are documented in Table 3A (North of Delta) and 5A (South of Delta) of Appendix D:Delivery Specifications. Incremental Level 4 refuge water needs have been documented as part of the assumptions of future water transfers.

[g] PCWA demand in the foreseeable existing condition is 8.5 TAF/yr of CVP contract supply diverted at the new American River PCWA Pump Station. In the future scenario, PCWA is allowed 35 TAF/yr. Assumptions regarding American River water rights and CVP contracts are documented in Table 5 of Appendix D: Delivery Specifications section.

[h] The new CalSim-II representation of the San Joaquin River has been included in this model package (CalSim-II San Joaquin River Model, Reclamation, 2005). Updates to the San Joaquin River have been included since the preliminary model release in August 2005. The model reflects the difficulties of on-going groundwater overdraft problems. The 2030 level of development representation of the San Joaquin River Basin does not make any attempt to offer solutions to on-going groundwater overdraft problems. In addition, a dynamic groundwater simulation is not yet developed for San Joaquin River Valley. Groundwater extraction/ recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions. These limitations should be considered in the analysis of results.

	Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II

[i] Study 6.0 demands for CCWD are assumed equal to Study 7.0 due to data availablity with the revised CalSim-II model framework. For all Studies, Los Vaqueros Reservoir storage capacity is 100 TAF.

[j] Table A deliveries into the San Francisco Bay Area Region for existing cases are based on a variable demand and a full Table A for future cases. The variable demand is dependent on the availability of other water during wet years resulting in less demand for Table A. In the future cases it is assumed that the demand for full Table A will be independent of other water sources. Article 21 demand assumes MWD demand of 100 TAF/mon (Dec-Mar), Kern demand of 180 TAF/mon (Jan-Dec), and other contractor demand of 34 TAF/mon (Jan-Dec).

[k] PCWA American River pumping facility upstream of Folsom Lake is under construction.

[l] Mokelumne River flows reflect EBMUD supplies associated with the Freeport Regional Water Project.

[m] The CCWD Alternate Intake Project (AIP), an intake at Victoria Canal, which operates as an alternate Delta diversion for Los Vaqueros Reservoir is not included in Study 8.0. AIP is included as a separate consultation. AIP will be further evaluated after regulatory and operational managment assumptions have been determined.

[n] The allocation representation in CalSim-II replicates key processes, shortage changes are checked by post-processing.

[o] This Phase 8 requirement is assumed to be met through Sacramento Valley Water Management Agreement Implementation.

[p] OCAP BA 2004 modeling used available hydrology at the time which was data developed based on 1965 Yuba County Water Agency -Department of Fish of Game Agreement. Since the OCAP BA 2004 modeling, Yuba River hydrology was revised. Interim D-1644 is assumed to be fully implemented with or without the implementation of the Lower Yuba River Accord. This is consistent with the future no-action condition being assumed by the Lower Yuba River Accord EIS/EIR study team. For studies with the Lower Yuba River Accord, an adjusted hydrology is used.

[q] It is assumed that either VAMP, a functional equivalent, or D-1641 requirements would be in place in 2030.

[r] The Draft Transitional Operations Plan assumptions are discussed in Chapter 2.

[s] For Studies 7.0, 7.1, and 8.0 the flow components of the proposed American River Flow Management are included and applied using the CVPIA 3406(b)(2). For Study 8.0 the American River Flow Management is assumed to be the new minimum instream flow.

[t] OCAP assumes the flexibility of diversion location but does not assume the Sacramento Area Water Forum Water Forum "replacement water" in drier water year types.

[u] Aqueduct improvements that would allow an increase in South Bay Aqueduct demand at the time of model development were expected to be operational within 6 months. However, a delay in the construction has postponed the completion.

	Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II

[v]The Artificial Neural Network (ANN) was updated for both salinity and X2 calculations. Study 3a does not include an updated ANN, Study 6.1 has an updated salinity but not X2, and all remaining Studies include both the updated salinity and X2.

[w] North Bay Article 21 deliveries are dependent on excess conditions rather than being dependent on San Luis storage.

Assumed Future Demands

The CalSim-II model results are very sensitive to assumed demands for the CVP and SWP systems. The modeled representation of future demands are assumed as full water right and contract demands for the CVP and full Table A for the SWP. Assumed delivery specifications for diversion locations in the CalSim-II model are listed in detail for both the existing and future levels of development in the Appendix D.

The following explains only the significant future delivery assumptions that deviate from the previous OCAP BA model representation (OCAP BA, 2004):

- The future total American River Basin water demand is greater than the demands assumed for 2004 BA analysis and, does not include the representation of the Water Forum program for demand reductions in certain dry and critical hydrologic conditions. The modeling assumes 311,800 af/yr in future water right demands for the city of Sacramento which is also greater than the previous models (the OCAP BA 2004 simulated a year 2020 level of development, the current OCAP BA simulates a year 2030 level of development). Finally, the modeling does not include the representation of the Water Forum program for additional releases from the Middle Fork Project. These changes represent a more realistic picture of the CVP's ability to meet water rights and water contract obligations. Another important change is the representation of the American River minimum flow requirements below Lake Natoma. These flows are augmented according to the proposed American River Flow Management schedule.
- The Sacramento River Reliability Project also affects the future representation which reduces the delivery burden on the American River by shifting demands to a Sacramento River diversion. Assumed delivery specifications for the American River are also listed in the CalSim-II modeling Appendix D.
- The City of Stockton Delta Water Supply Project is included in the future representation. This captures the expansion of future Delta demands with the development of the 30 mgd Delta Water Supply Project.
- The modeling of SWP deliveries has been significantly refined in the latest version of CalSim-II to better reflect current delivery classification practices. The three significant changes in the delivery modeling are 1) the incorporation of a three-pattern demand, 2) explicit modeling of the previous year's Table A supplies that are delivered in the current year ("Carryover" or Article 56 deliveries), and 3) increased assumption for Article 21 demands.
    - The three-pattern demand allows for demand adjustments associated with various levels of Table A allocation. Based on the amount of Table A allocation one of the three demand patterns is selected to more accurately model the monthly delivery pattern.
    - In the model used for the 2004 BA, a single demand pattern was used with the current year's Article 56 water inappropriately delivered at the beginning of the current year rather than being carried over for delivery in the following year. This artificially increased the Table A demand at the beginning of each year, and

potentially reduced Article 21 deliveries during the early part of the year. The new delivery methodology allows for the storage, delivery and "spilling" of the previous year's Article 56 carryover at the beginning of the current year. Delivery of the previous year's Article 56 is typically within the first three months of the current year. As the SWP share of San Luis Reservoir fills, there is a chance that Article 56 will "spill" i.e. it is converted to the current year's Table A supply.

- The new model also incorporates an Article 21 demand increase that more accurately represents actual Article 21 demand. However, with the incorporation of the three-pattern Table A demand, Article 56, and increased Article 21 demand, the overall total delivery remains largely the same. The previous version of the model tended to overestimate the delivery of Table A and underestimate the delivery of Article 21 by a like amount.
- The existing condition studies (Study 7.0, and Study 7.1) used a variable annual Table A demand which is consistent with the 2004 modeling. This assumes that the demand for Table A water would be less during very wet years, but would be greater in dry years.
- The future condition studies (Study 8.0, and Studies 9 suite) used full entitlement demand in all years. This condition assumes that, independent on the year type, the demand would remain the same. By contrast, the 2004 modeling assumed a variable demand for the future condition studies.

Modeling Results

Hydrologic Modeling Results

A summary of long-term averages (i.e., WY1922 to WY2003) and critical drought-period averages (i.e., WY1928 to WY1934) is shown in Table 9-6 for flows, storages, Delta output, and deliveries. These values represent long-term averages, for example CalSim-II results for CVP SOD Agricultural allocations range from 0 to 100 percent. The remaining section presents results for 3406 CVPIA (b)(2) accounting and EWA. Discussions of results are presented in Chapter 10: Streams Controlled by CVP and SWP Operations and Chapter 12: CVP and SWP Delta Operations. Additional results, including month-by-year tables, exceedance charts, monthly averages by water-year type, and monthly percentiles for selected CalSim-II outputs, are located in the appendix (Appendix E).

Selected results in this chapter are shown in exceedance charts for a particular month or set of months, average and percentile monthly data, and sorted by water-year type for a particular month. The probability-of-exceedance charts show values on the y-axis with the percent of time (probability of exceedance) that the value was exceeded. For example, the end-of-September exceedance charts show the probability that the reservoir was able to carry over storage into the next water year for each of the studies. The exceedance charts are also a good measure of trend between the studies, either higher or lower on average. Averages by water-year type are sorted in this chapter based on the 40-30-30 Sacramento Valley Index and show how the average changes from Wet to Critical years. The 60-20-20 San Joaquin Valley Index was used for sorting temperature and CalSim-II output from the Stanislaus and San Joaquin rivers. The percentile graphs show monthly values for the 50^{th}, 5^{th}, and 95^{th} percentiles for a given output variable and were used to indicate how flows are being affected by flood and minimum-flow requirements.

Table 9-6. Long-term Averages and 28-34 Averages From Each of the Five Studies

	Study 3a Today EWA 2004 OCAP BA		Study 6.0 Today EWA: Revised Model/Study 3a Assumptions		Study 7.0 Today EWA		Study 7.1 Near Future Limited EWA		Study 8.0 Future Limited EWA	
End of Sep Storages (TAF)	1922-94	1929-34	1922-2003	1929-34	1922-2003	1929-34	1922-2003	1929-34	1922-2003	1929-34
Trinity	1302	579	1417	718	1424	697	1417	697	1422	735
Whiskeytown	232	213	235	235	234	226	234	226	234	227
Shasta	2590	1176	2867	1682	2893	1659	2772	1400	2772	1558
Folsom	533	387	546	409	560	400	542	381	522	382
New Melones	1380	832	1470	864	1488	887	1497	882	1556	1043
CVP San Luis	243	388	180	133	180	146	218	198	211	289
SWP San Luis	339	359	390	428	444	397	501	359	417	328
Total San Luis	596	893	585	571	633	555	742	572	646	631
Trinity-Shasta-Folsom	4424	2142	4831	2810	4877	2756	4732	2478	4716	2675
River Flows (cfs)										
Trinity Release	925	566	970	566	970	566	972	566	970	566
Clear Creek Tunnel	747	503	738	467	737	516	736	488	737	469
Clear Creek Release	165	95	173	120	168	106	168	103	171	117
Keswick Release	8355	5544	8558	5421	8560	5502	8570	5478	8568	5375
Nimbus Release	3456	1940	3493	1886	3482	1904	3482	1867	3319	1751
Mouth of American	3325	1803	3323	1719	3355	1782	3356	1746	2945	1375
Sac River blw Red Bluff Diversion Dam	10929	6973	11282	6814	11276	6883	11290	6870	11322	6843
Wilkin's Slough	8924	5505	9409	5694	9378	5785	9213	5544	9187	5472
Sac at Freeport	22108	11571	22690	11745	22614	11943	22375	11490	22355	11379
Goodwin Release	600	301	629	156	654	352	662	415	654	366
Stanislaus Mouth	886	488	763	196	790	408	798	471	790	422
SJR Flow w/o Stanislaus	2844	1235	3341	950	3383	1457	3378	1449	3335	1418
Flow at Vernalis	3694	1685	4192	1885	4209	1888	4212	1943	4161	1862
Yolo Bypass	2016	167	2742	129	2720	131	2685	148	2657	158
Mokelumne	869	278	924	281	924	281	918	286	918	286
Spring Creek Tunnel	926	518	934	444	938	506	937	481	935	449

	Study 3a Today EWA 2004 OCAP BA		Study 6.0 Today EWA: Revised Model/Study 3a Assumptions		Study 7.0 Today EWA		Study 7.1 Near Future Limited EWA		Study 8.0 Future Limited EWA	
Delta Parameters										
SWP Banks (cfs)	4172	2368	4393	2468	4453	2662	4601	2760	4646	2679
CVP Banks (cfs)	172	39	131	54	108	42	116	35	110	22
Jones (cfs)	3157	2010	3209	2171	3205	2214	3335	2302	3305	2149
Total Banks (cfs)	4487	2671	4748	2829	4803	3056	4808	2864	4849	2768
Cross Valley Pumping (cfs)	105	20	104	40	93	41	96	35	93	22
Sac Flow at Freeport (cfs)	22108	11571	22690	11745	22614	11943	22375	11490	22355	11379
Flow at Rio Vista (cfs)	18127	7254	19394	7361	19238	7460	19011	7139	18956	7079
Excess Outflow (cfs)	11969	1380	15608	1729	15366	1599	14907	1262	14742	1312
Required Outflow (cfs)	7766	6014	5691	5631	5728	5632	5778	5699	5800	5693
X2 Position (km)	76	82	76	85	76	85	76	85	76	85
Yolo Bypass (cfs)	2016	167	2742	129	2720	131	2685	148	2657	158
Mokelumne Flow (cfs)	869	278	924	281	924	281	918	286	918	286
SJR + Calaveras Flow (cfs)	3887	1755	4351	1911	4354	1899	4356	1955	4308	1876
Modeled Required DO (cfs)	7506	5669	5698	5648	5734	5656	5778	5699	5800	5693
Flow at Georgiana Slough (cfs)	3769	2368	3847	2391	3837	2417	3805	2357	3802	2342
DXC Flow (cfs)	1749	1594	1738	1607	1746	1637	1734	1582	1739	1562
Flow below DXC (cfs)	16590	7609	17106	7747	17031	7889	16836	7551	16814	7474
North Bay Aqueduct (cfs)	54	27	64	47	123	91	120	91	134	92
CCWD (cfs)	171	159	175	185	174	186	174	185	224	234
Total Outflow (cfs)	19735	7394	21300	7359	21094	7231	20685	6961	20542	7005
Total Inflow (cfs)	28881	13772	30707	14067	30612	14255	30335	13878	30239	13698
Old&Middle River (cfs)	--	--	-4833	-3471	-4870	-3717	-4992	-3589	-5031	-3410
QWEST (cfs)	--	--	1892	12	1784	-260	1604	-209	1501	-107
Deliveries (TAF)										
CVP										
North of Delta										
Agriculture	228	32	251	83	254	85	249	73	241	45
Settlement Contracts	1832	1750	1661	1564	1672	1543	1838	1727	1857	1735
M&I	26	27	46	40	80	62	80	62	219	155

	Study 3a Today EWA 2004 OCAP BA		Study 6.0 Today EWA: Revised Model/Study 3a Assumptions		Study 7.0 Today EWA		Study 7.1 Near Future Limited EWA		Study 8.0 Future Limited EWA	
Refuge	101	91	72	62	71	62	72	62	90	78
Total	2199	1899	2029	1748	2077	1753	2239	1923	2407	2013
South of Delta										
Agriculture	1074	161	1104	420	1078	428	1092	354	1089	232
Exchange	841	737	852	741	852	741	852	741	852	741
M&I	119	84	124	98	123	100	127	98	127	92
Refuge	274	240	294	246	295	252	296	253	273	234
Total**	2503	1406	2558	1689	2533	1702	2550	1624	2525	1483
SWP										
Allocation	2798	1449	3343	1583	3369	1539	3276	1571	3251	1526
Table A	2798	1449	2967	1508	2565	1394	2513	1457	2996	1455
Article 56	0	0	0	0	342	136	340	107	113	38
Article 21	162	173	291	200	444	384	470	347	285	348
Table A + Art 56	2798	1449	2967	1508	2907	1531	2853	1564	3109	1493
Table A + Art 56 + Art 21	2960	1622	3258	1708	3350	1915	3323	1911	3394	1841
Anticipated Carryover	0	0	0	0	485	71	458	40	181	4
Allocations (%)										
CVP Allocation										
North of Delta										
Agriculture	69%	18%	74%	31%	75%	34%	73%	29%	69%	21%
M&I	87%	64%	91%	74%	91%	74%	90%	73%	89%	67%
South of Delta										
Agriculture	60%	18%	61%	31%	61%	33%	60%	29%	60%	21%
M&I	86%	64%	87%	74%	87%	74%	87%	73%	87%	67%
SWP										
All SWC	68%	35%	79%	38%	80%	36%	77%	37%	77%	36%

CVPIA 3406 (b)(2)

This section analyzes water use for the CVPIA Section 3046 (b)(2), known as "(b)(2)" actions. Results from the CalSim-II accounting describe the long-term average (b)(2) costs for each study by water year type (see Table 9-8, Table 9-9, and Table 9-10). The long-term average annual cost of (b)(2) water use ranges from 671 taf annually to 689 taf annually.

Simulated (b)(2) costs for individual years (1922 – 2003) are presented in Figure 9-8, Figure 9-9,

Figure 9-10, and

Figure 9-10. These plots show the Water Quality Control Plan (WQCP) costs (non-discretionary) that are accounted up to 500 taf per year and discretionary or (b)(2) costs. The (b)(2) allocation, based on hydrologic conditions, are also noted for each year. CalSim-II does not use any forecasting algorithm for overall (b)(2) costs. This also results in over- and under-utilization of the allocated amount of (b)(2) water. The years when the (b)(2) costs are less than the allocated amount are generally Wet years, because flood releases are nearly identical between the D-1485 baseline and (b)(2) annual simulations, and VAMP export curtailments are up to the 2:1 ratio when non-VAMP flows are greater than 8,600 cfs.

An additional measure of (b)(2) performance is the probability of exceeding the 200 taf target during the October–January period. The probability of exceeding 200 taf October – January for Study 6.0, Study 7.0, Study 7.1, and Study 8.0 is 20%, 17%, 15%, and 25% respectively (Figure 9-13, Figure 9-14, and Figure 9-13). Exceeding the 200-taf target is generally a result of the model taking high-cost upstream actions (at Nimbus and Keswick) before the accounting algorithms can reduce costs for this period. Another reason for high costs during this period is Delta salinity requirements during Dry and Critical years in the WQCP accounting. Similar percent exceedence graphics are presented for the total annual WQCP and (b)(2) costs in Figure 9-17, Figure 9-18, and Figure 9-16.

Table 9-11 shows the average required costs for a (b)(2) export action and what the simulated (b)(2) operation was able to support with the water available in the account and anticipated WQCP costs for Studies 6.0, 7.0, 7.1, and 8.0. Study 8.0 shows a shift in actions where June Ramping and May Shoulders slightly increased and April-May VAMP slightly decreased. However, the frequency of (b)(2) releases and export reductions are similar between Studies 6.0, 7.0, 7.1, and 8.0. This is presented in Table 9-12 which lists the percentage of times that the simulated actions were triggered under the assumptions for taking an action.

Table 9-7 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 6.0 Today

Study 6.0	Oct	Nov	Dec	Jan	Oct-Jan Sub total	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	5	8	8	1	22	20	14	5	8	64	11	30	35	208
WQCP Export Cost	4	3	8	2	17	13	25	44	19	3	23	68	2	214
WQCP Total Cost	9	10	16	3	39	33	40	48	27	67	33	97	37	421
(b)(2) Release Cost	20	38	48	30	136	28	40	38	29	49	13	22	19	375
(b)(2) Export Cost	4	1	1	2	7	14	27	79	61	11	29	72	6	306
(b)(2) Total Cost	23	39	49	32	143	42	68	117	90	61	43	94	25	682

Table 9-8 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 7.0 Today

Study 7.0	Oct	Nov	Dec	Jan	Oct-Jan Subtotal	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	14	19	30	15	79	14	9	7	16	60	10	28	41	264
WQCP Export Cost	1	2	6	5	13	17	27	46	18	3	41	81	3	249
WQCP Total Cost	15	21	36	20	93	31	35	53	35	63	50	109	45	513
(b)(2) Release Cost	16	35	49	32	133	18	25	36	33	51	12	28	26	361
(b)(2) Export Cost	2	1	6	3	13	15	28	77	62	9	43	85	6	338
(b)(2) Total Cost	18	36	55	36	145	33	53	113	95	60	55	112	32	699

Table 9-9 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 7.1 Near Future

Study 7.1	Oct	Nov	Dec	Jan	Oct-Jan Subtotal	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	13	24	26	19	82	19	8	7	13	62	7	29	32	260
WQCP Export Cost	2	2	9	5	18	21	32	42	16	5	26	68	2	229
WQCP Total Cost	16	26	35	24	101	40	40	49	30	66	33	97	34	489
(b)(2) Release Cost	15	33	44	29	120	24	25	20	18	48	8	28	20	312
(b)(2) Export Cost	2	1	8	5	16	23	41	70	65	11	32	70	5	332
(b)(2) Total Cost	17	33	52	34	136	47	66	90	83	59	40	98	25	643

Table 9-10 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 8.0 Future

Study 8.0	Oct	Nov	Dec	Jan	Oct-Jan Subtotal	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	12	26	27	21	87	16	11	4	14	59	10	20	35	256
WQCP Export Cost	2	1	7	5	15	21	28	40	20	8	22	67	2	224
WQCP Total Cost	14	28	34	26	103	38	38	44	34	66	32	88	38	480
(b)(2) Release Cost	15	37	44	31	127	26	28	20	19	50	10	23	20	322
(b)(2) Export Cost	3	1	7	4	15	18	37	64	68	13	28	70	5	318
(b)(2) Total Cost	18	38	51	36	142	43	65	84	86	63	38	93	25	640

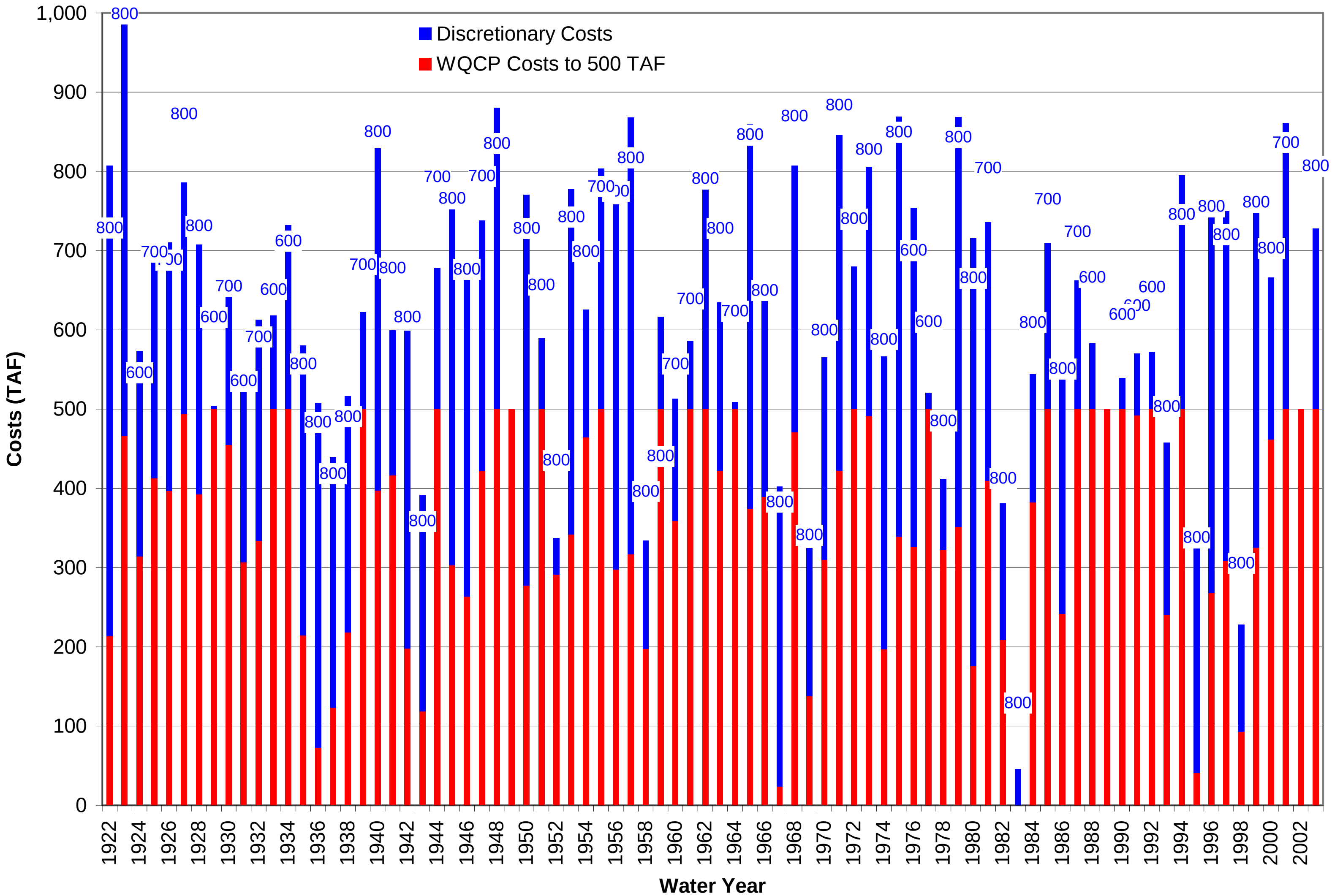


Figure 9-7 Study 6.0 Total Annual WQCP and Total (b)(2) Costs

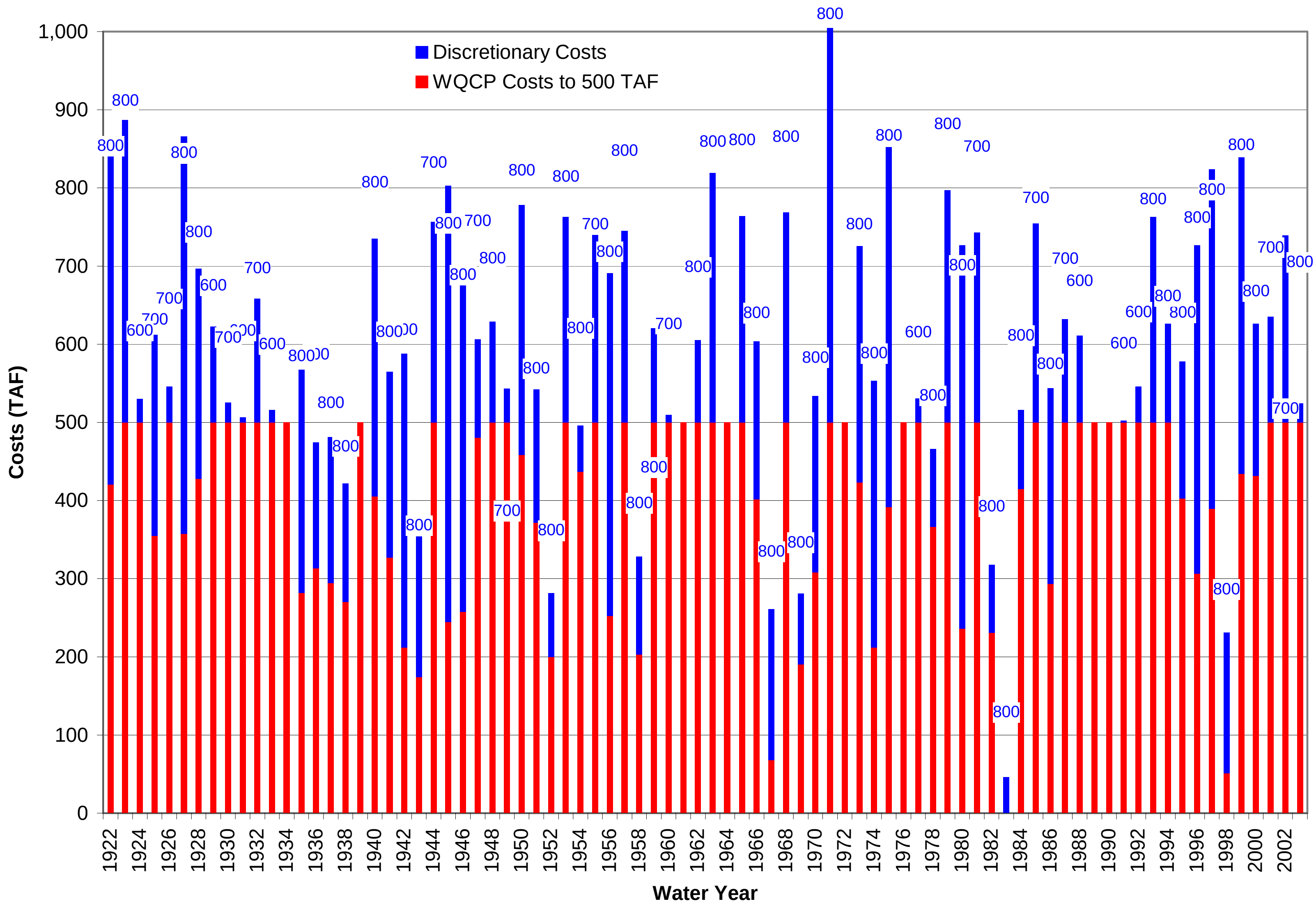


Figure 9-8 Study 7.0 Total Annual WQCP and Total (b)(2) Costs

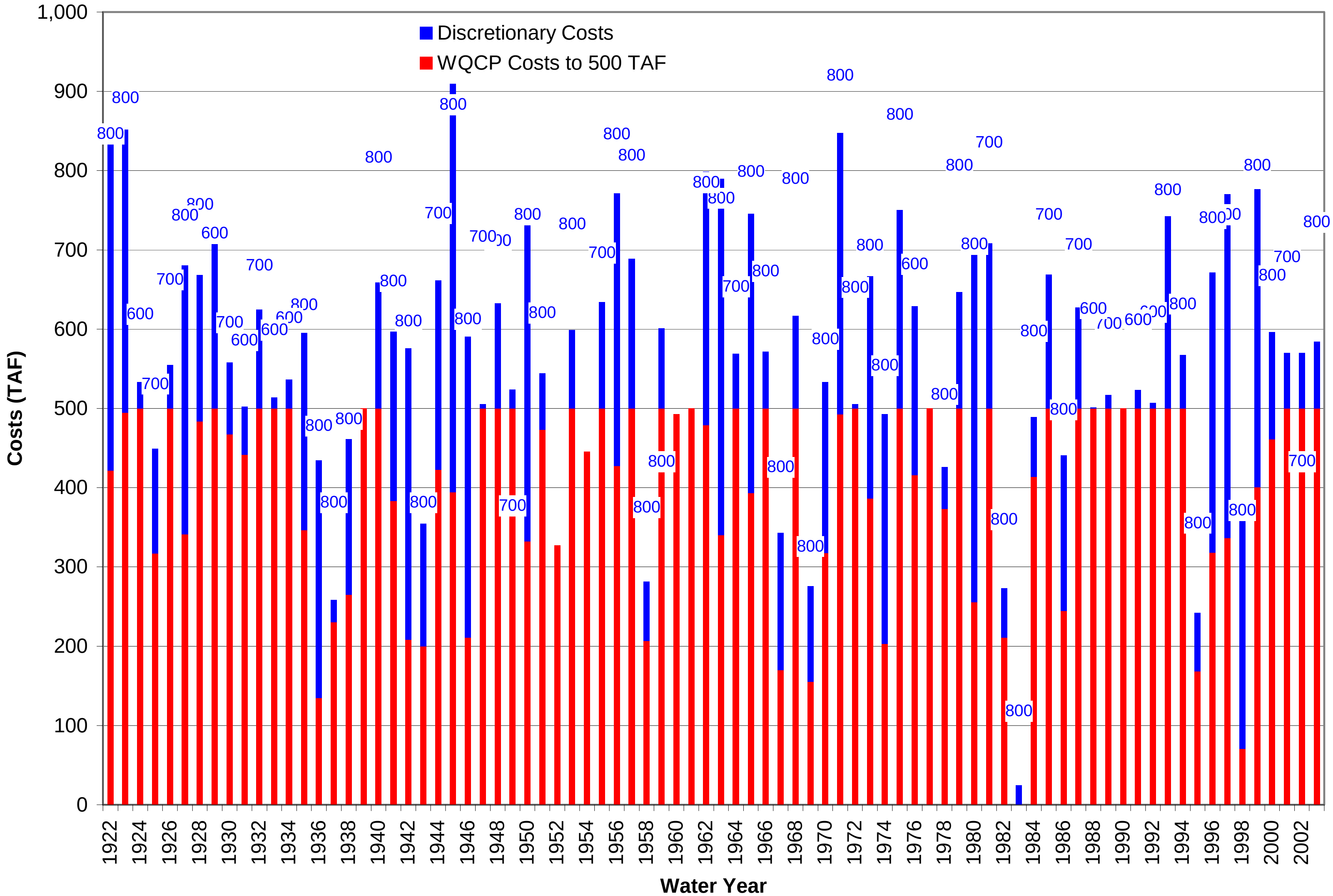


Figure 9-9 Study 7.1 Total Annual WQCP and Total (b)(2) Costs

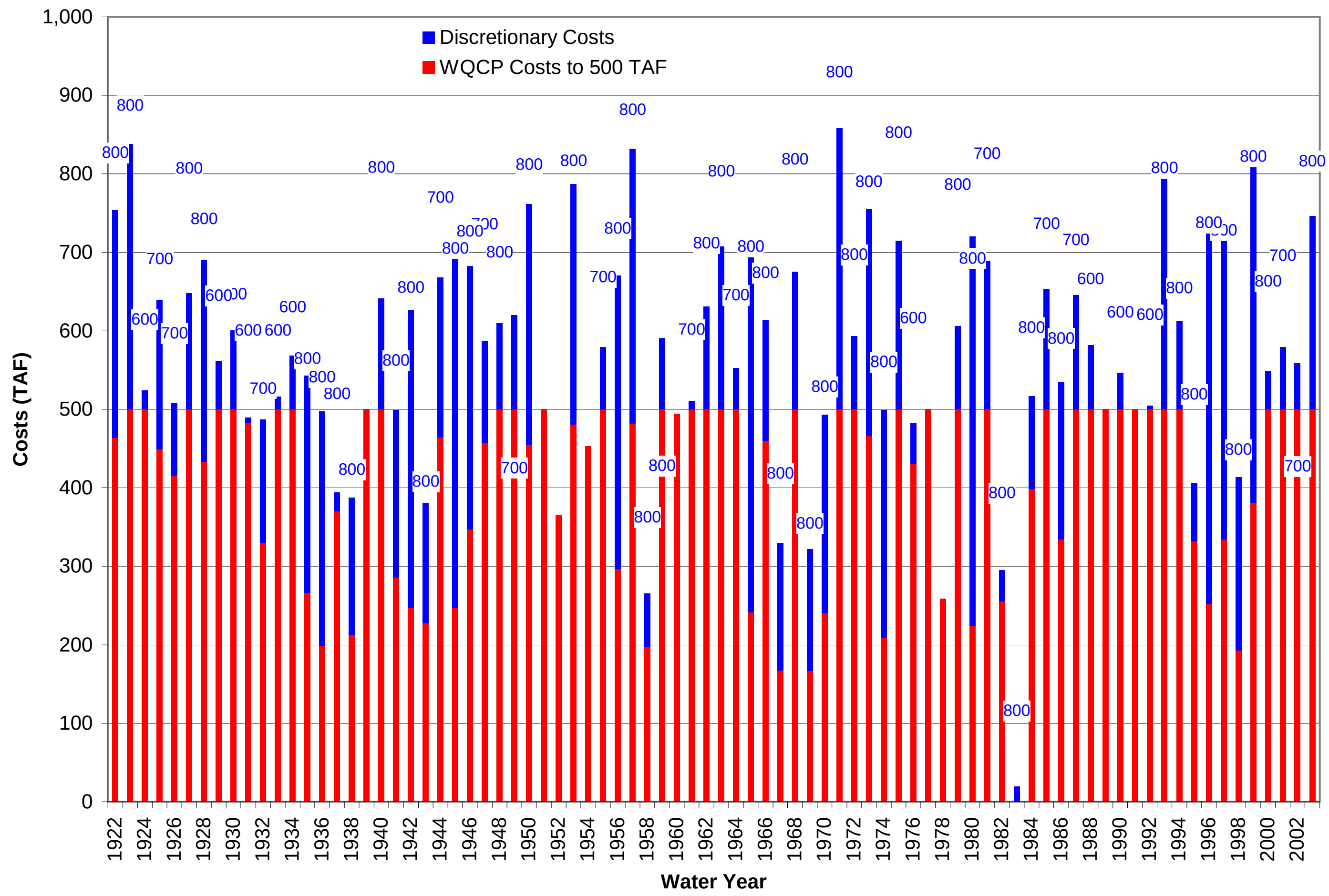


Figure 9-10 Study 8.0 Total Annual WQCP and Total (b)(2) Costs

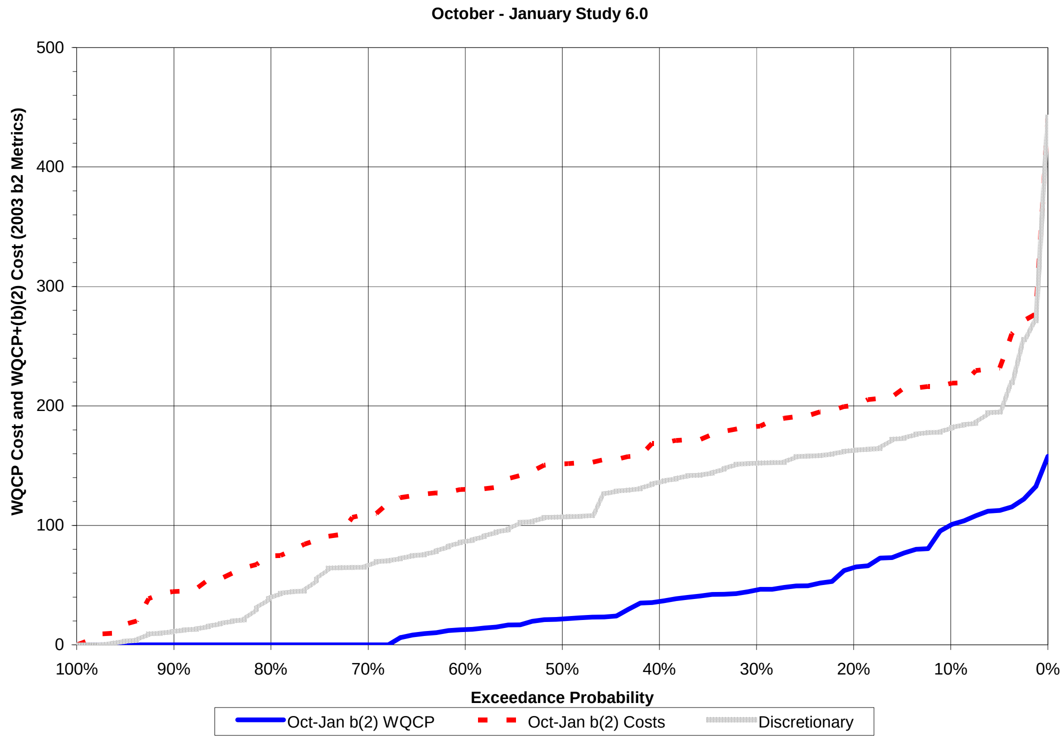


Figure 9-11 Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 6.0

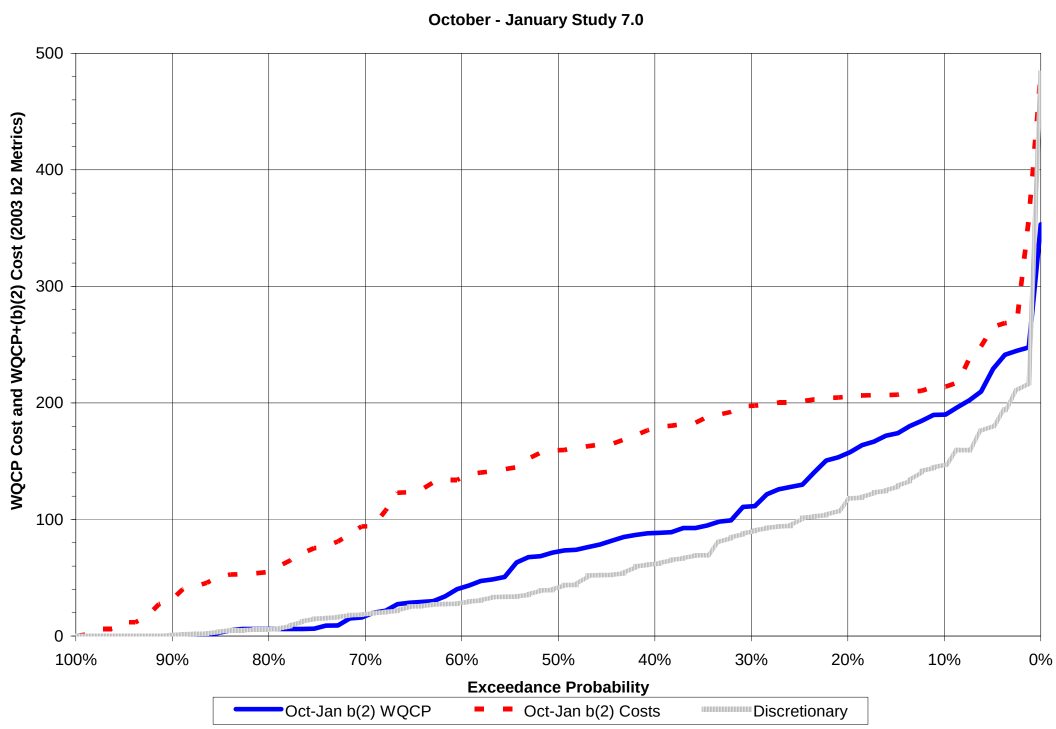


Figure 9-12 Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 7.0

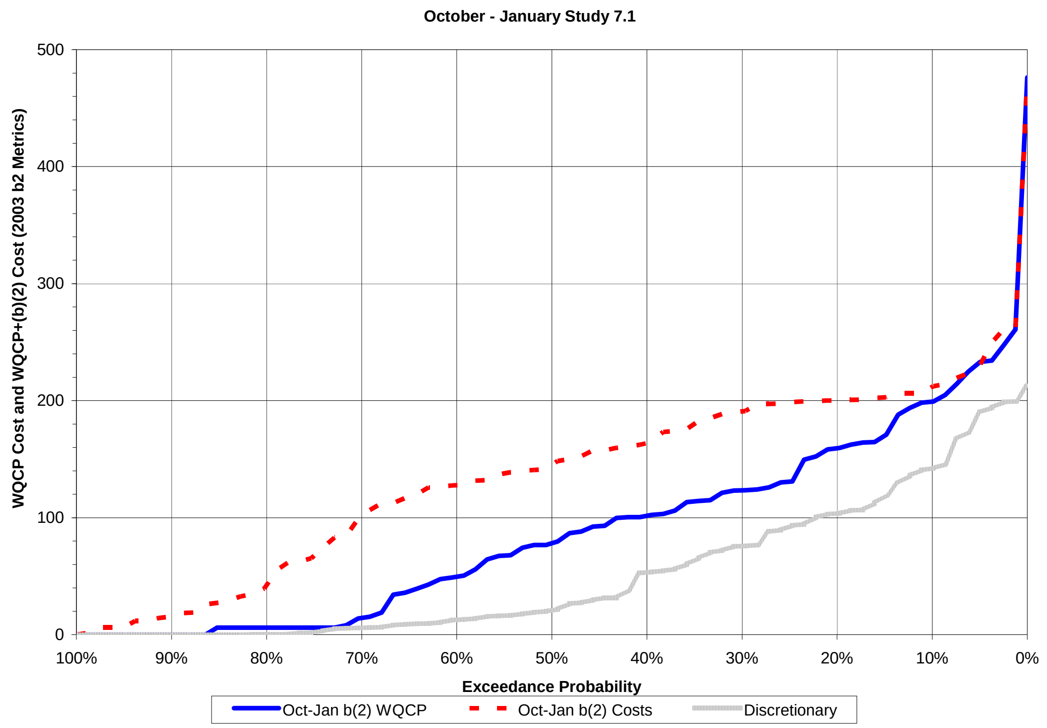


Figure 9-13 Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 7.1

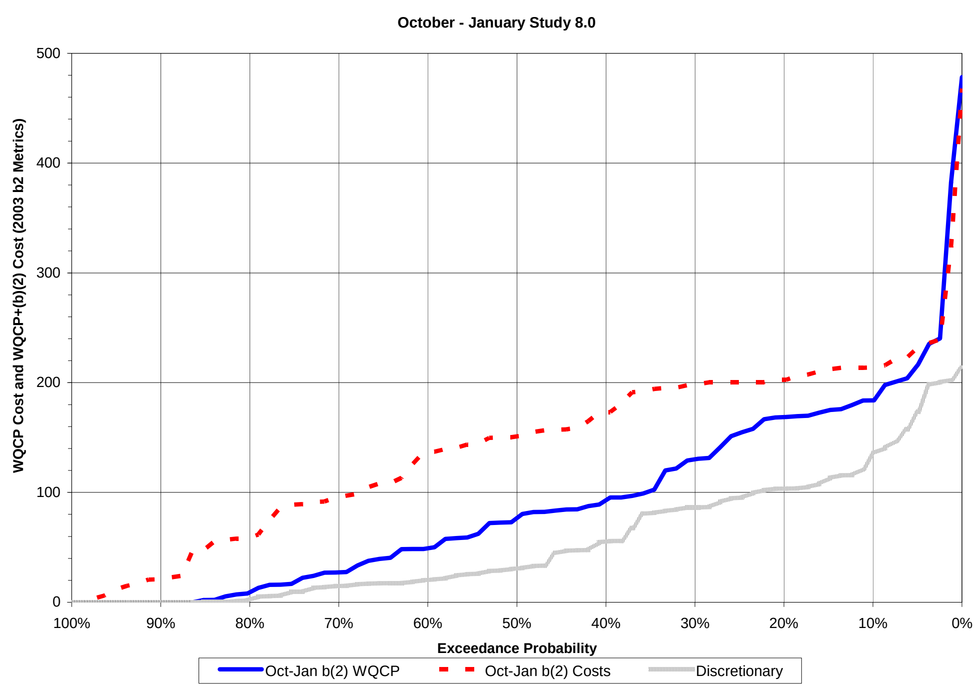


Figure 9-14. Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 8.0

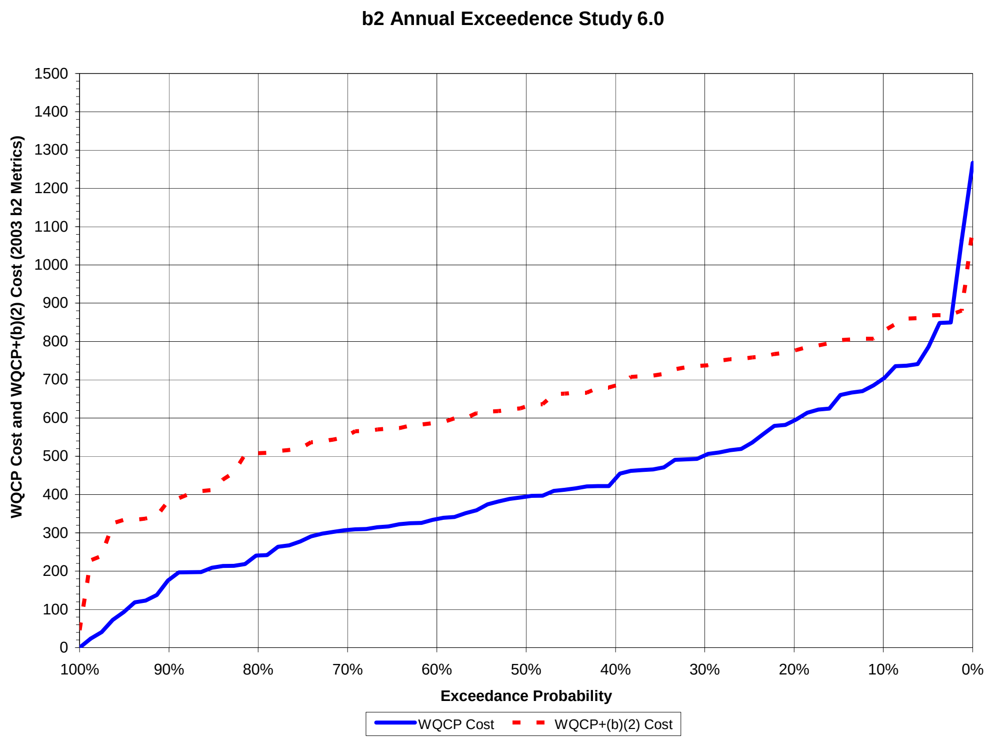


Figure 9-15 Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 6.0

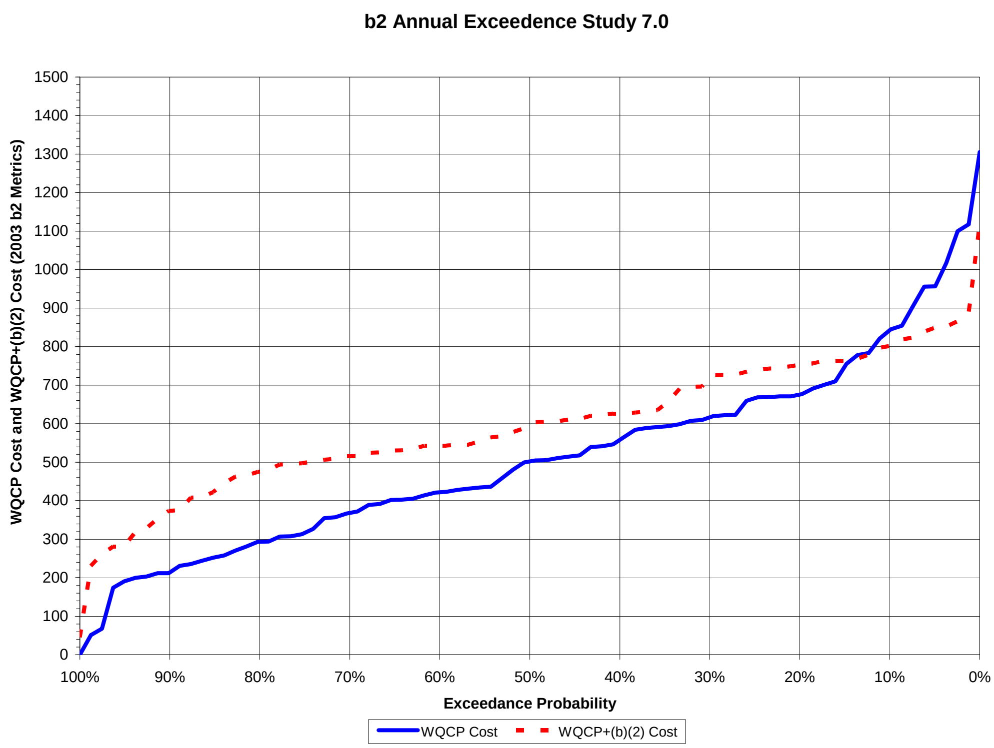


Figure 9-16. Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 7.0

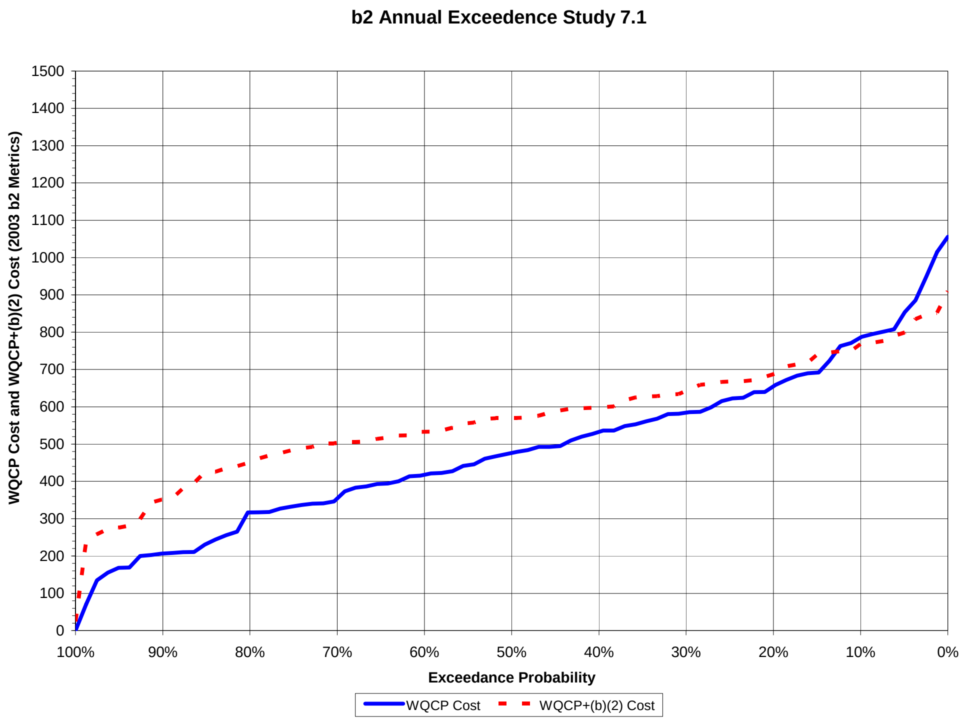


Figure 9-17. Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 7.1

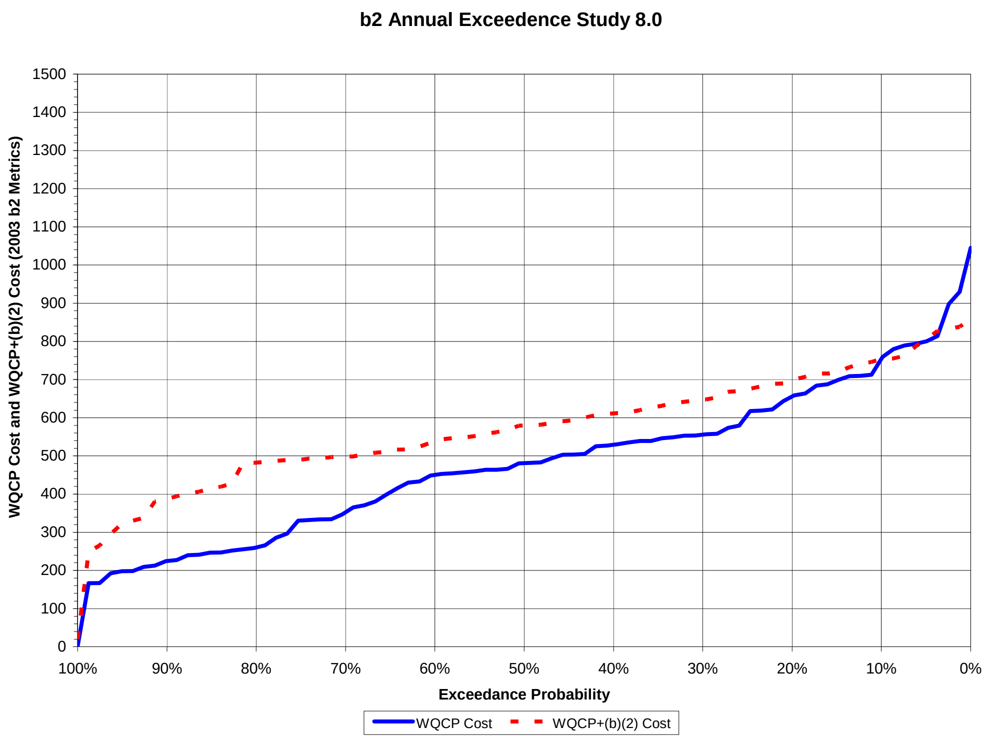


Figure 9-18. Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 8.0

Table 9-11. Total (b)(2) Water Requested for Export Actions Versus Amount of (b)(2) Water Used

	Total Water Requested			Simulated (b)(2) Water Used		
Study 6.0	**Apr-May VAMP**	**May Shoulder**	**June Ramping**	**Apr-May VAMP**	**May Shoulder**	**June Ramping**
Average	**104**	**32**	**12**	**104**	**22**	**8**
W	**85**	**42**	**16**	**85**	**30**	**8**
AB	**127**	**35**	**12**	**127**	**23**	**8**
BN	**125**	**30**	**11**	**125**	**26**	**11**
D	**111**	**26**	**9**	**111**	**14**	**12**
C	**88**	**18**	**8**	**88**	**8**	**1**
Study 7.0	**Apr-May VAMP**	**May Shoulder**	**June Ramping**	**Apr-May VAMP**	**May Shoulder**	**June Ramping**
Average	102	38	14	102	31	8
W	83	42	16	83	48	8
AB	128	42	14	128	33	13
BN	122	33	11	122	23	12
D	110	34	11	110	15	5
C	84	37	15	84	21	5
Study 7.1	**Apr-May VAMP**	**May Shoulder**	**June Ramping**	**Apr-May VAMP**	**May Shoulder**	**June Ramping**
Average	99	39	15	99	31	10
W	79	42	18	79	50	11
AB	136	42	14	136	27	13
BN	126	40	16	126	26	12
D	97	41	15	97	24	12
C	79	26	7	79	11	1
Study 8.0	**Apr-May VAMP**	**May Shoulder**	**June Ramping**	**Apr-May VAMP**	**May Shoulder**	**June Ramping**
Average	97	40	15	97	33	11
W	80	42	16	77	48	9
Study 8.0	**Apr-May**	**May**	**June**	**Apr-May**	**May**	**June**

	Total Water Requested			Simulated (b)(2) Water Used		
	VAMP	Shoulder	Ramping	VAMP	Shoulder	Ramping
AB	137	42	14	137	29	13
BN	122	37	15	122	32	13
D	96	41	15	96	25	16
C	74	33	12	74	16	4

Table 9-12. Percent That Possible Occurrences Action Was Triggered

Actions	Study 6.0	Study 7.0	Study 7.1	Study 8.0
Keswick Releases	71%	67%	73%	74%
Whiskeytown Releases	98%	97%	97%	98%
Nimbus Releases	74%	100%	100%	100%
Dec-Jan Export Cuts	NA	NA	NA	NA
VAMP Export Cuts	100%	100%	100%	100%
Late May Export Cuts	76%	89%	91%	93%
Jun Export Cuts	63%	73%	79%	78%
Early Apr Export Cuts	NA	NA	NA	NA
Feb-Mar Export Cuts	NA	NA	NA	NA

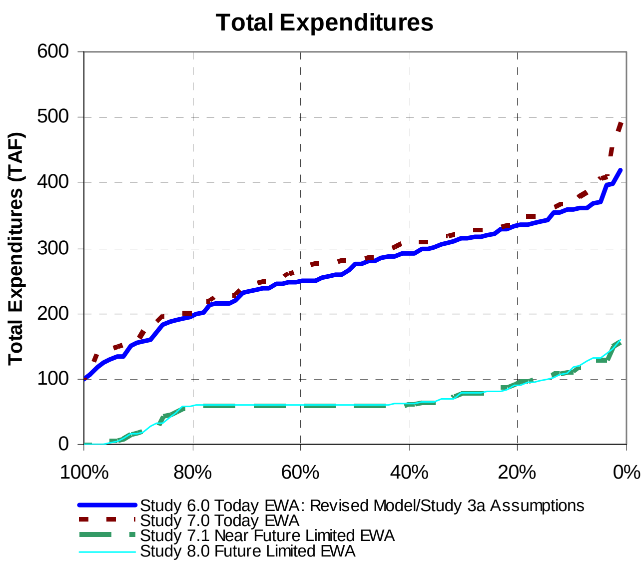
Environmental Water Account

This section summarizes the EWA operations for Study 6.0 (i.e., Today EWA: Revised Model/Study 3a Assumptions), Study 7.0 (i.e., Today EWA), Study 7.1 (i.e., Near Future Limited EWA), and Study 8.0 (i.e., Future Limited EWA). Operations are summarized for the following categories:

- Annual costs of EWA actions (i.e., expenditures) measured as export reductions
- Delivery debt status and payback (i.e., adherence to the No Harm Principle)
- Carryover debt conditions from year-to-year
- Annual accrual of EWA assets to mitigate impacts of EWA actions (i.e., water purchases, (b)(2) gains, use of JPOD capacity, wheeling of backed-up water)
- Spilling of carryover EWA debt situated at SWP San Luis
- Annual costs specific to each EWA action measured as export reductions

The annual EWA expenditures for the simulation are shown on Figure 9-19, first as the sum of expenditures associated with winter and spring EWA actions, and second as the expenditures only associated with the spring VAMP action (i.e., EWA Action 3). The Full EWA had annual expenditures ranging from 100,000 af to 600,000 af. whereas both of the Limited EWA studies had annual expenditures ranging from 0 af to 77,000 af. Looking at the VAMP costs it can be seen that for the Full EWA the range of expenditure is 0 af to 235,000 af, but for the Limited EWA nearly all of the costs are associated with EWA.

Another way of viewing annual EWA expenditures is to consider their year-type-dependent averages. The Sacramento River Basin 40-30-30 index was used to classify and sort years. Average annual expenditures by year type are listed in Table 9-13. Comparing Full EWA (Study6.0 and Study 7.0) and Limited EWA (Study 7.1 and Study 8.0) results, the year-type-dependent averages are quite different.



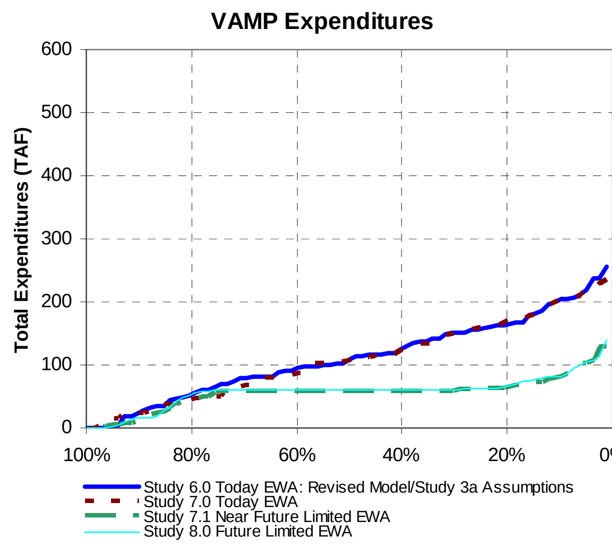
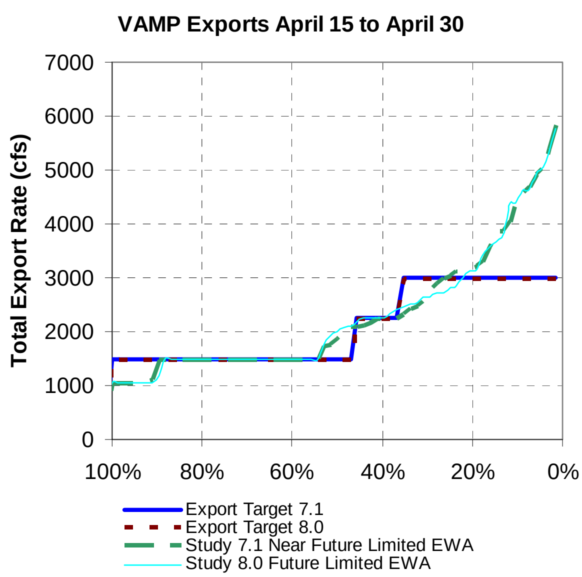


Figure 9-19. Annual EWA expenditures simulated by CalSim-II, measured in terms of export reductions from exports under the EWA Regulatory Baseline relative to exports with EWA operations.

Table 9-13. Annual EWA Expenditures Simulated by CalSim-II, Averaged by Hydrologic Year Type, Defined According to the Sacramento River 40-30-30 Index.

Hydrologic Year Type	Study 6.0 (TAF)	Study 7.0 (TAF)	Study 7.1 (TAF)	Study 8.0 (TAF)
Average	264	279	66	66
Wet	293	315	63	63
Above Normal	306	319	70	77
Below Normal	254	268	69	76
Dry	255	277	88	77
Critical	183	175	34	34

Under limited EWA there are times when the VAMP export reductions are not fully covered by assets acquired from the Yuba Accord and other operational assets. However, for the most part VAMP export reductions could be met most of the time. Figure 9-20 shows exceedance plots of the April 15 to April 30 and May 1 to May 15 periods that cover the assumed time for the VAMP in the model. The figure shows the amount of time in which the total exports meet the export limits described in the San Joaquin River Agreement in years when a Vernalis flow target is specified. Since the agreement does not specifically prescribe an export limit for years in which the San Joaquin River flow is greater than 7000 cfs these simulated years are not included in the figure. In addition, when the Vernalis flow target is 7000 cfs, the SJRA specifies two possible export rates, 1500 cfs and 3000 cfs. For the purposes of Figure 9-20 an export limit of 3000 cfs was assumed for every simulated year when the Vernalis target is 7000 cfs.



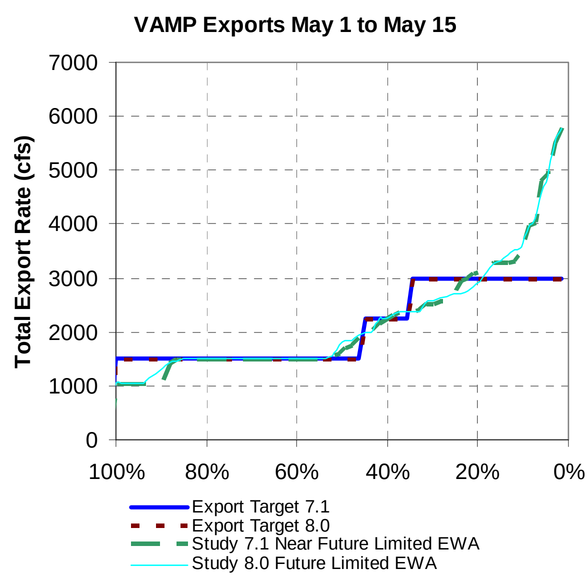


Figure 9-20Combined Banks and Jones export rate simulated by CalSim-II, during the April and May VAMP period compared to export target flow specified in the San Joaquin River Agreement.

The measure of "deliveries debt payback" is the key indicator of whether the simulated EWA operations adhere to the No Harm to Deliveries principle set forth in the CALFED ROD. In CalSim-II modeling, SOD delivery debt is assessed in the month after it occurs.

A debt is to be repaid in full upon assessment through dedication of an EWA asset available SOD (either as a SOD purchase planned for that month, a wheeled NOD asset planned for that month, or an EWA San Luis storage withdrawal that month). Instances when SOD delivery debt could not be repaid in full can be seen through post-simulation analysis of CalSim-II results. As shown in Table 9-14 there were no instances of not adhering to the "No Harm Principle" for Study 7.0, Study 7.1 and Study 8.0. Study 7.1 and Study 8.0 assumed a Limited EWA and no debt was allowed to accumulate.

Table 9-14. Instances of not Adhering to the EWA "No Harm Principle" (i.e., not repaying delivery debt in full upon assessment), Simulated by CalSim-II.

Delivery Debt Account	Study 6.0 (Full EWA)	Study 7.0 (Full EWA)	Study 7.1 (Limited EWA)	Study 8.0 (Limited EWA)
CVP South of Delta	None	None	No debt allowed	No debt allowed
SWP South of Delta	None	None	No debt allowed	No debt allowed

A key feature of simulated and real EWA operations that enable increased flexibility to mitigate the impacts of EWA actions is the allowance for carryover debt. In the CalSim-II modeling, because of the model structure, Figure 9-3, the annual interruption of the simulated EWA operational baseline necessitates special measures to account for carryover debt relative to debt caused by this year's actions (i.e., "new debt" in CalSim-II semantics). The result of these measures is separate debt accounts for carryover and new debt. Unpaid new debt ultimately gets rolled over into the carryover debt account, which can represent one or more years of unpaid debt.

The rollover of new debt into the carryover debt account occurs in November. Results on carryover debt conditions at total CVP/SWP San Luis are shown on Figure 9-21 for the 82 Octobers and Novembers simulated. These carryover debt conditions are at a maximum in November, after which they are managed to a minimum in October through dedication of physical EWA assets available SOD or spilling of carryover debt at SWP San Luis.

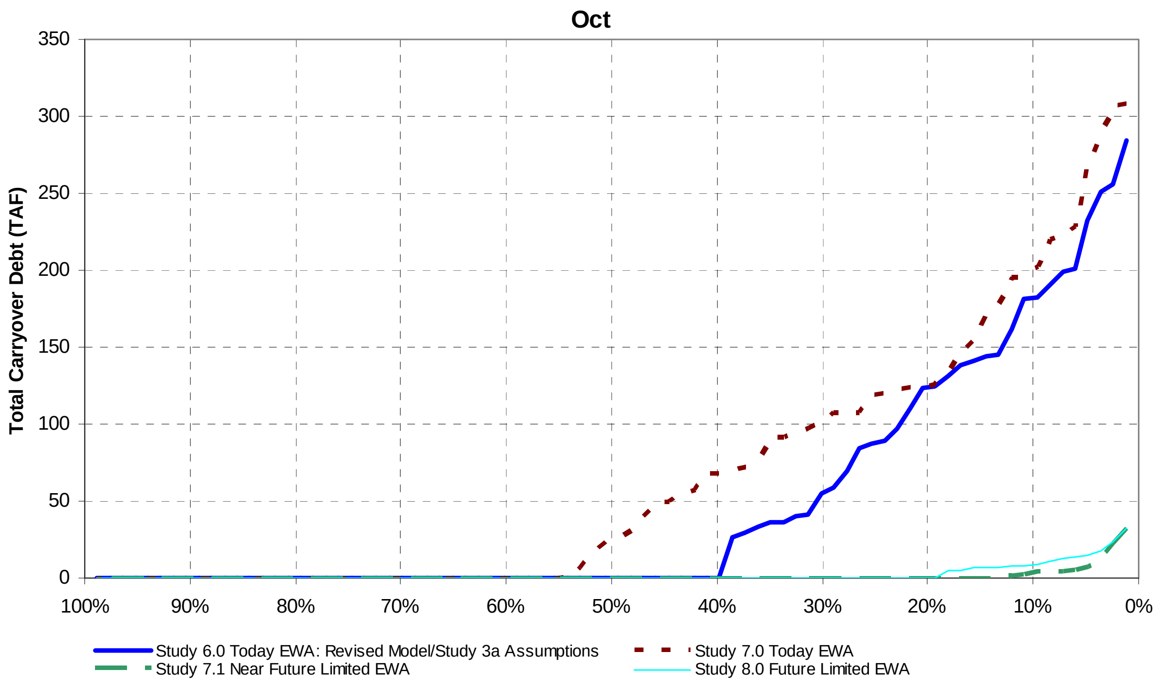


Figure 9-21. Combined Carryover Debt at CVP and SWP San Luis, Simulated in CalSim- II, at the End (Oct) and Start (Nov) of the Carryover Debt Assessment Year

The comparative ranges of acquired EWA assets under Full EWA (Study 6.0 and Study 7.0) and Limited EWA (Studies 7.1 and 8.0) are summarized on Figure 9-22. In Figure 9-22 the "Total Acquired Assets" includes water purchases and operational assets (i.e., EWA acquisition of 50 percent of SWP gains from B2 releases, EWA conveyance of Delta Surplus flows using 50 percent of JPOD capacity or summer dedicated capacity, EWA conveyance of backed-up water caused by Spring EWA actions on exports.

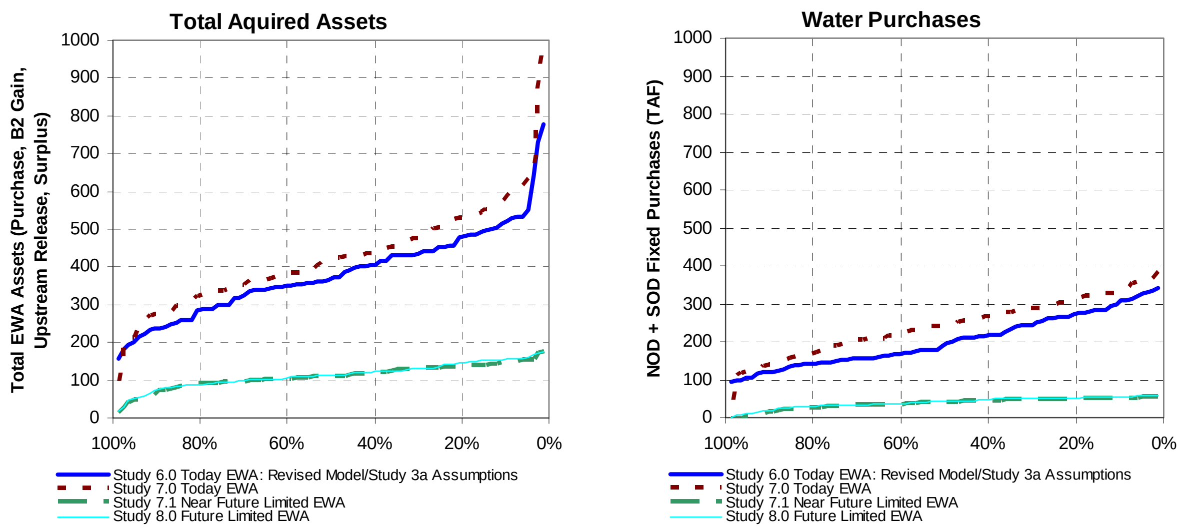


Figure 9-22. Annual EWA assets simulated in CalSim-II.

A unique tool for managing carryover debt at SWP San Luis is debt spilling, described earlier. In CalSim-II, carryover debt conditions need to be present and severe enough to trigger the use of this tool under the spill conditions that were outlined earlier. Also note that there is a semantics difference between what is called "spill" in CalSim-II and what is called "spill" by EWAT. CalSim-II only designates erasing of carryover debt at SWP San Luis, or reservoir filling in NOD reservoirs as "spilling" debt; it does not designate "pumping-to-erase" new debt at San Luis as "spill," even though this is a term sometimes used by EWAT. That distinction noted, the occurrence of carryover debt spilling at SWP San Luis is depicted on Figure 9-23.

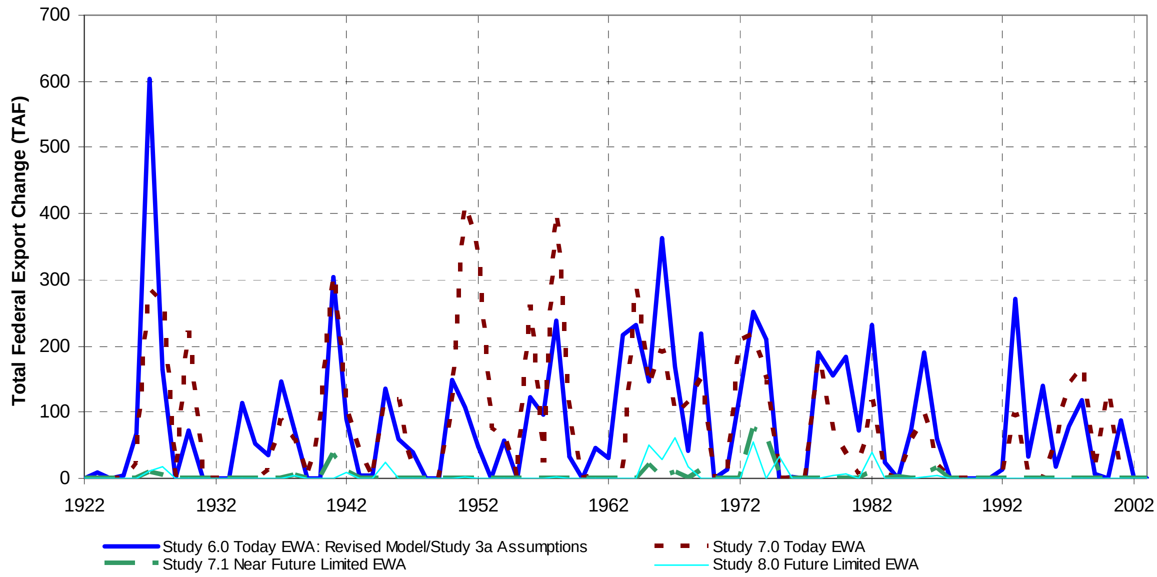


Figure 9-23. Annual Carryover-debt Spilling at SWP San Luis, Simulated in CalSim-II.

EWA action-specific expenditures for Winter Export Reductions are expected to be 50,000 af for each month in which they are implemented, according to modeling assumptions. Generally, this is the case, as indicated by simulated export reductions measured between Step 4 and Step 5 in Full EWA study (Figure 9-24). The action is always taken in December and January, and it is also taken in February if the Sacramento River 40-30-30 Index defines the year to be Above Normal or Wet. Simulation results show that export reductions are always as expected for January and February and nearly always as expected for December (approximately 95 percent of the years).

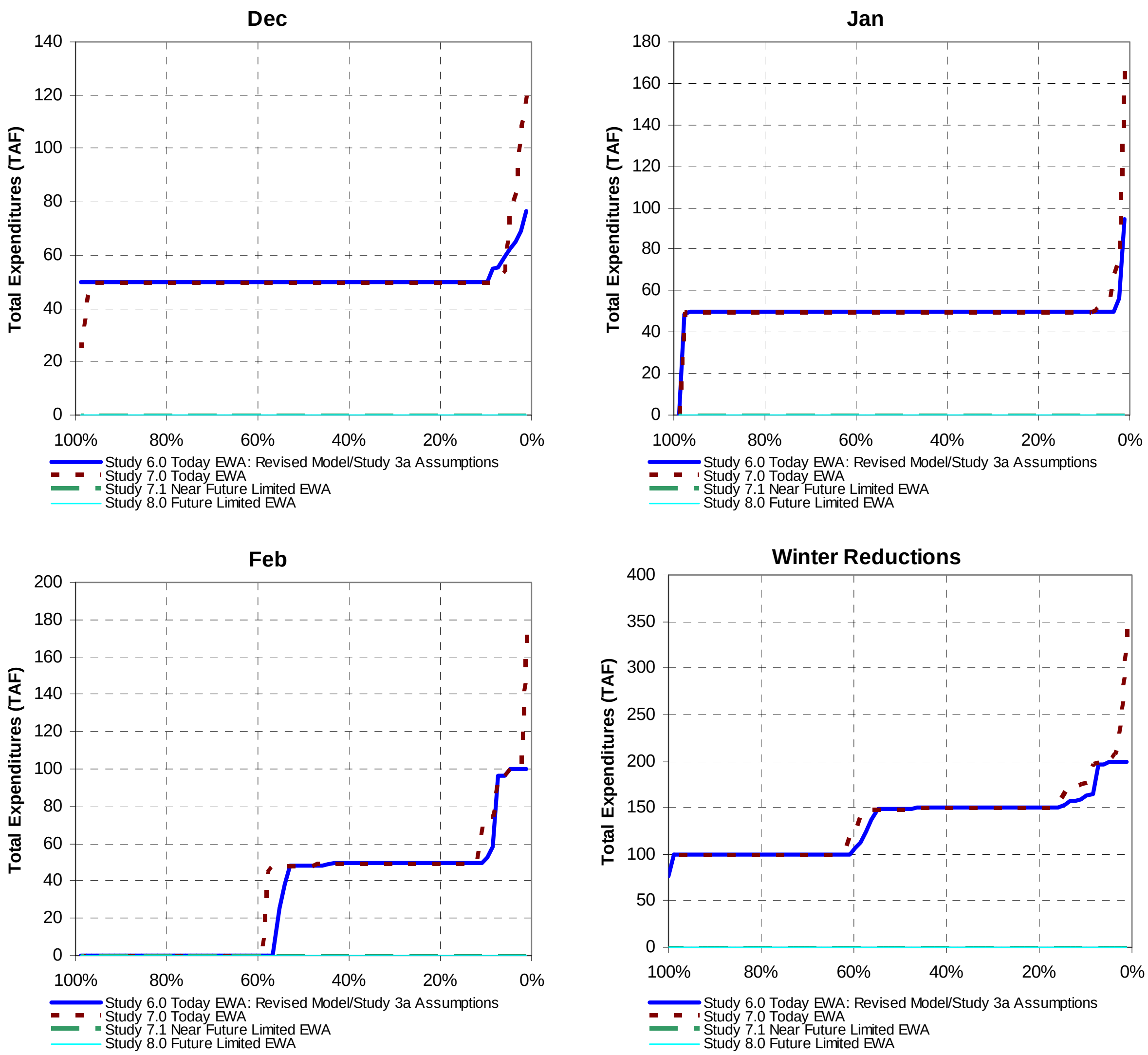


Figure 9-24. Simulated Export Reductions Associated with Taking EWA Action 2 (i.e., Winter Export Reductions). Note that Export Reductions for Studies 7.1 and 8.0 are zero.

Expectations for spring actions expenditures are more difficult to predict prior to simulation compared to expenditures for winter actions. This is because spring actions are not linked to spending goals, but are instead linked to target export restriction levels related to VAMP. Results show that action-specific export costs for spring actions are slightly higher in the Full EWA study compared to the Limited EWA studies (Figure 9-25 through Figure 9-27). Moreover, the frequency of implementing June export reductions only occurs in the Full EWA.

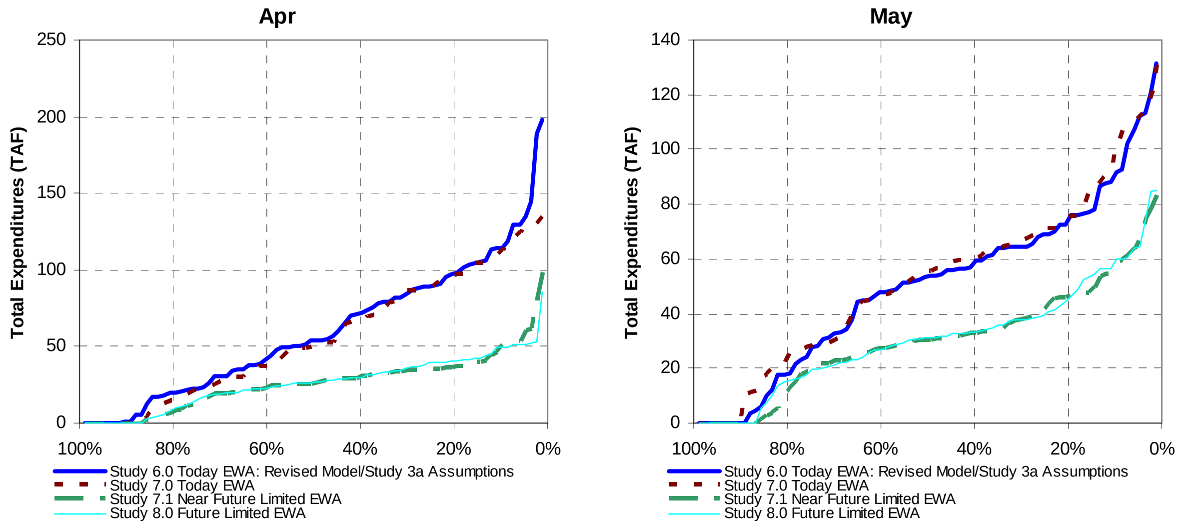


Figure 9-25 – Simulated Export Reductions Associated with Taking EWA Action 3 (i.e., VAMP-related restrictions).

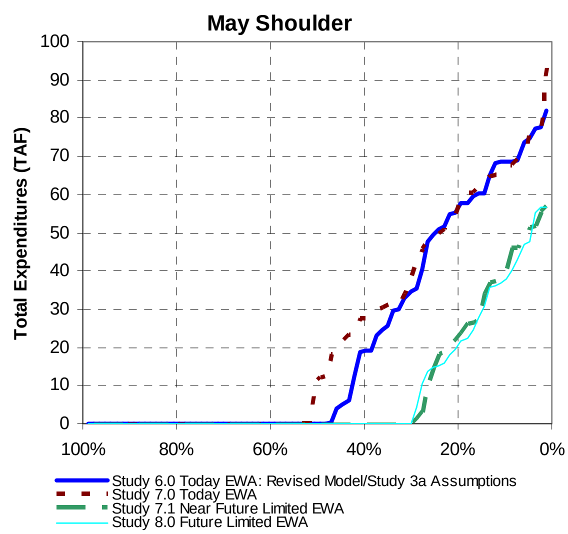


Figure 9-26 – Simulated Export Reductions Associated with Taking EWA Action 5 (i.e., extension of VAMP-related restrictions into May 16–May 31 (i.e., the May Shoulder)).

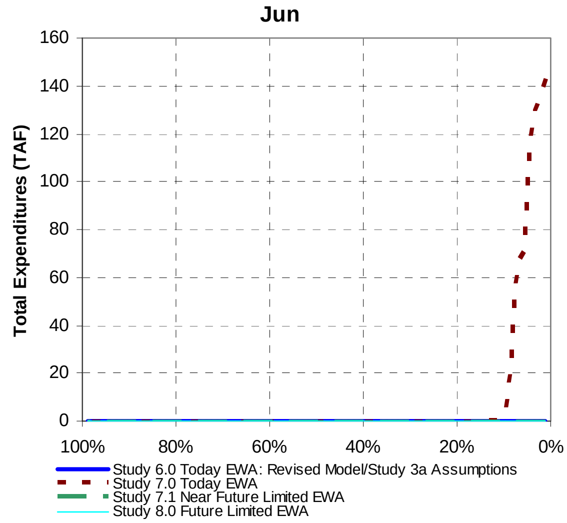


Figure 9-27– Simulated Export Reductions Associated with Taking EWA Action 6 (i.e., representation of June "ramping" from May Shoulder restriction to June Export-to-Inflow restriction).

The additional 500 cfs summer (July through September) capacity is an important element of the full EWA, limited EWA, and theYuba Accord. Assets acquired North of the Delta from theYuba Accord, or stored in upstream reservoirs can be pumped to repay previous fishery imposed export reductions. Much of the time this repayment would need to occur before the end of September to reduce the chance of impacting project deliveries. Figure 9-28 shows the simulated use of the additional 500 cfs and the total assets pumped through the use of this additional capacity. Generally, the limited EWA studies use the full capacity less than 25 percent of the time, while the full EWA studies use the full capacity less than 35 percent of the time.

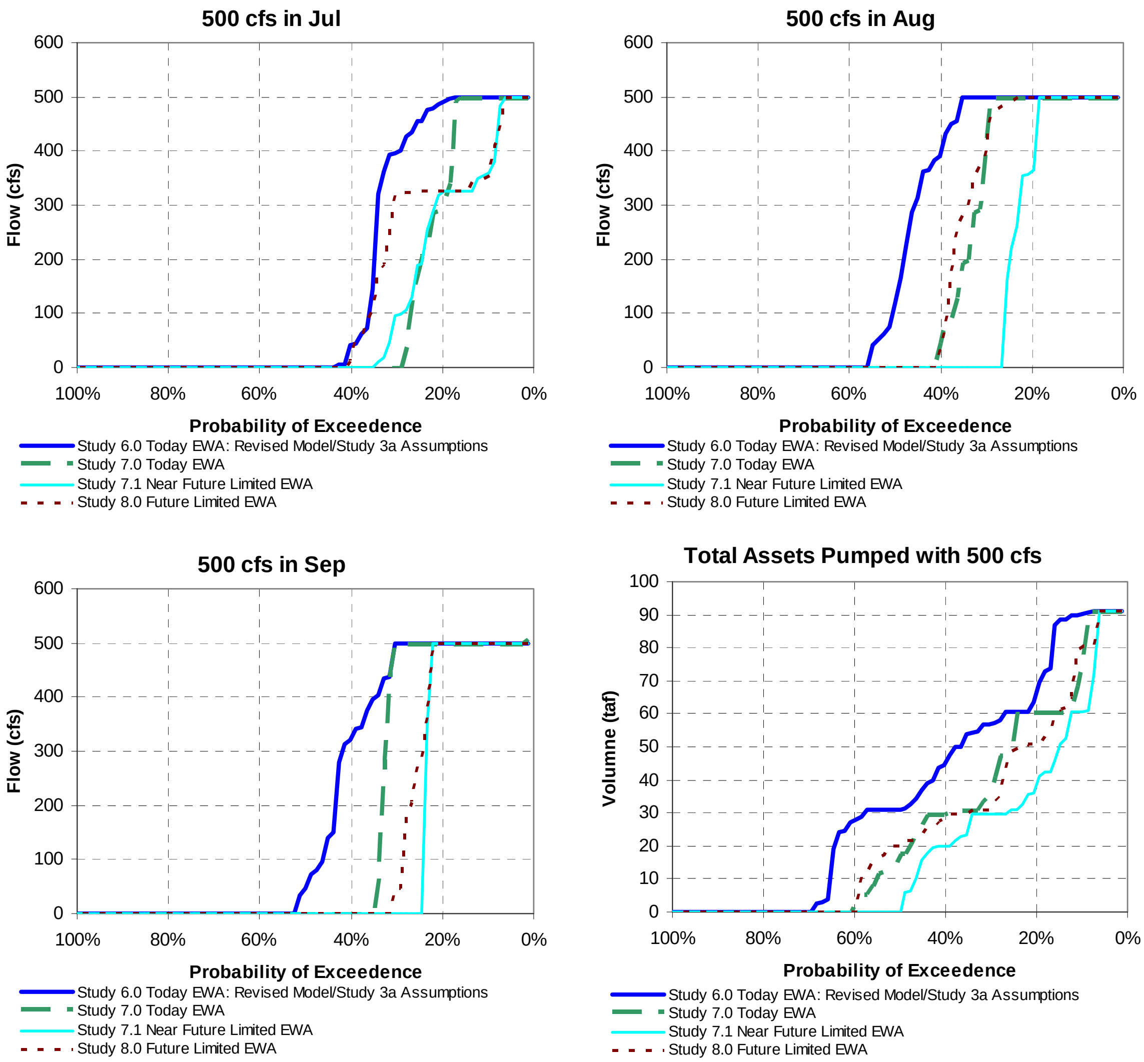


Figure 9-28 Simulated use of additional 500 cfs Banks fishery capacity in summer months (Jul, Aug, and Sep) and total assets pumped using additional capacity (taf).

Delta Hydrodynamic Results

The DSM2-Hrodro was run from water years 1976 to 1991 and output was provided for a number of locations in the Delta. Figure 9-29 shows a map of the Delta and all of the available output locations as well as the direction of positive flow and velocity for each location. Table 9-15 lists these output locations along with the common name, representative DSM2 channel number and distance in channel. All of the results from DSM2-Hydro are provided in spreadsheets, but for purposes of this BA and Appendix G, only four sites were selected for discussion. These four sites were generally a combination of flows that represent an imaginary boundary internal to the Delta. These four sites were:

- Cross Delta flow – a combination of Georgiana Slough, North Fork of Mokelumne, and South Fork of the Mokelumne (GEORGIANA_SL, NORTH_FORK_MOKE, and RSMKL008 as respectively labeled in Figure 9-29).
- QWest flow – a combination of San Joaquin River at Blind Point, Three Mile Slough, and Dutch Slough (RSAN014,SLTRM004, and SLDUT007 as respectively labeled in Figure 9-29).
- Old and Middle River flow – a combination of Old River at Bacon Island and Middle River at Middle River (ROLD024, and RMID015 as respectively labeled in Figure 9-29).
- Old River at Head – described by a single output location ROLD074 as labeled in Figure 9-29.

One location from each of the groups was used to give an indication of the average velocity. From the Cross Delta group GEORGIANA_SL is presented for velocity. From the Qwest group RANS014 is presented for velocity, and from Old and Middle River RMID015 is presented.

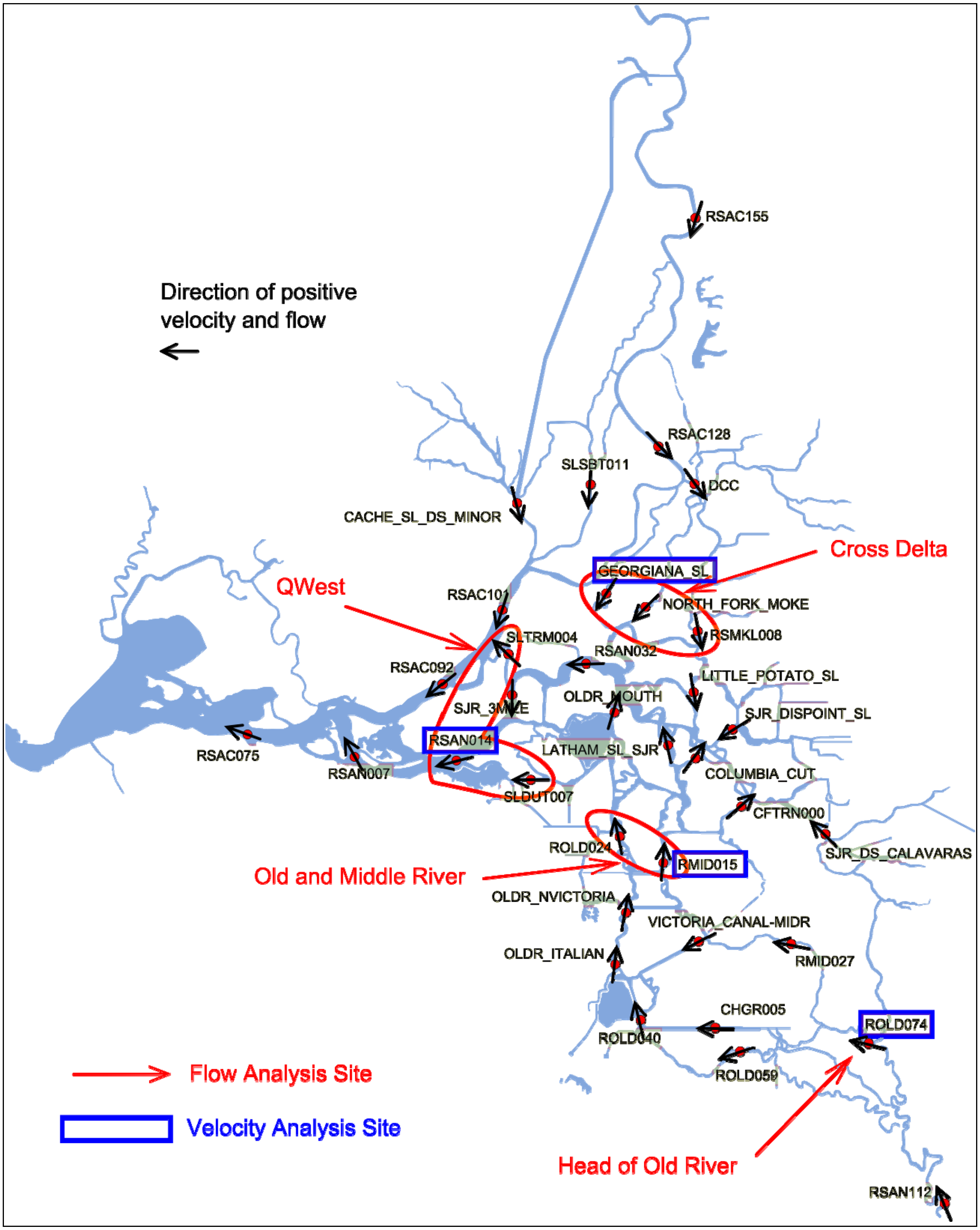


Figure 9-29. DSM2-Hydro locations of output for flow (cfs) and velocity (ft/s). Arrows represent the direction of positive flow and velocity.

Table 9-15. Definitions for the DSM2 output

DSM2 Output Name	Channel	Distance	Common Name
CFTRN000	172	727	Turner Cut
CHGRL005	211	1585	Grant Line Canal (West Position)
RMID015	144 - 145	838	Middle River at Middle River (west channel)
RMID027	133	3641	Middle River at Tracy Blvd
ROLD014	117	0	Old River at Holland Cut
ROLD024	106	2718	Old River at Bacon Island
ROLD040	82	2609	Old River at Clifton Court Ferry
ROLD059	71	3116	Old River at Tracy Road
ROLD074	54	735	Head of Old River
RSAC075	437	11108	Sacramento River at Mallard Island
RSAC092	434	435	Sacramento River at Emmaton
RSAC101	430	9684	Sacramento River at Rio Vista
RSAC128	421	8585	Sacramento River above Delta Cross Channel
RSAC155	414	11921	Sacramento River at Freeport
RSAN007	52	366	San Joaquin River at Antioch
RSAN014	49	9570	San Joaquin River at Blind Point
RSAN024	47	8246	San Joaquin River at Bradford Isl.
RSAN032	349	9672	San Joaquin River at San Andreas Landing
RSAN058	20	2520	San Joaquin River at Stockton Ship Channel
RSAN112	17	4744	San Joaquin River at Vernalis
RSMKL008	344	7088	South Fork Mokelumne at Staten Island
SLDUT007	274	7351	Dutch Slough
SLSBT011	385	2273	Steamboat Slough
SLTRM004	310	540	Three Mile Slough
DCC	365	0	Delta Cross Channel
COLUMBIA_CUT	160	50	Columbia Cut
SJR_DS_CALAVARAS	21	0	San Joaquin River downstream Calaveras River
SJR_3MILE	49	9570	San Joaquin River at Three Mile Slough

DSM2 Output Name	Channel	Distance	Common Name
OLDR_ITALIAN	88	0	Old River at Italian Slough
OLDR_NVICTORIA	91	4119	Old River at North Victoria Canal
OLDR_MOUTH	124	7062	Mouth of Old River
LATHAM_SL_SJR	161	10808	Latham Slough at San Joaquin River
VICTORIA_CANAL_MIDR	226	4153	Victoria Canal at Middle River
SJR_DISPOINT_SL	314	8130	Disappointment Slough at San Joaquin River
LITTLE_POTATO_SL	325	9962	Little Potato Slough
NORTH_FORK_MOKE	363	6133	North Fork Mokelumne River
GEORGIANA_SL	371	7766	Georgiana Slough
CACHE_SL_DS_MINOR	398	0	Cache Slough downstream Minor Slough
OMR	144 - 145 + 106	--	Old and Middle River
QWEST	274 + 49 + 310	--	Western Flow (QWEST)
XDELTA	371 + 363 + 344	--	Cross Delta Flow

The DSM2-Hydro results were aggregated from a fifteen-minute time-step to a daily average. A Godin filter was first applied to the data to remove the tidal variations, and then a daily average of the filtered data was applied. This is the same process that the United States Geological Survey (USGS) uses to determine daily averages for locations under tidal influence. The flow results are presented in Table 9-16 and velocity results are presented in Table 9-17. Both tables present the minimum, 25 percentile, median, 75 percentile, and maximum value for water-years 1976 to 1991, broken down into groups representing annual quarters, and year type groups. The monthly output was grouped into the annual quarters: January through March (Jan-Mar), April through June (Apr-Jun), July through September (Jul-Sep), and October through December (Oct-Dec). The year types were grouped into two representative groups: Wet and Above Normal (W-AN), and Below Normal, Dry and Critical (C-D-BN). For regional flows that cross more than one individual location, for example Old and Middle River includes two output locations, a simple time period summation was conducted.

Appendix G presents DSM2-Hydro results in graphical form. Box plots show the minimum, 25 percentile, median, 75 percentile, and maximum value. Along with the box plots results are also displayed in exceedence plots that show the percent of time in which a certain value was exceeded.

Table 9-16. DSM2-Hydro tidally filtered daily average flow for water-years 1976 to 1991. Shading indicates negative (landward) flows. Positive flows are towards the ocean.

Name	Year Types	Month Range	Study 6.0 Min	Study 6.0 25%	Study 6.0 50%	Study 6.0 75%	Study 6.0 Max	Study 7.0 Min	Study 7.0 25%	Study 7.0 50%	Study 7.0 75%	Study 7.0 Max	Study 7.1 Min	Study 7.1 25%	Study 7.1 50%	Study 7.1 75%	Study 7.1 Max	Study 8.0 Min	Study 8.0 25%	Study 8.0 50%	Study 8.0 75%	Study 8.0 Max
Head of Old River	W AN	Jan-Mar	1433	3772	8297	9708	17657	1433	3782	8322	9726	17688	1195	3712	8073	9555	16726	1180	3676	8047	9557	16691
		Apr-Jun	1292	3669	5517	9014	10450	1276	3690	5544	9026	10491	0	3601	5670	8719	10098	0	3598	5659	8646	10119
		Jul-Sep	830	1354	1610	3731	9939	833	1339	1615	3732	9956	451	1736	1958	3964	9582	450	1766	1963	3924	9588
		Oct-Dec	225	715	1539	3545	9992	202	721	1544	3544	10006	141	301	857	1556	9634	126	299	851	1545	9621
	C D BN	Jan-Mar	728	1085	1441	1696	4776	728	1093	1441	1694	4785	610	1046	1307	1593	4561	517	964	1254	1564	4516
		Apr-Jun	202	411	657	893	4497	176	409	650	917	4497	0	0	663	1092	4114	0	0	569	1007	4100
		Jul-Sep	159	341	626	803	1294	110	332	616	797	1286	185	301	366	451	1263	186	302	353	447	1171
		Oct-Dec	249	568	1001	1222	1745	257	582	1003	1242	1742	155	247	410	1066	1624	147	241	407	1083	1589
Old and Middle River	W AN	Jan-Mar	-9811	-6197	-2189	3590	23765	-9811	-6343	-2271	3508	22248	-10969	-6522	-2063	4484	22446	-10993	-5916	-2654	3720	22029
		Apr-Jun	-8033	-3638	-704	1326	9011	-8041	-4094	-662	1613	8614	-7621	-3870	-2607	754	8392	-7825	-3851	-2645	797	8378
		Jul-Sep	-11481	-9831	-8699	-7877	1425	-11285	-9669	-8482	-7576	1469	-10871	-9188	-8070	-7439	1268	-11402	-9571	-8727	-7826	1312
		Oct-Dec	-10847	-8723	-7753	-4430	9519	-10845	-8793	-7908	-3575	5659	-11664	-10197	-9060	-3196	6273	-11635	-10192	-9062	-3043	6153
	C D BN	Jan-Mar	-10175	-7812	-5800	-2408	544	-10174	-7724	-5642	-3220	64	-11482	-7540	-5743	-4164	-340	-11481	-8348	-5851	-3640	682
		Apr-Jun	-9451	-4413	-1967	-1345	2021	-9709	-4702	-1997	-1382	2020	-9662	-4514	-2559	-1994	-593	-9785	-4221	-2592	-1990	-241
		Jul-Sep	-12031	-9614	-6523	-4991	-3129	-12203	-8860	-7152	-5059	-1123	-12383	-9010	-5839	-4278	-1150	-12393	-9432	-5454	-3986	-912
		Oct-Dec	-10768	-8355	-6918	-5595	-2106	-10766	-8718	-7312	-6188	-2134	-11992	-9625	-8022	-5652	-2870	-11974	-9313	-7789	-5600	-1811
QWEST	W AN	Jan-Mar	-5104	8082	19171	33695	72635	-5164	7431	19078	32600	70980	-6395	6555	18054	33265	71822	-6493	6484	17660	32651	71360
		Apr-Jun	-1869	5739	8228	17578	41974	-1937	5409	7970	18127	41570	-3594	4921	7265	17684	41546	-3788	4871	7161	17730	41550
		Jul-Sep	-6667	-2124	-971	1007	17117	-5627	-2076	-708	1794	21810	-5696	-2060	-837	1944	21523	-6123	-2571	-1299	1468	21335
		Oct-Dec	-13103	-1699	500	5628	45661	-12124	-1855	600	5608	41532	-14146	-2360	243	5198	42381	-14114	-2368	245	5223	42274
	C D BN	Jan-Mar	-9637	-2293	-63	2040	11260	-9891	-2182	-281	1926	10678	-11004	-2390	-489	1424	11640	-11159	-2353	-433	1614	11391
		Apr-Jun	-6869	-425	1096	2851	12199	-7266	-563	1059	2782	11992	-7095	-624	881	2633	10704	-7343	-736	904	2669	10655
		Jul-Sep	-8152	-3057	-1656	-408	3460	-7810	-2788	-1614	-305	4657	-8359	-2708	-1166	274	4670	-8497	-2921	-1217	313	4669
		Oct-Dec	-11901	-2510	-1096	247	6832	-11824	-2742	-1389	-56	6723	-12941	-3048	-1462	-79	5480	-12743	-2965	-1400	54	5925
Cross Delta	W AN	Jan-Mar	4817	9224	13431	16622	23914	4753	9174	13388	16632	23917	4818	8857	13351	16402	23672	4734	8895	13346	16435	23691
		Apr-Jun	3315	4402	6699	9147	18430	3286	4422	6518	9124	18437	3038	4375	6365	9149	18412	3005	4337	6295	9075	18448
		Jul-Sep	5178	6436	7109	7803	10081	5543	6539	7028	7856	10955	5358	6375	6911	7933	10666	5451	6564	7066	8018	10484
		Oct-Dec	2104	5156	7152	9344	17461	2111	5578	7232	9207	17475	2129	5516	6971	9198	17451	2118	5555	6768	9191	17483
	C D BN	Jan-Mar	1672	3036	3888	5333	10418	1984	3124	4023	5693	10134	2039	3367	4009	5799	10368	2080	3312	3977	5661	10072
		Apr-Jun	1502	2434	3165	4839	7405	1510	2421	3122	4673	7966	1443	2406	3119	4512	8072	1530	2439	3143	4371	8183
		Jul-Sep	3925	5058	5795	7183	8860	3638	4986	5814	6758	8513	3371	4382	5540	6684	8740	2953	4404	5410	6898	8900
		Oct-Dec	1980	4069	5266	5824	9625	1886	4189	5495	6022	9518	1962	4083	5197	6000	9490	1963	4076	5195	5976	9512

Table 9-17. DSM2-Hydro tidally filtered daily average velocity for water-years 1976 to 1991. Shading indicates negative (landward) velocities. Positive velocities are towards the ocean.

Name	Year Types	Month Range	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Head of Old River	W AN	Jan-Mar	0.89	1.70	2.55	2.61	3.29	0.89	1.70	2.56	2.62	3.29	0.74	1.68	2.52	2.58	3.19	0.73	1.68	2.52	2.58	3.19
		Apr-Jun	0.69	1.66	1.99	2.62	2.66	0.68	1.66	2.00	2.62	2.66	0.00	1.66	2.13	2.57	2.62	0.00	1.66	2.13	2.56	2.62
		Jul-Sep	0.50	0.74	0.85	1.56	2.68	0.50	0.74	0.85	1.56	2.68	0.29	0.98	1.07	1.73	2.63	0.30	1.00	1.07	1.72	2.63
		Oct-Dec	0.14	0.44	0.83	1.52	2.67	0.13	0.44	0.84	1.52	2.67	0.09	0.21	0.53	0.88	2.63	0.08	0.20	0.53	0.88	2.63
	C D BN	Jan-Mar	0.50	0.68	0.88	0.99	1.94	0.50	0.68	0.88	0.99	1.94	0.40	0.64	0.79	0.92	1.89	0.34	0.59	0.76	0.91	1.88
		Apr-Jun	0.12	0.27	0.41	0.57	1.89	0.11	0.27	0.41	0.60	1.89	0.00	0.00	0.42	0.67	1.79	0.00	0.00	0.37	0.61	1.78
		Jul-Sep	0.09	0.20	0.38	0.48	0.72	0.07	0.19	0.37	0.47	0.71	0.12	0.20	0.24	0.29	0.76	0.12	0.19	0.23	0.29	0.72
		Oct-Dec	0.16	0.34	0.59	0.75	0.99	0.17	0.35	0.59	0.76	0.99	0.10	0.16	0.28	0.67	0.92	0.10	0.16	0.27	0.67	0.90
Middle River at Middle River	W AN	Jan-Mar	-0.26	-0.16	-0.06	0.09	0.58	-0.26	-0.17	-0.06	0.09	0.54	-0.29	-0.17	-0.05	0.12	0.54	-0.29	-0.16	-0.07	0.10	0.53
		Apr-Jun	-0.22	-0.09	-0.01	0.04	0.23	-0.22	-0.11	-0.01	0.05	0.22	-0.21	-0.10	-0.07	0.03	0.22	-0.21	-0.10	-0.07	0.03	0.22
		Jul-Sep	-0.31	-0.26	-0.23	-0.21	0.04	-0.30	-0.26	-0.23	-0.20	0.04	-0.29	-0.25	-0.21	-0.19	0.04	-0.31	-0.26	-0.23	-0.20	0.04
		Oct-Dec	-0.29	-0.23	-0.21	-0.12	0.25	-0.29	-0.24	-0.21	-0.10	0.15	-0.31	-0.28	-0.25	-0.09	0.16	-0.31	-0.28	-0.25	-0.08	0.16
	C D BN	Jan-Mar	-0.27	-0.21	-0.15	-0.06	0.02	-0.27	-0.21	-0.15	-0.08	0.01	-0.31	-0.20	-0.15	-0.11	-0.01	-0.31	-0.23	-0.16	-0.10	0.02
		Apr-Jun	-0.25	-0.12	-0.05	-0.03	0.06	-0.26	-0.13	-0.05	-0.04	0.06	-0.26	-0.12	-0.07	-0.05	-0.02	-0.26	-0.11	-0.07	-0.05	-0.01
		Jul-Sep	-0.33	-0.26	-0.17	-0.13	-0.08	-0.34	-0.24	-0.19	-0.13	-0.03	-0.34	-0.24	-0.15	-0.11	-0.03	-0.34	-0.25	-0.14	-0.11	-0.02
		Oct-Dec	-0.29	-0.22	-0.19	-0.15	-0.06	-0.29	-0.24	-0.20	-0.16	-0.06	-0.33	-0.26	-0.22	-0.15	-0.08	-0.33	-0.25	-0.21	-0.15	-0.05
San Joaquin River at Blind Point	W AN	Jan-Mar	0.00	0.16	0.28	0.42	0.86	0.00	0.15	0.28	0.42	0.85	-0.01	0.14	0.27	0.42	0.85	-0.01	0.14	0.26	0.41	0.85
		Apr-Jun	0.05	0.12	0.15	0.24	0.50	0.05	0.12	0.15	0.25	0.50	0.03	0.12	0.14	0.24	0.50	0.03	0.12	0.14	0.24	0.50
		Jul-Sep	-0.02	0.04	0.06	0.08	0.24	0.00	0.04	0.06	0.09	0.28	-0.01	0.04	0.06	0.09	0.28	-0.01	0.04	0.05	0.08	0.28
		Oct-Dec	-0.06	0.05	0.07	0.14	0.56	-0.05	0.05	0.07	0.14	0.52	-0.07	0.04	0.07	0.14	0.53	-0.07	0.04	0.07	0.14	0.53
	C D BN	Jan-Mar	-0.04	0.05	0.07	0.09	0.20	-0.03	0.05	0.07	0.09	0.19	-0.04	0.04	0.06	0.09	0.20	-0.06	0.04	0.06	0.09	0.20
		Apr-Jun	0.00	0.06	0.08	0.10	0.20	0.00	0.06	0.08	0.09	0.20	0.00	0.06	0.07	0.09	0.19	0.00	0.06	0.07	0.09	0.19
		Jul-Sep	-0.02	0.03	0.05	0.06	0.10	-0.02	0.03	0.05	0.06	0.12	-0.03	0.03	0.05	0.07	0.12	-0.03	0.03	0.05	0.07	0.12
		Oct-Dec	-0.06	0.04	0.05	0.07	0.13	-0.06	0.04	0.05	0.06	0.13	-0.08	0.03	0.05	0.06	0.12	-0.07	0.04	0.05	0.06	0.12
Georgiana Slough	W AN	Jan-Mar	1.01	1.99	2.45	2.60	2.74	1.00	1.99	2.44	2.60	2.74	1.02	1.99	2.44	2.60	2.74	1.01	1.99	2.45	2.60	2.74
		Apr-Jun	0.66	0.87	1.02	1.61	2.71	0.71	0.87	1.01	1.61	2.71	0.67	0.88	1.01	1.59	2.71	0.65	0.87	1.01	1.60	2.71
		Jul-Sep	0.68	0.79	0.85	0.94	1.41	0.70	0.78	0.83	0.94	1.38	0.64	0.76	0.81	0.95	1.37	0.67	0.79	0.83	0.95	1.36
		Oct-Dec	0.51	0.73	1.00	1.69	2.76	0.51	0.74	1.00	1.81	2.76	0.42	0.75	1.00	1.73	2.76	0.39	0.75	1.00	1.66	2.76
	C D BN	Jan-Mar	0.45	0.84	1.03	1.41	2.40	0.68	0.89	1.03	1.37	2.35	0.68	0.91	1.07	1.34	2.11	0.60	0.88	1.05	1.32	2.08
		Apr-Jun	0.56	0.73	0.82	0.91	1.49	0.56	0.73	0.83	0.91	1.49	0.54	0.74	0.85	0.91	1.42	0.57	0.70	0.85	0.92	1.42
		Jul-Sep	0.54	0.66	0.74	0.87	1.06	0.54	0.65	0.73	0.83	1.02	0.50	0.60	0.70	0.83	1.05	0.47	0.60	0.70	0.84	1.06
		Oct-Dec	0.54	0.67	0.73	0.89	1.59	0.53	0.70	0.76	0.91	1.56	0.52	0.69	0.75	0.89	1.58	0.53	0.67	0.74	0.88	1.59

DSM2-PTM was run for each month in water-years 1976 to 1991. In each simulation 1000 particles were injected over a period of 24 hours at the nodes described in Table 9-18. Particles were injected starting at the beginning of the forth day of each month. The particles were then tracked until the end of the twenty-fifth day, so the particle locations were reported after approximately twenty-one days. The particles were counted at each of the output locations in Table 9-19. These output locations represent the major locations where particles could go. “Past Chipps” represents the percentage of particles that travel past Chipps Island and into the Suisun Bay. “Exports” represents the combined percentage of particles that end up in Banks Pumping Plant and Jones Pumping Plant. “Other Diversion” represents the combined percentage of particles that end up in the Contra Costa Water District diversions on Old River and Rock Slough, North Bay Aqueduct, and agricultural diversions. The particles that remain in the Delta are grouped into two groups “In North Delta” and “In South Delta”. The delineation line between North and South is shown in Figure 9-30.

For the purposes of this document only three injection locations are presented, however output for all of the injection locations are available in the spreadsheets provided in Appendix G. The injection locations selected for presentation were the San Joaquin River at Mossdale (node 7), Little Potato Slough (node 249), and Sacramento River at Rio Vista (node 350).

The PTM results are presented in Table 9-20 for the injection at node 7, Table 9-21 for the injection at node 249, and Table 9-22 for the injection at node 350. The three tables present the minimum, 25 percentile, median, 75 percentile, and maximum value for water-years 1976 to 1991, broken down into groups representing annual quarters, and year type groups. The monthly output was grouped into the annual quarters: January through March (Jan-Mar), April through June (Apr-Jun), July through September (Jul-Sep), and October through December (Oct-Dec). The year types were grouped into two representative groups: Wet and Above Normal (W-AN), and Below Normal, Dry and Critical (C-D-BN).

Appendix G presents DSM2-PTM results in graphical form. Box plots show the minimum, 25 percentile, median, 75 percentile, and maximum value. Results are also displayed in exceedence plots that show the percent of time in which a certain value was exceeded. Additionally graphical comparisons are made between percent of particles at the exports to Old and Middle River flow, Qwest flow, and Cross Delta flow.

Table 9-18. Injection Locations

Node	Common Name
335	Sacramento River at Freeport
341	Sacramento River above Cross Channel
321	Cache Slough
350	Sacramento River at Rio Vista
353	Sacramento River at Emmaton
355	Sacramento River at Collinsville

Node	Common Name
45	San Joaquin River at Blind Point
272	Mokelumne River near San Joaquin River
249	Little Potato Slough
21	San Joaquin River at Stockton
7	San Joaquin River at Mossdale

Table 9-19. PTM Output

Name	Description
Past Chipps	Particles that pass Chipps Island
In North Delta	Particles that remain in the Northern Delta (Figure 9-30)
In South Delta	Particles that remain in the Southern Delta (Figure 9-30)
Exports	Combined SWP and CVP exports
Other Diversion	Agricultural Diversions, CCWD Diversions, and North Bay Aqueduct

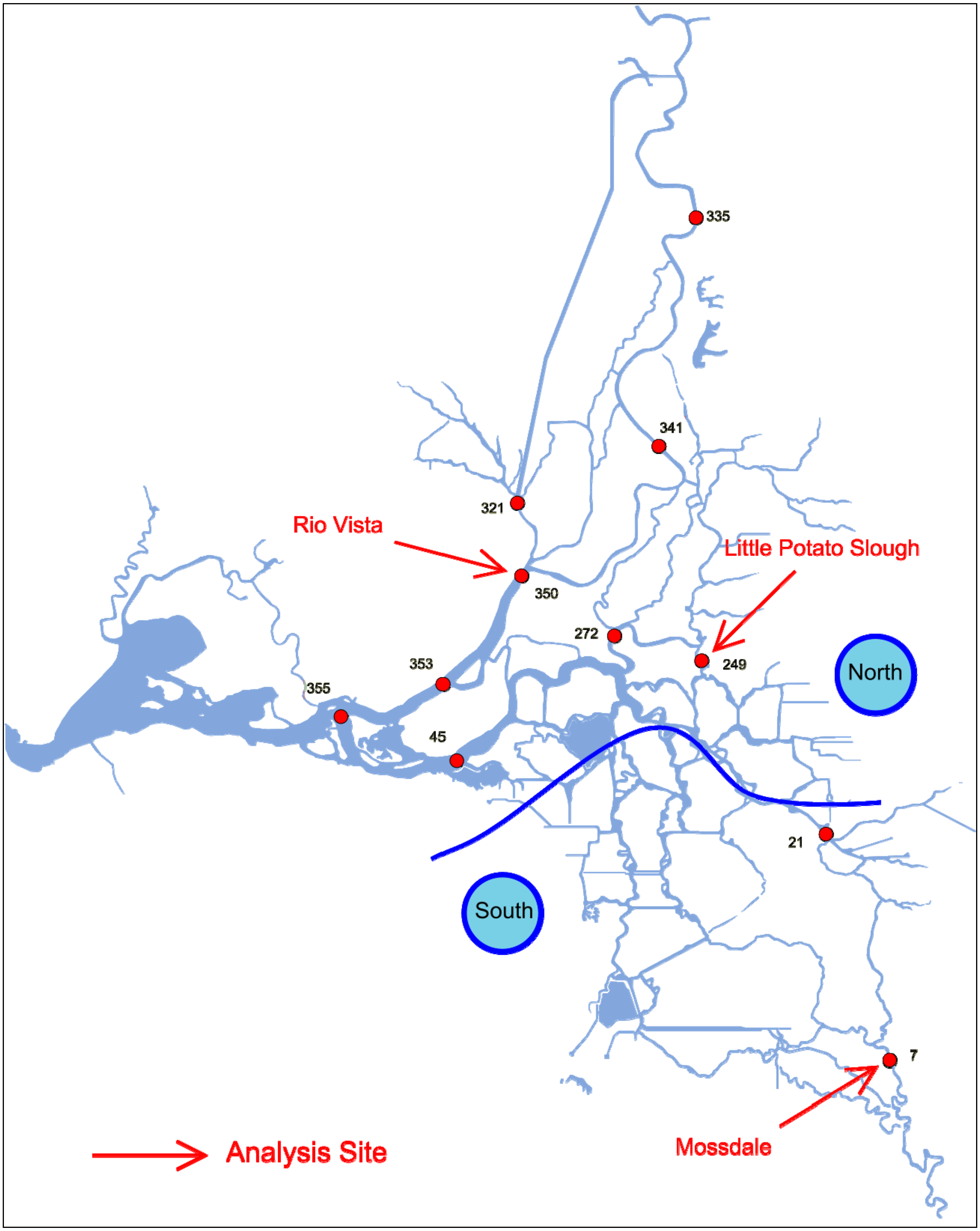


Figure 9-30. DSM2-PTM locations for particle injection.

Table 9-20. Percent particle fate percentiles after 21 days for particle injection at node 7.

Name	Year Types	Month Range	Study 6.0 Min	25%	50%	75%	Max	Study 7.0 Min	25%	50%	75%	Max	Study 7.1 Min	25%	50%	75%	Max	Study 8.0 Min	25%	50%	75%	Max
Past Chipps	W AN	Jan-Mar	0	2	35	60	91	0	2	36	57	89	0	2	38	61	91	0	2	36	58	91
		Apr-Jun	0	1	5	36	77	0	1	5	39	76	0	1	4	38	76	0	1	4	39	76
		Jul-Sep	0	0	0	0	40	0	0	0	0	43	0	0	0	0	44	0	0	0	0	43
		Oct-Dec	0	0	0	0	80	0	0	0	0	67	0	0	0	1	69	0	0	0	0	68
	C D BN	Jan-Mar	0	0	0	0	3	0	0	0	0	2	0	0	0	0	5	0	0	0	0	4
		Apr-Jun	0	0	0	0	5	0	0	0	0	2	0	0	0	0	10	0	0	0	0	9
		Jul-Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Oct-Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In North Delta	W AN	Jan-Mar	0	1	2	5	11	0	1	2	4	12	0	1	2	3	10	0	1	2	4	10
		Apr-Jun	1	5	14	19	34	1	5	11	19	38	1	5	11	18	43	1	5	11	18	44
		Jul-Sep	1	2	2	3	8	1	2	2	4	6	1	2	3	4	6	1	2	3	3	7
		Oct-Dec	0	2	3	6	38	1	2	3	5	37	2	2	3	5	33	1	3	4	5	43
	C D BN	Jan-Mar	0	6	10	21	29	0	5	9	21	29	1	5	9	15	31	1	5	10	22	34
		Apr-Jun	0	11	19	26	35	0	11	19	26	35	0	0	15	28	42	0	0	16	28	41
		Jul-Sep	0	0	4	12	46	0	0	3	10	46	0	1	5	14	29	0	0	5	16	47
		Oct-Dec	1	3	7	15	33	2	3	5	12	41	2	3	5	11	22	2	4	6	13	25
In South Delta	W AN	Jan-Mar	0	2	5	7	11	0	2	5	8	11	0	1	5	6	10	0	2	5	7	10
		Apr-Jun	1	8	14	19	36	1	7	13	19	33	1	9	12	16	28	1	8	13	17	28
		Jul-Sep	3	6	7	8	15	3	6	7	9	18	5	6	8	9	14	4	6	7	8	9
		Oct-Dec	2	7	8	17	38	2	6	8	16	37	2	5	5	12	49	2	5	6	11	46
	C D BN	Jan-Mar	1	6	9	13	29	1	6	8	15	19	3	8	13	19	27	2	6	12	19	49
		Apr-Jun	6	13	20	34	44	1	13	20	36	43	1	14	19	47	56	1	14	19	44	57
		Jul-Sep	2	9	14	22	50	2	11	21	25	54	0	10	16	27	38	0	7	16	30	37
		Oct-Dec	2	6	13	23	46	4	7	14	18	40	4	6	13	29	48	2	6	12	30	55
Exports	W AN	Jan-Mar	9	33	58	81	92	11	37	58	82	93	9	36	55	82	94	9	36	57	81	93
		Apr-Jun	15	33	49	54	70	15	36	50	57	71	20	35	53	62	74	20	35	55	60	74
		Jul-Sep	40	70	82	86	89	40	69	78	85	89	39	71	78	86	89	39	76	82	86	91
		Oct-Dec	16	46	78	87	89	15	59	77	87	90	21	59	79	88	93	12	60	78	88	93
	C D BN	Jan-Mar	33	61	76	83	92	49	61	76	85	91	41	61	76	84	95	7	61	73	83	95
		Apr-Jun	0	13	27	46	56	0	11	28	49	67	0	12	39	55	64	0	17	36	56	64
		Jul-Sep	0	20	30	49	80	0	15	30	51	79	12	38	55	69	78	10	31	50	70	82
		Oct-Dec	24	55	74	83	91	21	60	77	84	91	28	60	72	88	93	20	58	72	87	92
Other Diversions	W AN	Jan-Mar	0	0	0	1	4	0	0	0	0	4	0	0	0	0	4	0	0	0	1	4
		Apr-Jun	0	1	4	9	29	0	1	4	9	28	0	1	4	7	29	0	1	4	7	29
		Jul-Sep	1	5	9	19	37	1	5	9	19	35	1	4	9	13	22	1	5	9	13	30

Name	Year Types	Month Range	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
		Oct-Dec	0	1	2	4	17	0	1	2	4	19	0	1	2	3	13	0	1	2	3	13
	C D BN	Jan-Mar	0	1	2	8	18	0	1	2	5	17	0	1	1	3	13	0	1	1	3	14
		Apr-Jun	2	14	24	45	71	3	13	23	45	71	5	9	14	30	61	5	9	16	33	66
		Jul-Sep	5	19	42	58	98	5	19	41	57	98	4	13	22	30	65	3	12	22	31	65
		Oct-Dec	2	2	4	6	19	2	2	4	7	24	1	1	3	4	11	1	2	3	5	12

Table 9-21. Percent particle fate percentiles after 21 days for particle injection at node 249.

Name	Year Types	Month Range	Study 6.0					Study 7.0					Study 7.1					Study 8.0				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Past Chipps	W AN	Jan-Mar	0	28	94	99	100	0	28	94	99	100	0	24	95	99	100	0	24	94	99	100
		Apr-Jun	0	10	30	91	100	0	10	29	88	100	0	11	23	91	100	0	8	19	90	100
		Jul-Sep	0	0	0	0	88	0	0	0	0	93	0	0	0	0	93	0	0	0	0	93
		Oct-Dec	0	0	0	3	100	0	0	0	3	100	0	0	0	5	100	0	0	0	4	100
	C D BN	Jan-Mar	0	0	0	1	25	0	0	0	0	17	0	0	0	0	34	0	0	0	0	31
		Apr-Jun	0	0	0	0	24	0	0	0	0	15	0	0	0	0	18	0	0	0	0	15
		Jul-Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Oct-Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In North Delta	W AN	Jan-Mar	0	0	2	7	27	0	0	2	6	23	0	0	2	5	25	0	0	2	4	24
		Apr-Jun	0	4	28	53	73	0	5	34	55	71	0	4	38	48	64	0	3	39	51	68
		Jul-Sep	1	2	4	8	19	1	3	5	13	24	1	3	6	13	27	1	2	4	13	18
		Oct-Dec	0	3	4	9	47	0	3	6	8	40	0	3	4	9	45	0	2	5	8	53
	C D BN	Jan-Mar	1	4	14	34	72	1	5	16	29	63	2	4	13	27	59	2	4	13	30	75
		Apr-Jun	5	20	47	57	64	4	13	42	56	65	3	16	31	50	62	3	20	31	48	63
		Jul-Sep	1	2	5	11	17	1	2	5	10	33	1	2	5	20	39	1	2	8	21	42
		Oct-Dec	2	6	9	15	42	2	5	7	13	37	2	4	9	13	28	2	4	9	15	44
In South Delta	W AN	Jan-Mar	0	0	2	9	23	0	0	2	9	24	0	0	2	8	22	0	0	2	7	21
		Apr-Jun	0	3	12	19	41	0	3	13	18	40	0	3	16	19	36	0	4	17	20	36
		Jul-Sep	2	4	10	12	20	1	5	9	15	24	1	5	11	14	29	1	5	8	13	23
		Oct-Dec	0	5	7	16	46	0	6	8	12	50	0	4	7	10	47	0	4	7	11	47
	C D BN	Jan-Mar	5	11	21	39	57	5	11	27	44	54	4	12	25	39	52	4	11	24	41	54
		Apr-Jun	15	31	38	45	60	12	32	37	47	61	17	31	42	54	63	17	32	44	55	63
		Jul-Sep	2	5	22	39	53	3	9	17	36	54	3	8	28	47	54	3	7	33	49	56
		Oct-Dec	4	13	19	27	52	4	10	16	24	49	3	9	18	35	48	6	10	16	37	51
Exports	W	Jan-Mar	0	0	1	38	85	0	0	2	41	85	0	0	1	42	88	0	0	2	41	89

Name	Year Types	Month Range	Study 6.0 Min	25%	50%	75%	Max	Study 7.0 Min	25%	50%	75%	Max	Study 7.1 Min	25%	50%	75%	Max	Study 8.0 Min	25%	50%	75%	Max
	AN	Apr-Jun	0	0	0	9	36	0	0	1	9	35	0	0	4	15	57	0	0	4	15	62
		Jul-Sep	0	62	74	84	91	0	57	73	81	93	0	58	71	80	89	0	59	79	82	88
		Oct-Dec	0	25	72	87	92	0	18	77	85	94	0	12	79	88	93	0	10	77	88	93
	C D BN	Jan-Mar	0	7	52	80	92	0	15	53	81	92	0	24	53	77	93	0	21	60	81	92
		Apr-Jun	0	0	1	17	54	0	0	3	29	68	0	1	7	23	57	0	1	7	15	59
		Jul-Sep	15	40	61	80	93	0	42	67	81	91	0	28	46	79	88	0	24	41	79	92
		Oct-Dec	12	55	69	79	88	15	61	75	82	89	24	47	73	83	90	3	44	73	82	89
Other Diversions	W AN	Jan-Mar	0	0	0	1	3	0	0	0	1	2	0	0	0	1	2	0	0	1	1	3
		Apr-Jun	0	2	3	5	11	0	2	3	6	12	0	2	3	6	14	0	2	3	6	12
		Jul-Sep	2	5	8	10	15	3	4	8	10	16	3	4	8	12	21	3	5	8	12	16
		Oct-Dec	0	1	2	3	5	0	1	2	3	4	0	2	2	2	4	0	1	2	3	4
	C D BN	Jan-Mar	1	1	2	2	4	1	1	2	2	4	1	1	2	3	5	1	1	2	2	6
		Apr-Jun	3	4	5	16	21	3	4	6	15	21	3	5	6	17	23	3	5	6	16	21
		Jul-Sep	2	6	10	15	23	2	6	10	15	25	3	8	10	17	25	3	6	10	16	25
		Oct-Dec	2	2	3	3	5	2	2	3	3	6	1	2	3	3	7	2	2	3	4	6

Table 9-22. Percent particle fate percentiles after 21 days for particle injection at node 350.

Name	Year Types	Month Range	Study 6.0 Min	25%	50%	75%	Max	Study 7.0 Min	25%	50%	75%	Max	Study 7.1 Min	25%	50%	75%	Max	Study 8.0 Min	25%	50%	75%	Max
Past Chipps	W AN	Jan-Mar	84	100	100	100	100	85	100	100	100	100	79	100	100	100	100	77	100	100	100	100
		Apr-Jun	55	93	99	100	100	45	94	99	100	100	51	91	98	100	100	51	89	98	100	100
		Jul-Sep	19	26	45	59	99	16	25	47	59	99	18	26	38	62	99	19	25	39	66	100
		Oct-Dec	12	34	74	98	100	22	32	73	99	100	10	34	66	98	100	8	37	64	98	100
	C D BN	Jan-Mar	25	60	71	85	100	38	62	73	86	100	40	64	77	86	100	42	64	76	86	100
		Apr-Jun	8	28	48	66	99	10	29	50	68	97	9	29	49	64	96	7	32	48	64	96
		Jul-Sep	7	21	25	30	43	5	18	22	29	44	6	18	22	28	45	5	18	23	29	54
		Oct-Dec	21	28	39	49	91	17	31	40	50	90	13	26	32	45	89	14	27	34	43	90
In North Delta	W AN	Jan-Mar	0	0	0	0	12	0	0	0	0	10	0	0	0	0	13	0	0	0	0	16
		Apr-Jun	0	0	0	5	39	0	0	1	4	50	0	0	2	7	41	0	0	2	9	41
		Jul-Sep	0	29	43	51	65	0	29	43	54	66	0	29	46	55	65	0	24	44	52	63
		Oct-Dec	0	1	19	52	78	0	1	19	51	72	0	1	22	50	83	0	1	23	50	84
	C D BN	Jan-Mar	0	8	23	34	72	0	9	18	33	55	0	9	18	30	56	0	10	19	31	53
		Apr-Jun	1	30	44	64	82	2	29	45	62	83	3	29	45	64	85	3	29	43	62	84
		Jul-Sep	34	46	57	67	83	37	50	59	66	85	35	50	62	70	86	27	52	60	70	86

Name	Year Types	Month Range	Study 6.0 Min	Study 6.0 25%	Study 6.0 50%	Study 6.0 75%	Study 6.0 Max	Study 7.0 Min	Study 7.0 25%	Study 7.0 50%	Study 7.0 75%	Study 7.0 Max	Study 7.1 Min	Study 7.1 25%	Study 7.1 50%	Study 7.1 75%	Study 7.1 Max	Study 8.0 Min	Study 8.0 25%	Study 8.0 50%	Study 8.0 75%	Study 8.0 Max
		Oct-Dec	5	39	52	60	72	4	37	50	54	73	5	41	53	57	77	5	43	50	58	77
In South Delta	W AN	Jan-Mar	0	0	0	0	2	0	0	0	0	3	0	0	0	0	3	0	0	0	0	3
		Apr-Jun	0	0	0	0	2	0	0	0	0	2	0	0	0	0	4	0	0	0	0	3
		Jul-Sep	0	2	6	10	12	0	1	7	9	14	0	2	7	11	15	0	2	8	11	13
		Oct-Dec	0	0	4	8	11	0	0	3	7	12	0	0	5	10	13	0	0	6	10	13
	C D BN	Jan-Mar	0	1	3	5	9	0	1	2	5	9	0	2	3	5	11	0	1	2	5	11
		Apr-Jun	0	2	4	5	9	0	2	4	6	9	0	3	4	6	9	0	3	4	6	9
		Jul-Sep	5	9	10	11	13	6	8	11	11	16	4	7	9	12	14	5	6	8	11	13
		Oct-Dec	2	5	6	9	13	1	5	7	9	15	2	6	8	10	16	2	6	8	11	17
Exports	W AN	Jan-Mar	0	0	0	0	2	0	0	0	0	3	0	0	0	0	5	0	0	0	0	5
		Apr-Jun	0	0	0	0	1	0	0	0	0	1	0	0	0	0	3	0	0	0	0	2
		Jul-Sep	0	3	5	7	17	0	2	5	7	11	0	2	5	7	11	0	2	7	9	16
		Oct-Dec	0	0	3	5	9	0	0	3	6	8	0	0	4	7	14	0	0	4	6	14
	C D BN	Jan-Mar	0	0	1	5	8	0	0	1	2	9	0	1	1	3	8	0	1	1	3	12
		Apr-Jun	0	0	0	1	4	0	0	0	2	3	0	0	0	1	4	0	0	0	1	4
		Jul-Sep	1	2	4	10	20	0	2	5	8	19	0	1	3	9	17	0	1	3	11	19
		Oct-Dec	0	2	4	5	8	1	3	4	5	8	1	2	5	7	10	0	2	5	7	9
Other Diversions	W AN	Jan-Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Apr-Jun	0	0	0	1	3	0	0	0	1	3	0	0	0	1	2	0	0	0	1	2
		Jul-Sep	0	1	2	2	3	0	1	2	2	3	0	1	2	2	4	0	1	2	2	3
		Oct-Dec	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1
	C D BN	Jan-Mar	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1
		Apr-Jun	0	1	1	2	4	0	1	1	2	3	0	1	1	2	4	0	1	1	2	3
		Jul-Sep	1	1	2	3	4	0	1	2	3	4	1	1	2	3	4	1	1	2	3	4
		Oct-Dec	0	0	0	0	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1	1

Temperature Results

Simulated temperature results for Study 7.0, Study 7.1, and Study 8.0 are located in Chapter 10, Upstream Effects and in Appendices I and K. The treatment of the Feather River Temperature modeling is different than the other reaches previously mentioned is presented in Appendix K and described below

The Oroville Facilities Relicensing Draft Environmental Impact Report (DEIR) and Biological Assessment (BA) included evaluation of modeling output for three alternatives: the Existing Conditions, the No Project, and the Proposed Project. Operations under OCAP Study 7.0 include the same flow and water temperature requirements as the Existing Conditions Alternative. The Proposed Project simulation utilized flow requirements and water temperature targets from the March 2006 Settlement Agreement for Licensing of the Oroville Facilities (Settlement Agreement), as evaluated in OCAP Study 7.1. While simulated storage conditions in Oroville Reservoir might be different under the 2008 OCAP BA, temperature management actions would follow the same procedures as the Proposed Project. Simulated operations for the 2008 OCAP BA would be able to utilize temperature management actions not exhausted in simulation of the Proposed Project.

The primary difference with regards to water temperature between OCAP Study 7.1 and 8.0 would be the construction of a facility modification to improve DWR’s ability to manage Feather River water temperatures. However, the specific configuration of a facility modification will be examined in a separate environmental process, so no water temperature modeling of a facility modification has been completed. While none of the previously conducted water temperature modeling is directly applicable to OCAP Study 8.0, because the respective flow requirements and water temperature objectives are the same, conditions at the Feather River Fish Hatchery and Robinson Riffle would also be expected to be similar.

Salmon Mortality, Population, and Life Cycle Results

Simulated salmon fishery results are discussed in Chapter 11: Upstream Effects and in Appendices M, O, and Q.

Climate Change Results

CalSim-II long-term average (1922-2003) and dry period average (1929-1934) climate change results are reported in Table 9-23. Appendix R discusses the results of the climate change and sea level rise sensitivity evaluation. The Base Model is the future condition, Study 8.0, simulating the D1641 step. The studies examined include:

1. **Study 9.0 Base Without 1 ft Sea Level Change**: Base Model without the 1 foot sea level rise and 4 inch increase in tidal amplitude
2. **Study 9.1 Base With 1 ft Sea Level Change:** Base Model with 1 foot sea level rise and 4 inch increase in tidal amplitude
3. **Study 9.2 Wetter, Less Warming**: Same assumptions as Study 9.1 hydrology inputs modified for a wetter, less warming climate

4. **Study 9.3 Wetter, More Warming**: Same assumptions as Study 9.1 with hydrology inputs modified for a wetter , more warming climate
5. **Study 9.4 Drier, Less Warming**: Same assumptions as Study 9.1 with hydrology inputs modified for a drier, less warming climate
6. **Study 9.5 Drier, More Warming**: Same assumptions as Study 9.1with hydrology inputs modified for a drier, more warming climate

Table 9-23. Climate Change and Sea Level Rise Long-term Averages and 28-34 Averages

	Study 9.0 Base Without 1' Sea Level Change		Study 9.1 Base With 1' Sea Level Change		Study 9.2 Wetter, Less Warming		Study 9.3 Wetter, More Warming		Study 9.4 Drier, Less Warming		Study 9.5 Drier, More Warming	
End of Sep Storages (TAF)	1922-94	1929-34	1922-94	1929-34	1922-94	1929-34	1922-94	1929-34	1922-94	1929-34	1922-94	1929-34
Trinity	1394	728	1325	642	1524	937	1387	838	1313	607	1120	440
Shasta	2709	1533	2591	1211	2906	2163	2686	1843	2525	1043	2286	835
Oroville	1973	1206	1891	981	2290	1629	1929	1365	1538	885	1474	892
Folsom	492	395	476	369	518	448	472	417	428	300	402	249
New Melones	1533	1043	1533	1045	1695	1304	1594	1190	1022	289	1254	536
CVP San Luis	237	322	209	215	234	228	195	257	154	115	179	162
SWP San Luis	406	296	368	291	483	333	344	265	279	147	257	191
Total San Luis	643	618	576	506	716	561	539	521	433	262	436	352
River Flows (cfs)												
Trinity Release	974	566	958	566	1142	585	1131	585	978	585	874	528
Keswick Release	8674	5430	8693	5513	10049	6159	9967	6020	8907	5617	8019	5160
Nimbus Release	3321	1751	3327	1743	4221	2203	4139	2137	2518	1301	2581	1350
Flow Below Thermalito	4384	2269	4396	2286	5731	2926	5734	2866	3454	1836	3431	1860
Goodwin Release	654	366	654	365	976	387	826	371	389	331	451	354
Flow at Vernalis	4162	1862	4161	1861	5338	1992	4626	1913	3086	1790	3437	1812
Delta Parameters												
SWP Banks (cfs)	4669	2612	4450	2325	4940	3031	4726	2951	4029	2017	3977	2134
CVP Banks (cfs)	108	21	101	14	93	28	107	16	96	8	85	4
Jones (cfs)	3510	2126	3334	1991	3628	2448	3479	2208	3237	1933	3030	1753
Total Banks (cfs)	4777	2634	4551	2338	5034	3060	4834	2967	4124	2026	4062	2137
Cross Valley Pumping (cfs)	108	21	101	14	93	28	107	16	96	8	85	4
Sac Flow at Freeport (cfs)	22303	11281	22488	11541	25474	13114	24685	12933	20956	11072	19900	10950
Excess Outflow (cfs)	14175	1169	15105	1912	20331	2346	19608	2406	11876	1842	11479	1766
Required Outflow (cfs)	6193	5908	5790	5849	5300	6014	5460	6003	6220	5705	6058	5755
Total Inflow (cfs)	30190	13605	30313	13861	35833	15649	34918	15363	26980	13266	26151	13176

Old&Middle River (cfs)	-5151	-3265	-4785	-2874	-4812	-3873	-4906	-3615	-4931	-2576	-4481	-2501
QWEST (cfs)	1378	26	1843	533	2883	-120	2381	74	815	664	1300	731
Deliveries (TAF)												
CVP												
North of Delta												
Agriculture	240	44	221	28	269	73	238	33	201	17	176	8
Settlement Contracts	1857	1735	1857	1735	1879	1899	1879	1899	1864	1794	1825	1616
M&I	201	147	196	138	207	158	200	140	188	127	181	126
Refuge	90	78	90	78	92	89	92	89	91	82	88	69
Total	2388	2005	2364	1980	2447	2219	2409	2161	2345	2019	2270	1818
South of Delta												
Agriculture	1210	224	1097	143	1322	361	1190	166	995	83	889	40
Exchange	852	741	852	741	867	840	867	841	856	774	834	707
M&I	129	92	123	85	132	94	126	86	119	79	115	77
Refuge	273	234	268	226	274	245	273	261	269	226	262	211
Total**	2647	1474	2520	1377	2776	1721	2637	1538	2419	1343	2279	1216
SWP												
Allocation	3209	1484	3085	1377	3332	2032	3312	1954	2772	1280	2739	1337
Table A	2959	1414	2845	1309	3072	1938	3050	1846	2563	1213	2534	1270
Article 56	110	38	112	36	106	47	120	72	111	3	107	34
Article 21	284	309	237	189	371	159	223	130	200	113	195	76
Table A + Art 56	3069	1452	2957	1344	3178	1985	3170	1917	2674	1217	2641	1304
Table A + Art 56 + Art 21	3353	1761	3193	1534	3550	2144	3392	2047	2874	1330	2836	1380
Anticipated Carryover	177	4	167	2	185	28	186	42	137	1	134	1
Allocations (%)												
CVP Allocation												
North of Delta												
Agriculture	68%	20%	63%	16%	76%	29%	68%	17%	57%	13%	50%	8%
M&I	88%	66%	86%	61%	92%	72%	88%	63%	83%	59%	79%	56%
South of Delta												
Agriculture	67%	20%	61%	16%	74%	29%	67%	17%	55%	13%	49%	8%
M&I	88%	66%	86%	61%	91%	72%	88%	63%	83%	59%	79%	56%
SWP												
All SWC	78%	36%	73%	33%	79%	48%	78%	46%	65%	30%	65%	32%

The DSM2-Hydro climate change analysis was run from Water Year 1976 to 1991 and output was provided for a number of locations in the Delta. The boundary tide incorporated a one-foot and four-inch (10% increase) amplitude adjustment for sea-level rise which was consistent with the ANN used in CalSim-II. Figure 9-29 shows a map of the Delta and all of the available output locations as well as the direction of positive flow and velocity for each location. Table 9-15 lists these output locations along with the common name, representative DSM2 channel number and distance in channel. All of the results from DSM2-Hydro are provided in spreadsheets, but for purposes of this document and Appendix G only four sites were selected for discussion. These four sites were generally a combination of flows that represent an imaginary boundary internal to the Delta. These four sites were:

- **Cross Delta flow –** a combination of Georgiana Slough, North Fork of Mokelumne, and South Fork of the Mokelumne (GEORGIANA_SL, NORTH_FORK_MOKE, and RSMKL008 as respectively labeled in Figure 9-29).
- **QWest flow –** a combination of San Joaquin River at Blind Point, Three Mile Slough, and Dutch Slough (RSAN014,SLTRM004, and SLDUT007 as respectively labeled in Figure 9-29).
- **Old and Middle River flow –** a combination of Old River at Bacon Island and Middle River at Middle River (ROLD024, and RMID015 as respectively labeled in Figure 9-29).
- **Old River at Head –** described by a single output location ROLD074 as labeled in Figure 9-29.

One location from each of the groups was used to give an indication of the average velocity. From the Cross Delta group GEORGIANA_SL is presented for velocity. From the Qwest group RANS014 is presented for velocity, and from Old and Middle River RMID015 is presented.

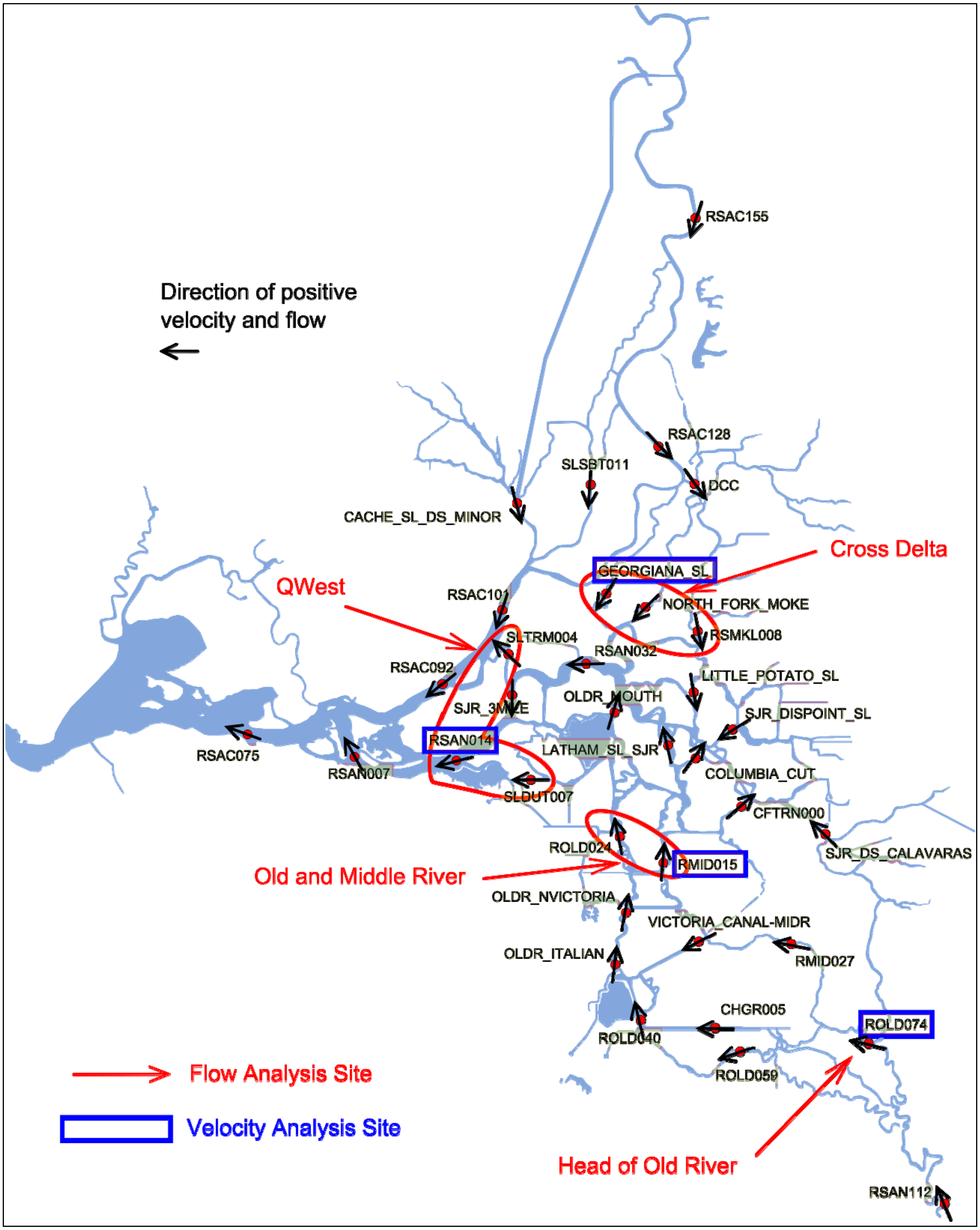


Figure 9-31. DSM2-Hydro locations of output for flow (cfs) and velocity (ft/s). Arrows represent the direction of positive flow and velocity.

Table 9-24. Definitions for the DSM2 output

DSM2 Output Name	Channel	Distance	Common Name
CFTRN000	172	727	Turner Cut
CHGRL005	211	1585	Grant Line Canal (West Position)
RMID015	144 - 145	838	Middle River at Middle River (west channel)
RMID027	133	3641	Middle River at Tracy Blvd
ROLD014	117	0	Old River at Holland Cut
ROLD024	106	2718	Old River at Bacon Island
ROLD040	82	2609	Old River at Clifton Court Ferry
ROLD059	71	3116	Old River at Tracy Road
ROLD074	54	735	Head of Old River
RSAC075	437	11108	Sacramento River at Mallard Island
RSAC092	434	435	Sacramento River at Emmaton
RSAC101	430	9684	Sacramento River at Rio Vista
RSAC128	421	8585	Sacramento River above Delta Cross Channel
RSAC155	414	11921	Sacramento River at Freeport
RSAN007	52	366	San Joaquin River at Antioch
RSAN014	49	9570	San Joaquin River at Blind Point
RSAN024	47	8246	San Joaquin River at Bradford Isl.
RSAN032	349	9672	San Joaquin River at San Andreas Landing
RSAN058	20	2520	San Joaquin River at Stockton Ship Channel
RSAN112	17	4744	San Joaquin River at Vernalis
RSMKL008	344	7088	South Fork Mokelumne at Staten Island
SLDUT007	274	7351	Dutch Slough
SLSBT011	385	2273	Steamboat Slough
SLTRM004	310	540	Three Mile Slough
DCC	365	0	Delta Cross Channel
COLUMBIA_CUT	160	50	Columbia Cut
SJR_DS_CALAVARAS	21	0	San Joaquin River downstream Calaveras River
SJR_3MILE	49	9570	San Joaquin River at Three Mile Slough

DSM2 Output Name	Channel	Distance	Common Name
OLDR_ITALIAN	88	0	Old River at Italian Slough
OLDR_NVICTORIA	91	4119	Old River at North Victoria Canal
OLDR_MOUTH	124	7062	Mouth of Old River
LATHAM_SL_SJR	161	10808	Latham Slough at San Joaquin River
VICTORIA_CANAL_MIDR	226	4153	Victoria Canal at Middle River
SJR_DISPOINT_SL	314	8130	Disappointment Slough at San Joaquin River
LITTLE_POTATO_SL	325	9962	Little Potato Slough
NORTH_FORK_MOKE	363	6133	North Fork Mokelumne River
GEORGIANA_SL	371	7766	Georgiana Slough
CACHE_SL_DS_MINOR	398	0	Cache Slough downstream Minor Slough
OMR	144 - 145 + 106	--	Old and Middle River
QWEST	274 + 49 + 310	--	Western Flow (QWEST)
XDELTA	371 + 363 + 344	--	Cross Delta Flow

The DSM2-Hydro results were aggregated from a fifteen-minute time-step to a daily average. A Godin filter was first applied to the data to remove the tidal variations, and then a daily average of the filtered data was applied. This is the same process that the USGS uses to determine daily averages for locations under tidal influence.

The flow results for the more warming case are presented in Table 9-25 and the less warming case results are presented in Table 9-26. The velocity results for the more warming case are presented in Table 9-27 and the less warming case results are presented in Table 9-28 The tables present the minimum, twenty five percentile, median, seventy five percentile, and maximum value for water-years 1976 to 1991, broken down into groups representing annual quarters, and year type groups. The monthly output was grouped into the annual quarters: January through March (Jan-Mar), April through June (Apr-Jun), July through September (Jul-Sep), and October through December (Oct-Dec). The year types were grouped into two representative groups: Wet and Above Normal (W-AN), and Below Normal, Dry and Critical (C-D-BN). For regional flows that cross more than one individual location, for example Old and Middle River includes two output locations, a simple time period summation was conducted.

Table 9-25. DSM2-Hydro tidally filtered daily average flow for water-years 1976 to 1991. Shading indicates negative (landward) flows. Positive flows are towards the ocean.

Name	Year Types	Month Range	Base Min	Base 25%	Base 50%	Base 75%	Base Max	Wetter, Less Warming Min	Wetter, Less Warming 25%	Wetter, Less Warming 50%	Wetter, Less Warming 75%	Wetter, Less Warming Max	Wetter, More Warming Min	Wetter, More Warming 25%	Wetter, More Warming 50%	Wetter, More Warming 75%	Wetter, More Warming Max
Head of Old River	W AN	Jan-Mar	1349	3722	8039	9468	16708	1408	5568	8701	10567	17974	1350	4932	8627	11291	18550
		Apr-Jun	0	3685	5707	8645	11252	0	5068	7442	9164	12909	0	2157	4167	8547	11885
		Jul-Sep	449	1889	2102	3978	9682	440	2239	3063	4963	12213	406	1743	2012	3010	8612
		Oct-Dec	112	313	822	1612	9549	112	322	1144	5461	13201	112	321	752	1664	11307
	C D BN	Jan-Mar	578	1021	1367	1683	4575	637	1057	1370	1779	6363	637	1093	1376	1742	7728
		Apr-Jun	0	0	606	1133	4163	0	0	735	1202	5474	0	0	673	1171	4027
		Jul-Sep	214	314	384	449	1244	202	329	389	491	1931	190	314	391	463	1444
		Oct-Dec	131	257	408	1042	1612	160	265	433	1059	2227	155	260	399	1058	1861
Old and Middle River	W AN	Jan-Mar	-10896	-6733	-3180	5100	22138	-10321	-5610	94	7920	24229	-10340	-5744	-555	8693	25160
		Apr-Jun	-9316	-5840	-4015	-693	12606	-9394	-5124	-3347	1183	14326	-8525	-5525	-3182	-925	14585
		Jul-Sep	-11350	-8709	-7526	-6793	3258	-11723	-8291	-7259	-6022	9579	-9463	-7967	-7270	-6540	-1793
		Oct-Dec	-11595	-9764	-7528	-4080	6749	-11595	-9561	-8094	-3879	15507	-11595	-9725	-8293	-4043	11925
	C D BN	Jan-Mar	-11345	-8206	-5811	-3671	766	-11344	-7636	-5925	-3313	-267	-11344	-8612	-6377	-4186	-372
		Apr-Jun	-9490	-4555	-2439	-1865	-555	-8275	-4719	-3137	-2149	-482	-9102	-5222	-2912	-1964	-234
		Jul-Sep	-11959	-8619	-5276	-4092	-1132	-12339	-8325	-6258	-3939	-882	-11746	-7731	-5990	-4286	-583
		Oct-Dec	-11213	-7839	-6565	-4660	-326	-11502	-10118	-8299	-5212	-1687	-11222	-8547	-7055	-4796	-392
QWEST	W AN	Jan-Mar	-6574	6496	17895	33459	71816	-6552	9410	21975	38206	77058	-6825	12946	21760	41638	78955
		Apr-Jun	-4603	3672	6819	16307	46694	-4285	5299	9846	20458	50574	-4590	3932	6708	14821	51392
		Jul-Sep	-5226	-1140	405	3421	26442	-5381	75	1798	4390	34053	-3994	-854	740	2673	17883
		Oct-Dec	-11968	-891	1475	5921	43199	-10791	-799	1977	9127	63503	-11237	-1304	937	5810	54501
	C D BN	Jan-Mar	-11554	-2331	-21	2332	11441	-10823	-1957	446	2448	18108	-11338	-2575	-18	2020	17987
		Apr-Jun	-7833	76	1634	3345	8902	-7116	114	1897	3676	8515	-7555	-148	1572	3302	8560
		Jul-Sep	-6955	-1600	-162	1138	6148	-6900	-1514	-227	1297	5034	-6431	-1301	-172	1242	5178
		Oct-Dec	-11923	-1707	178	2028	7002	-12037	-2247	-264	1648	5767	-11785	-1774	195	1839	6789
Cross Delta	W AN	Jan-Mar	4630	8704	13143	16306	23616	5342	9527	14193	16979	25965	5109	10864	15158	17440	29161
		Apr-Jun	3296	4427	6497	9757	18349	3381	4856	6112	9872	19128	3213	4078	7323	8956	18829
		Jul-Sep	5464	6448	7066	8611	11596	5200	6164	6881	7574	10475	5069	5972	6430	8492	10444
		Oct-Dec	2159	5448	7331	9106	17428	2185	5365	7391	9714	22800	2171	5157	6916	8717	20272
	C D BN	Jan-Mar	2174	3284	4108	5804	10507	2151	3324	4448	6250	13008	2134	3468	4456	6408	12933
		Apr-Jun	1458	2596	3572	4778	9422	1549	2767	3530	5297	9345	1521	2816	3543	4912	9823
		Jul-Sep	3644	4876	5638	7571	9210	2556	4991	5867	7219	9642	2830	4962	5613	7346	9443
		Oct-Dec	1875	4006	5376	6448	9609	2193	4630	6176	7048	10088	2113	4374	5540	6908	10413

Table 9-26. DSM2-Hydro tidally filtered daily average flow for water-years 1976 to 1991. Shading indicates negative (landward) flows. Positive flows are towards the ocean.

Name	Year Types	Month Range	Base					Drier, Less Warming					Drier, More Warming				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Head of Old River	W AN	Jan-Mar	1349	3722	8039	9468	16708	1348	2951	4495	7080	14338	1347	3228	5323	8823	18182
		Apr-Jun	0	3685	5707	8645	11252	0	1608	2432	6105	10492	0	2040	2762	6707	11622
		Jul-Sep	449	1889	2102	3978	9682	395	491	1849	2258	5630	402	511	1927	2504	5968
		Oct-Dec	112	313	822	1612	9549	112	284	522	1557	8693	111	275	700	1610	9008
	C D BN	Jan-Mar	578	1021	1367	1683	4575	661	1023	1298	1531	3148	584	1016	1310	1544	3434
		Apr-Jun	0	0	606	1133	4163	0	0	524	1018	2199	0	0	522	967	2904
		Jul-Sep	214	314	384	449	1244	186	294	350	414	1115	202	293	355	417	1182
		Oct-Dec	131	257	408	1042	1612	131	254	375	923	1629	106	249	381	870	1620
Old and Middle River	W AN	Jan-Mar	-10896	-6733	-3180	5100	22138	-11017	-8454	-6368	-1875	18085	-11018	-8363	-4360	1616	24586
		Apr-Jun	-9316	-5840	-4015	-693	12606	-8838	-5660	-4458	-2545	10193	-7793	-4734	-3673	-1624	13746
		Jul-Sep	-11350	-8709	-7526	-6793	3258	-10959	-9488	-8476	-7403	-4947	-11093	-8490	-7520	-6514	-3975
		Oct-Dec	-11595	-9764	-7528	-4080	6749	-11592	-9570	-7090	-4364	2692	-11595	-9522	-5789	-3140	3915
	C D BN	Jan-Mar	-11345	-8206	-5811	-3671	766	-11344	-8295	-6270	-2114	-17	-11343	-7309	-5451	-2400	-105
		Apr-Jun	-9490	-4555	-2439	-1865	-555	-8619	-3452	-2311	-1745	-560	-7367	-2563	-2032	-1577	-555
		Jul-Sep	-11959	-8619	-5276	-4092	-1132	-10322	-6409	-4499	-3466	-1024	-10853	-5711	-4275	-3371	-1383
		Oct-Dec	-11213	-7839	-6565	-4660	-326	-11253	-8462	-6418	-3810	341	-11236	-7928	-5776	-2900	336
QWEST	W AN	Jan-Mar	-6574	6496	17895	33459	71816	-6915	4733	11456	18506	62135	-7296	5480	13635	25127	76519
		Apr-Jun	-4603	3672	6819	16307	46694	-4790	2288	4982	9346	40762	-3972	3069	5662	9170	47956
		Jul-Sep	-5226	-1140	405	3421	26442	-5262	-1652	-326	1341	10976	-5058	-1129	273	2005	8864
		Oct-Dec	-11968	-891	1475	5921	43199	-10970	-665	1209	4478	34664	-11951	-554	1666	5473	36036
	C D BN	Jan-Mar	-11554	-2331	-21	2332	11441	-11914	-2393	9	1962	9714	-11955	-1903	74	2267	7714
		Apr-Jun	-7833	76	1634	3345	8902	-7198	395	1919	3586	9258	-6221	817	2258	3763	8593
		Jul-Sep	-6955	-1600	-162	1138	6148	-6752	-748	500	1905	6150	-5355	-491	612	1892	5690
		Oct-Dec	-11923	-1707	178	2028	7002	-10344	-1661	490	2551	7737	-9683	-1264	851	2905	10217
Cross Delta	W AN	Jan-Mar	4630	8704	13143	16306	23616	4359	8008	12013	14968	21386	3982	7498	10903	15635	21323
		Apr-Jun	3296	4427	6497	9757	18349	3201	3957	5936	9104	16566	2960	3675	6023	7769	17482
		Jul-Sep	5464	6448	7066	8611	11596	4946	6737	7867	8461	11306	4760	6153	6802	7962	11315
		Oct-Dec	2159	5448	7331	9106	17428	2133	4952	6971	9333	15201	2159	5191	6362	8663	14828
	C D BN	Jan-Mar	2174	3284	4108	5804	10507	1872	3021	3780	4975	10435	1786	3046	3708	4974	10477
		Apr-Jun	1458	2596	3572	4778	9422	1580	2460	3152	4962	8666	1503	2409	3032	5003	7445
		Jul-Sep	3644	4876	5638	7571	9210	3320	4669	5294	5867	8206	3223	4396	5009	5792	9001
		Oct-Dec	1875	4006	5376	6448	9609	1897	3922	5139	6578	9303	1830	3858	5025	6128	9922

Table 9-27. DSM2-Hydro tidally filtered daily average velocity for water-years 1976 to 1991. Shading indicates negative (landward) velocities. Positive velocities are towards the ocean.

Name	Year Types	Month Range	Base Min	Base 25%	Base 50%	Base 75%	Base Max	Wetter, Less Warming Min	Wetter, Less Warming 25%	Wetter, Less Warming 50%	Wetter, Less Warming 75%	Wetter, Less Warming Max	Wetter, More Warming Min	Wetter, More Warming 25%	Wetter, More Warming 50%	Wetter, More Warming 75%	Wetter, More Warming Max
Head of Old River	W AN	Jan-Mar	0.76	1.63	2.48	2.54	3.17	0.79	2.04	2.52	2.59	3.28	0.76	1.90	2.54	2.67	3.33
		Apr-Jun	0.00	1.63	2.10	2.53	2.67	0.00	1.96	2.42	2.57	2.86	0.00	1.08	1.77	2.54	2.71
		Jul-Sep	0.26	0.97	1.06	1.67	2.60	0.25	1.09	1.42	1.91	2.78	0.23	0.90	1.03	1.42	2.56
		Oct-Dec	0.07	0.19	0.46	0.86	2.60	0.07	0.19	0.61	2.03	2.87	0.07	0.19	0.43	0.89	2.69
	C D BN	Jan-Mar	0.32	0.55	0.74	0.89	1.84	0.37	0.59	0.74	0.94	2.23	0.37	0.61	0.75	0.92	2.47
		Apr-Jun	0.00	0.00	0.35	0.64	1.75	0.00	0.00	0.42	0.66	2.07	0.00	0.00	0.39	0.64	1.68
		Jul-Sep	0.12	0.18	0.23	0.27	0.72	0.11	0.19	0.23	0.29	1.02	0.11	0.18	0.23	0.27	0.84
		Oct-Dec	0.08	0.15	0.24	0.57	0.87	0.09	0.16	0.26	0.59	1.14	0.09	0.15	0.24	0.59	0.99
Middle River at Middle River	W AN	Jan-Mar	-0.27	-0.16	-0.08	0.13	0.51	-0.27	-0.14	0.01	0.20	0.55	-0.27	-0.14	-0.01	0.21	0.58
		Apr-Jun	-0.23	-0.15	-0.10	-0.01	0.31	-0.24	-0.12	-0.08	0.04	0.35	-0.21	-0.14	-0.07	-0.01	0.35
		Jul-Sep	-0.29	-0.22	-0.18	-0.16	0.09	-0.30	-0.21	-0.18	-0.14	0.25	-0.23	-0.20	-0.18	-0.16	-0.04
		Oct-Dec	-0.29	-0.25	-0.19	-0.10	0.17	-0.29	-0.24	-0.20	-0.09	0.38	-0.29	-0.25	-0.21	-0.10	0.29
	C D BN	Jan-Mar	-0.29	-0.21	-0.15	-0.09	0.02	-0.29	-0.19	-0.15	-0.08	0.00	-0.29	-0.22	-0.16	-0.10	0.00
		Apr-Jun	-0.23	-0.11	-0.06	-0.04	-0.01	-0.21	-0.12	-0.08	-0.05	-0.01	-0.22	-0.13	-0.07	-0.05	-0.01
		Jul-Sep	-0.30	-0.22	-0.13	-0.10	-0.02	-0.31	-0.21	-0.15	-0.09	-0.02	-0.30	-0.19	-0.15	-0.10	-0.01
		Oct-Dec	-0.29	-0.20	-0.16	-0.12	-0.01	-0.30	-0.26	-0.21	-0.13	-0.04	-0.29	-0.22	-0.18	-0.12	-0.01
San Joaquin River at Blind Point	W AN	Jan-Mar	-0.01	0.14	0.25	0.41	0.80	0.00	0.18	0.30	0.45	0.86	0.00	0.21	0.29	0.49	0.89
		Apr-Jun	0.03	0.11	0.13	0.23	0.53	0.02	0.12	0.16	0.26	0.57	0.03	0.11	0.13	0.21	0.58
		Jul-Sep	0.00	0.05	0.08	0.10	0.30	0.00	0.07	0.09	0.11	0.38	0.01	0.06	0.08	0.10	0.22
		Oct-Dec	-0.04	0.06	0.09	0.13	0.51	-0.03	0.06	0.09	0.20	0.74	-0.03	0.05	0.08	0.17	0.65
	C D BN	Jan-Mar	-0.05	0.05	0.07	0.10	0.20	-0.03	0.05	0.08	0.10	0.25	-0.05	0.05	0.07	0.10	0.25
		Apr-Jun	0.01	0.07	0.09	0.10	0.17	0.01	0.07	0.09	0.11	0.17	0.01	0.07	0.09	0.10	0.17
		Jul-Sep	-0.01	0.05	0.07	0.08	0.13	-0.01	0.05	0.06	0.08	0.12	-0.01	0.05	0.07	0.08	0.12
		Oct-Dec	-0.05	0.05	0.07	0.09	0.14	-0.06	0.05	0.07	0.08	0.13	-0.05	0.05	0.07	0.08	0.13
Georgiana Slough	W AN	Jan-Mar	0.94	1.84	2.31	2.50	2.64	1.25	1.91	2.43	2.53	2.62	1.19	2.07	2.48	2.54	2.66
		Apr-Jun	0.60	0.88	1.01	1.52	2.60	0.64	0.91	1.07	1.65	2.59	0.68	0.86	0.98	1.59	2.60
		Jul-Sep	0.62	0.74	0.80	0.91	1.31	0.61	0.74	0.80	0.90	1.72	0.57	0.69	0.77	0.91	1.32
		Oct-Dec	0.49	0.75	0.93	1.53	2.65	0.49	0.80	1.16	1.94	2.68	0.49	0.77	0.88	1.65	2.67
	C D BN	Jan-Mar	0.57	0.85	1.00	1.23	2.01	0.57	0.85	1.01	1.40	2.68	0.51	0.87	1.05	1.35	2.68
		Apr-Jun	0.51	0.66	0.84	0.97	1.61	0.54	0.75	0.88	0.98	1.92	0.54	0.77	0.90	0.99	1.94
		Jul-Sep	0.49	0.62	0.69	0.87	1.05	0.43	0.63	0.70	0.84	1.08	0.45	0.62	0.68	0.85	1.05
		Oct-Dec	0.48	0.65	0.74	0.85	1.36	0.51	0.72	0.80	0.98	1.69	0.50	0.67	0.78	0.88	1.42

Table 9-28. DSM2-Hydro tidally filtered daily average velocity for water-years 1976 to 1991. Shading indicates negative (landward) velocities. Positive velocities are towards the ocean.

Name	Year Types	Month Range	Base					Drier, Less Warming					Drier, More Warming				
			Min	25%	50%	75%	Max	Min	25%	50%	75%	Max	Min	25%	50%	75%	Max
Head of Old River	W AN	Jan-Mar	0.76	1.63	2.48	2.54	3.17	0.76	1.35	1.80	2.31	2.96	0.76	1.46	1.99	2.53	3.30
		Apr-Jun	0.00	1.63	2.10	2.53	2.67	0.00	0.86	1.21	2.16	2.62	0.00	1.02	1.33	2.28	2.70
		Jul-Sep	0.26	0.97	1.06	1.67	2.60	0.23	0.29	0.95	1.13	2.04	0.23	0.30	1.00	1.23	2.12
		Oct-Dec	0.07	0.19	0.46	0.86	2.60	0.07	0.17	0.29	0.83	2.57	0.07	0.16	0.40	0.86	2.59
	C D BN	Jan-Mar	0.32	0.55	0.74	0.89	1.84	0.37	0.56	0.71	0.82	1.45	0.33	0.55	0.73	0.82	1.51
		Apr-Jun	0.00	0.00	0.35	0.64	1.75	0.00	0.00	0.30	0.57	1.10	0.00	0.00	0.30	0.54	1.35
		Jul-Sep	0.12	0.18	0.23	0.27	0.72	0.11	0.17	0.20	0.24	0.65	0.12	0.17	0.20	0.24	0.69
		Oct-Dec	0.08	0.15	0.24	0.57	0.87	0.08	0.15	0.22	0.50	0.88	0.06	0.14	0.23	0.47	0.88
Middle River at Middle River	W AN	Jan-Mar	-0.27	-0.16	-0.08	0.13	0.51	-0.28	-0.21	-0.16	-0.04	0.42	-0.28	-0.21	-0.11	0.05	0.56
		Apr-Jun	-0.23	-0.15	-0.10	-0.01	0.31	-0.22	-0.14	-0.11	-0.06	0.25	-0.19	-0.11	-0.09	-0.03	0.34
		Jul-Sep	-0.29	-0.22	-0.18	-0.16	0.09	-0.27	-0.24	-0.21	-0.18	-0.12	-0.28	-0.21	-0.18	-0.16	-0.10
		Oct-Dec	-0.29	-0.25	-0.19	-0.10	0.17	-0.29	-0.24	-0.18	-0.11	0.07	-0.29	-0.24	-0.14	-0.07	0.10
	C D BN	Jan-Mar	-0.29	-0.21	-0.15	-0.09	0.02	-0.29	-0.21	-0.16	-0.05	0.00	-0.29	-0.18	-0.14	-0.06	0.00
		Apr-Jun	-0.23	-0.11	-0.06	-0.04	-0.01	-0.21	-0.08	-0.05	-0.04	-0.01	-0.18	-0.06	-0.05	-0.04	-0.01
		Jul-Sep	-0.30	-0.22	-0.13	-0.10	-0.02	-0.26	-0.16	-0.11	-0.08	-0.02	-0.27	-0.14	-0.10	-0.08	-0.03
		Oct-Dec	-0.29	-0.20	-0.16	-0.12	-0.01	-0.29	-0.22	-0.16	-0.09	0.01	-0.29	-0.20	-0.14	-0.07	0.01
San Joaquin River at Blind Point	W AN	Jan-Mar	-0.01	0.14	0.25	0.41	0.80	-0.01	0.13	0.19	0.28	0.71	-0.02	0.13	0.21	0.33	0.83
		Apr-Jun	0.03	0.11	0.13	0.23	0.53	0.02	0.09	0.12	0.16	0.47	0.03	0.10	0.13	0.16	0.54
		Jul-Sep	0.00	0.05	0.08	0.10	0.30	0.00	0.05	0.07	0.08	0.17	0.00	0.05	0.07	0.09	0.17
		Oct-Dec	-0.04	0.06	0.09	0.13	0.51	-0.03	0.06	0.08	0.11	0.43	-0.04	0.06	0.09	0.12	0.44
	C D BN	Jan-Mar	-0.05	0.05	0.07	0.10	0.20	-0.06	0.05	0.07	0.09	0.16	-0.06	0.05	0.07	0.09	0.16
		Apr-Jun	0.01	0.07	0.09	0.10	0.17	0.01	0.07	0.09	0.10	0.17	0.02	0.08	0.09	0.11	0.17
		Jul-Sep	-0.01	0.05	0.07	0.08	0.13	0.00	0.06	0.07	0.09	0.13	0.01	0.06	0.07	0.09	0.12
		Oct-Dec	-0.05	0.05	0.07	0.09	0.14	-0.04	0.05	0.07	0.09	0.15	-0.01	0.06	0.08	0.09	0.16
Georgiana Slough	W AN	Jan-Mar	0.94	1.84	2.31	2.50	2.64	0.90	1.80	2.21	2.49	2.65	0.87	1.59	2.18	2.46	2.63
		Apr-Jun	0.60	0.88	1.01	1.52	2.60	0.74	0.90	1.04	1.36	2.60	0.70	0.83	0.91	1.24	2.59
		Jul-Sep	0.62	0.74	0.80	0.91	1.31	0.57	0.76	0.85	0.90	1.17	0.56	0.70	0.77	0.87	1.06
		Oct-Dec	0.49	0.75	0.93	1.53	2.65	0.49	0.73	0.85	1.29	2.62	0.49	0.70	0.87	1.48	2.60
	C D BN	Jan-Mar	0.57	0.85	1.00	1.23	2.01	0.45	0.80	0.93	1.18	1.82	0.44	0.79	0.93	1.15	1.84
		Apr-Jun	0.51	0.66	0.84	0.97	1.61	0.55	0.68	0.80	0.90	1.56	0.53	0.68	0.76	0.86	1.54
		Jul-Sep	0.49	0.62	0.69	0.87	1.05	0.46	0.59	0.66	0.72	0.99	0.46	0.58	0.63	0.71	1.01
		Oct-Dec	0.48	0.65	0.74	0.85	1.36	0.49	0.64	0.74	0.84	1.22	0.49	0.62	0.70	0.85	1.25

Model Limitations

The following model limitations are general and highlight key limitations of individual models. This list does not include all limitations associated with the models.

General Modeling Limitations

- The models are good representations of the laws of conservation, but nonetheless include simplifications or estimations of certain processes. For example, temporal and spatial resolution (i.e. monthly time step and geographic representation) is aggregated to simulate a longer period of time rather than a short period of time at a shorter time step for similar levels of effort and computation, and to simplify the spatial extent of the model. Therefore, model uncertainty is inherent in the results.
- Input model data are imperfect. Model parameter error can accumulate such as in this example: river flow data may be plus or minus 5-10%; temperature data and water quality data are subject to instrument resolution, deployment technique and location; geometry data can have considerable effects on temperature due to approximations in surface area depth/cross sectional area; meteorological data is often not local and model domains are sufficiently large that meteorological data can vary notably from one location to another. All input parameters introduce some level of uncertainty.
- The numerical solution to the governing equations included in the models can also introduce error.
- The OCAP BA models are designed to compare and contrast the effect of current and assumed future operational conditions. The models are not predictive; they are not intended to forecast the future (i.e. no forecast data or information are used).

CalSim-II

- The main limitation of CalSim-II model is the time step. Mean monthly flows do not define daily variations that could occur in the rivers from dynamic conditions. However, monthly results are still useful for general comparison of scenarios.
- The CalSim-II model is not a hydraulic model. CalSim-II does not use channel characteristics, such as channel roughness, cross-sectional geometry, etc., to simulate the routing of water as commonly found in other models simulating rainfall runoff response.
- CalSim-II cannot completely capture the policy-oriented operation and coordination the 800,000 af of dedicated CVPIA 3406 (b)(2) water and the CALFED EWA (regular WOMT, B2IT, and EWAT agencies meetings). The CalSim-II model is set up to run each step of the 3406(b)(2) on an annual basis and because the WQCP and Endangered Species Act (ESA) actions are set on a priority basis that can trigger actions using 3406(b)(2) water or EWA assets, the model will exceed at times the dedicated amount of 3406(b)(2) water that is available. Moreover, the 3406(b)(2) and EWA operations in CalSim-II are just one set of plausible actions aggregated to a monthly representation and

modulated by year type. However, they do not fully account for the potential weighing of assets versus cost or the dynamic influence of biological factors on the timing of actions. The monthly time-step of CalSim-II also requires day-weighted monthly averaging to simulate minimum in-stream flow levels, VAMP actions, export reductions, and X2-based operations that occur within a month. This averaging can either under- or over-estimate the amount of water needed for these actions.

- CalSim-II uses simplified rules and guidelines to simulate SWP and CVP delivery allocation. Therefore the results may not reflect how the SWP and CVP would actually operate under extreme hydrologic conditions (very wet or very dry). The allocation process in the modeling is weighted heavily on storage conditions and inflow to the reservoirs that are fed into the curves mentioned previously in the Hydrologic Modeling Methods section and does not project inflow from contributing streams when making an allocation. This curve-based approach does cause some variation in results between studies that would be closer with a more robust approach to the allocation process.
- There are a number of rule-curves embedded in CalSim-II and it is these rule-curves that drive the water balance between the reservoirs, determine how much water to carryover until the following year, and allocate the amount of water for delivery. It is difficult to produce a rule-curve in CalSim-II that produces good realistic results in the full spectrum of year types. CalSim-II rule-curves often produce sub-optimal results with respect to Project operations in the driest years. Some results imply that the projects would operate the reservoirs to unrealistically low levels in these dry year outliers. In reality the Projects could and would operate to higher reservoir elevations in these extremely dry years. An examination of modeling output suggests that this would be possible by reducing project releases and exports to minimums rather than the unrealistic rates often assumed by the models in these years.
- Transfer capacity is calculated by looking at the amount of flow available under the EI ratio and the amount of available capacity at the exports. This gives a very general view of the amount of water that could be transferred. However, to be more complete in the analysis transfers should also take the current salinity profile into account as well. Generally during a transfer, a unit of water will be released somewhere in the system and increase the inflow to the Delta. As that unit of water enters the Delta the exports will increase and a portion of that unit gets exported and the remaining portion goes to support the Delta standards. The portion of the unit that goes to support Delta standards is called “carriage water”. Transfers for OCAP were post-processed and incorporating constraints based on the salinity profile to determine carriage water was not done. So the estimated transfers will be on the high side.

DSM2

- DSM2 is a one-dimensional model. As such, it is only capable of simulating the flow in the longitudinal direction. Any detailed description such as vertical/lateral mixing, changing of the flow patterns due to bends or unusual expansion or contraction of the rivers are not simulated.

- DSM2 simulates reservoirs as constantly mixed reactors and each is essentially only a container that holds water. Any mixing of water in there occurs instantly. Reservoirs are used for five locations in the model: Clifton Court Forebay, Franks Tract, Little Franks Tract, Mildred Island, and Discovery Bay.
- DSM2 uses CalSim-II results for Delta inflows. These inflows are monthly average flows so the model at times may see very steep transitions in flow from month to month. Because of these transitions the hydrodynamic conditions may take a few simulation days to adjust to the new inflows. Given this transition period the results from DSM2-Hydro should not be used during the transitions between months. Therefore all of the PTM simulations were begun 4 days after these transitions, and particle fate collected 3 to 6 days before these transitions. However the hydrodynamic results do include periods up to the transition.
- The Delta Island Consumptive Use (DICU) simulates the agriculture diversions and return flows. The DICU for the model is consistent with the total monthly volume in CalSim-II. Though the DICU for DSM2 is more spatially represented it still assumes a constant monthly flow rate.
- The DSM2-PTM has the ability to use in channel dispersion but in order to run the simulations as quickly as possible only advection was used. This means that rather than using the pseudo three-dimensional velocity profiles to determine the velocity imposed on a particle, a one-dimensional velocity straight from DSM2-Hydro was used. This means that the particles only disperse when moving from channel to channel.

Temperature Models

- The monthly temperature models are unable to accurately simulate certain aspects of the actual operations strategies used when attempting to meet temperature objectives. This is especially true on the upper Sacramento River, and the American River where adjustments can be made for temperature control. The SRWQM and the Feather River models (with shorter time-steps) were applied to compensate for the deficiencies of the monthly model. Elsewhere, the monthly temperature model results may not capture the full range of daily temperature variability. In addition, imperfections in simulated monthly results from CalSim-II reservoir operations can influence cold water pool storage and downstream temperature results. Historical temperature observations are also presented in Appendix U where sub-monthly temperature model results are unavailable for the full period of evaluation.
- There is also uncertainty regarding performance characteristics of the Shasta TCD. Because of the hydraulic characteristics of the TCD, including leakage, overflow, and performance of the side intakes, the typical model releases are cooler than can be achieved in real-time operations; therefore, a more conservative approach is taken in real-time operations that is not fully represented by the models.

Salmon Mortality and Life Cycle Models

- The salmon mortality models (Reclamation salmon mortality model and SALMOD) are limited to temperature effects on early life stages of Chinook salmon. They do not evaluate potential direct or indirect temperature impacts on later life stages, such as emergent fry, smolts, juvenile out-migrants, or adults. Also, they do not consider other factors that may affect salmon mortality, such as in-stream flows, gravel sedimentation, diversion structures, predation, ocean harvest, etc.
- Because the salmon mortality model operates on a daily time step, a disaggregation procedure is required to use the monthly temperature model output. The salmon model computes daily temperatures by using linear interpolation between the monthly temperatures, which are assumed to occur on the 15th day of the month.
- The application of the IOS model is used to address salmon life cycle stages which are ecological, not evolutionary.
- Salmon models do not address mortality, life cycle, or temperature effects on green sturgeon, or delta smelt.

Chapter 10 CVP and SWP Reservoir Operations

This chapter focuses on how the operations of the Central Valley Project (CVP) and State Water Project (SWP) affect flow and water temperature in the river reaches downstream of project reservoirs. The following discussion refers to the monthly reservoir release exceedence charts and monthly water temperature exceedence charts found in CALSIM Modeling Appendix D and Temperature Modeling Appendix H, respectively. Recommended temperature ranges and flows for various species are later compared to the exceedence charts. Variation in temperatures and flows within months and days are not available from these modeling results, but these variations will be similar to what occurs currently. The modeling results display net changes by month and show the general trend of change useful for comparing operational studies. Monthly exceedence charts are shown for critical locations, and compare the modeling runs outlined in Chapter 9. With all models there are assumptions and limitations that are inherent within. Please refer to Chapter 9 for a list of model limitations on which this analysis was based.

Integrated Upstream CVP Reservoir Operations

Modeling

The 2004 OCAP BA described and analyzed significant operations influences to CVP/SWP reservoir operations. The 2004 OCAP BA also analyzed the integrated management and operation of CVP reservoirs to reflect long-term operations criteria that included significant water policy changes of the previous decade. A short list of the significant water management policy changes that influenced how the integrated upstream CVP reservoir management was reflected in the 2004 OCAP BA includes:

- Changes to Trinity River flow requirements through implementation of the Trinity River Restoration Program.
- Changes to seasonal reservoir release timing and magnitudes through implementation of CVPIA section 3406(b)(2) management. These changes include the seasonal timing and magnitude of releases necessary to meet the CVP commitments to SWRCB D-1641.
- Initial implementation to the EWA program.

The above management changes have had and will continue to have broad influences as to how the CVP reservoirs are operated and managed as an integrated system of reservoirs towards meeting all CVP authorized purposes.

The most significant new operational assumptions that will influence the timing and magnitude of CVP reservoir releases are:

- Use of 3406(b)(2) water to create a flow regime consistent with the proposed Lower American Flow Standard.
- Projected future increases in central valley urban water demands. The largest changes in future demand patterns occur in the American River basin.

- Modification to New Melones Reservoir operations for improved drought management and to better reflect the changing water quality dynamics in the overall San Joaquin Basin upstream of the influence of the Stanislaus River.

Figure 10-1 illustrates integrated CVP storage facilities (Trinity+Shasta+Folsom) storage trends for each of the studies. The first plot shows the time-series traces for studies 6.0, 7.0, 7.1, and 8.0. The other plots (Figure 10-2 and Figure 10-3) compare End-of-May and End-of-September exceedence storages. The end-of-May storages reflect the general high point in CVP storage for most years and the end-of-September storage is a good measure of reservoir conditions before the new water year begins. In general, the end-of-May storage exceedence plot shows a reduction to CVP storage conditions over time in the driest 30% to 40% of conditions. The end-of-September storage exceedence plot shows a reduction to CVP storage conditions over time in the driest 70% of conditions. The change to CVP storage conditions in September is a reflection of the increased water demands and operational changes introduced to CVP operations in study 7.1 and study 8.0. The less frequent depiction of change to CVP storage conditions for end-of-May storage reflects the potential for the CVP to refill reservoir storage between September and the following May.

Figure 10-4 to Figure 10-9 illustrate the major CVP reservoir releases in the central valley (Keswick+Nimbus) for each of the studies. There is a figure depicting average releases, as well as each release for yeartype. In general, these graphs depict the general seasonality of CVP reservoir releases, potential high release during winter months for flood control and the high releases during the peak of summer consumptive demand. In general, study 8 shows the highest overall releases for consumptive purposes and the least for flood control purposes. Figure 10-10 depicts this generalized trend between the studies as the increases in the median summertime consumptive releases for study 7.1 and study 8.0 and the changes to the frequency of flood control releases in January and February.

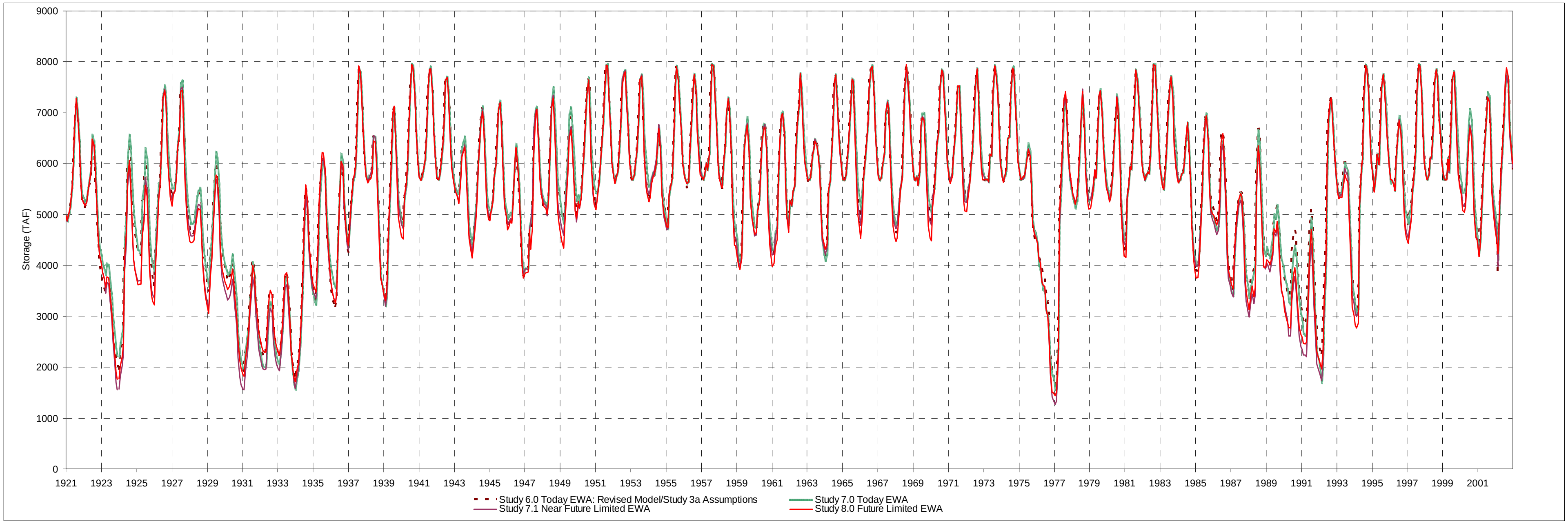


Figure 10-1 Trinity+Shasta+Folsom Storage Time-series

Trinity+Shasta+Folsom Exceedence Storage

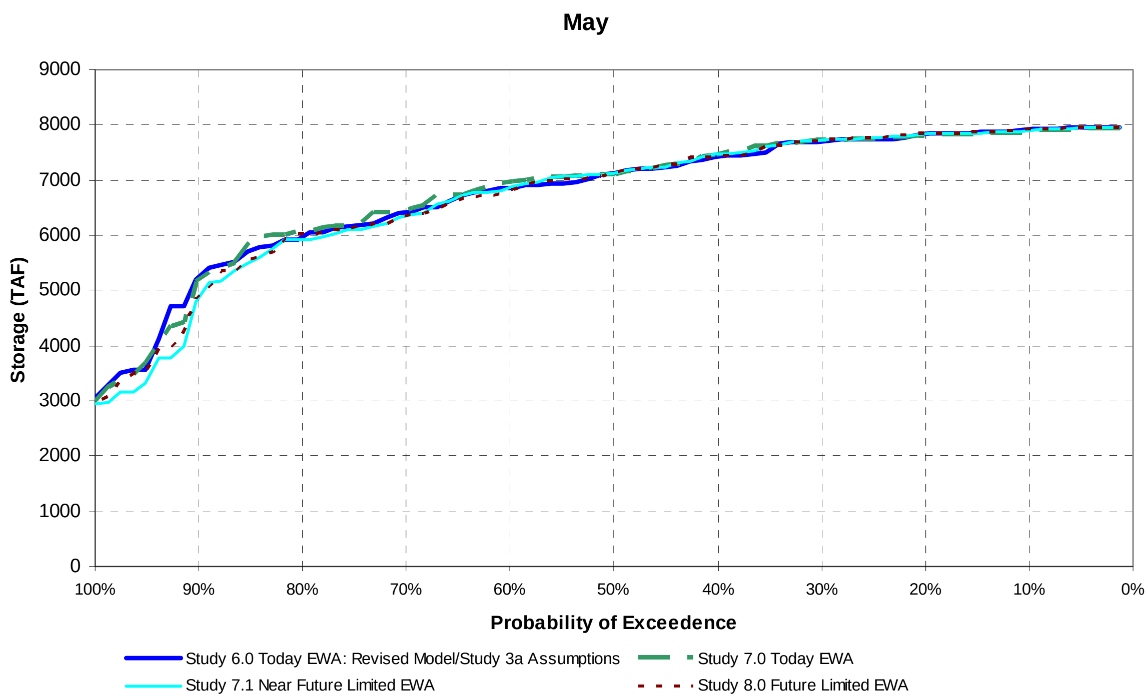


Figure 10-2 Trinity+Shasta+Folsom Exceedence Storage – End-of-May

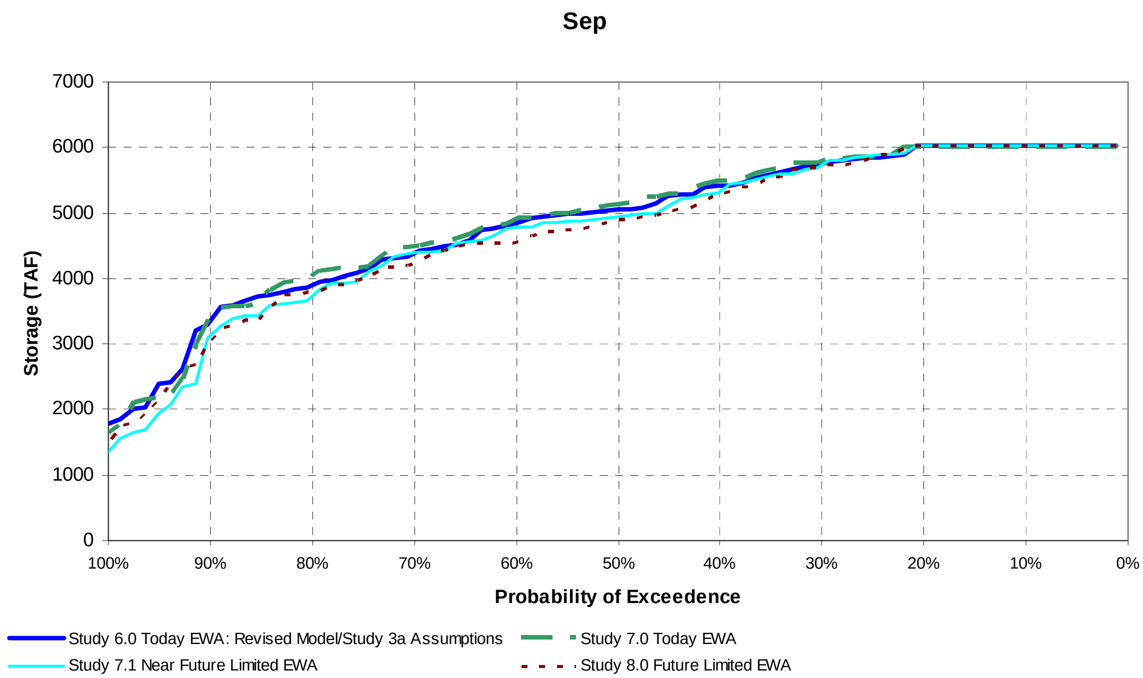


Figure 10-3 Trinity+Shasta+Folsom Exceedence Storage – End-of-September

Keswick+Nimbus Releases by Yeartype

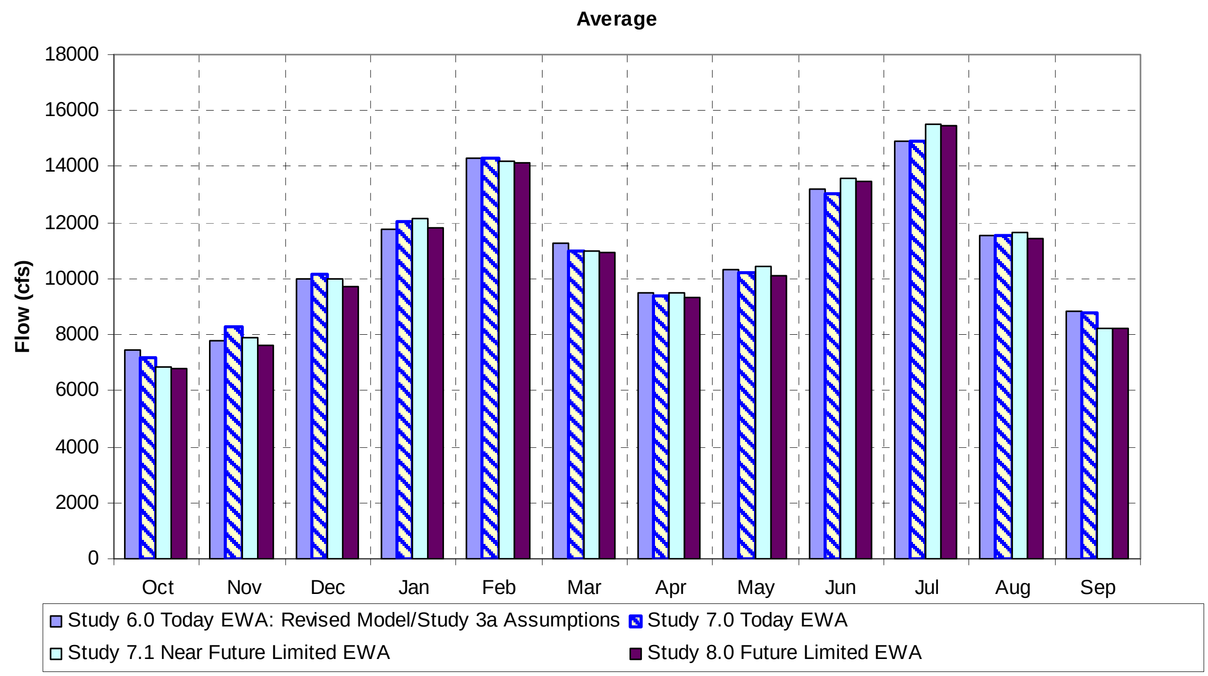


Figure 10-4 Keswick+Nimbus Releases - Average

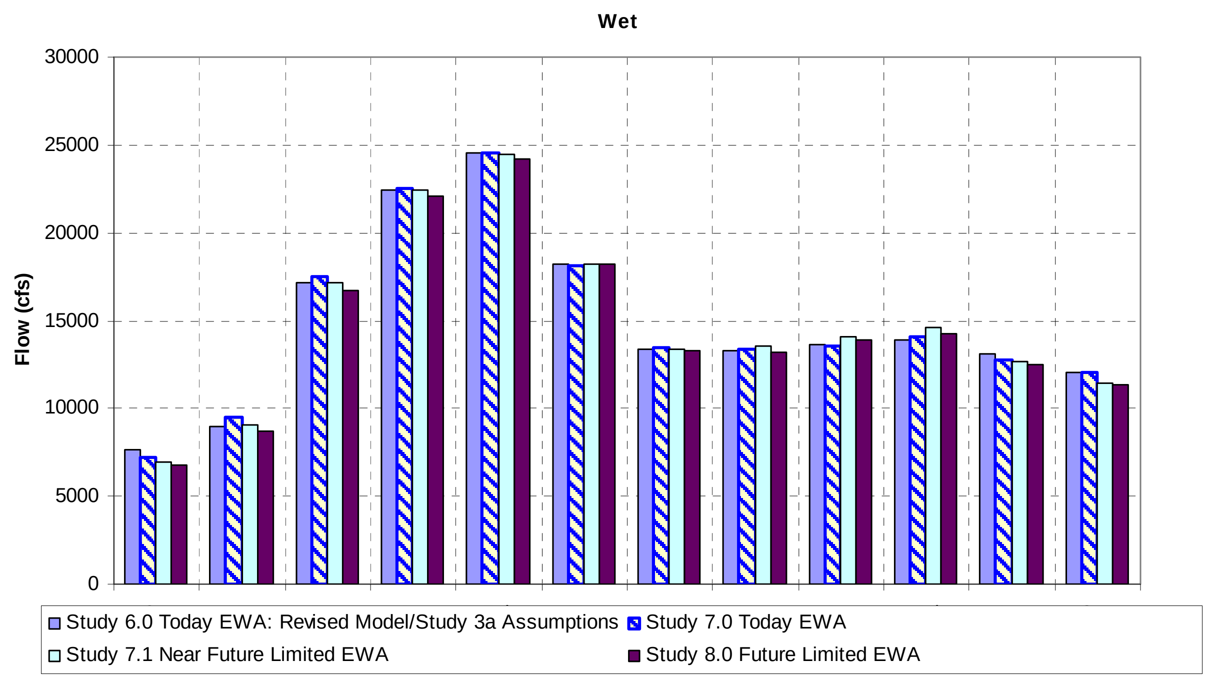


Figure 10-5 Keswick+Nimbus Releases - Wet

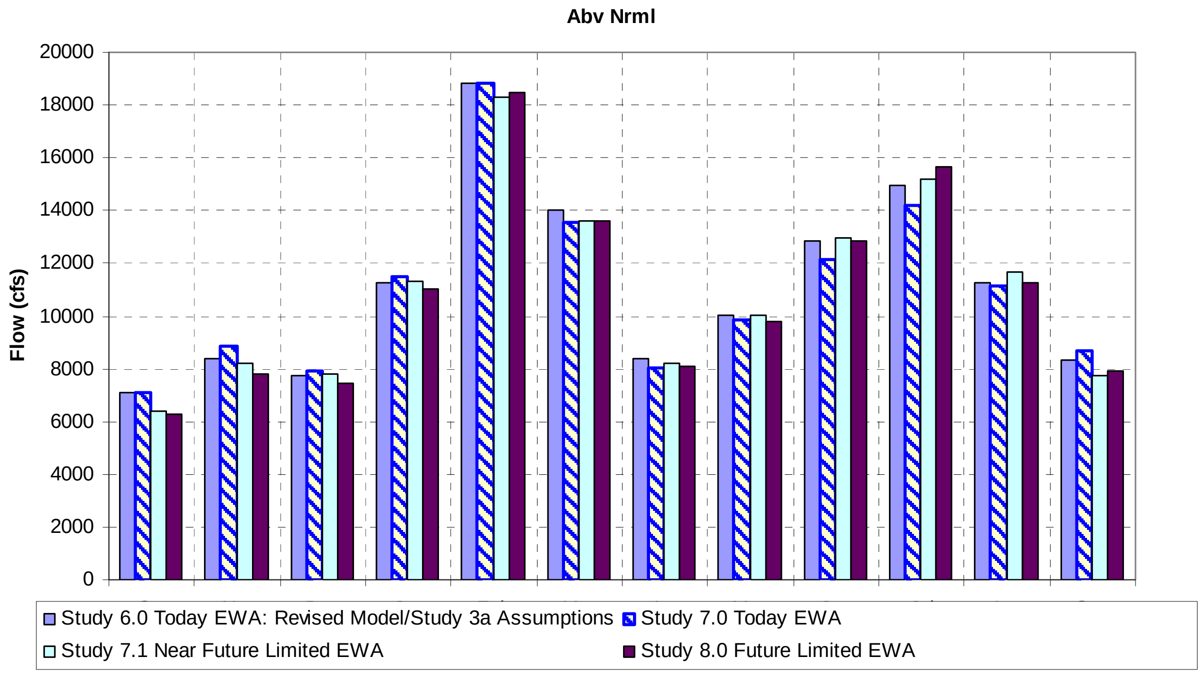


Figure 10-6 Keswick+Nimbus Releases – Above Normal

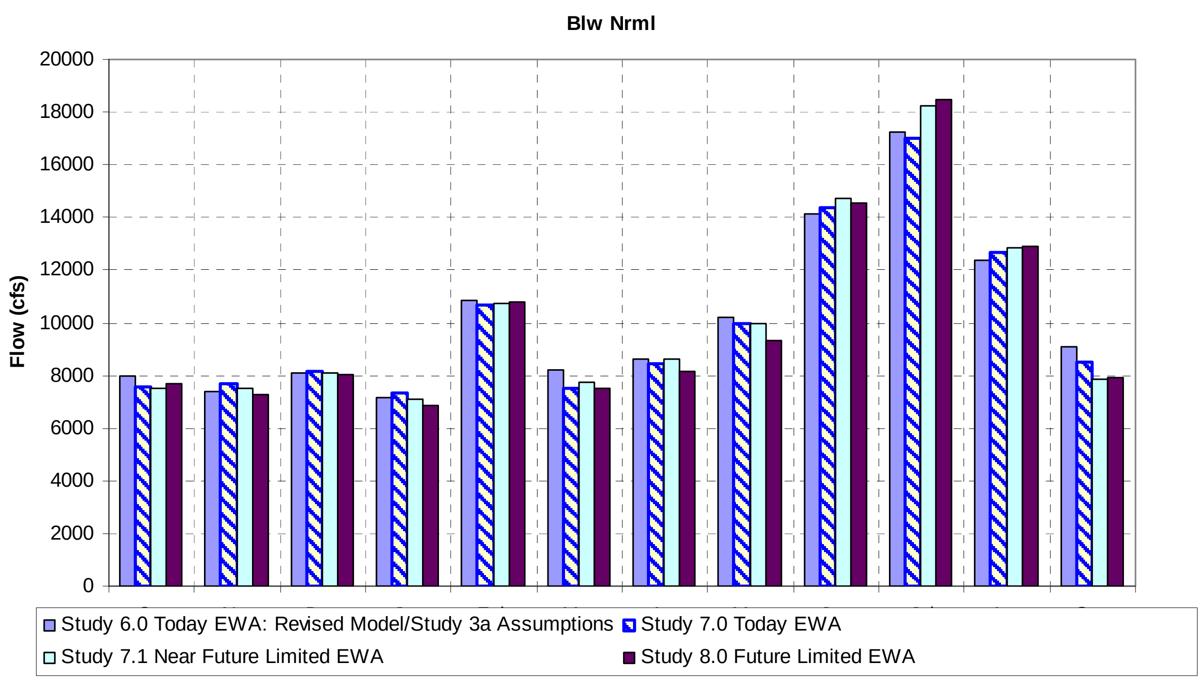


Figure 10-7 Keswick+Nimbus Releases – Below Normal

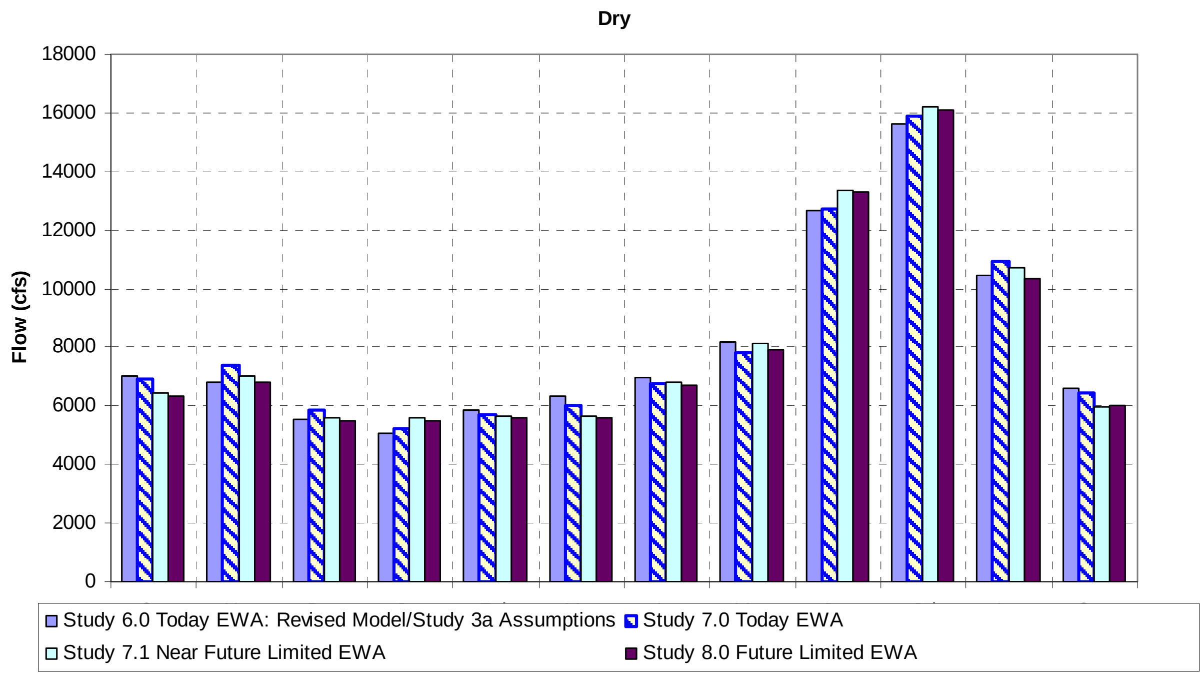


Figure 10-8 Keswick+Nimbus Releases - Dry

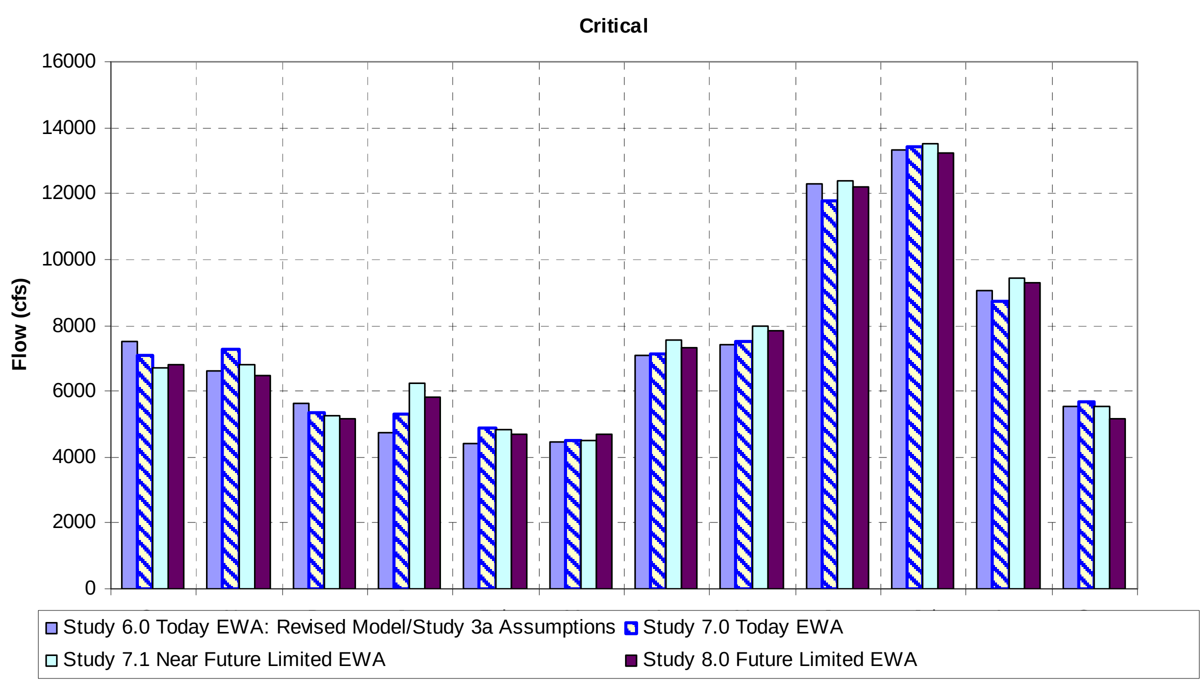


Figure 10-9 Keswick+Nimbus Releases - Critical

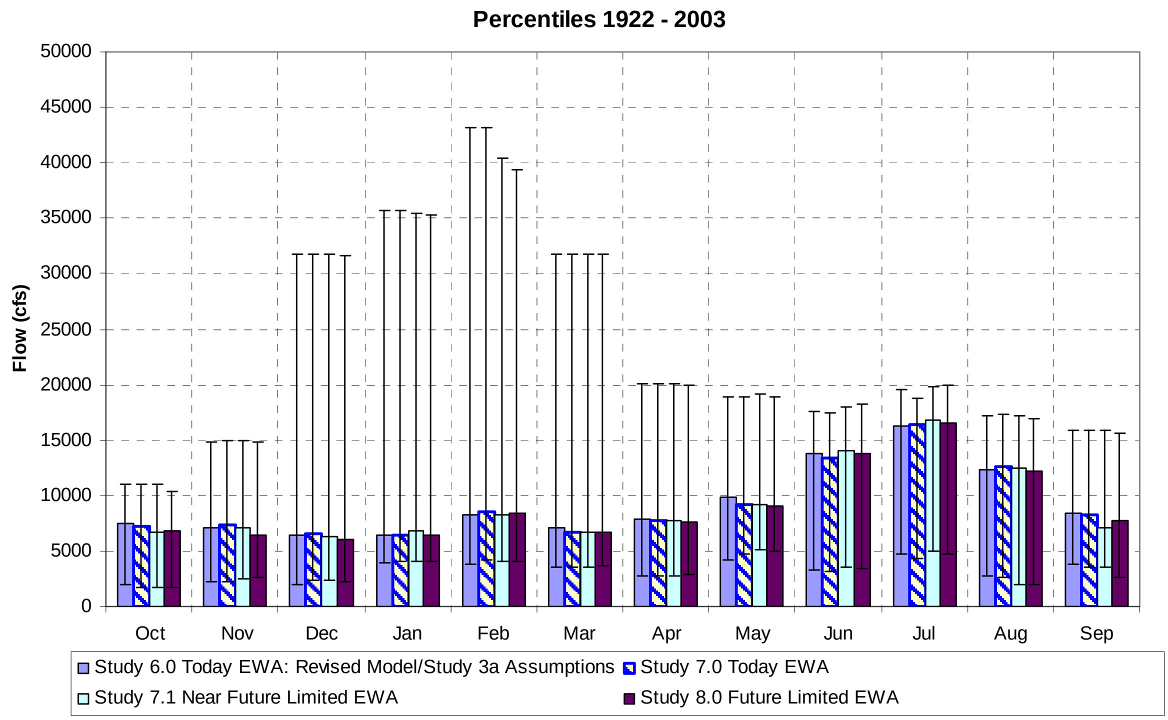


Figure 10-10 Keswick+Nimbus 50th Percentile Monthly Releases with the 5th and 95th as the Bars

Trinity River

Modeling

Figure 10-11 shows the chronology of Trinity storage using hydrologic data from October 1921 through September 2003. Figure 10-12 shows the end-of-September exceedence chart for Trinity.

All studies have similar carryover performance, with the notable exception of slight decreases in carryover under very low storage conditions for studies 7.1 and 8. Other figures presented in this section are the percentile of Trinity Releases (Figure 10-13) and the monthly averages for Lewiston releases by long-term average and by 40-30-30 Index water-year type (Figure 10-14 through Figure 10-19). Figure 10-20 shows the monthly percentile from imports from the Trinity through Clear Creek Tunnel. The graphs of averages and percentiles show how the flows in the Trinity generally adhere to the flow standard on average. The monthly percentiles for imports from Clear Creek tunnel show the general variation trends and timing of water imported to the Sacramento Basin. The vast majority of water is imported during the July to October timeframe to coincide with water temperature and power production objectives in the Sacramento Basin.

Table 10-1 Trinity River Longterm Annual Average

Longterm Annual Average

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Trinity End-of-September Storage	7	-6	-1	5
Annual Lewiston Release	0	1	0	-1
Annual Carr Powerplant Flows	0	-1	-1	0

29- 34 Difference

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Trinity End-of-September Storage	-21	0	38	38
Annual Lewiston Release	0	0	0	0
Annual Carr Powerplant Flows	35	-20	-34	-13

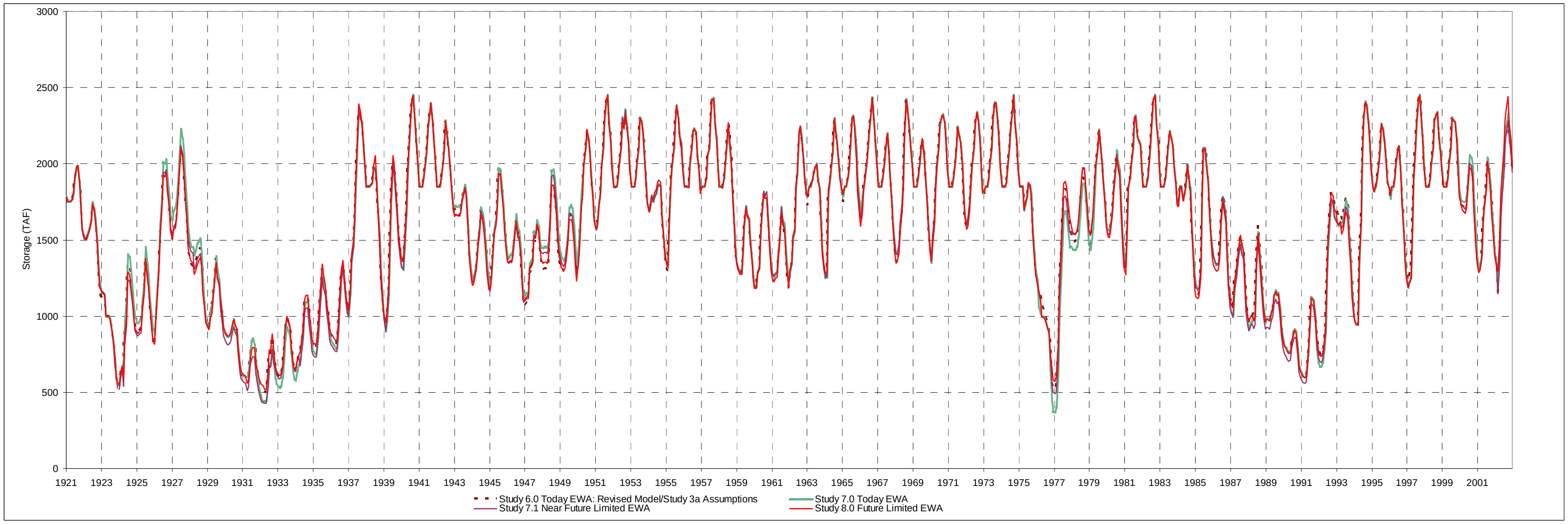


Figure 10-11 Chronology of Trinity Storage Water Year 1922 - 2003

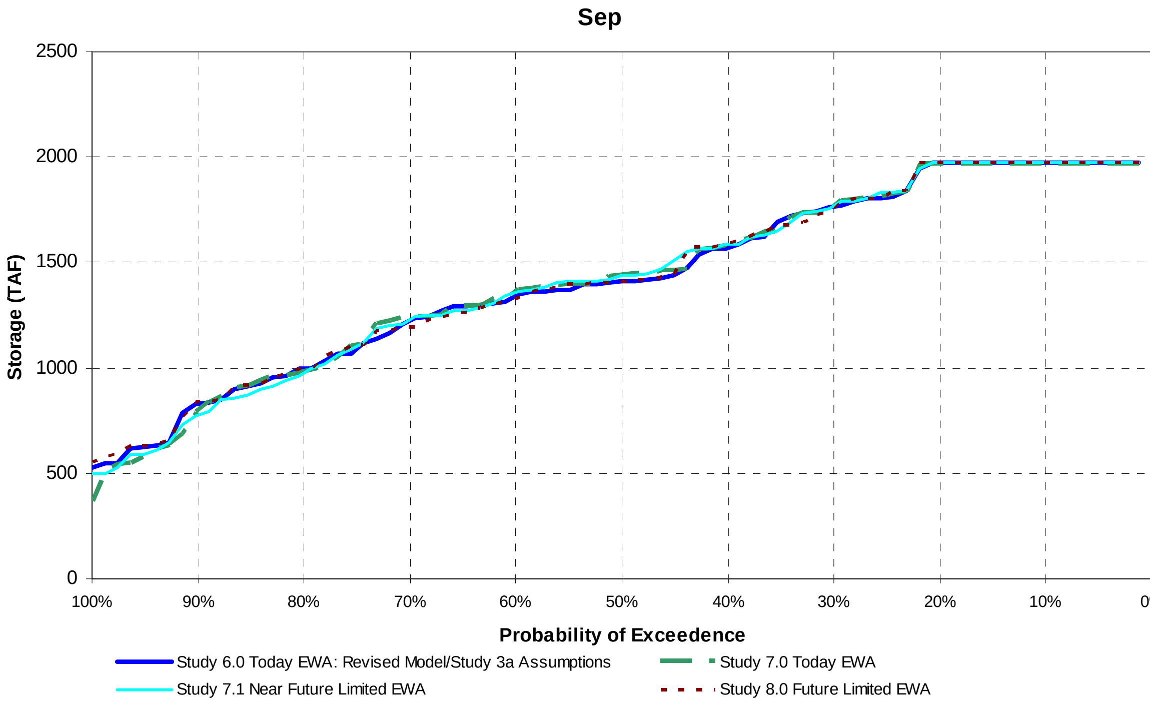


Figure 10-12 Trinity Reservoir End of September Exceedence

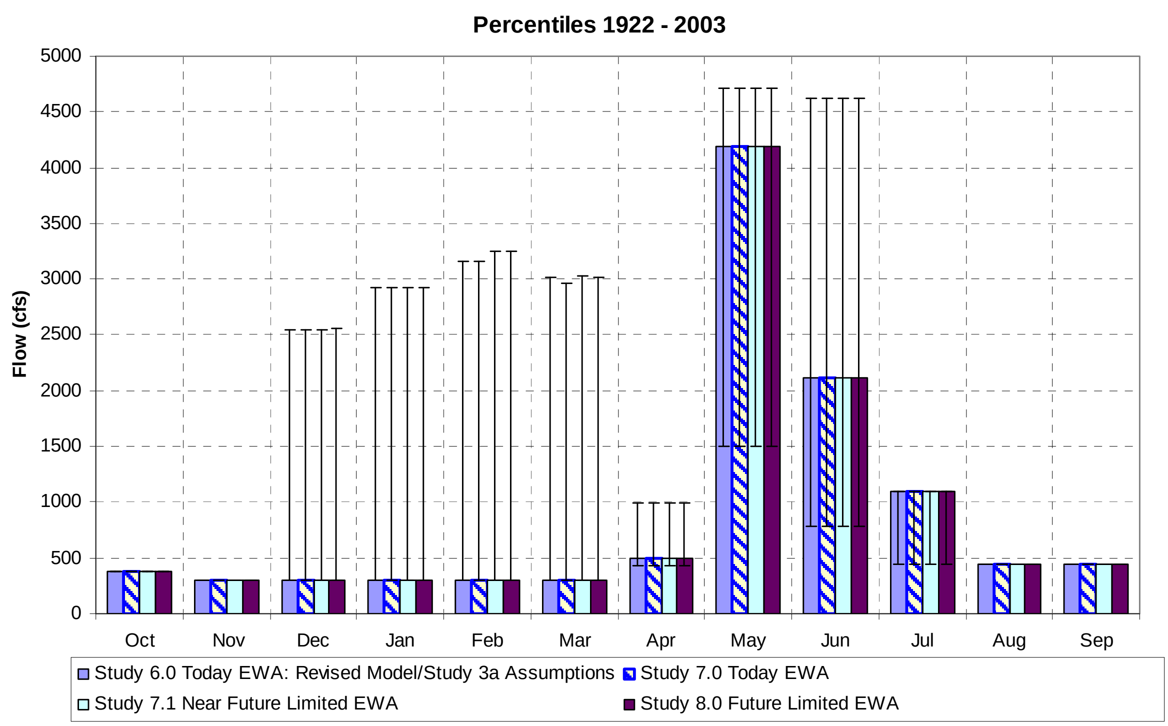


Figure 10-13 Lewiston 50th Percentile Monthly Releases with the 5th and 95th as the Bars

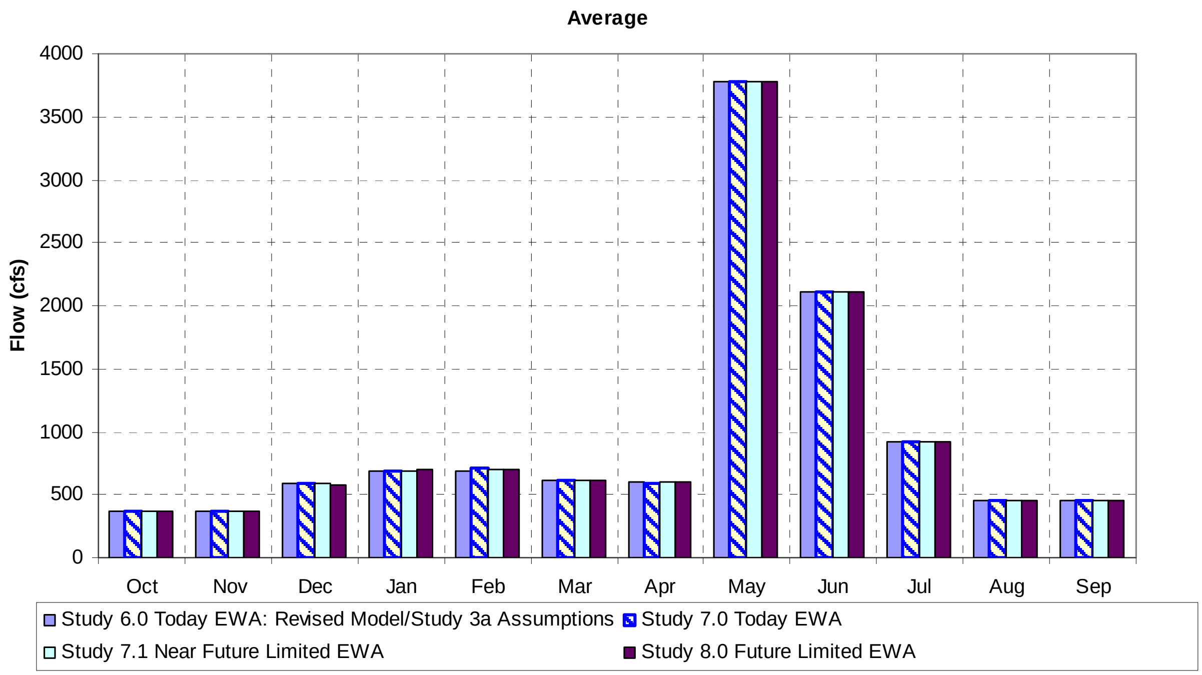


Figure 10-14 Average Monthly Releases to the Trinity from Lewiston

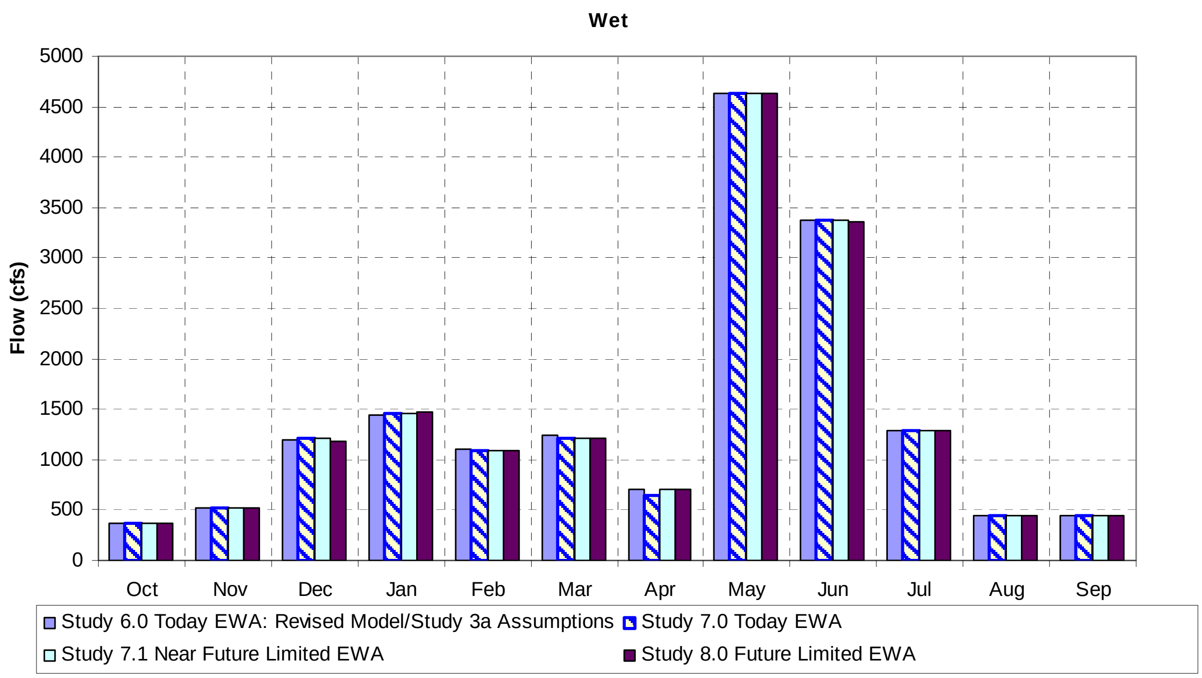


Figure 10-15 Average Wet Year (40-30-30 Classification) Monthly Releases to the Trinity

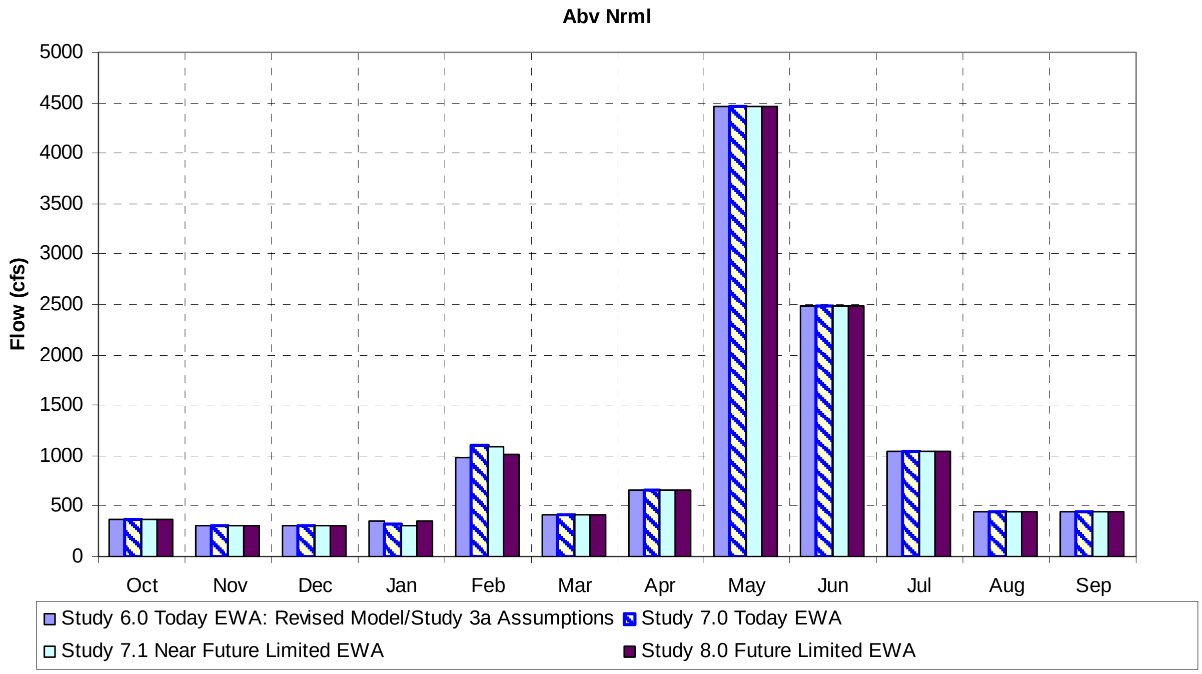


Figure 10-16 Average Above-normal Year (40-30-30 Classification) Monthly Releases to the Trinity

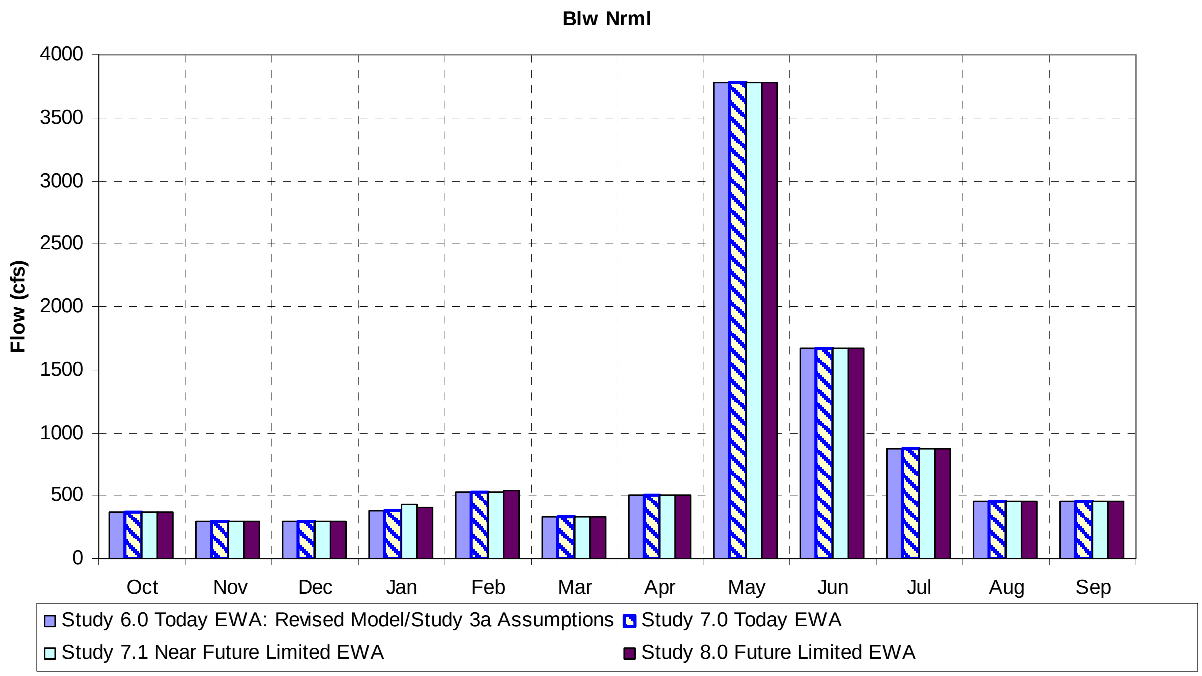


Figure 10-17 Average Below-normal Year (40-30-30 Classification) Monthly Releases to the Trinity

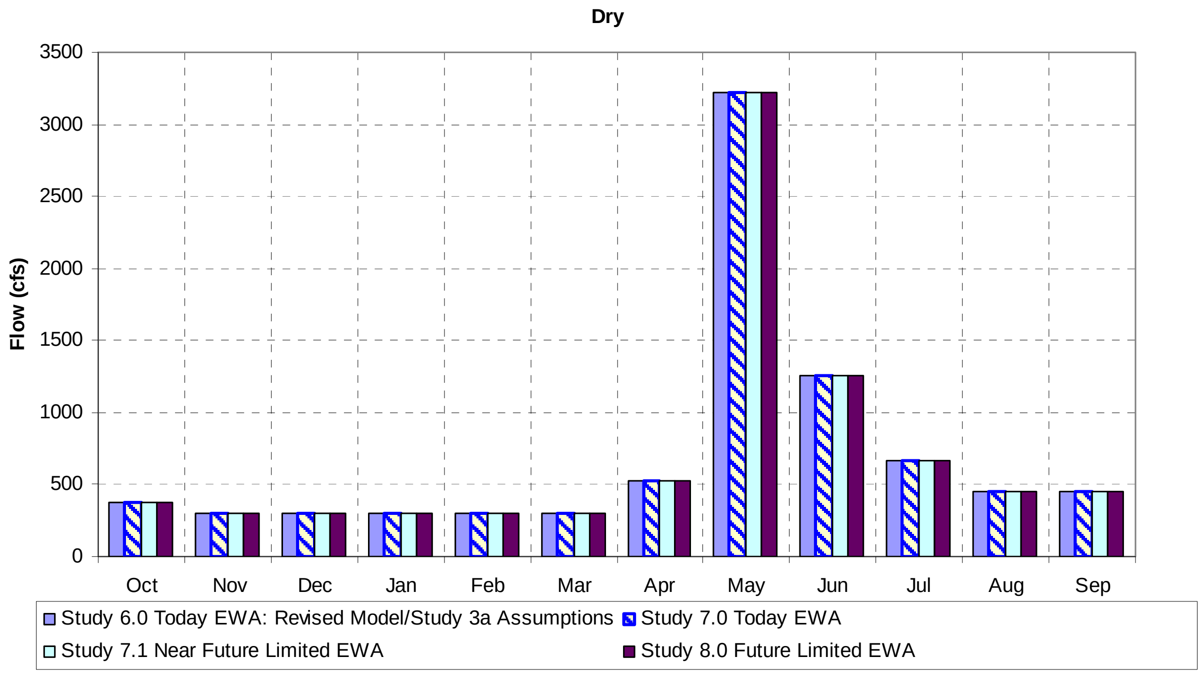


Figure 10-18 Average Dry-year (40-30-30 Classification) Monthly Releases to the Trinity

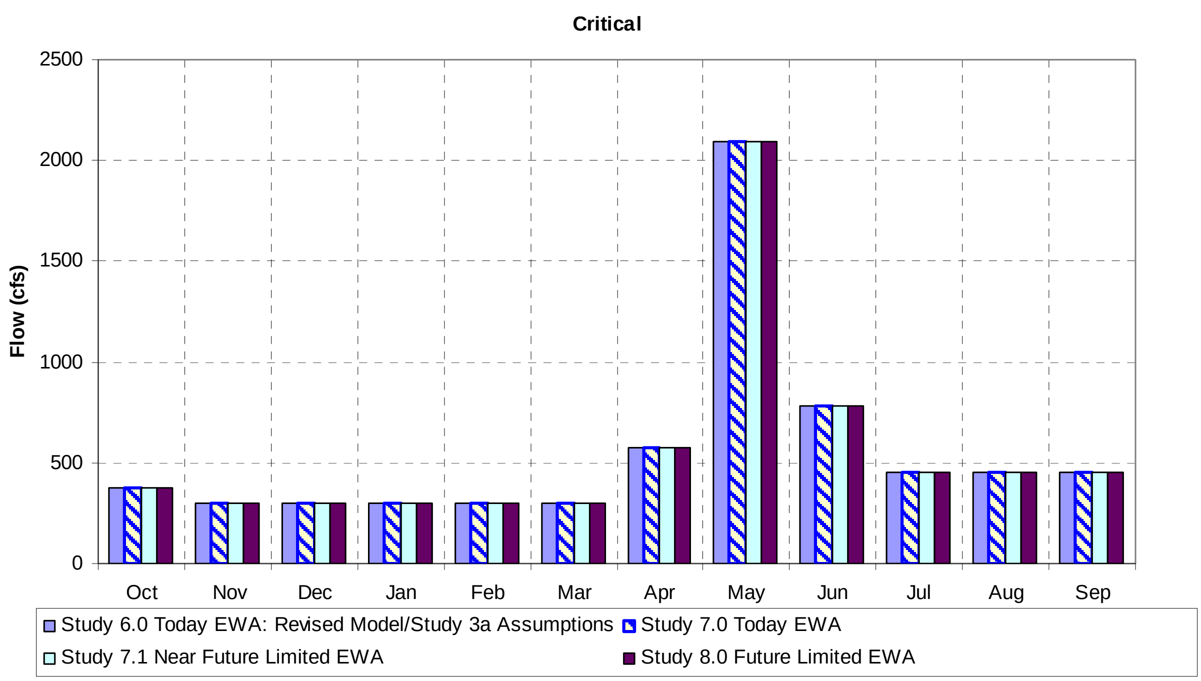


Figure 10-19 Average Critical-year (40-30-30 Classification) Monthly Releases to the Trinity

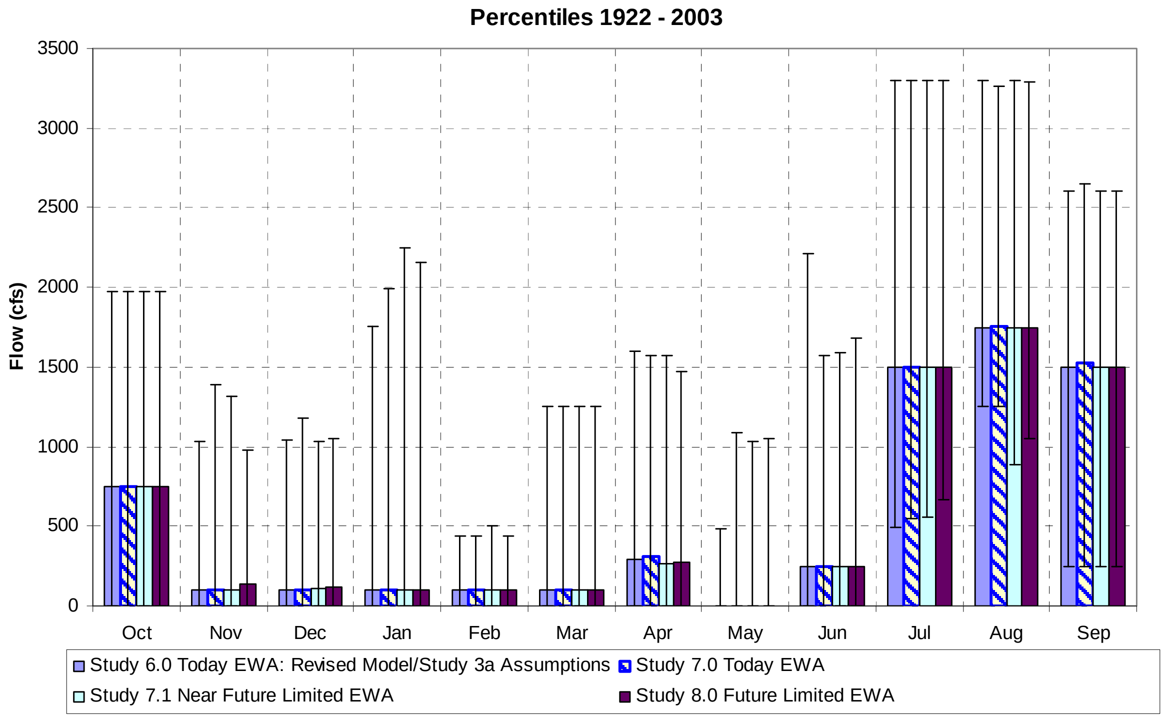


Figure 10-20 Clear Creek Tunnel 50th Percentile Monthly Releases with the 5th and 95th as the Bars

Trinity River Temperature Analysis

Figure 10-21 - Figure 10-27 illustrates potential water temperatures provided to the Trinity River at Douglas City. In general, the water temperatures are very similar for each of the studies. Each study shows difficulty meeting Trinity Basin water temperature objectives in approximately 20% of the drier years during September.

Douglas City Exceedence Plots

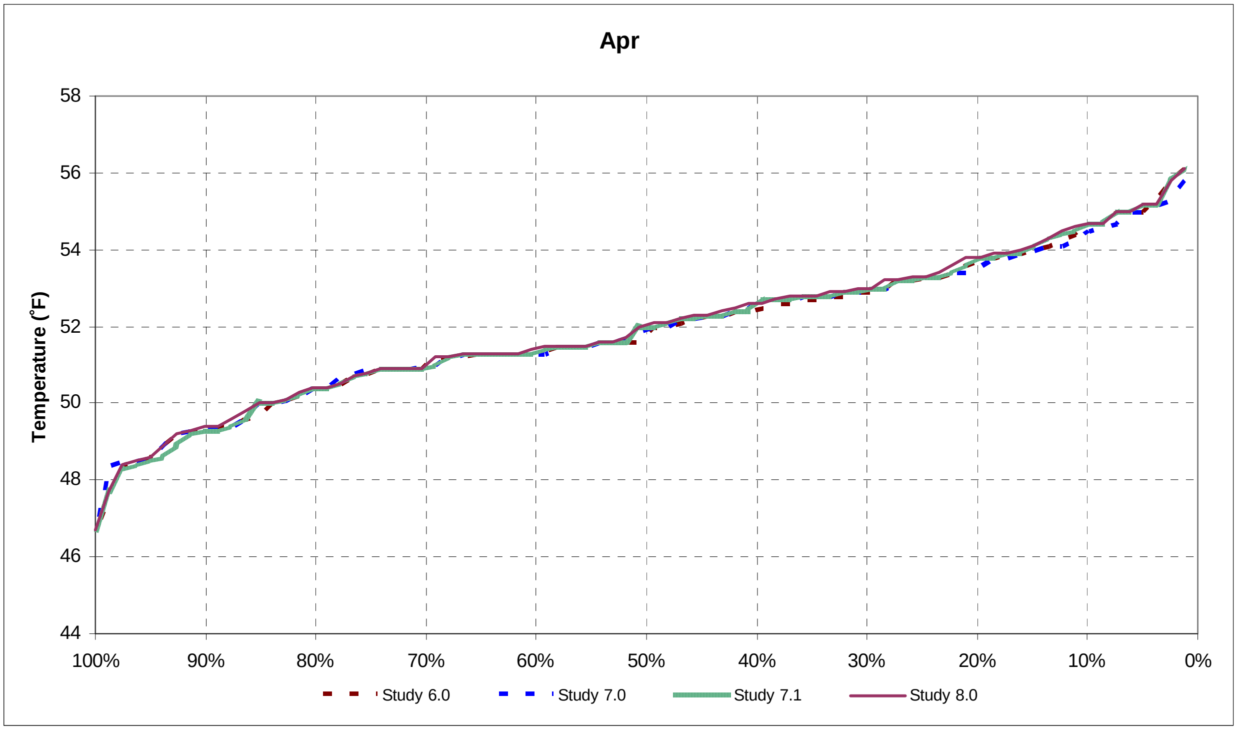


Figure 10-21 Douglas City Exceedence Plot – End-of-April

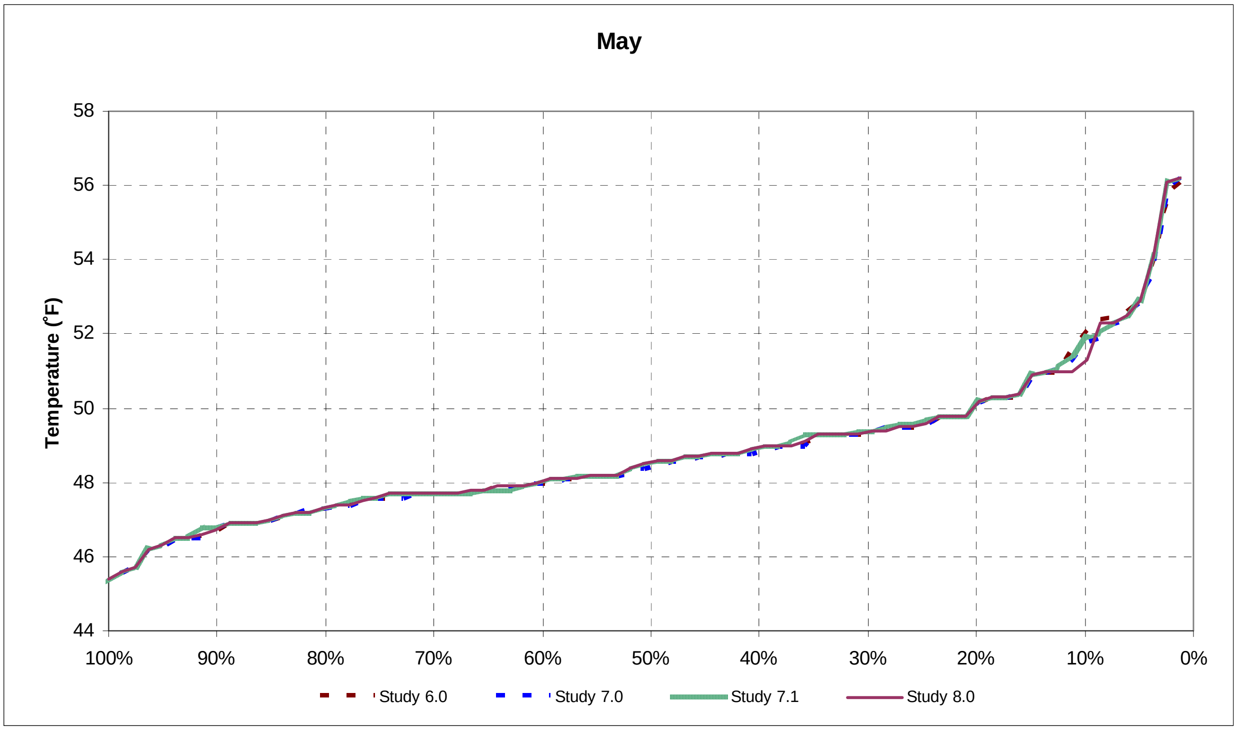


Figure 10-22 Douglas City Exceedence Plot – End-of-May

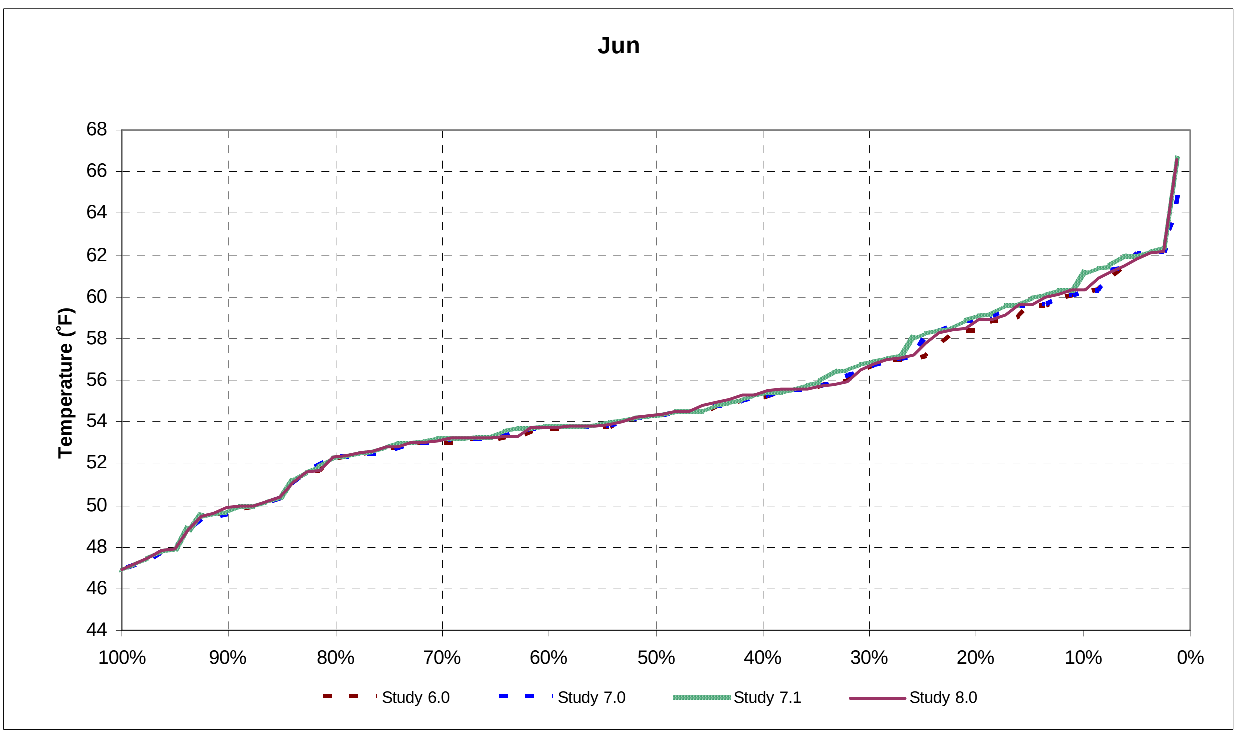


Figure 10-23 Douglas City Exceedence Plot – End-of-June

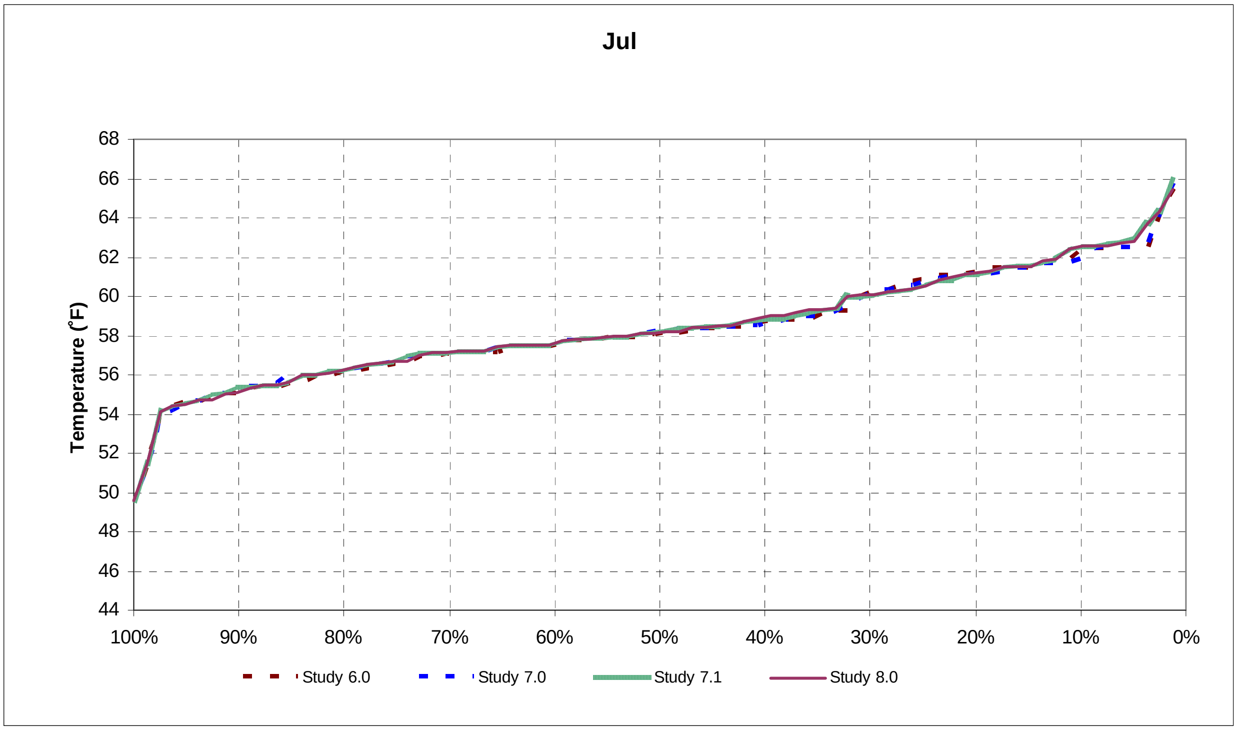


Figure 10-24 Douglas City Exceedence Plot – End-of-July

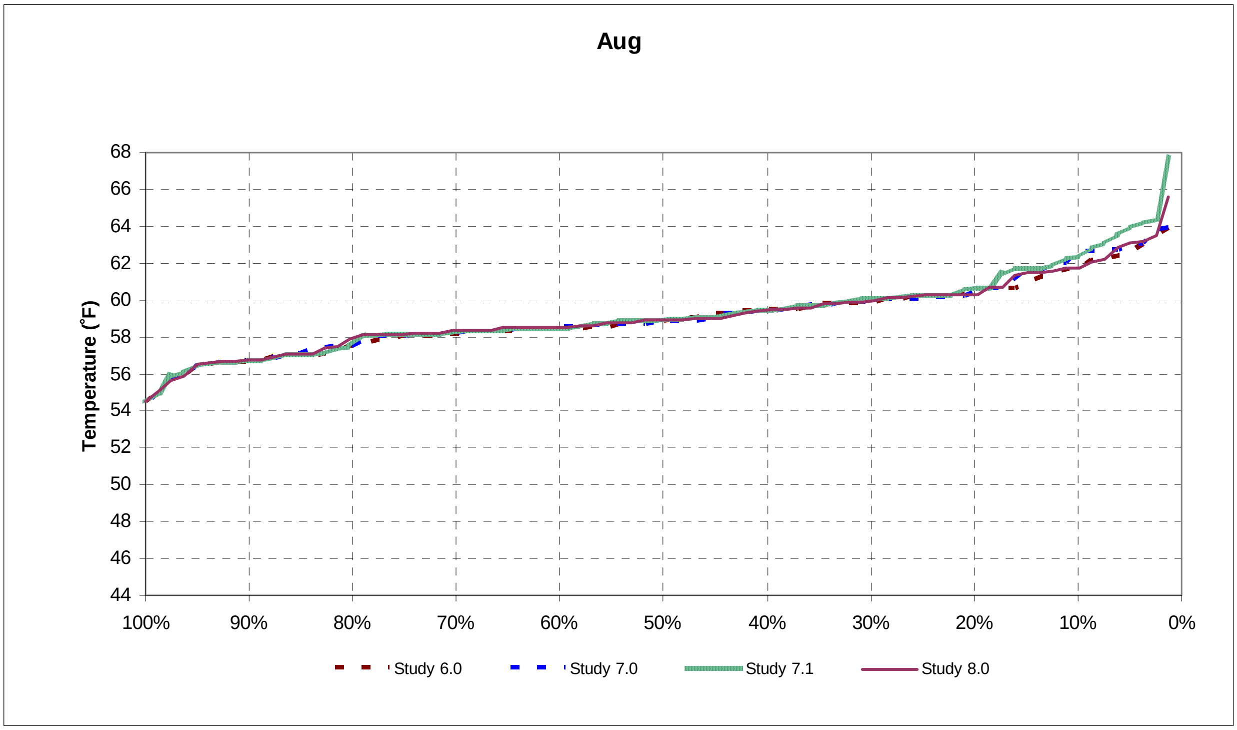


Figure 10-25 Douglas City Exceedence Plot – End-of-August

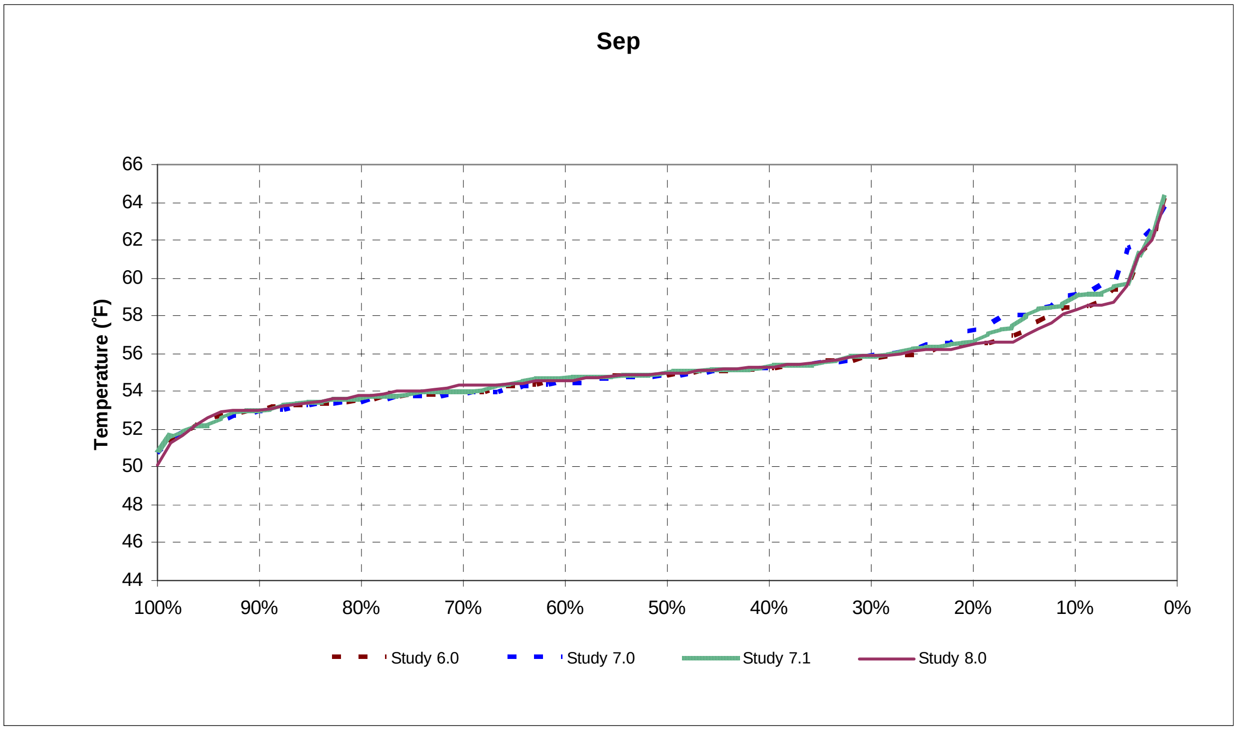


Figure 10-26 Douglas City Exceedence Plot – End-of-September

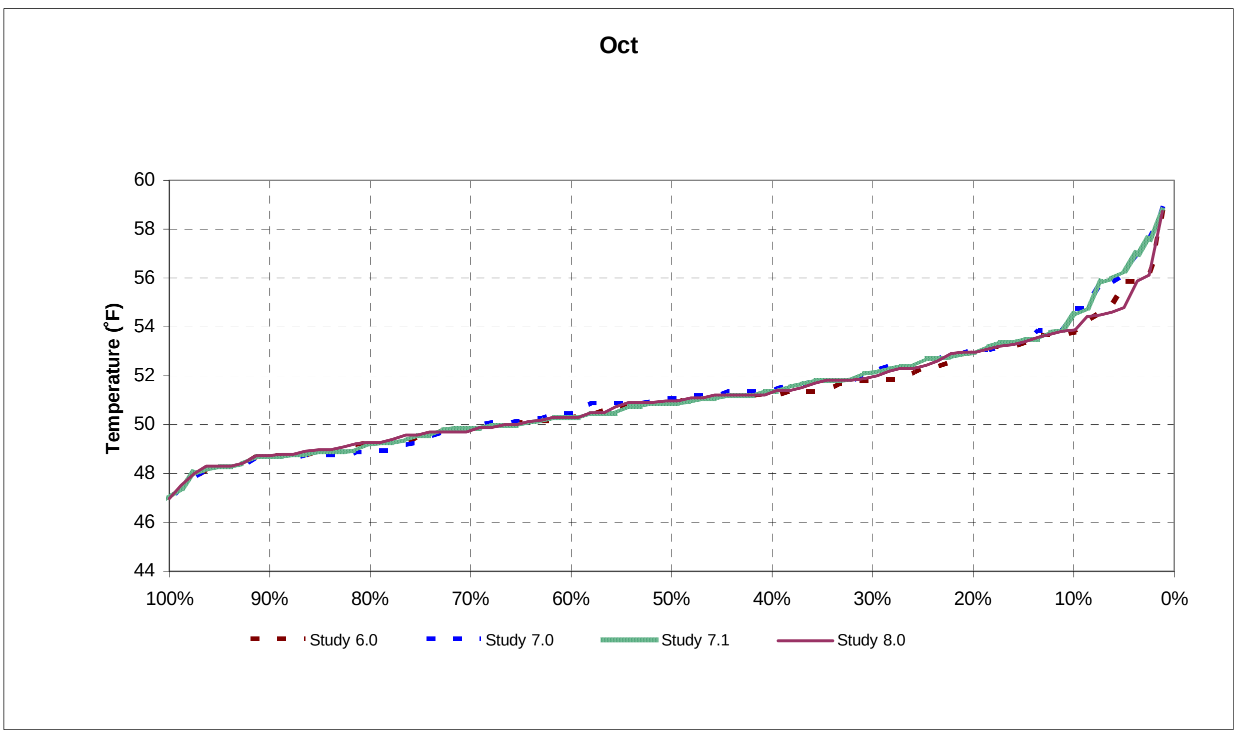


Figure 10-27 Douglas City Exceedence Plot – End-of-October

Clear Creek

Modeling

Whiskeytown Reservoir generally maintains a 235 thousand acre-feet (taf) end-of-September storage. Figure 10-28 shows that the end-of-September storage for Whiskeytown dropped from 235 taf to 180 taf only under the most extreme circumstances when Clear Creek inflows to Whiskeytown Reservoir and imports from the Clear Creek Tunnel could not support maintenance of Clear Creek release flows without some Whiskeytown Reservoir storage reduction.

Figure 10-29 shows that Clear Creek is mainly being driven by the 3406 (b)(2) management releases with the 50th and 95th percentiles for each month in all three studies. Figure 10-30 through Figure 10-35 illustrates the monthly averages by long-term average and by 40-30-30 Water Year Classification.

Figure 10-36 shows the Spring Creek Powerplant releases with the 50th and 95th percentiles for each month in all three studies. The seasonal pattern of releases reflects the goal to import water from the Trinity Reservoir system on a predominantly July to October pattern conducive with water temperature management and power generation needs. The variation during winter months generally reflects the movement of winter flows from the Trinity Reservoir system or winter flows produced as Clear Creek inflows to Whiskeytown Reservoir.

Table 10-2 Clear Creek Long-term Annual Average

Longterm Annual Average

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Annual Carr Powerplant Flows	0	-1	-1	0
Annual Clear Creek Release	-3	0	2	2
Annual Spring Creek Powerplant Flows	3	-1	-2	-2

29- 34 Difference

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Annual Carr Powerplant Flows	35	-20	-34	-13
Annual Clear Creek Release	-10	-2	8	10
Annual Spring Creek Powerplant Flows	45	-18	-42	-24

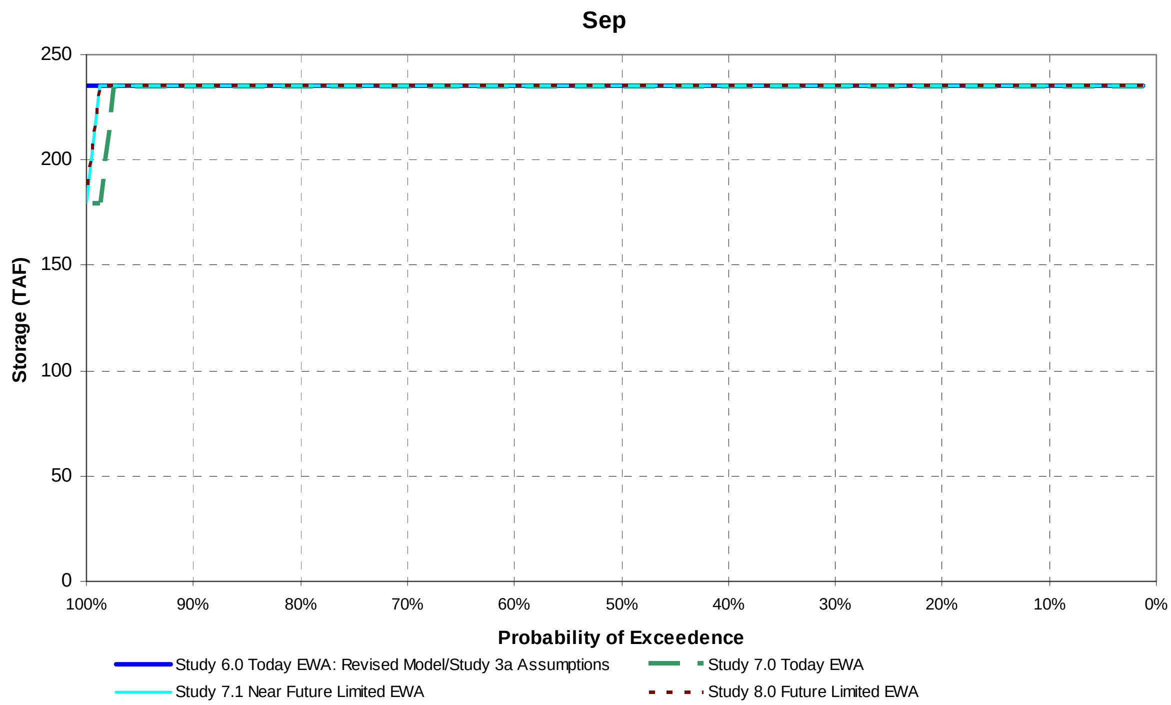


Figure 10-28. Whiskeytown Reservoir End-of-September Exceedence

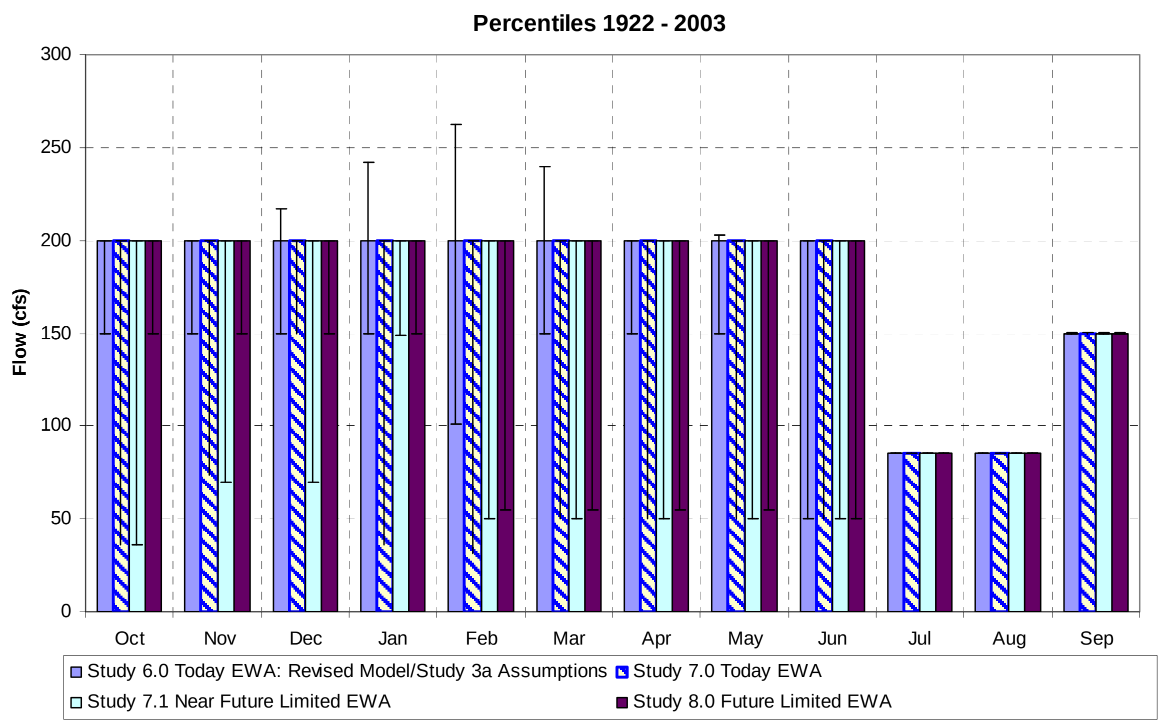


Figure 10-29 Clear Creek Releases 50th Percentile Monthly Releases with the 5th and 95th as the Bars

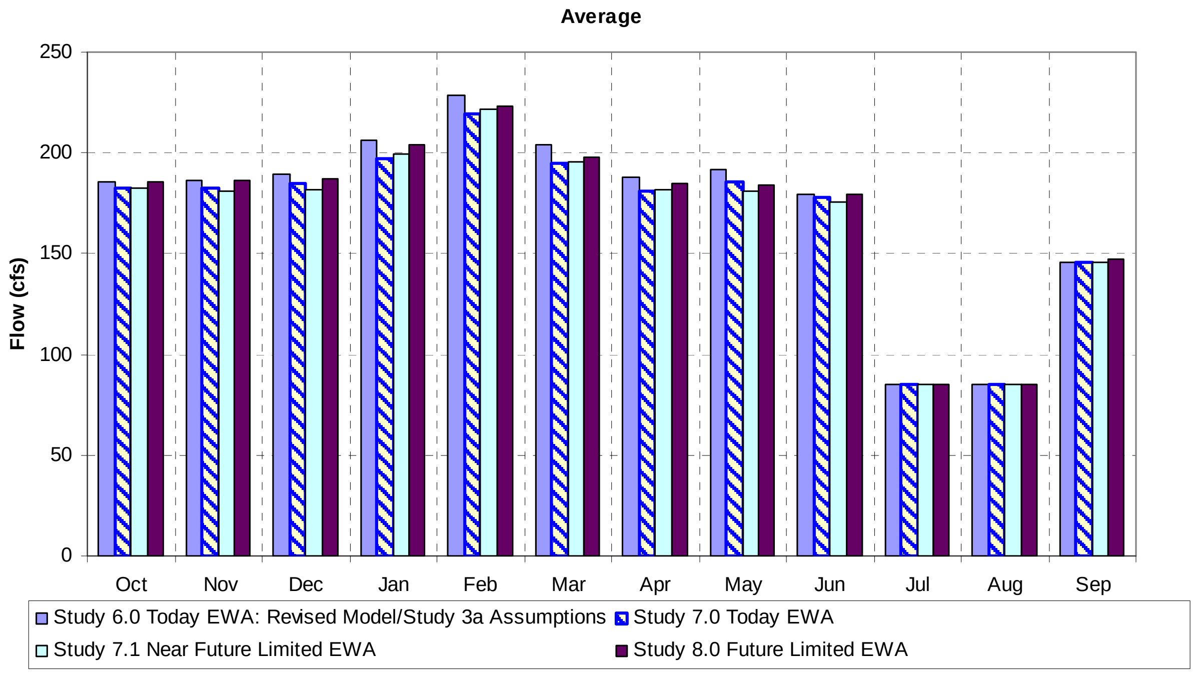


Figure 10-30 Long-term Average Monthly Releases to Clear Creek

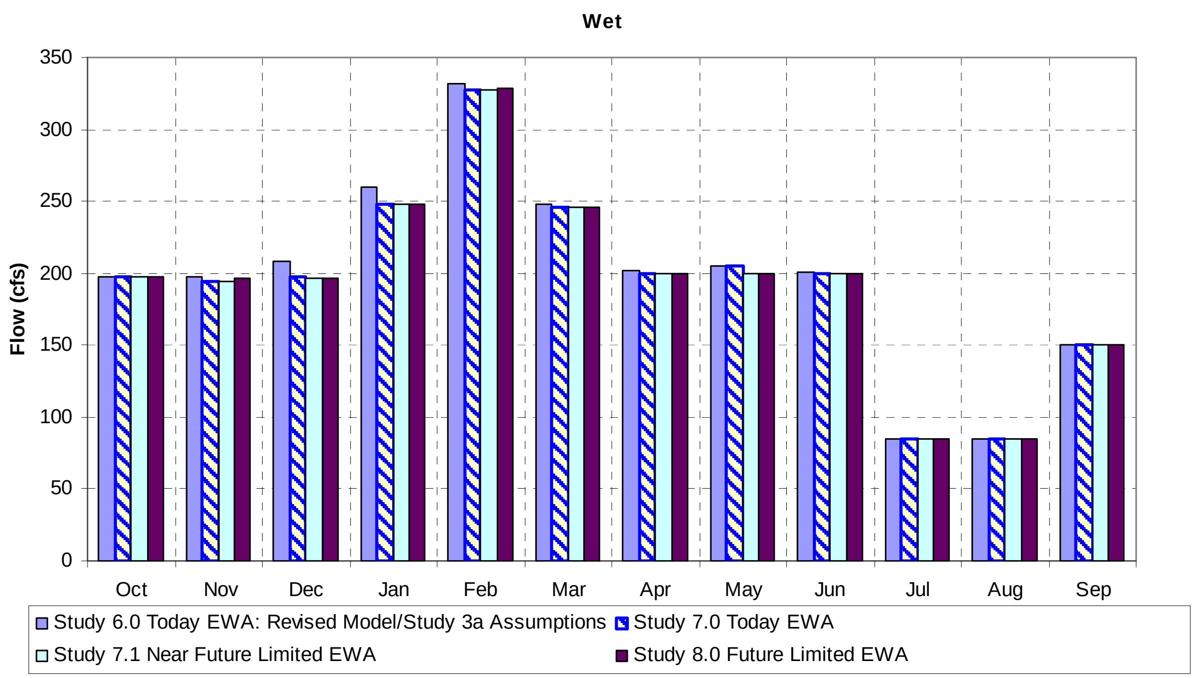


Figure 10-31 Average Wet Year (40-30-30 Classification) Monthly Releases to Clear Creek

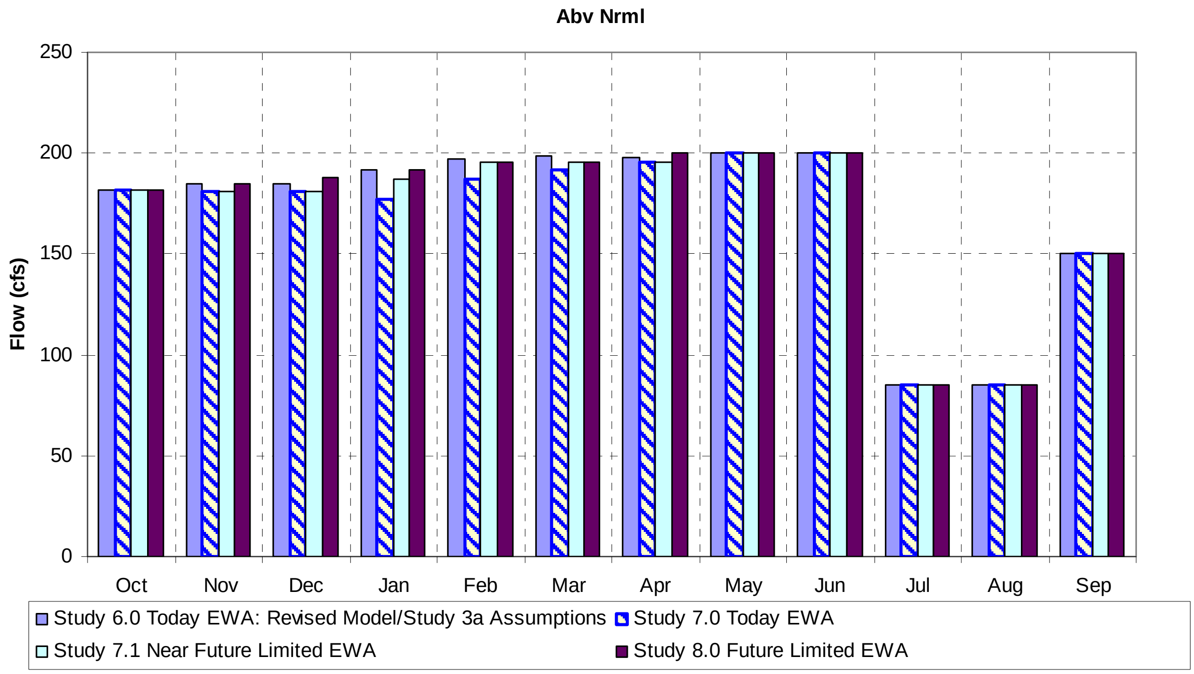


Figure 10-32 Average Above Normal Year (40-30-30 Classification) Monthly Releases to Clear Creek

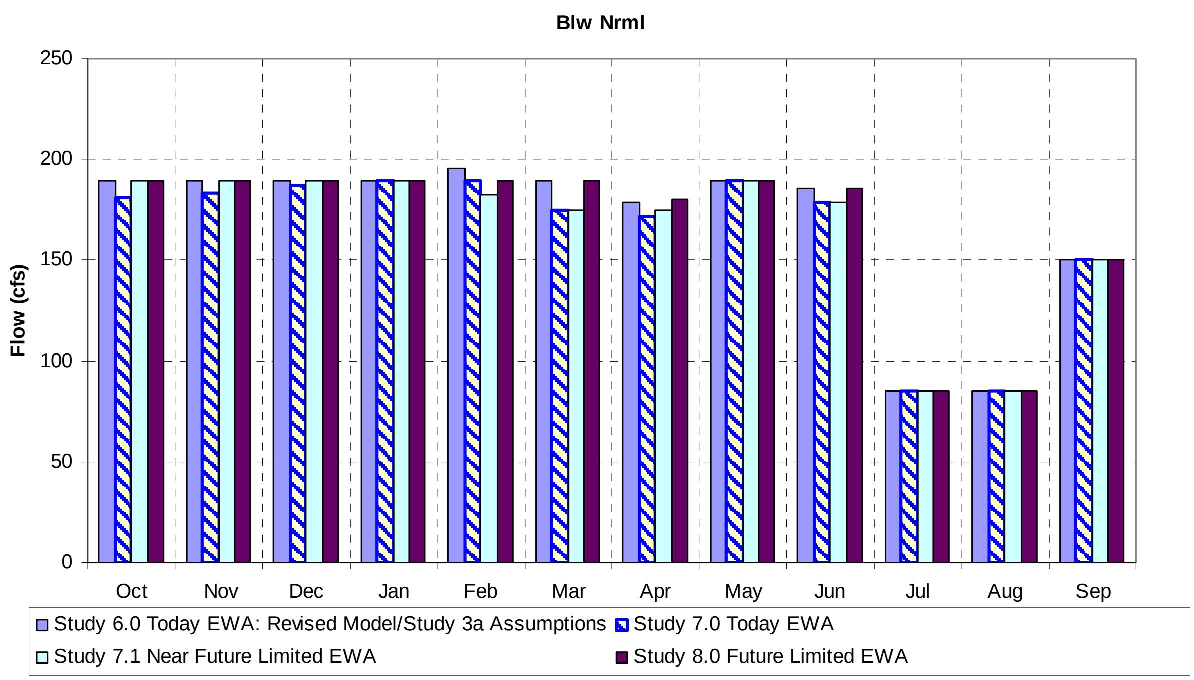


Figure 10-33 Average Below Normal Year (40-30-30 Classification) Monthly Releases to Clear Creek

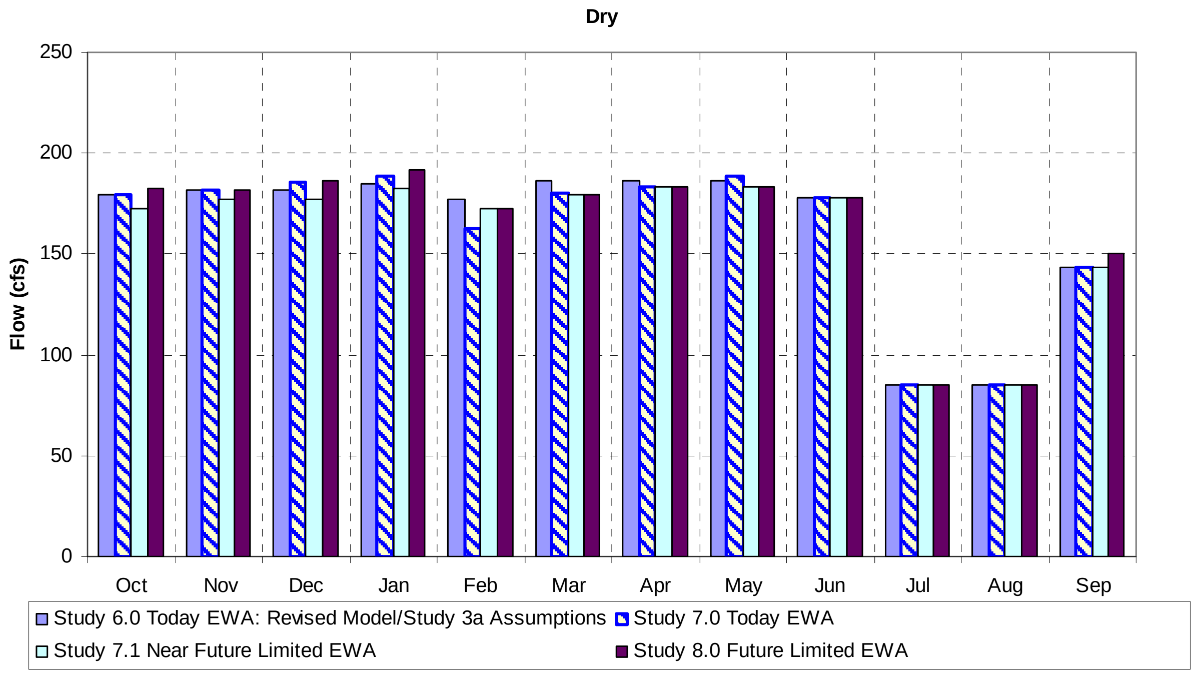


Figure 10-34 Average Dry Year (40-30-30 Classification) Monthly Releases to Clear Creek

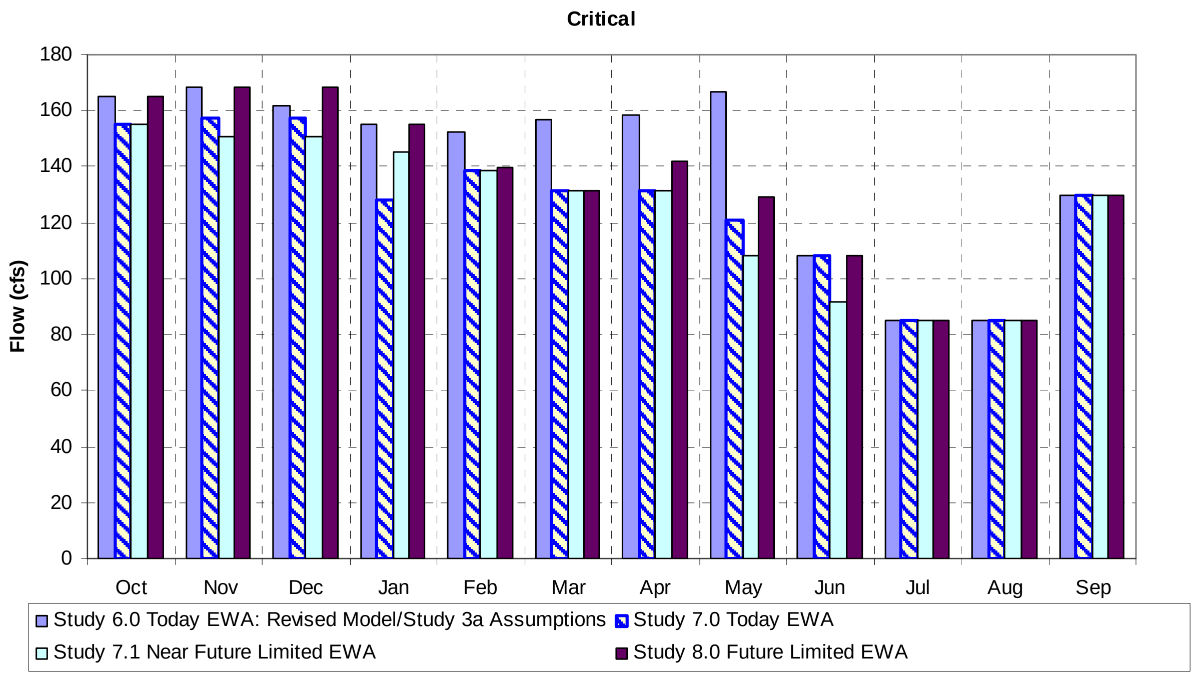


Figure 10-35 Average Critical Year (40-30-30 Classification) Monthly Releases to Clear Creek

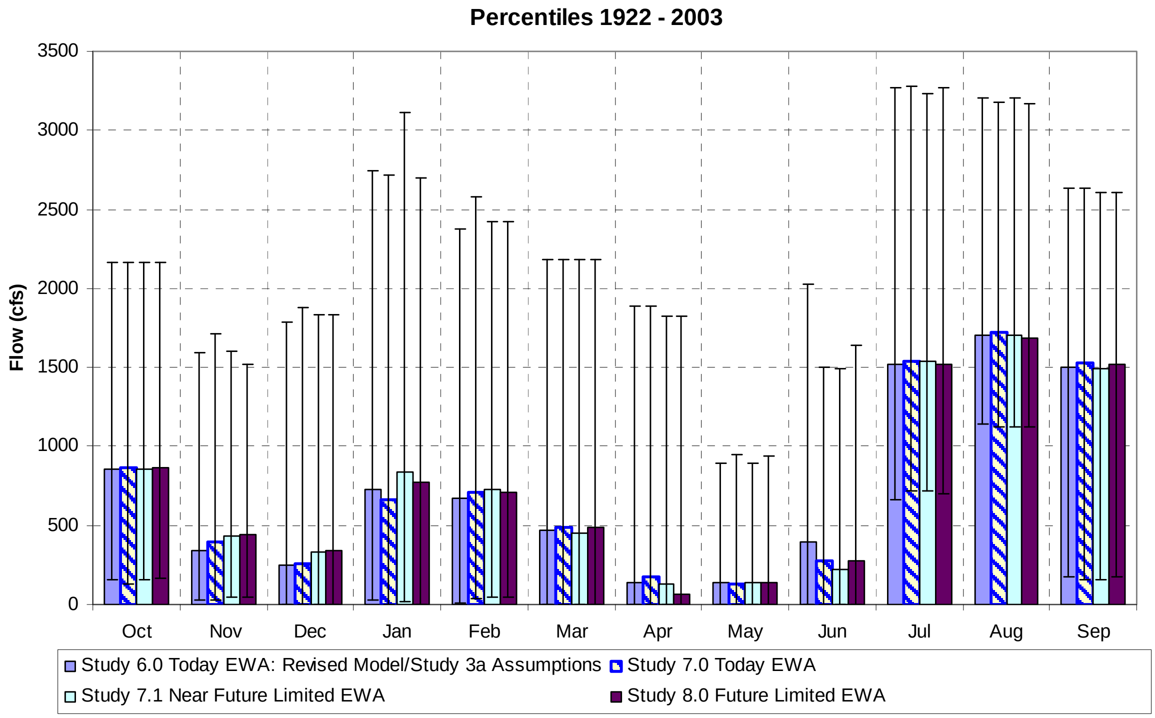


Figure 10-36 Spring Creek Tunnel 50th Percentile Monthly Releases with the 5th and 95th as the Bars

Clear Creek Temperature Analysis

Figure 10-37 to Figure 10-43 illustrates potential water temperatures provided to Clear Creek at Igo. In general, the water temperatures are very similar for each of the studies. Each study shows relatively good performance to the Igo water temperature objective. This analysis shows difficulty meeting the Igo water temperature goals in roughly 5% to 10% of the conditions. It has been Reclamation's recent experience that Igo water temperature goals have been more difficult to meet than planning modeling analysis suggests. Recent changes in the volume and temporal pattern of water imported from the Trinity River may not be well calibrated in the planning model as these parameters relate to changes to temperatures in Whiskeytown Reservoir.

Igo Exceedence Plots

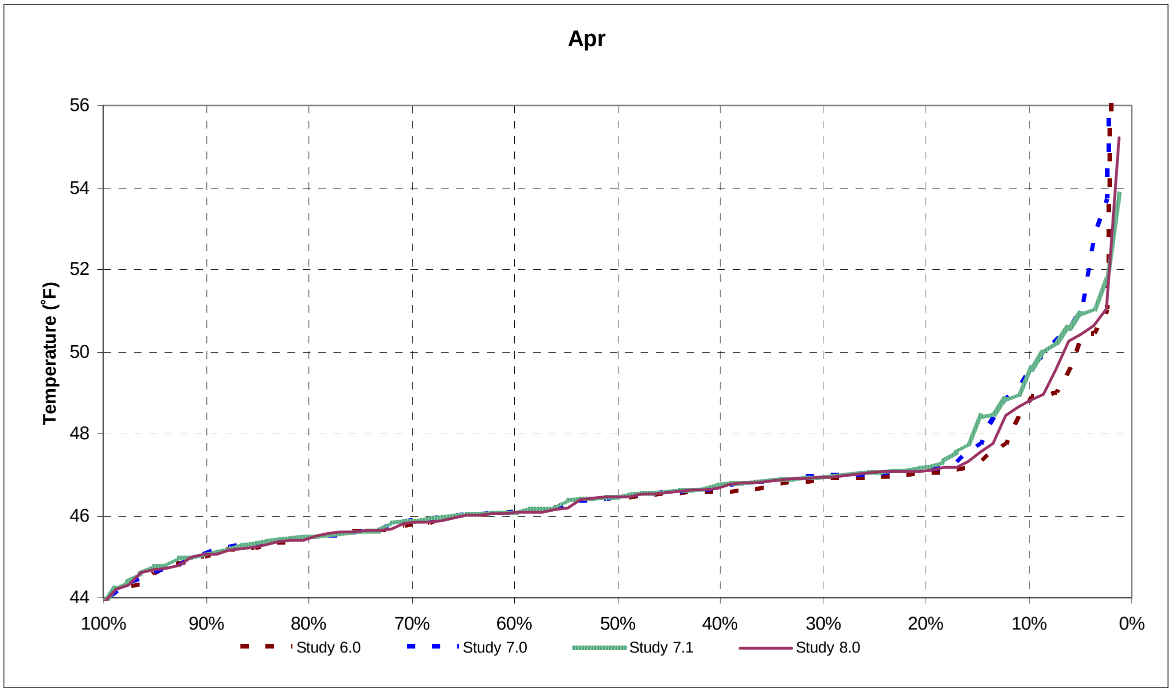


Figure 10-37 Igo Exceedence Plot – End-of-April

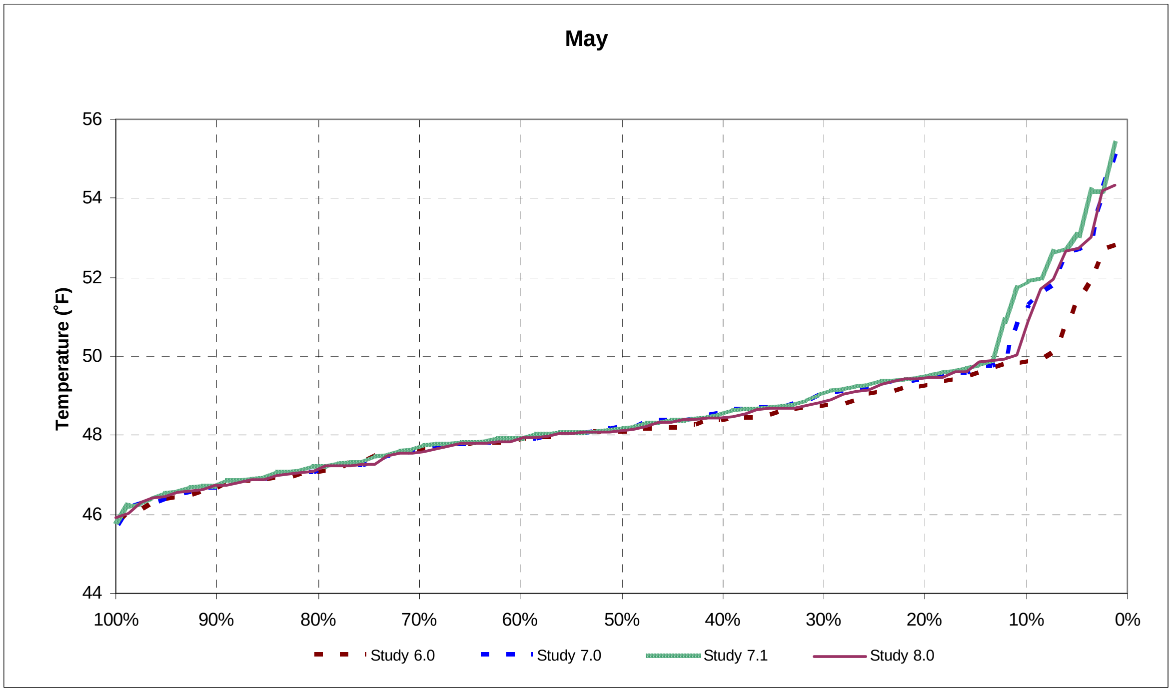


Figure 10-38 Igo Exceedence Plot – End-of-May

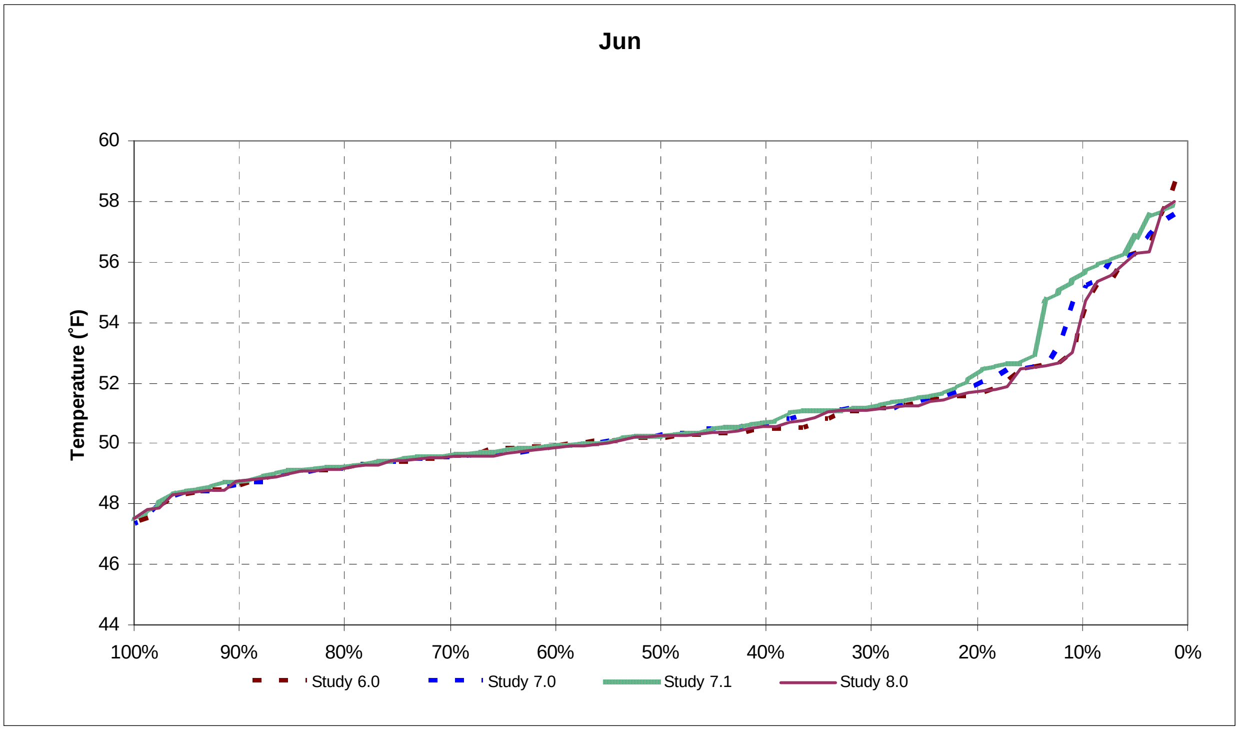


Figure 10-39 Igo Exceedence Plot – End-of-June

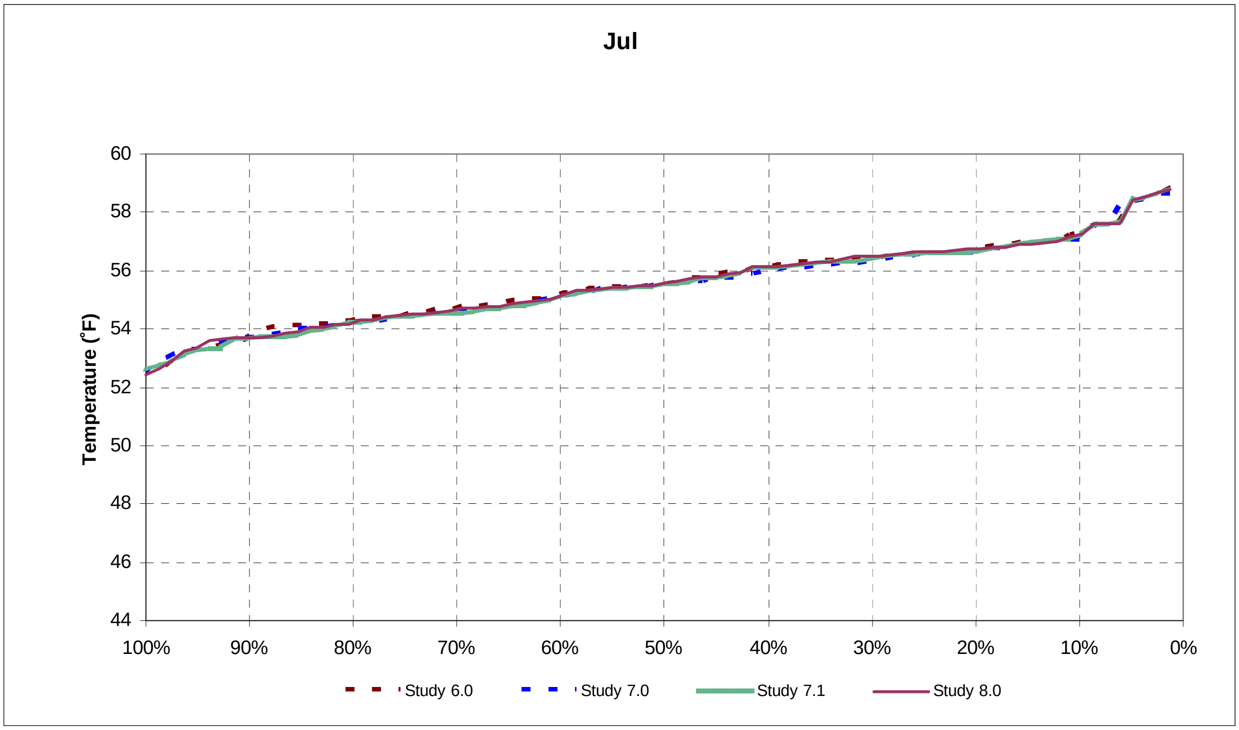


Figure 10-40 Igo Exceedence Plot – End-of-July

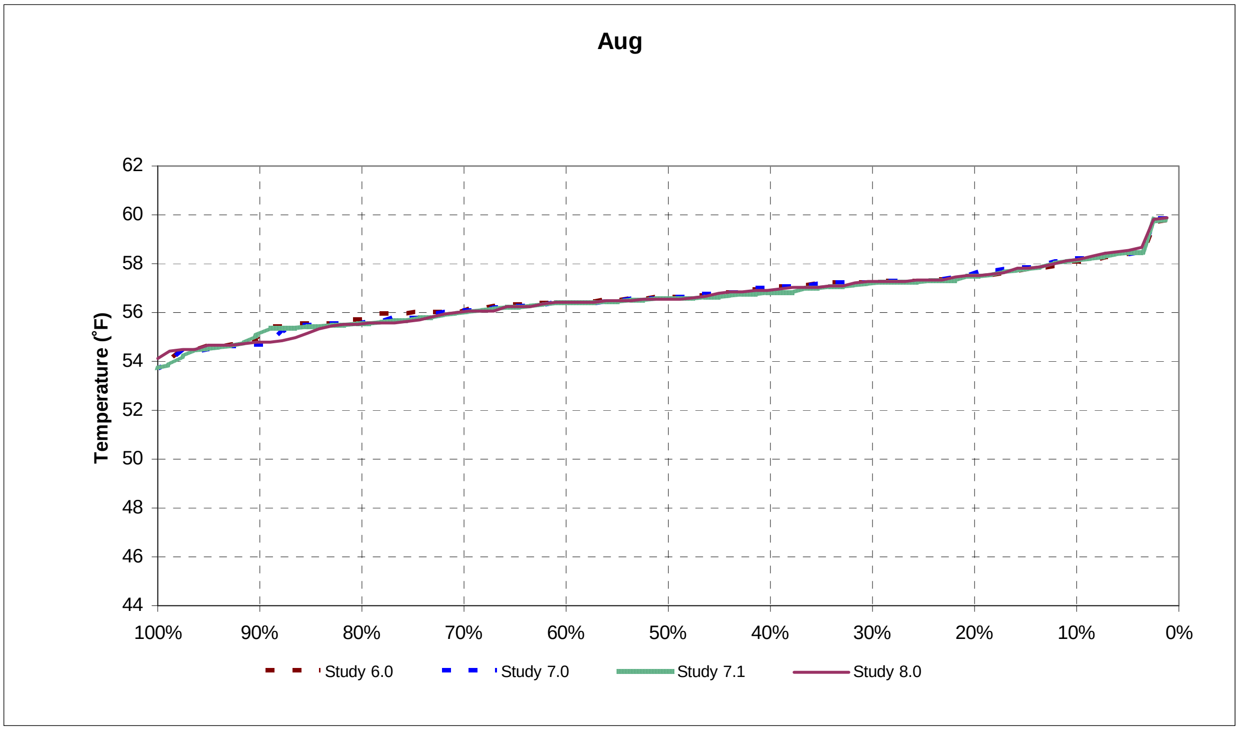


Figure 10-41 Igo Exceedence Plot – End-of-August

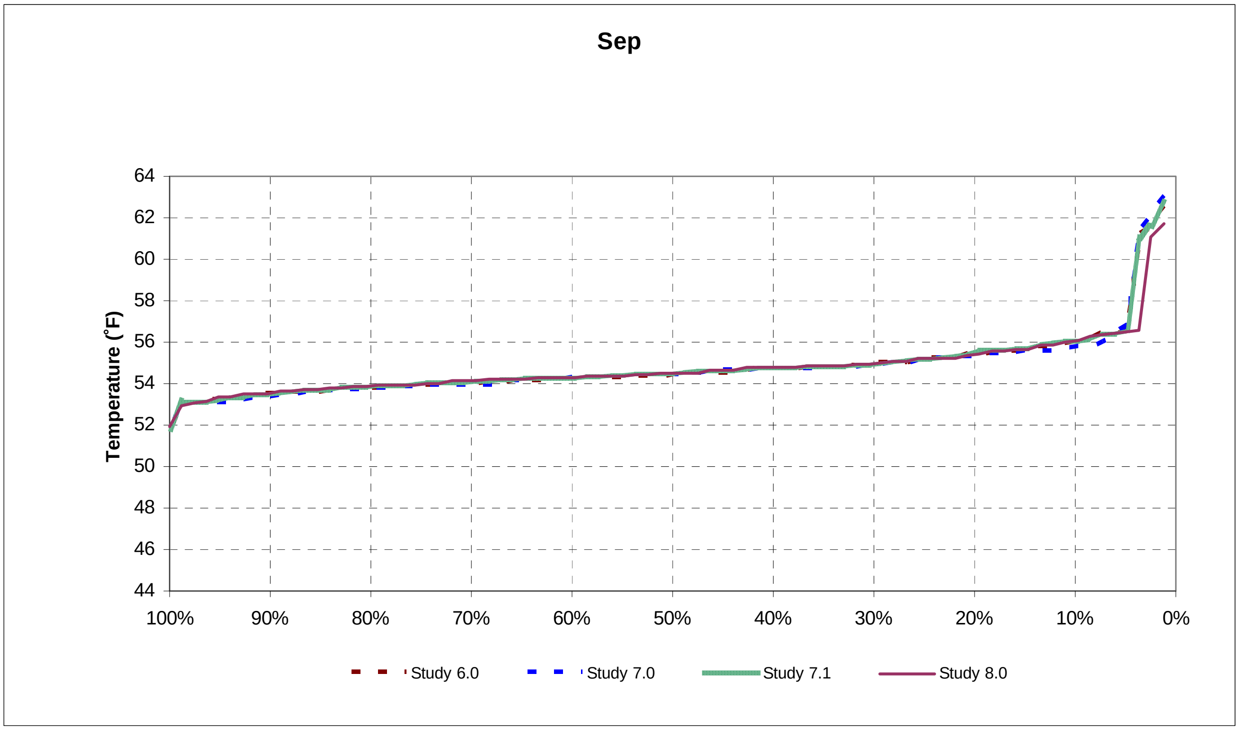


Figure 10-42 Igo Exceedence Plot – End-of-September

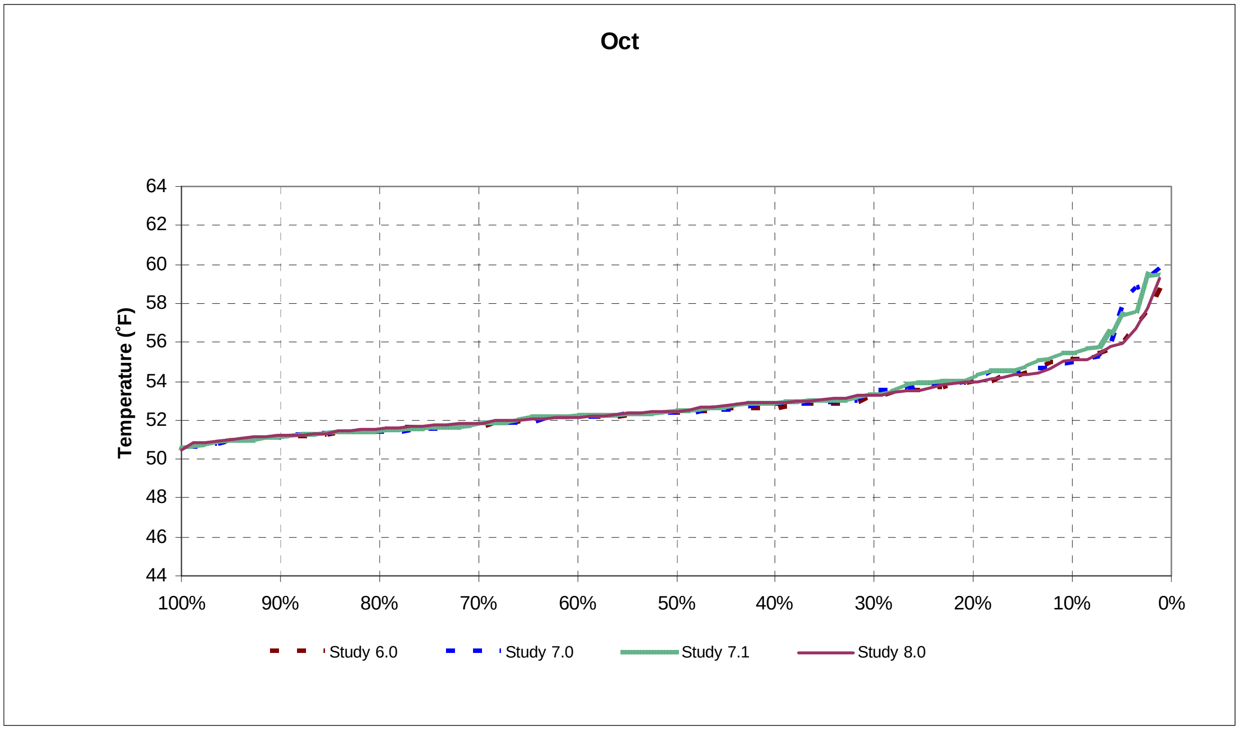


Figure 10-43 Igo Exceedence Plot – End-of-October

Sacramento River

Modeling

The most significant changes to Shasta reservoir operations are generally due to CVP reservoir integration and the changes occurring in the American Basin (Table 10-3).

Table 10-3. Shasta Storage, Spring Creek Tunnel Flow, and Keswick Release Longterm Annual Average

Longterm Annual Average

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Shasta End-of-September Storage	26	-121	-121	0
Annual Keswick Release	1	8	6	-2
Annual Spring Creek Powerplant Flows	3	-1	-2	-2

29- 34 Difference

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Shasta End-of-September Storage	-24	-258	-100	158
Annual Keswick Release	59	-18	-92	-74
Annual Spring Creek Powerplant Flows	45	-18	-42	-24

Figure 10-45 and Figure 10-46 shows the end-of-April and end-of-September exceedence for Shasta storage. The plots show that increased demands at other CVP reservoir facilities will influence Shasta Reservoir operations and storages.

This is the influence of the operationally integrated nature of CVP reservoirs. Shasta Reservoir metrics are most different between the studies during the summertime months. These differences reflect changed Keswick Reservoir releases due to changed conditions in the American Basin as well as increased water demand throughout the Central Valley. Figure 10-47 shows the monthly percentile flows for releases from Keswick Reservoir. Figure 10-48 to Figure 10-53 show the monthly average flows by long-term average and by Sacramento River Basin 40-30-30 Index water-year classification. The percentile and average charts indicate that as the overall water management changes occur at other CVP facilities and, as water demand increases, summertime releases from Keswick incrementally increase.

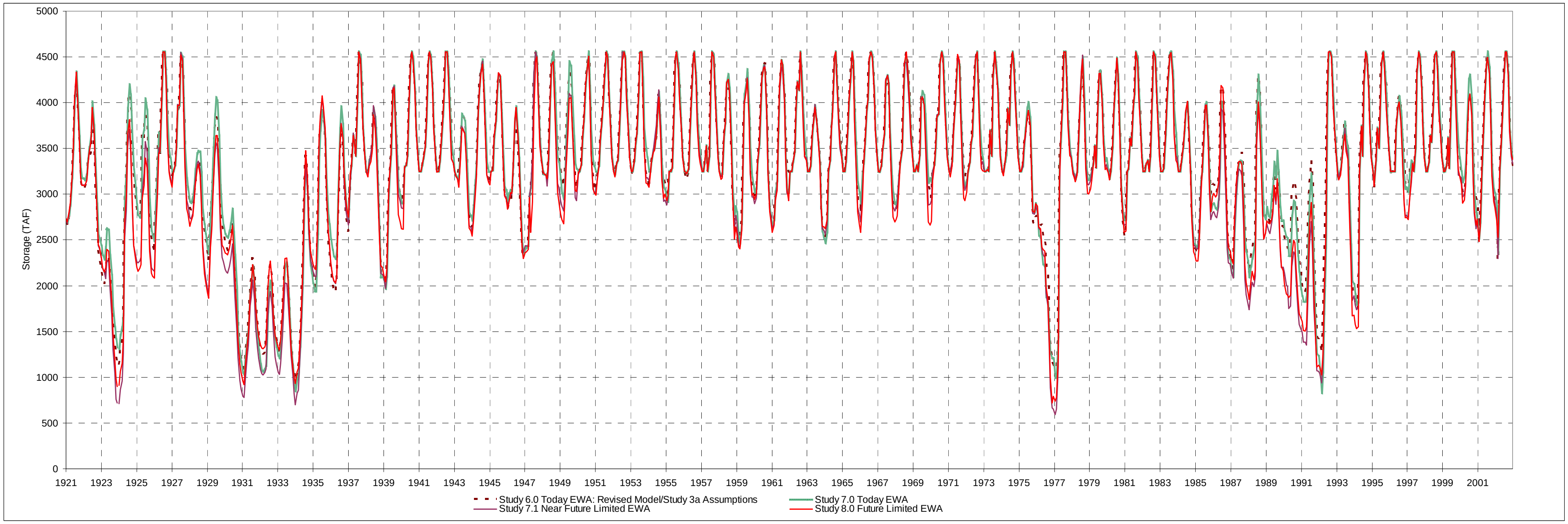


Figure 10-44. Chronology of Shasta Storage, Water Years 1922 – 2003

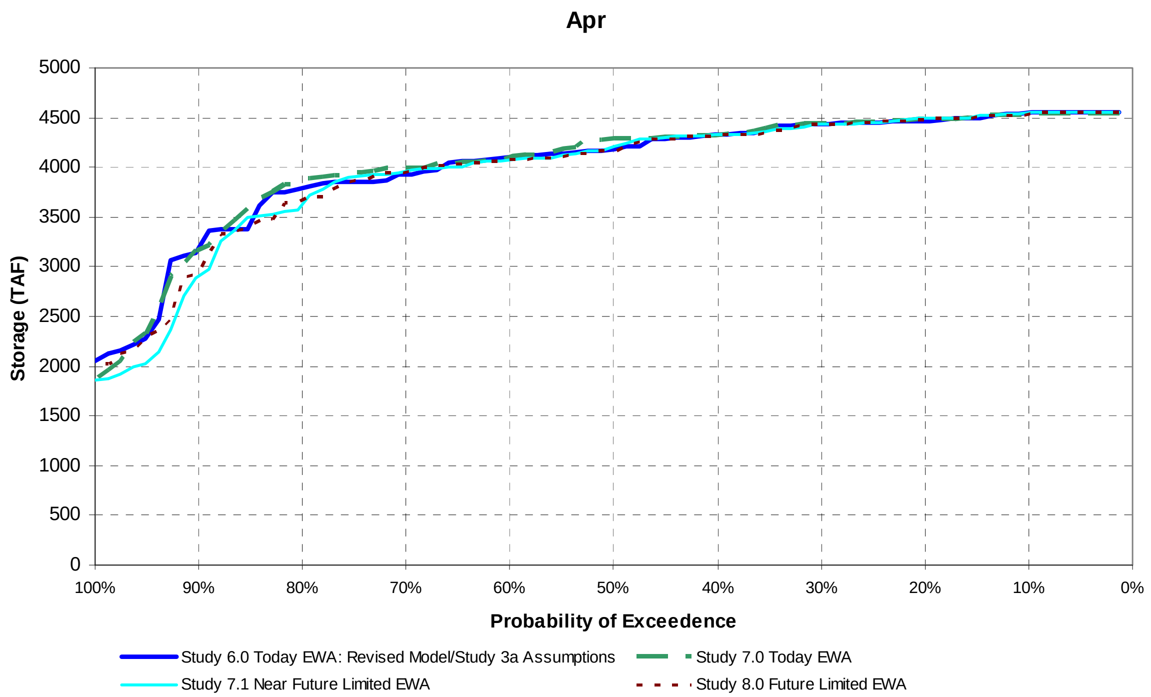


Figure 10-45 Shasta Reservoir End-of-April Exceedence

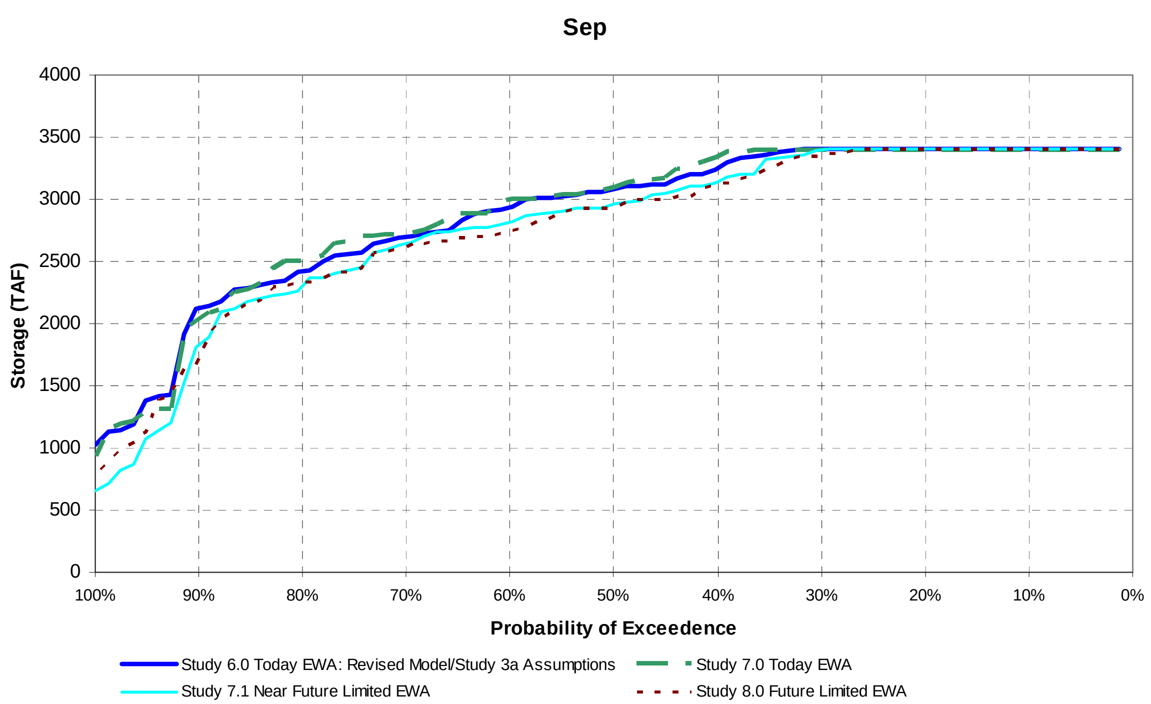


Figure 10-46 Shasta Reservoir End-of-September Exceedence

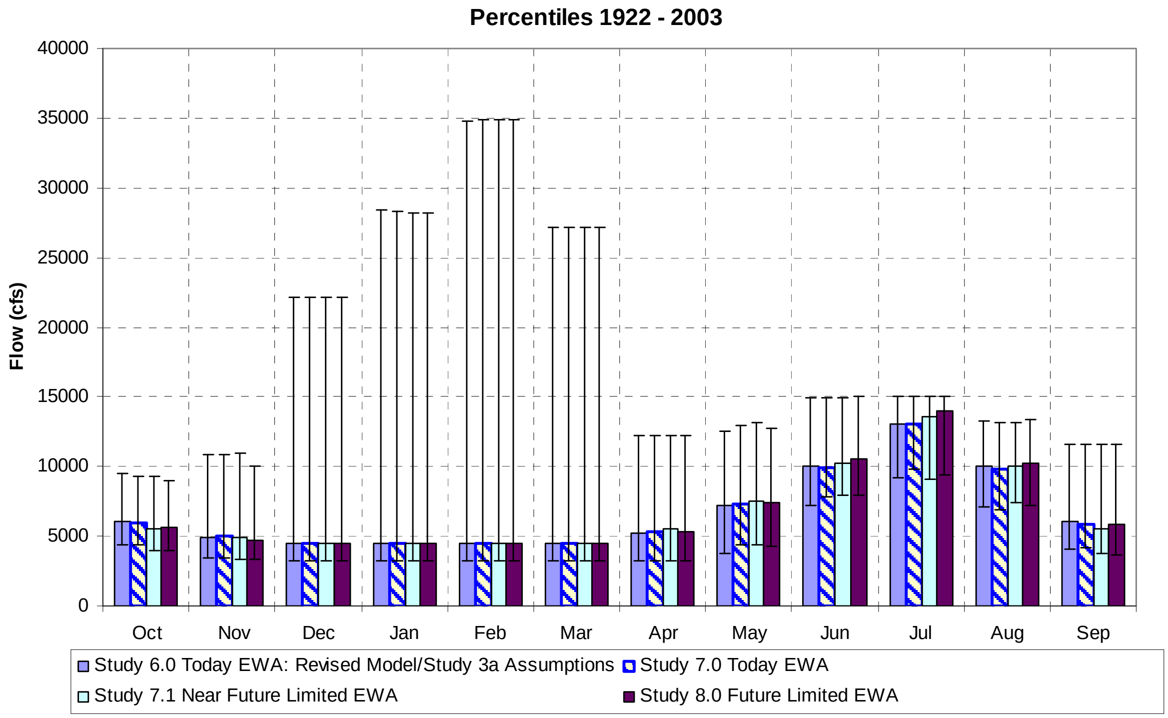


Figure 10-47 Keswick 50th Percentile Monthly Releases with the 5th and 95th as the Bars

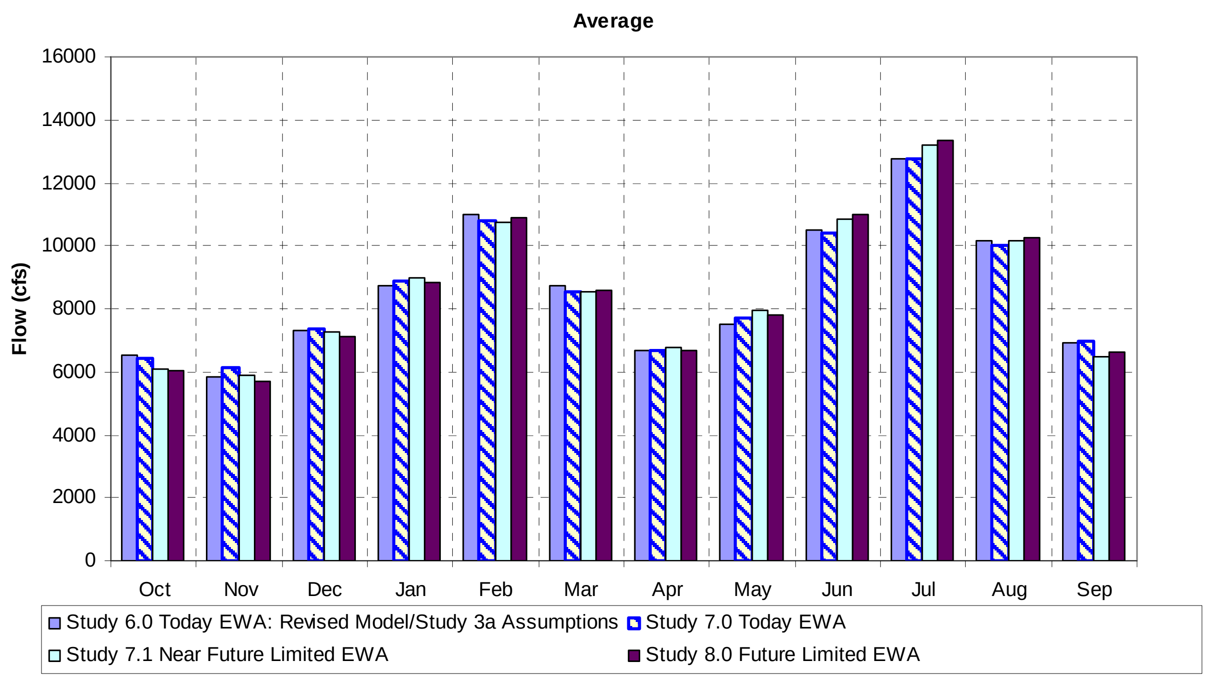


Figure 10-48 Average Monthly Releases from Keswick

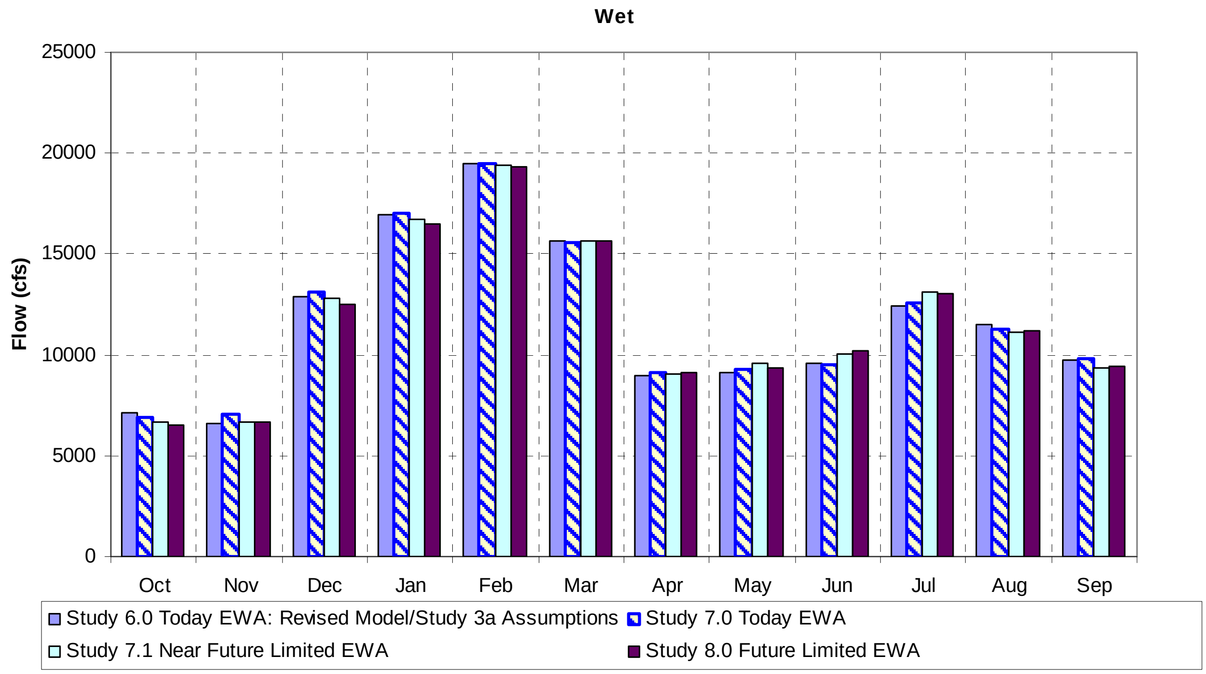


Figure 10-49 Average Wet Year (40-30-30 Classification) Monthly Releases from Keswick

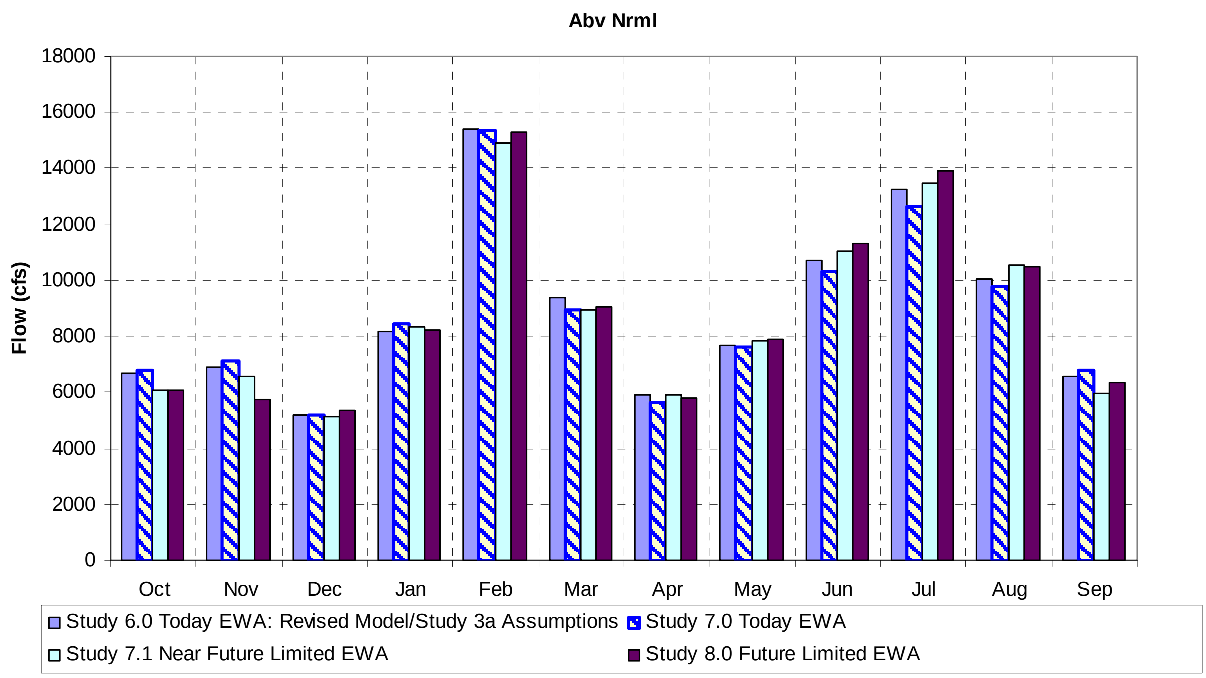


Figure 10-50 Average Above Normal Year (40-30-30 Classification) Monthly Releases from Keswick

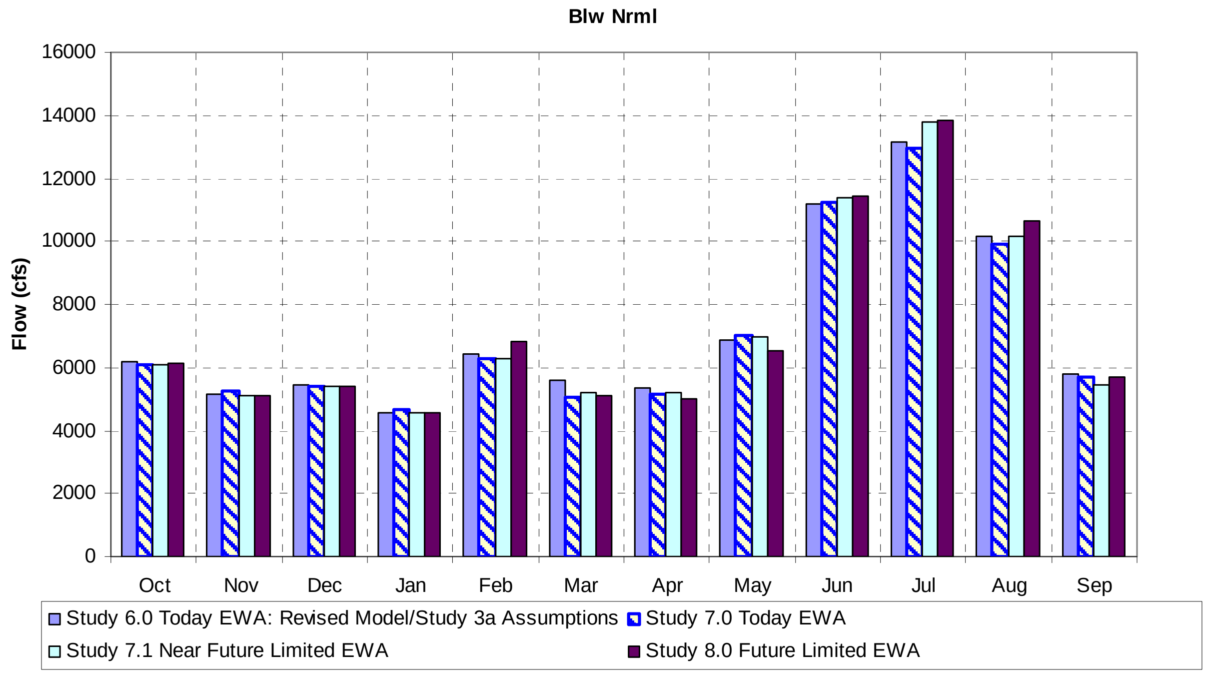


Figure 10-51 Average Below Normal Year (40-30-30 Classification) Monthly Releases from Keswick

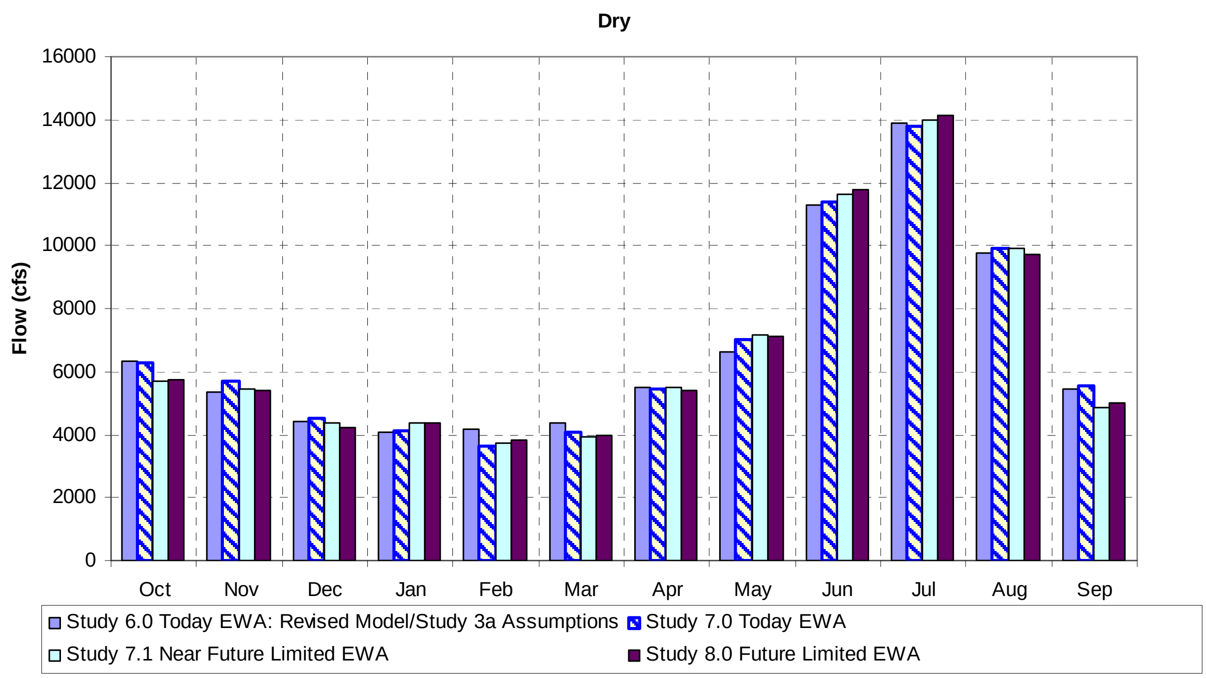


Figure 10-52 Average Dry Year (40-30-30 Classification) Monthly Releases from Keswick

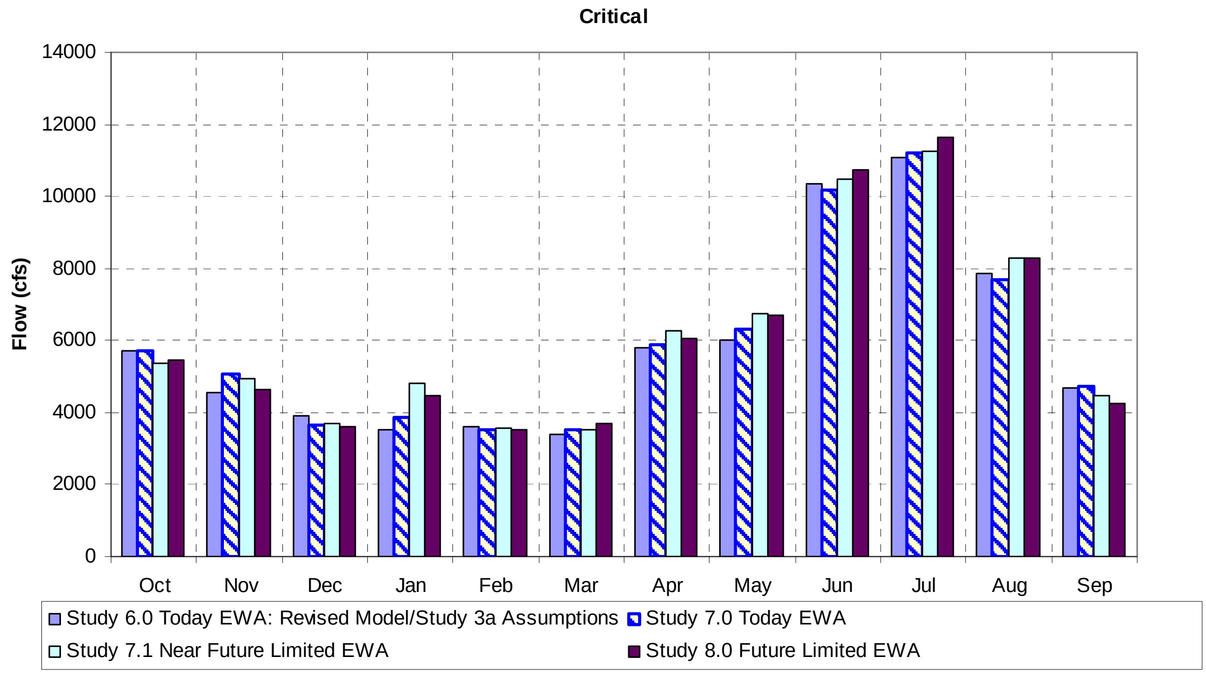


Figure 10-53 Average Critical Year (40-30-30 Classification) Monthly Releases from Keswick

Upper Sacramento River Temperature Analysis

Successful management of water temperatures to protect the fishery in any given year for the upper Sacramento River requires close coordination and analysis of several factors that influence water temperature. The general operational factors that will influence water temperature management are:

- Volume of coldwater availability in the spring,
- Shasta Temperature Control Device operational flexibility
- Projected Keswick Reservoir release rate over the temperature control season
  - Too low of release rates may require significantly colder source water to meet a target location leading to faster depletion of available coldwater.
  - Too high of release rates may deplete coldwater availability faster than anticipated and lead to faster depletion of available coldwater
- Designation of a water temperature compliance target location that best integrates the above three factors with water temperature habitat needs for sensitive lifestages of fish.

As described in Chapter 2, the Sacramento River Temperature Task Group evaluates all the above factors for a given year and designates a compliance target location downstream of Keswick Reservoir that balances all the relevant information and factors into a seasonal strategy for water temperature management. This adaptive management process updates and evaluates current information in order to make significant choices and tradeoffs for seasonal or inter-seasonal water temperature performance management. Reclamation utilizes this adaptive management process in order to comply with SWRCB WRO 90-5 objectives for water temperature management in the upper Sacramento River environment.

The modeling results presented here cannot completely simulate how the Sacramento River Temperature Task Group adaptively manages to all available information about operations and cold water resources to designate a temperature compliance location in any given year. The water temperature analysis presented here demonstrate the generalized relationships of cold water availability, generalized Shasta TCD operations and Keswick flow regimes associated with a specific set of assumptions for CVP operations. In this incremental sense, the modeled water temperature performance between different studies can be compared in a meaningful way to better understand the seasonal use of coldwater resources relative to each study framework. This water temperature analysis should not be construed as an absolute predictive analysis. The Sacramento River Temperature Task Group uses more detailed predictive management tools to designate a reasonable temperature compliance location in any given year.

Coldwater Availability

The most significant influence on water temperature is the volume of available cold water. The estimated volume of water colder than 52ºF stored in Shasta Reservoir on or about May 1 is a very useful way to generally relate cold water availability to potential seasonal compliance strategies. Generally, the larger the volume of 52ºF water in Shasta Reservoir, the greater potential to designate temperature control target locations farther downstream from Keswick

Reservoir, or the longer in time that a temperature control target location can be managed to 56ºF over the temperature control season with a greater assurance of not over-extending the available coldwater resources.

Figure 10-54 illustrates the 52ºF index of coldwater availability for all three studies. All three studies show similar coldwater availability conditions from the 0% to 80% exceedence range. The shape of this coldwater availability index is not the same as Figure 10-58 which shows the exceedence shape of total Shasta Reservoir storage at the end-of-April. The reason is the accumulation of coldwater storage in the spring months is influenced by many factors beyond just total storage in Shasta Reservoir. Figure 10-54 illustrates that the 52 ºF index of coldwater availability in the drier 80% to 100% exceedence range is closely related to overall storage in Shasta Reservoir.

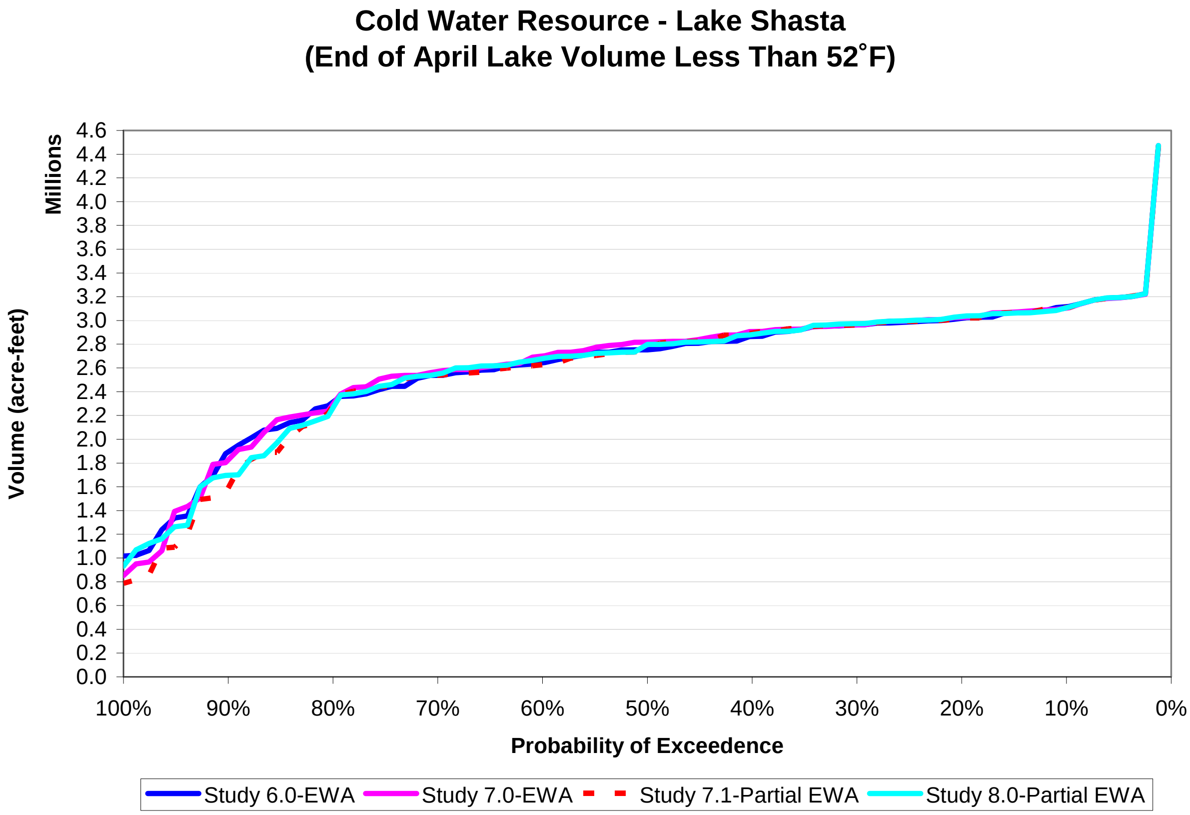


Figure 10-54 52ºF index of coldwater availability

Figure 10-55 to Figure 10-57 characterize the seasonal water temperatures that can occur for Spring Creek Powerplant releases into Keswick Reservoir. The reader should refer to Figure 10-36 (Spring Creek Tunnel Probability Plot) to reference the general quantities of water being diverted in association with these water temperature distributions. Spring Creek Powerplant releases are a source of coldwater conservation to Shasta Reservoir. When Spring Creek Powerplant releases are made to Keswick Reservoir, Shasta Reservoir releases are reduced, thereby conserving coldwater reserves for later use. The cooler the Spring Creek Powerplant releases are, the greater the conservation of the overall thermal potential at Shasta Reservoir.

This operation releases from the Shasta TCD to thermally mix the combination of Shasta Reservoir storage and Spring Creek Powerplant releases to produce the desired Keswick water temperatures. Figure 10-57 (90% Spring Creek) shows high water temperatures in the months of April through June, this is a modeling anomaly of having nearly zero water moved through Spring Creek Powerplant under very dry conditions. Generally these plots illustrate that during the upper Sacramento River temperature control season and during the prime Spring Creek Powerplant release month of July through September, the water temperatures will range from the lower 50 ºF's to the mid 50 ºF's. All studies show very similar water temperature characteristics at Spring Creek Powerplant.

The combination of coldwater availability below 52 ºF at Shasta Reservoir and expected seasonal volumes and water temperatures at Spring Creek Powerplant fully describe the coldwater availability Reclamation has to perform upper Sacramento River water temperature performance.

Spring Creek Tunnel Water Temperatures Seasonal Exceedence Plots

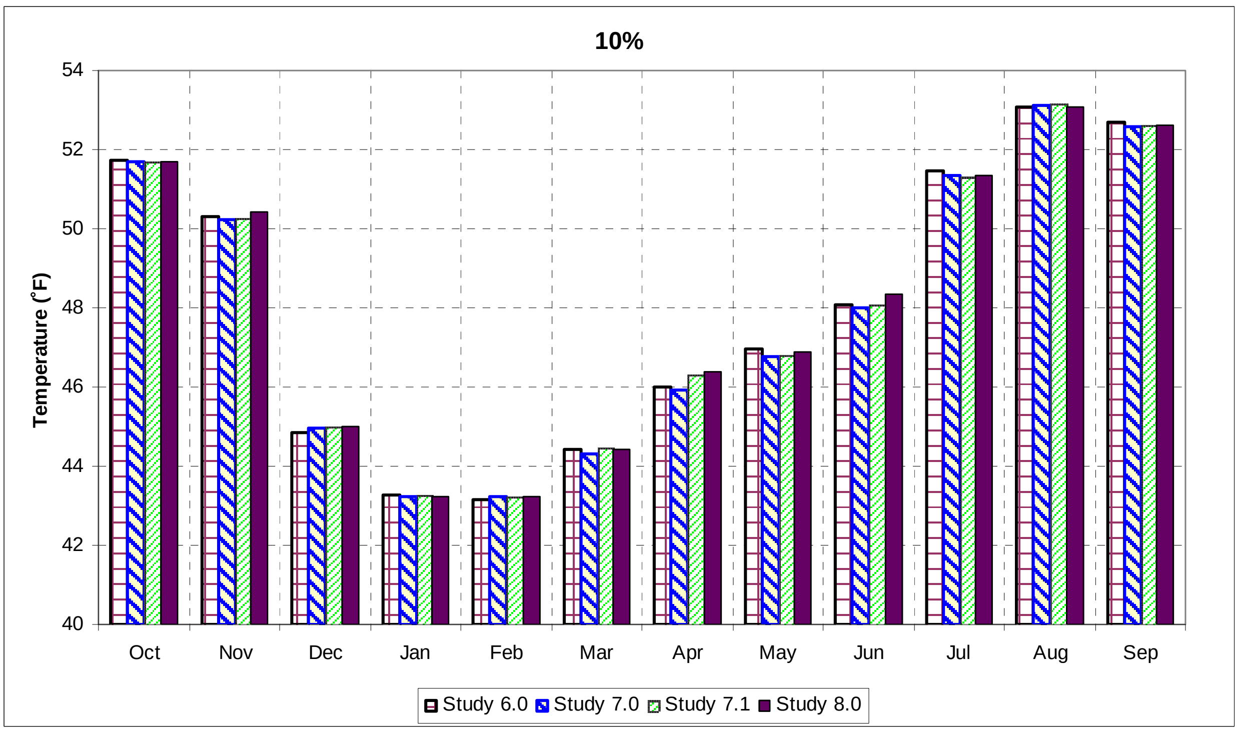


Figure 10-55 Spring Creek Tunnel Water Temperatures 10% exceedence

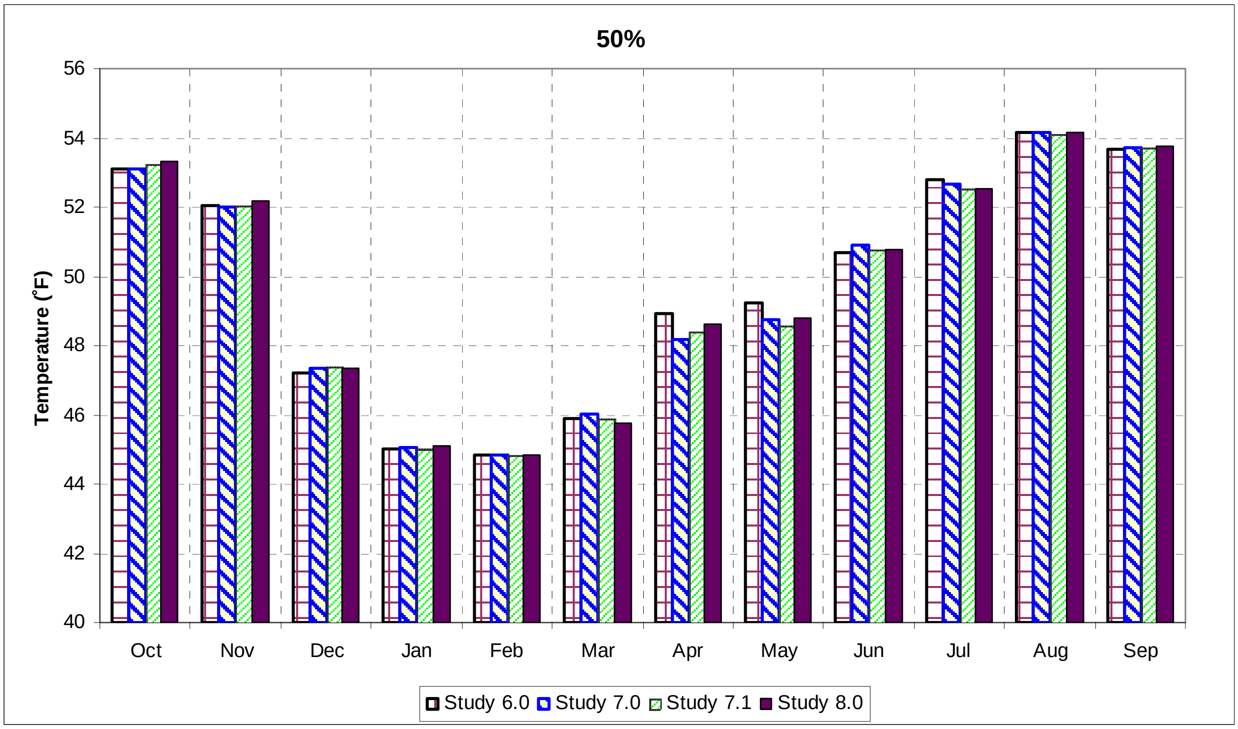


Figure 10-56 Spring Creek Tunnel Water Temperatures 50% exceedence

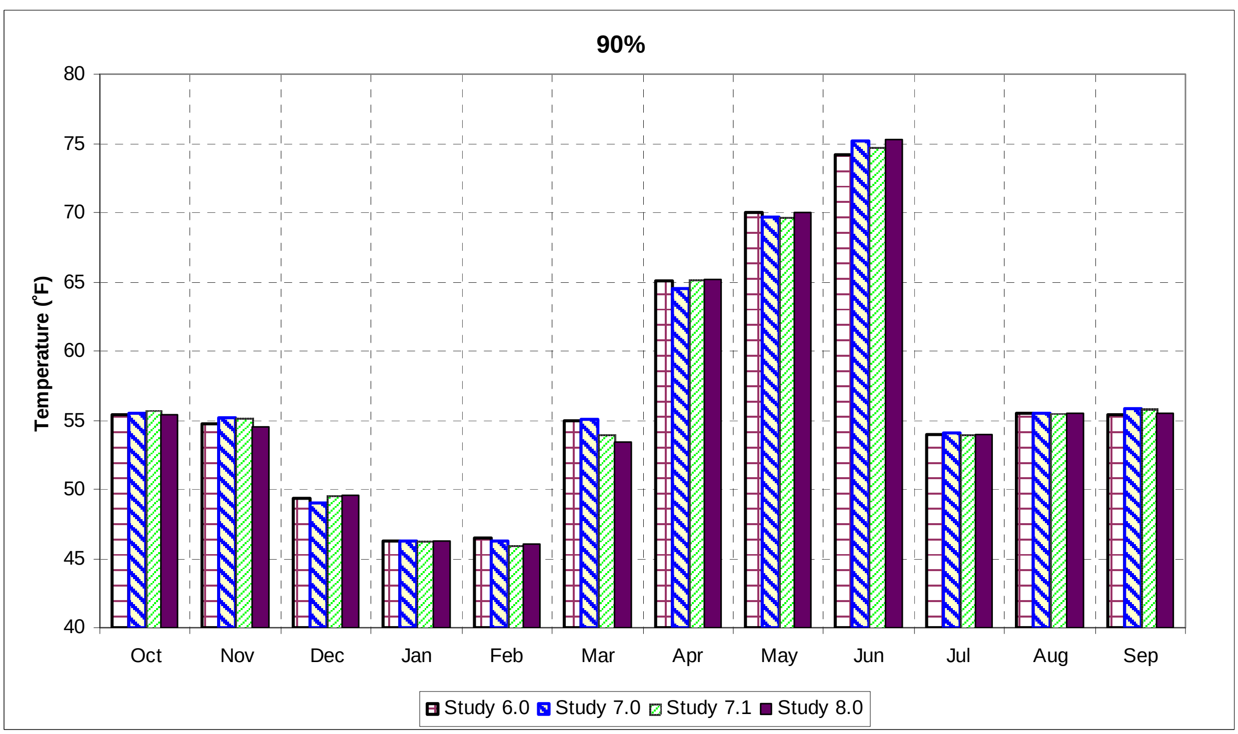


Figure 10-57 Spring Creek Tunnel Water Temperatures 90% exceedence

Figure 10-58 to Figure 10-65 illustrate the potential seasonal coldwater patterns for the studies at the Shasta Reservoir tailbay location. Each of the studies has been modeled using the same Shasta TCD target temperature logic. Since each study utilizes the same TCD operations logic to generate water temperature values, the results of this analysis will only characterize how the depletion of the annual coldwater resources at Shasta Reservoir varies among the studies. Given that the water temperature analysis uses the same TCD operations logic in each study, the model makes no attempt to adjust the water temperature target location within the season based on the availability of coldwater. The Sacramento River Temperature Task Group would consider this kind of information and make choices as to how to manage the temporal distribution of coldwater resources differently than may be portrayed with this water temperature analysis.

The usefulness of this analysis is to characterize the water temperature utilization between studies in order to evaluate general coldwater management and water temperature trends for each study framework.

The plots begin to show potential differences in the utilization of coldwater resources in July for approximately 40% of the years between studies.

Figure 10-66 to Figure 10-73 illustrate potential seasonal coldwater use patterns for the studies at the Keswick Reservoir. Keswick Reservoir is the key management point to water temperature operations for the upper Sacramento River because this is the location CVP operators have significant influence to the temperature of the water released on a daily basis before reaching the water temperature compliance location.

In realtime water temperature operations, CVP operators manage Keswick release water temperatures by adjusting and balancing the following operational factors for water temperature purposes;

- Flow from Shasta Dam
- Shasta TCD gate configuration
- Flow from Spring Creek Powerplant into Keswick Reservoir
- Total flow released from Keswick Reservoir
    - Changes re-affect the above flow contributions and thermal mixing ratios
    - Changes the residence time of water in Keswick Reservoir from Shasta Dam

This temperature analysis shows for all studies very similar water temperature performance characteristics at Keswick from April through July. Comparing the July graph for Keswick Releases (Figure 10-69) and the July graph for Shasta Tailbay (Figure 10-61) yields some useful information. The Keswick release water temperatures in July are very similar, yet the temperature of water released from Shasta Dam is generally warmer for Study 7.1 and Study 8. This relationship is due to generally higher Keswick Dam releases in study 7.1 and study 8, and the counter influence of Shasta TCD flexibility allowing for slightly warmer releases in order to conserve coldwater.

This temperature analysis shows for all four studies that at roughly the 10% exceedence level, each study has possible water temperature control problems by August. The difficulties are more pronounced for study 7.1 and study 8. Referring back to the August Shasta Tailbay plot (Figure 10-62), the information shows that for study 7.1 and study 8, roughly 10% of the time Shasta Reservoir has been depleted of useful coldwater, while in study 7, it is roughly 5% of the time. This information is consistent with Figure 10-54 showing lesser coldwater availability for study 7.1 and study 8 at the 10% exceedence level. This water temperature analysis confirms that the change in availability of coldwater resource will eventually produce a temporal change in water temperature performance.

The illustrations of Keswick release water temperatures for September and October show similar trends for all studies. Each study shows coldwater availability being a significant factor in 15 to 20% of the cases by September and 20-30% of cases in late October. There is a slight trend for better water temperature performance in study 7 relative to study 7.1 and study 8 in the non-depleted cases, this trend reflects the slightly improved coldwater availability and temporal coldwater conservation characteristics of study 7 relative to study 7.1 and study 8.

Figure 10-74 to Figure 10-81 and Figure 10-82 to Figure 10-89 illustrate how this water temperature analysis reflects water temperature performance characteristics at the Balls Ferry location and the Bend Bridge location respectively. In general, the two locations are showing the same water temperature/coldwater depletion characteristics as illustrated by the Keswick release water temperature issues.

Shasta Tailbay Water Temperatures Seasonal Exceedence Plots

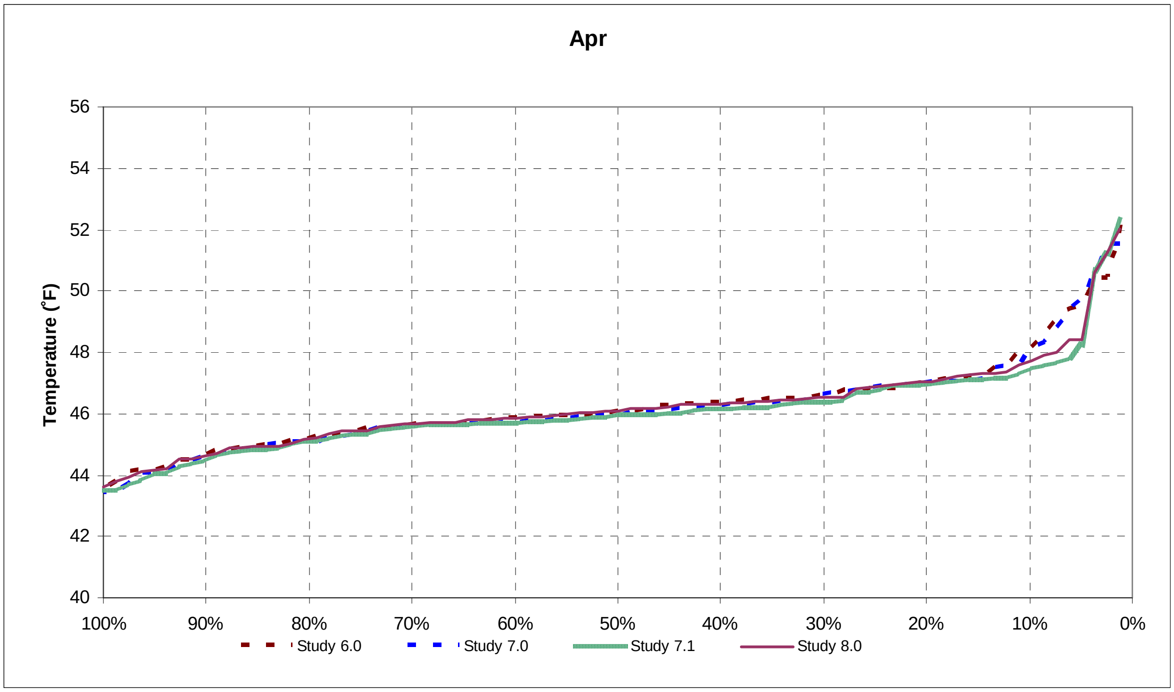


Figure 10-58 Shasta Tailbay End-of-April Exceedence

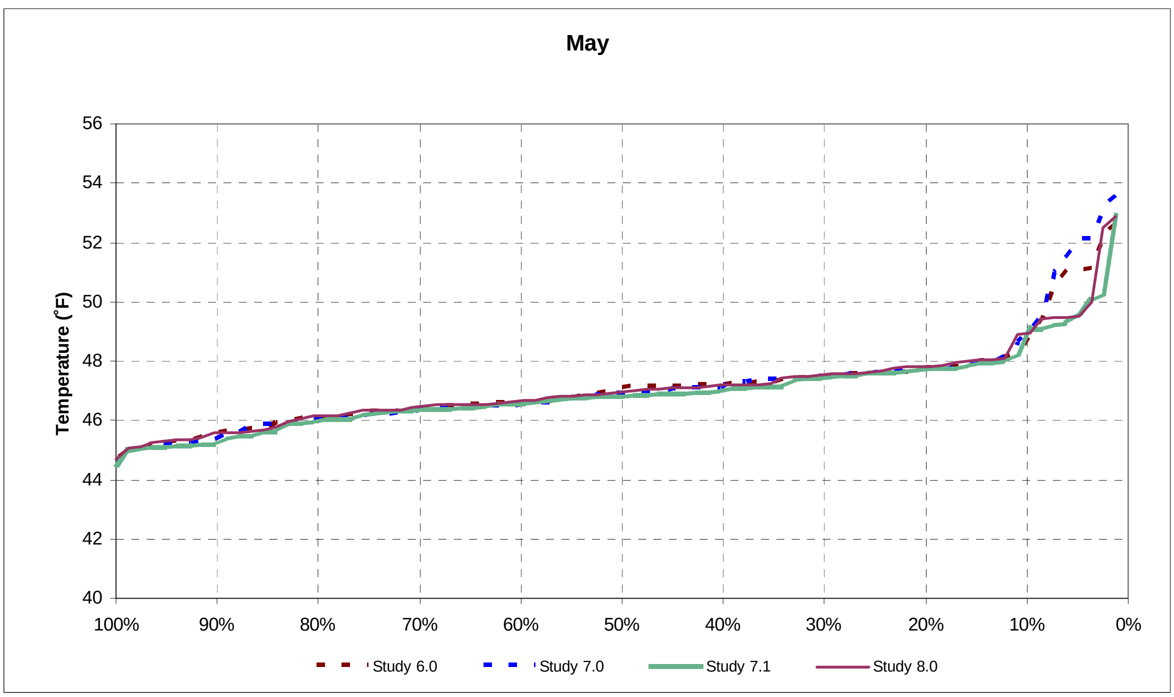


Figure 10-59 Shasta Tailbay End-of-May Exceedence

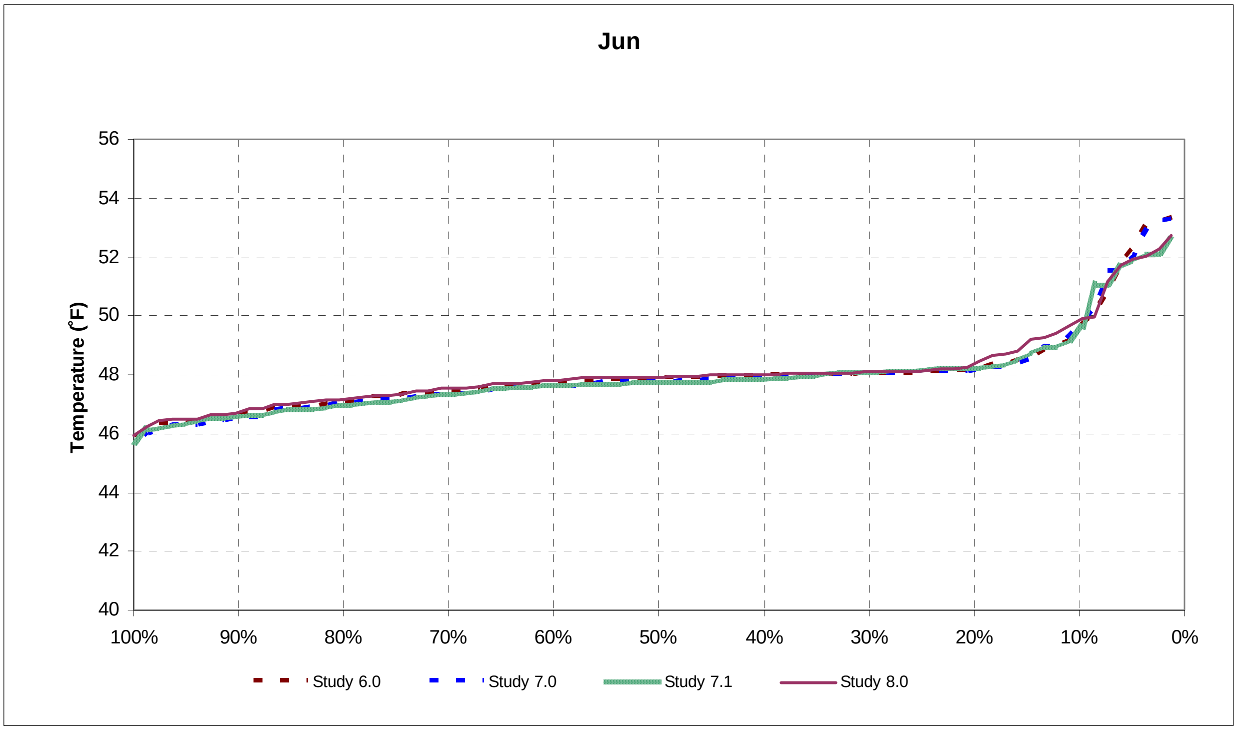


Figure 10-60 Shasta Tailbay End-of-June Exceedence

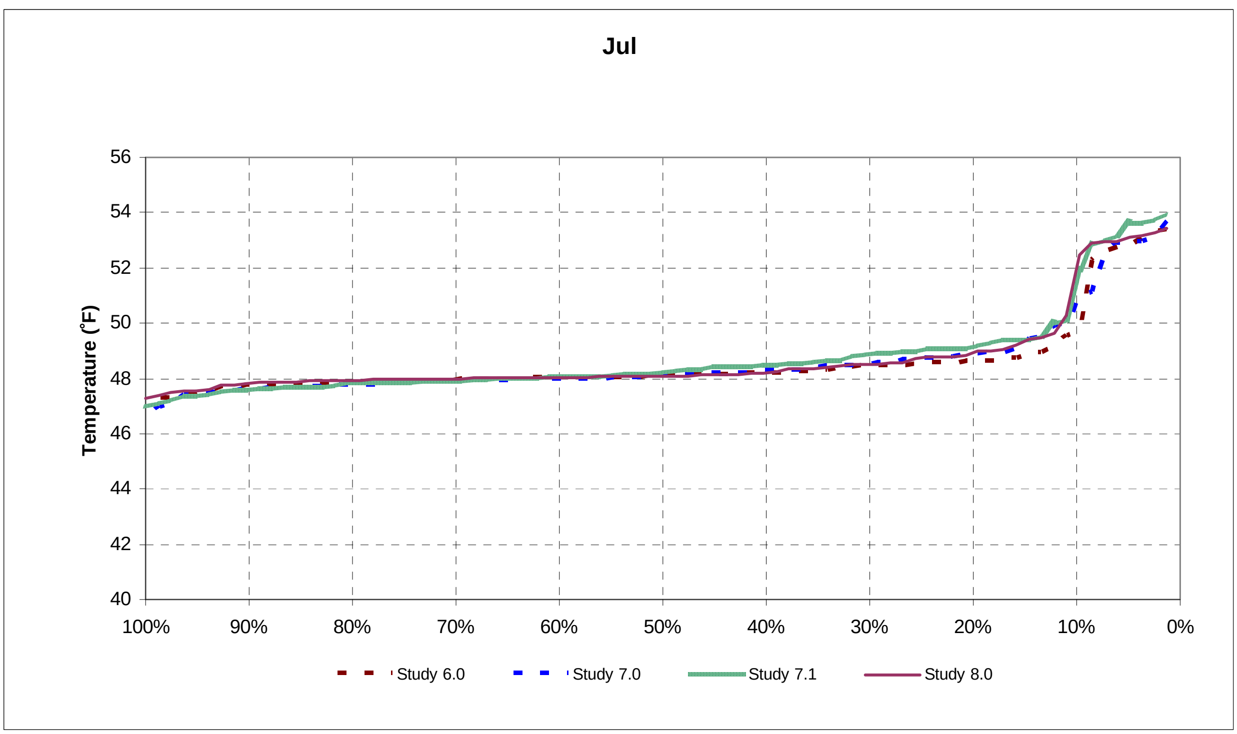


Figure 10-61 Shasta Tailbay End-of-July Exceedence

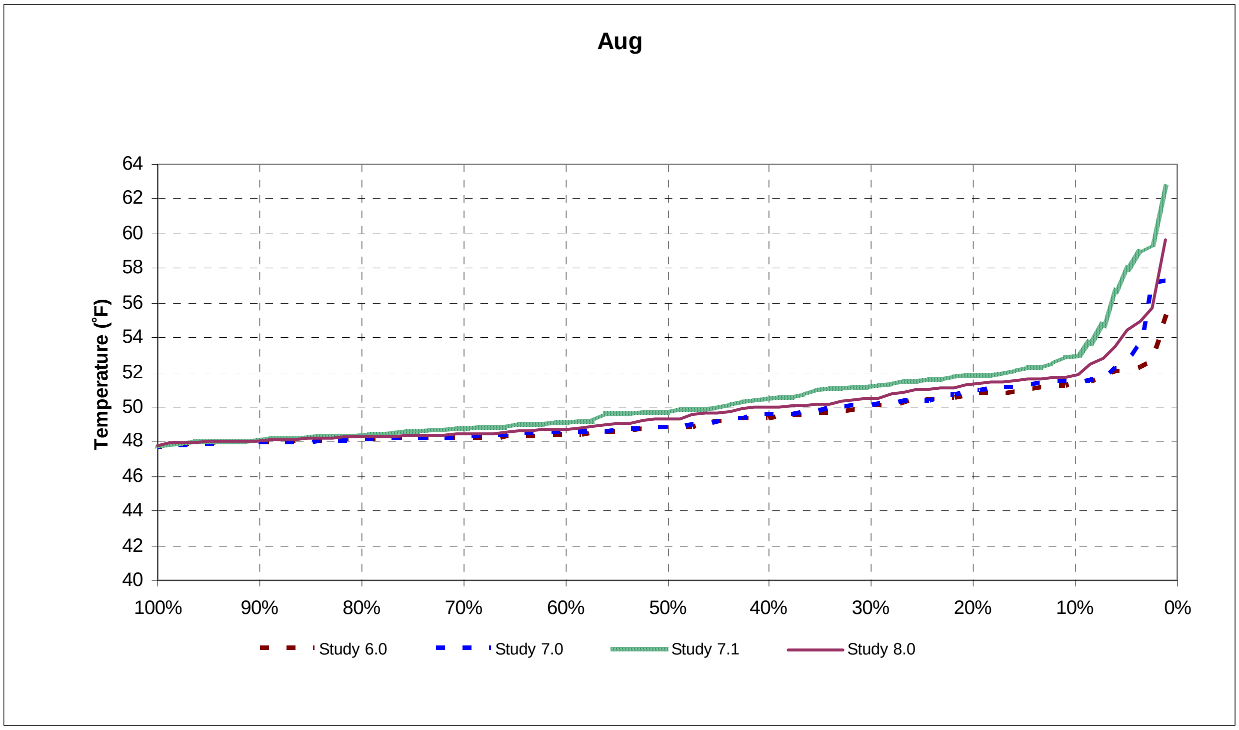


Figure 10-62 Shasta Tailbay End-of-Aug Exceedence

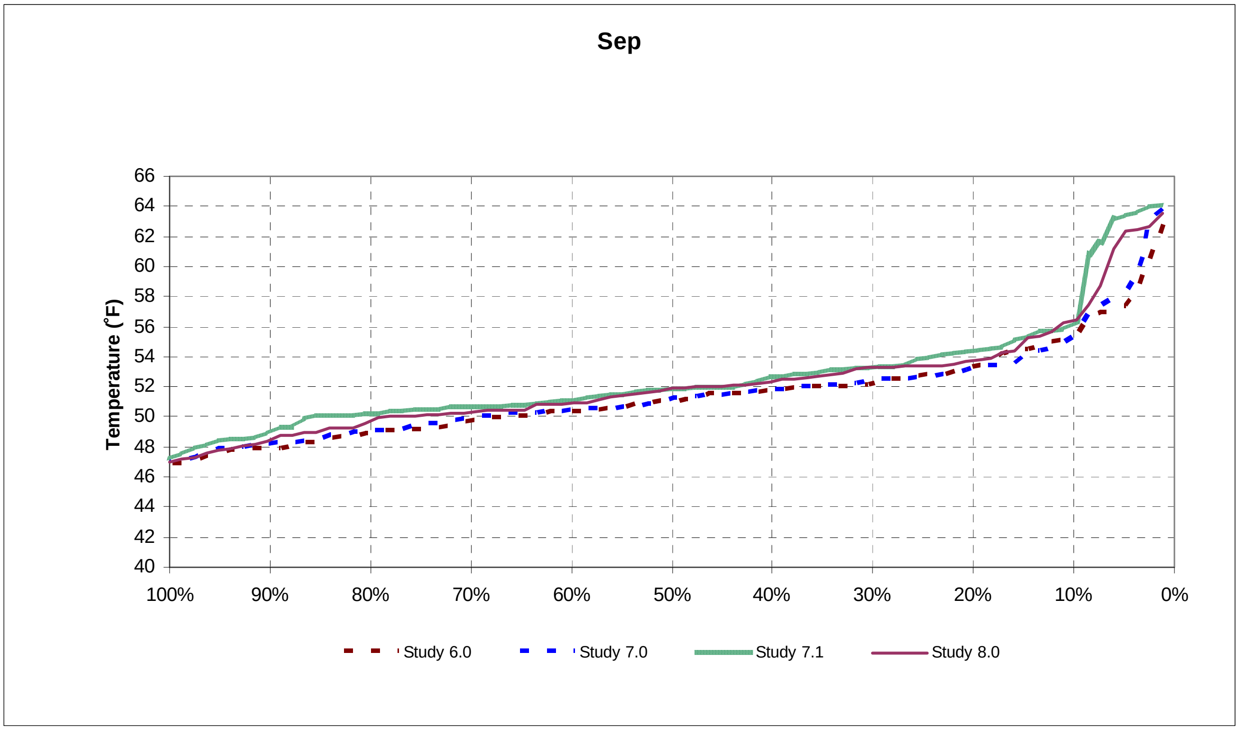


Figure 10-63 Shasta Tailbay End-of-September Exceedence

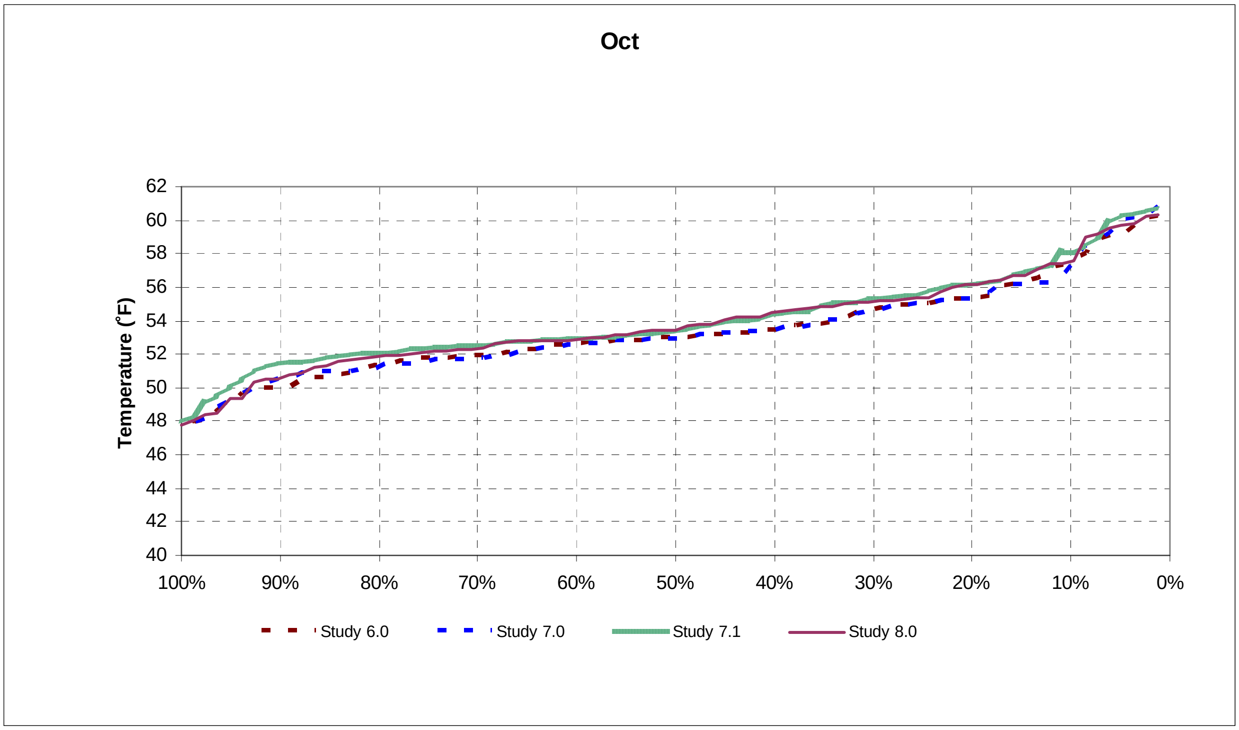


Figure 10-64 Shasta Tailbay End-of-October Exceedence

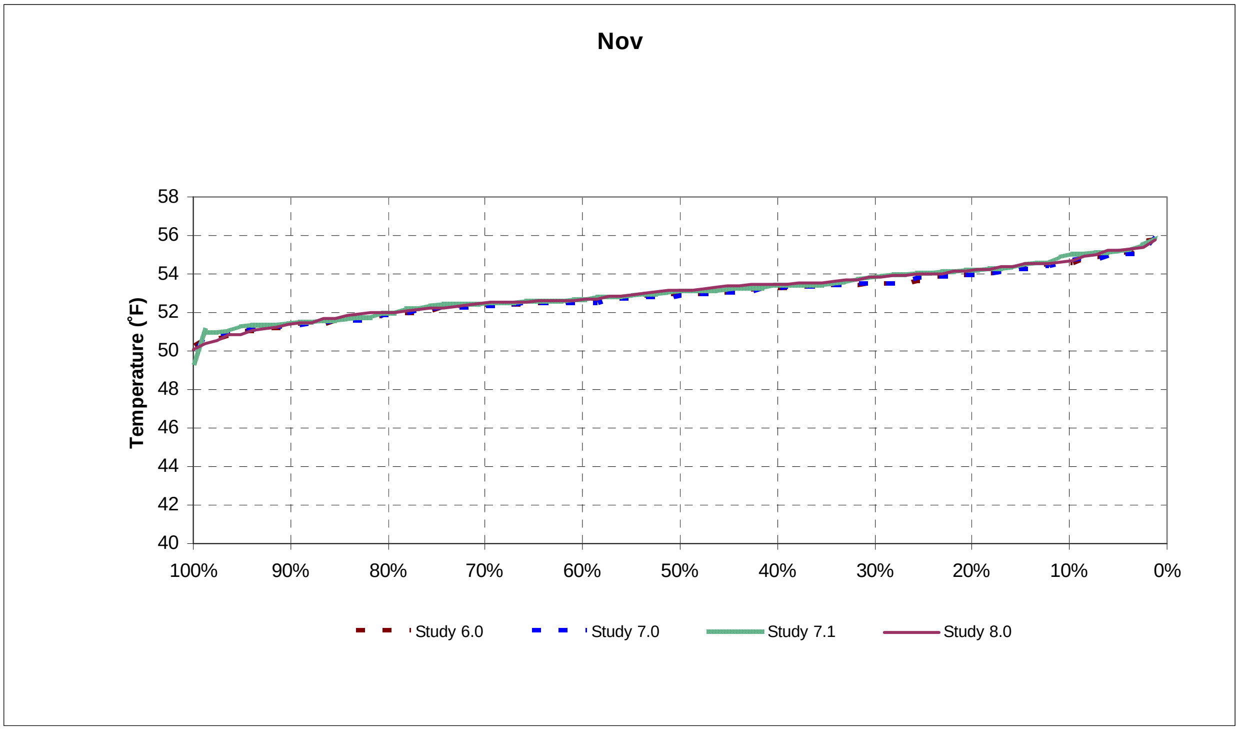


Figure 10-65 Shasta Tailbay End-of-November Exceedence

Keswick Water Temperatures Seasonal Exceedence Plots

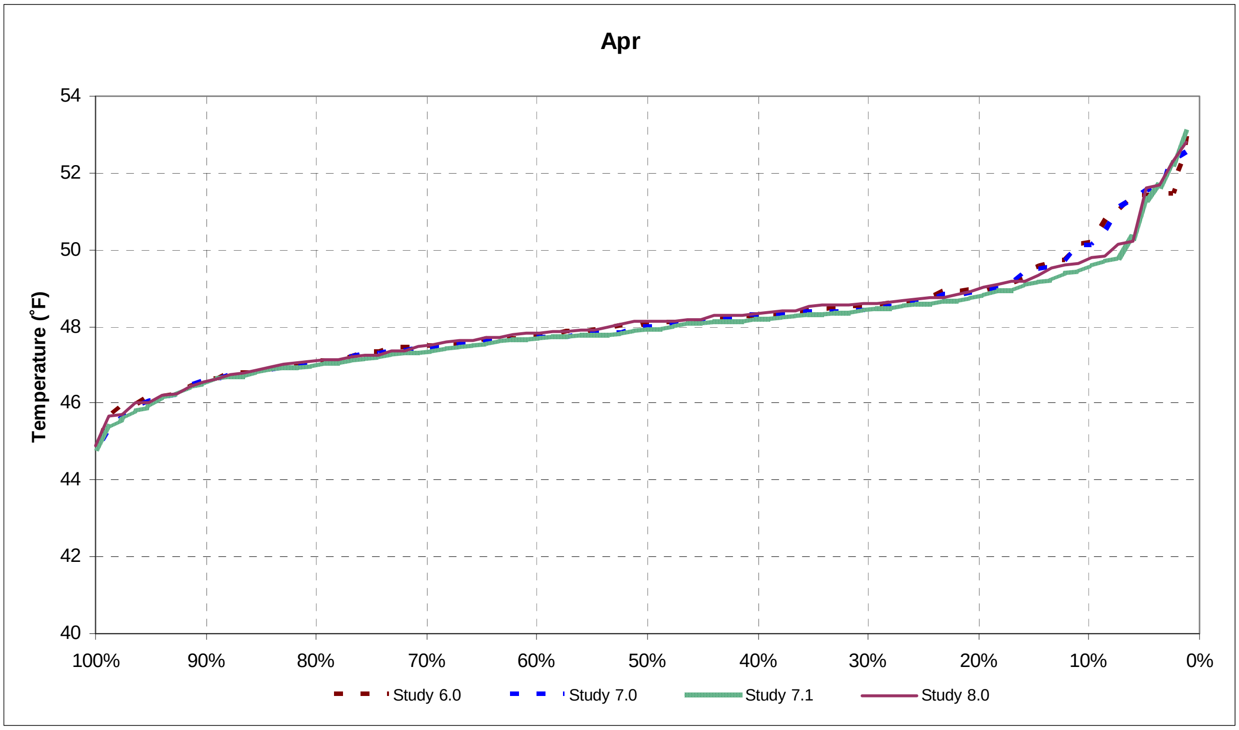


Figure 10-66 Keswick End-of-April Exceedence

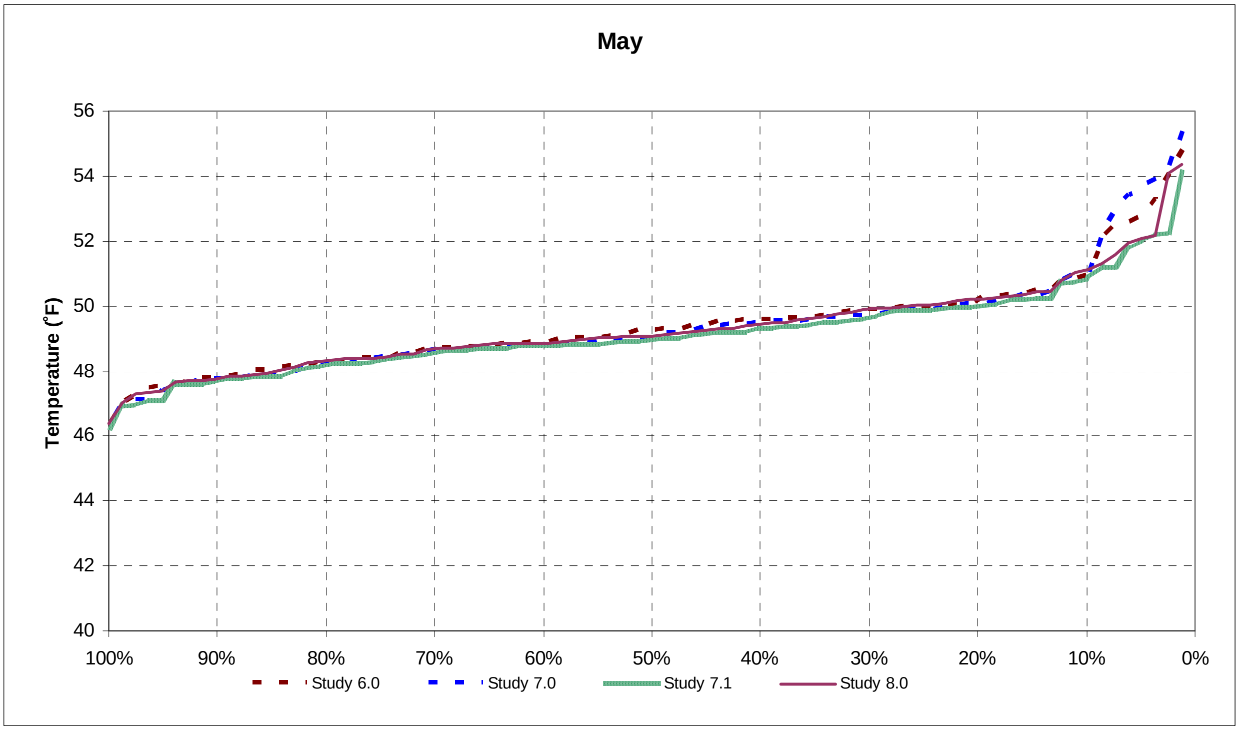


Figure 10-67 Keswick End-of-May Exceedence

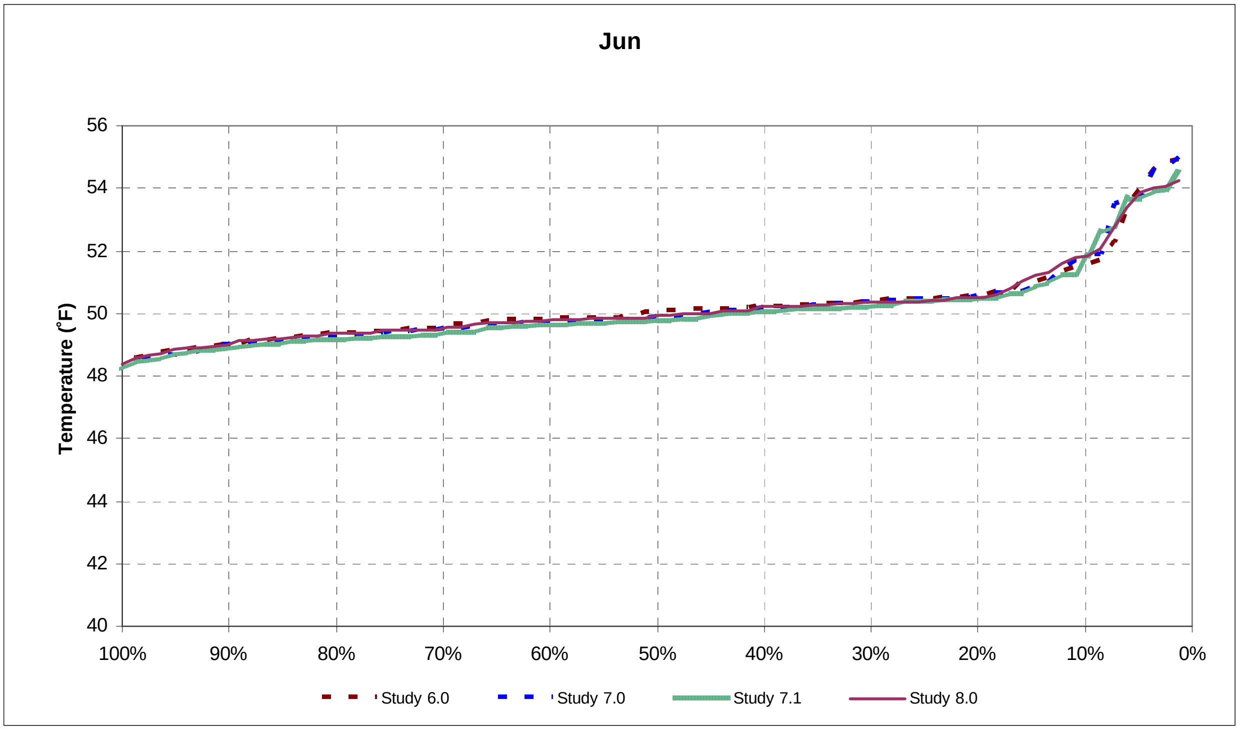


Figure 10-68 Keswick End-of-June Exceedence

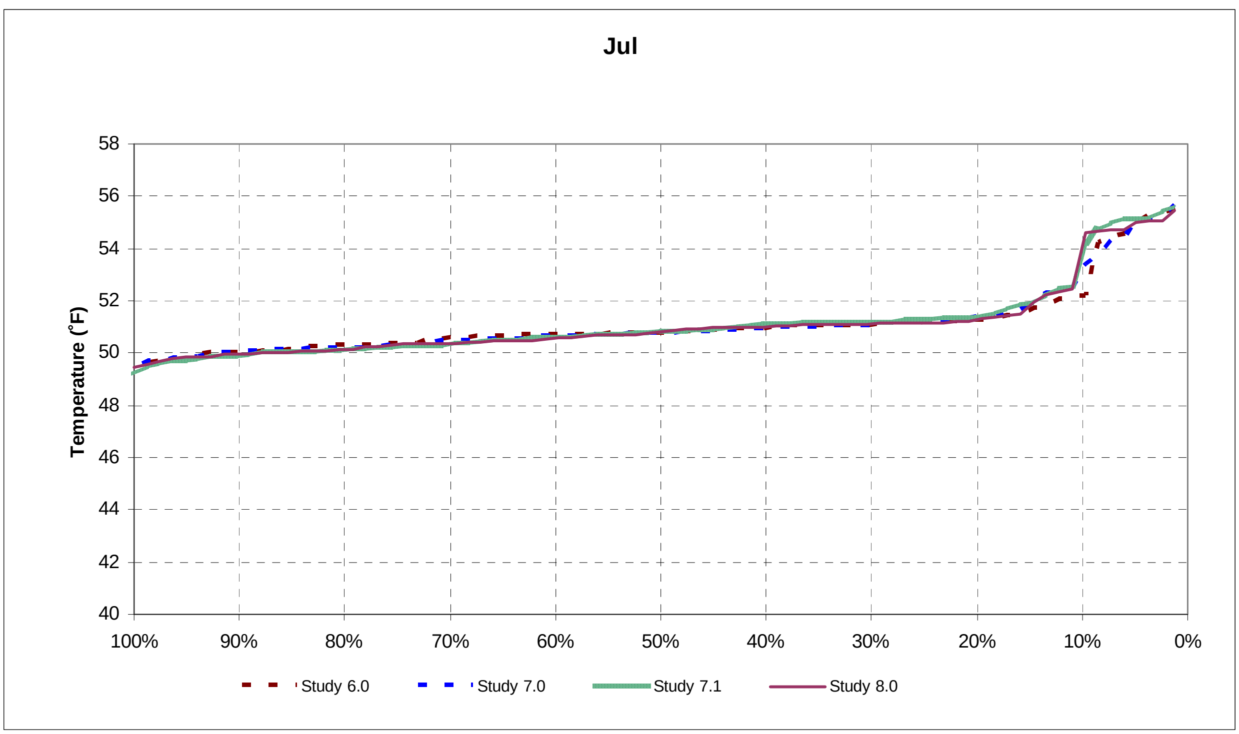


Figure 10-69 Keswick End-of-July Exceedence

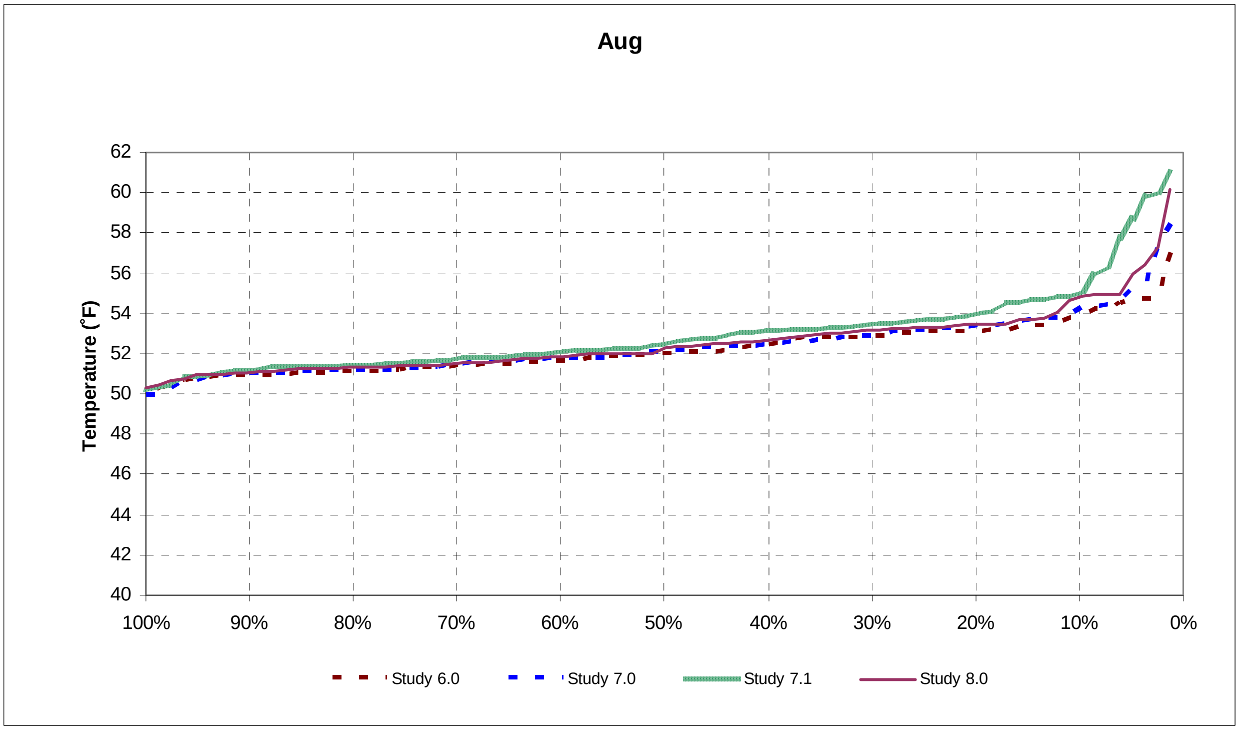


Figure 10-70 Keswick End-of-August Exceedence

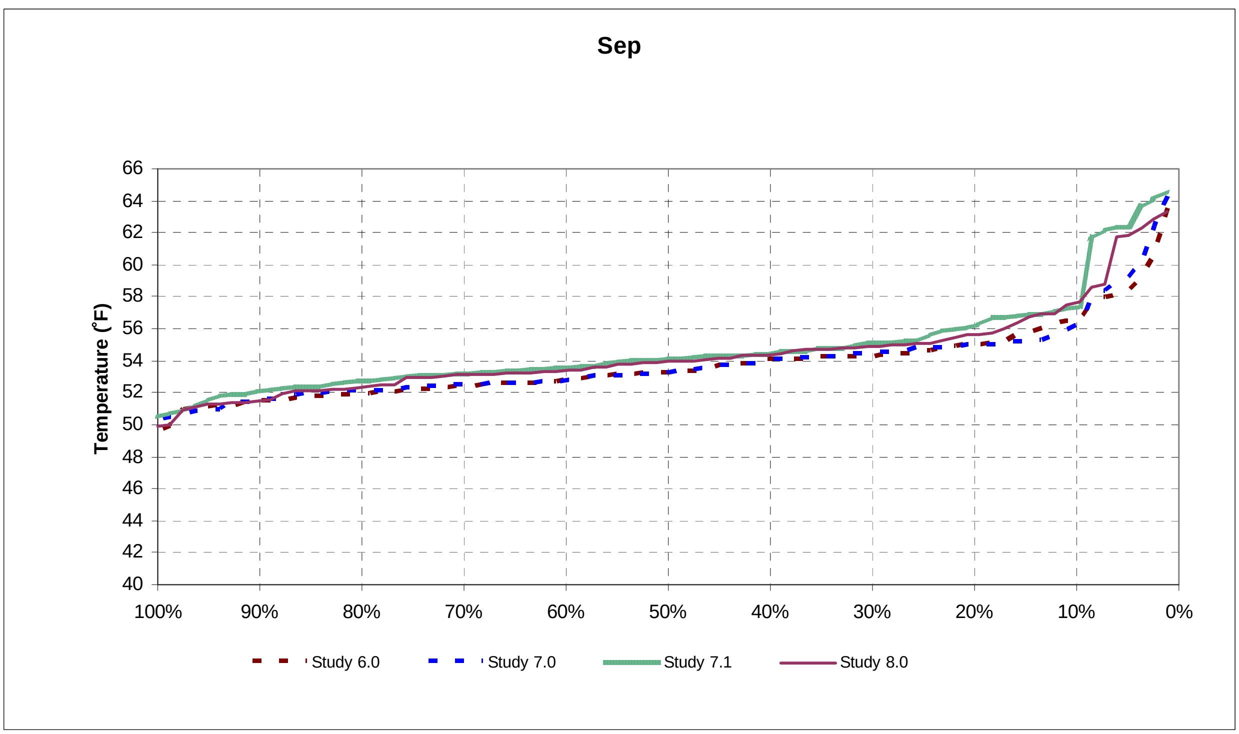


Figure 10-71 Keswick End-of-September Exceedence

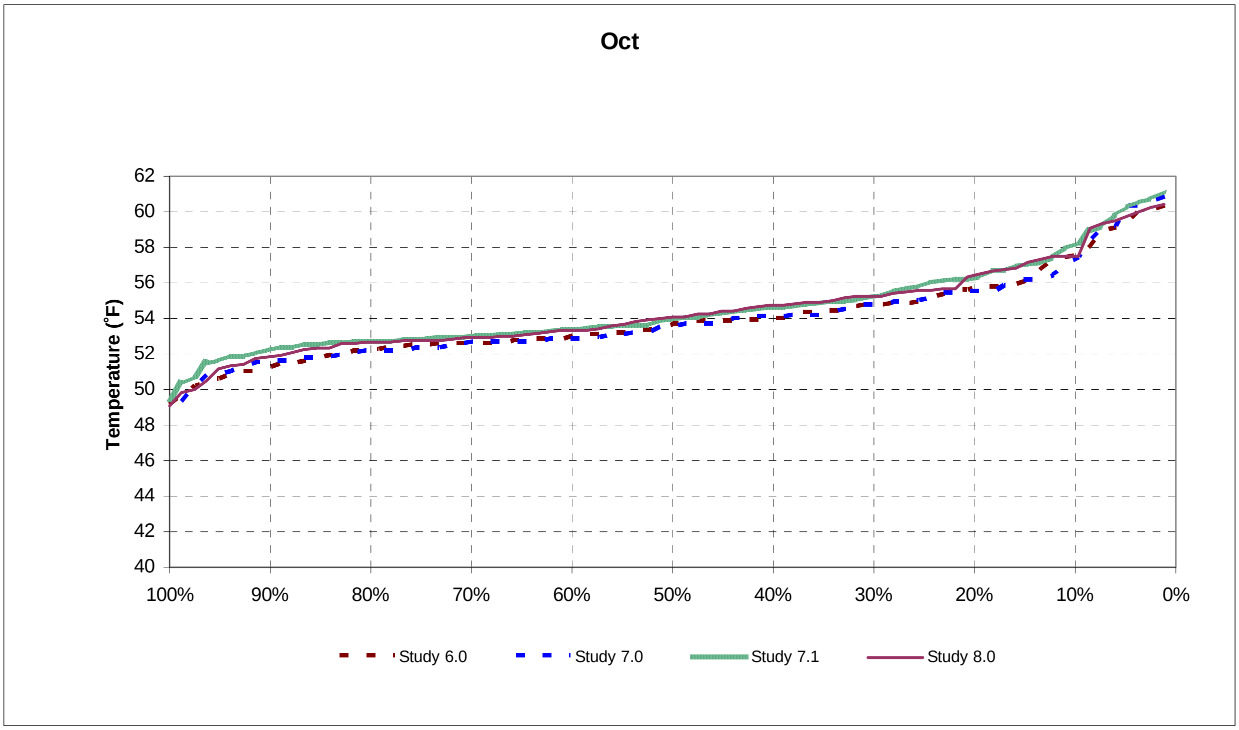


Figure 10-72 Keswick End-of-October Exceedence

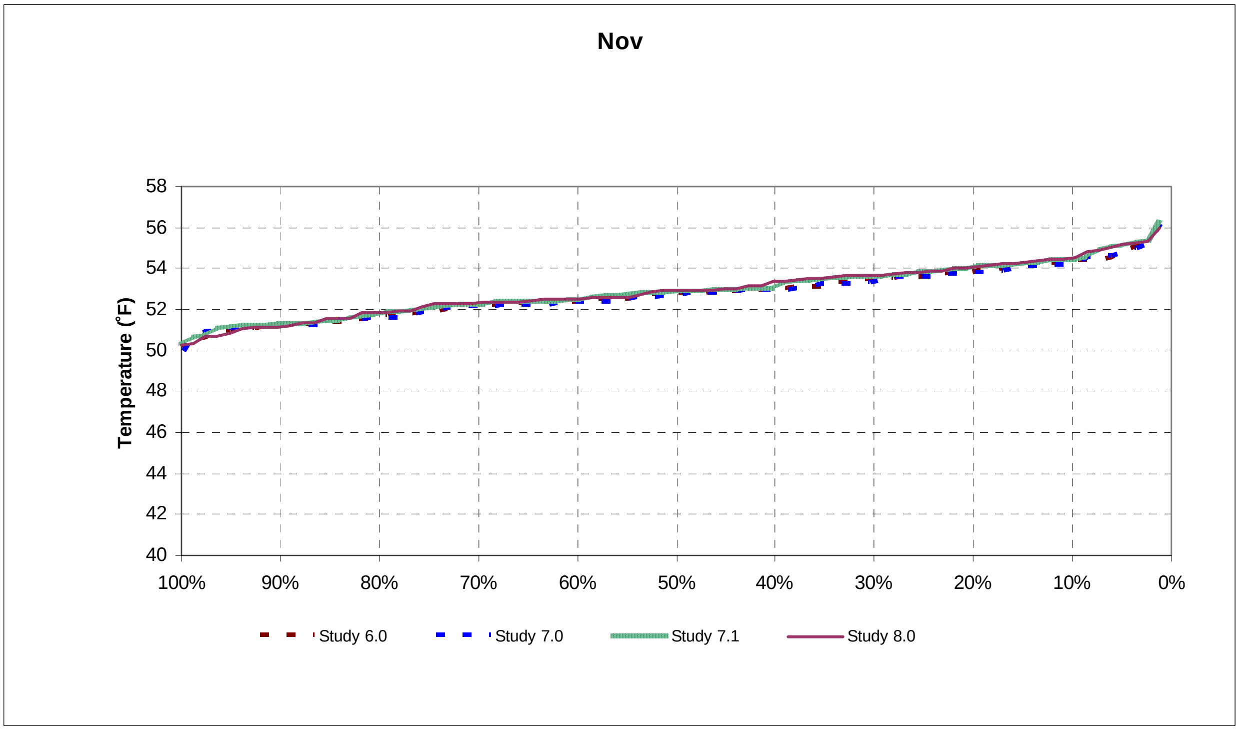


Figure 10-73 Keswick End-of-November Exceedence

Balls Ferry Water Temperatures Seasonal Exceedence Plots

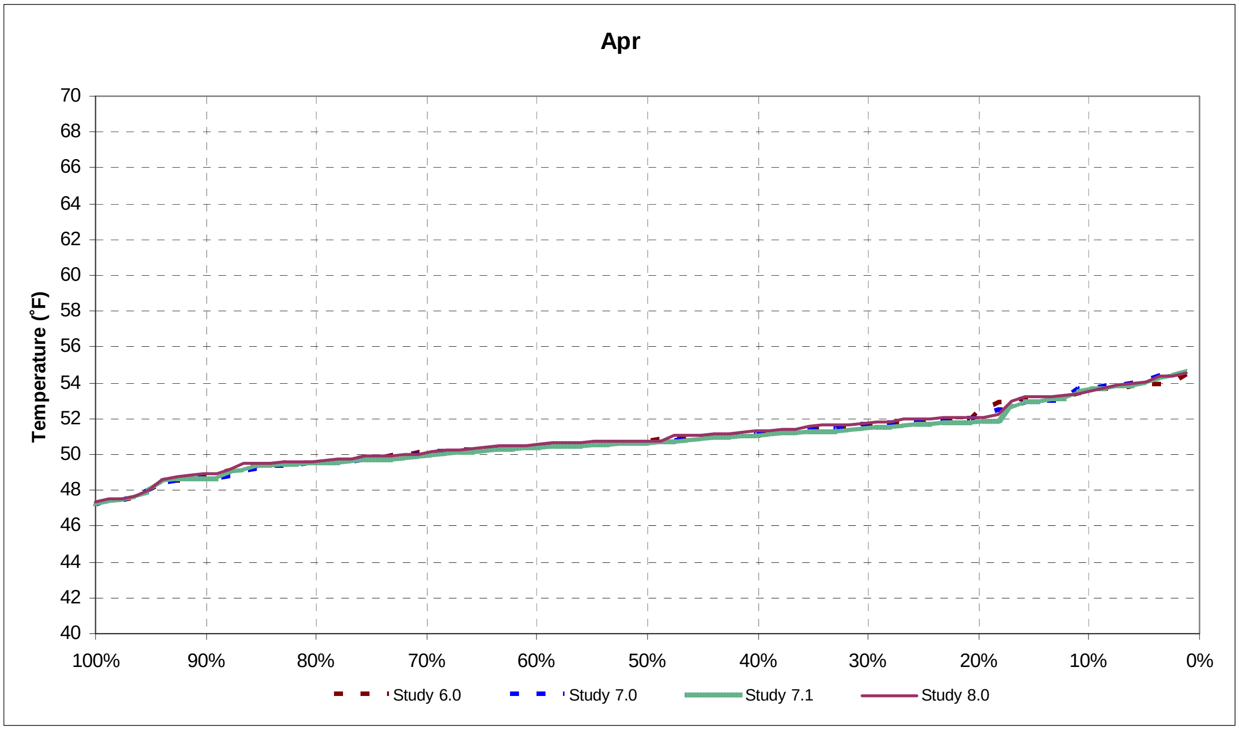


Figure 10-74 Balls Ferry End-of-April Exceedence

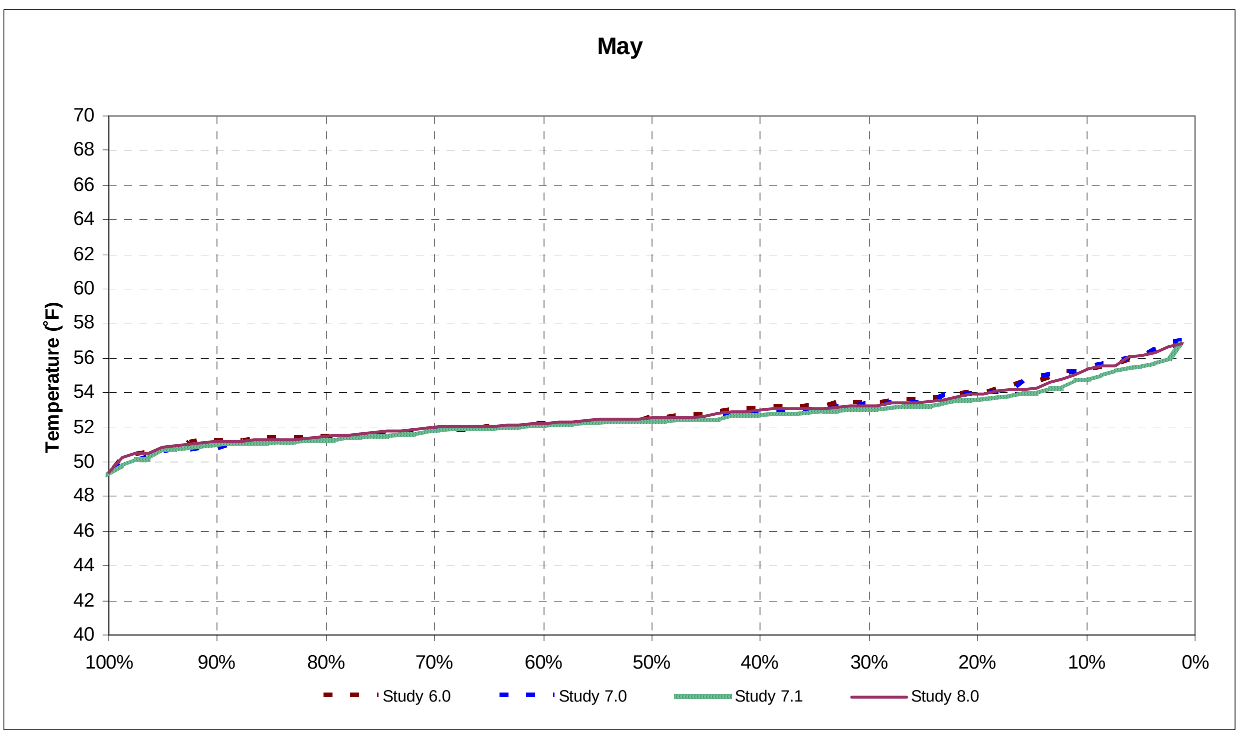


Figure 10-75 Balls Ferry End-of-May Exceedence

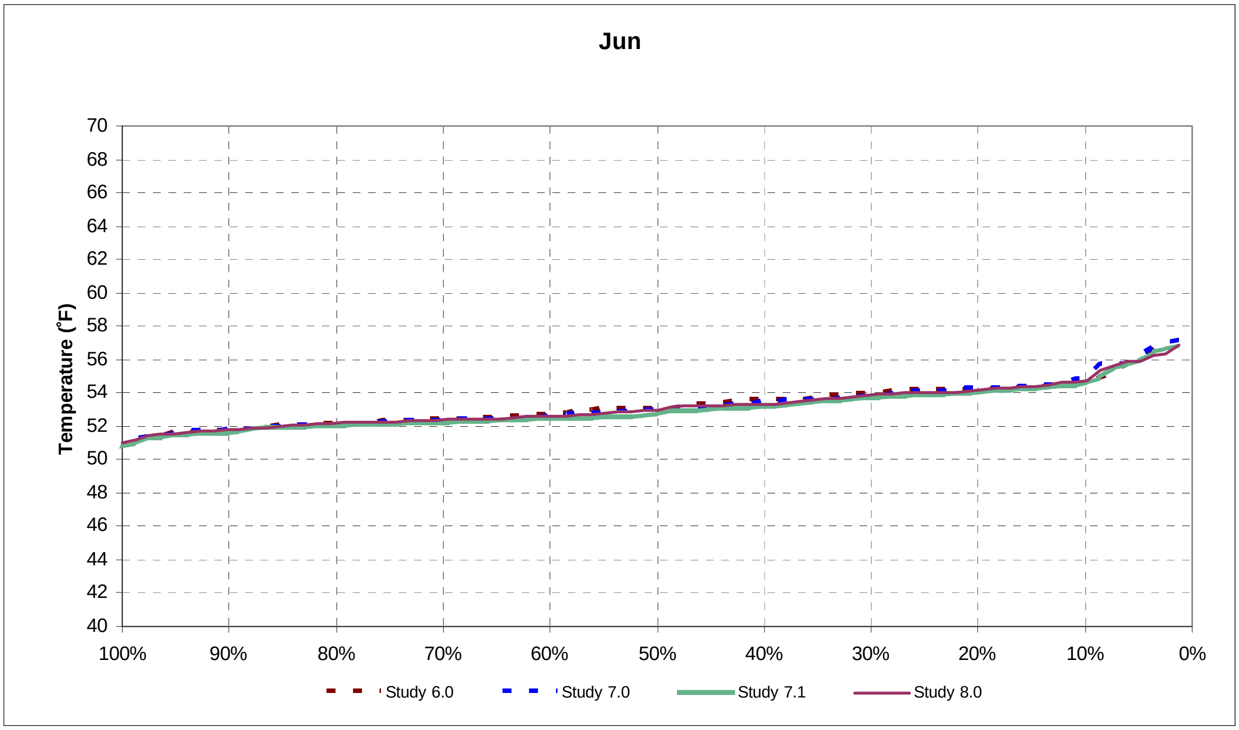


Figure 10-76 Balls Ferry End-of-June Exceedence

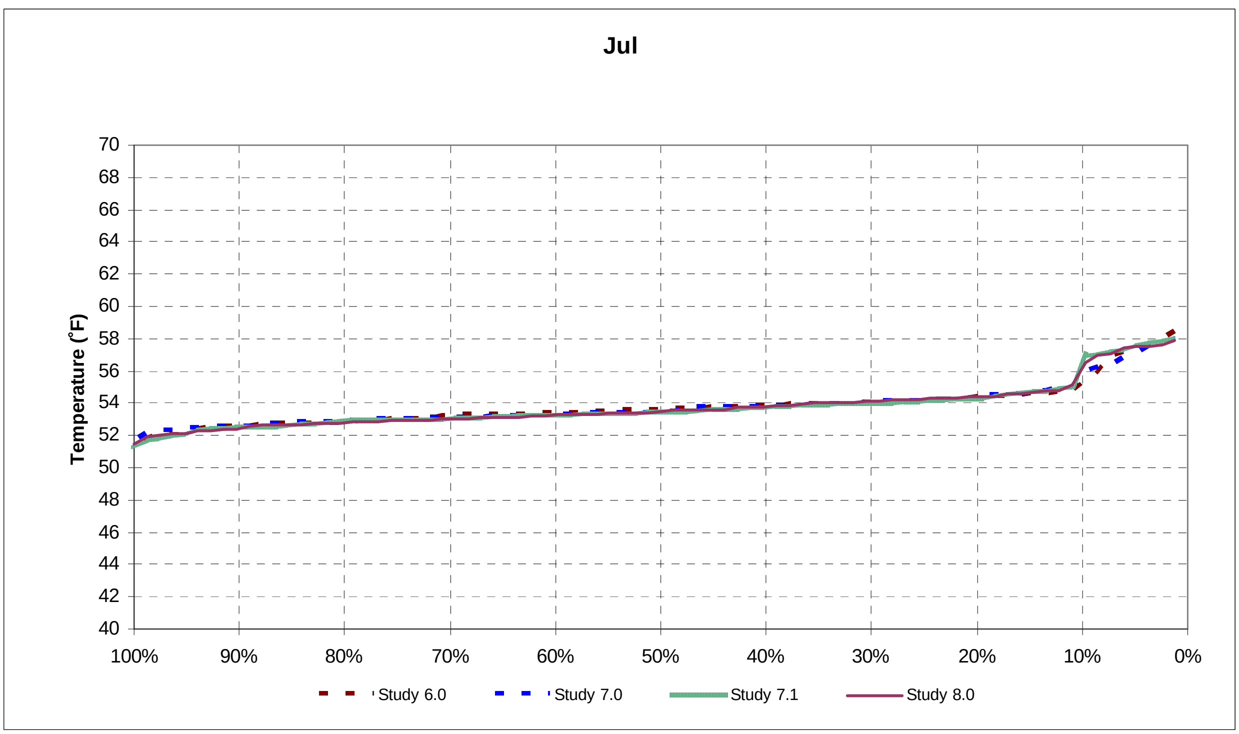


Figure 10-77 Balls Ferry End-of-July Exceedence

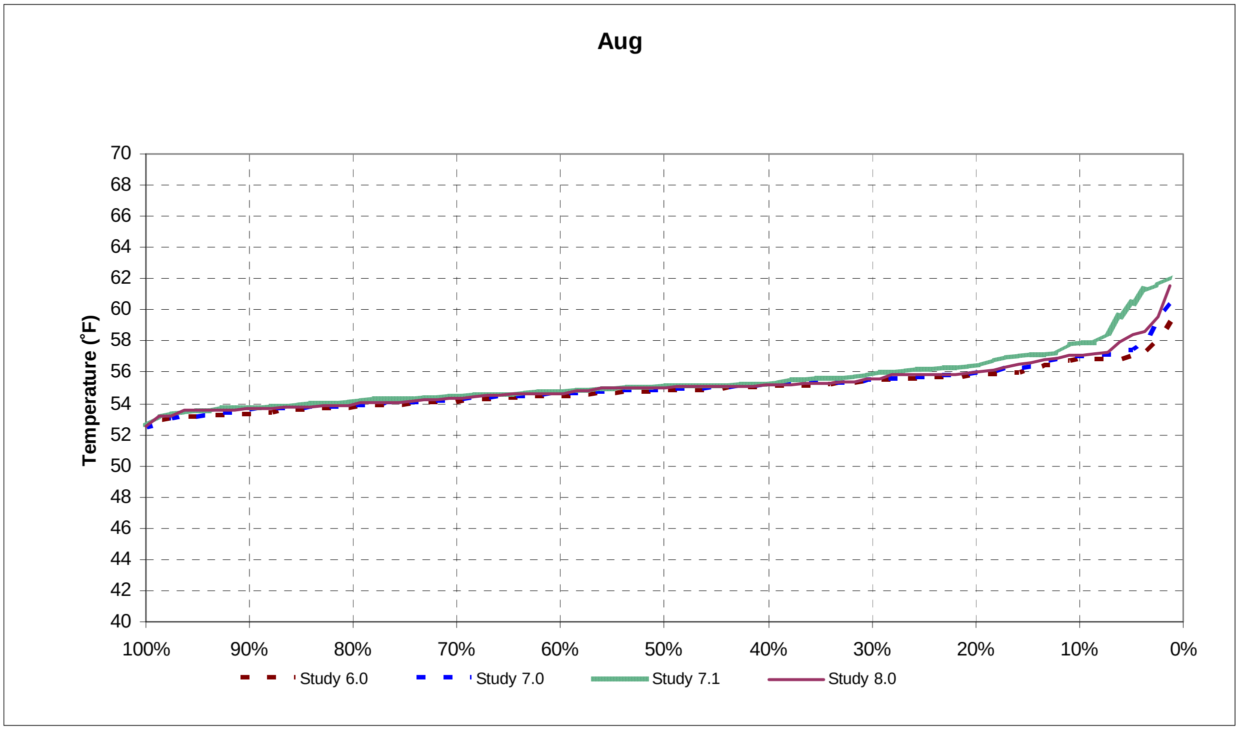


Figure 10-78 Balls Ferry End-of-August Exceedence

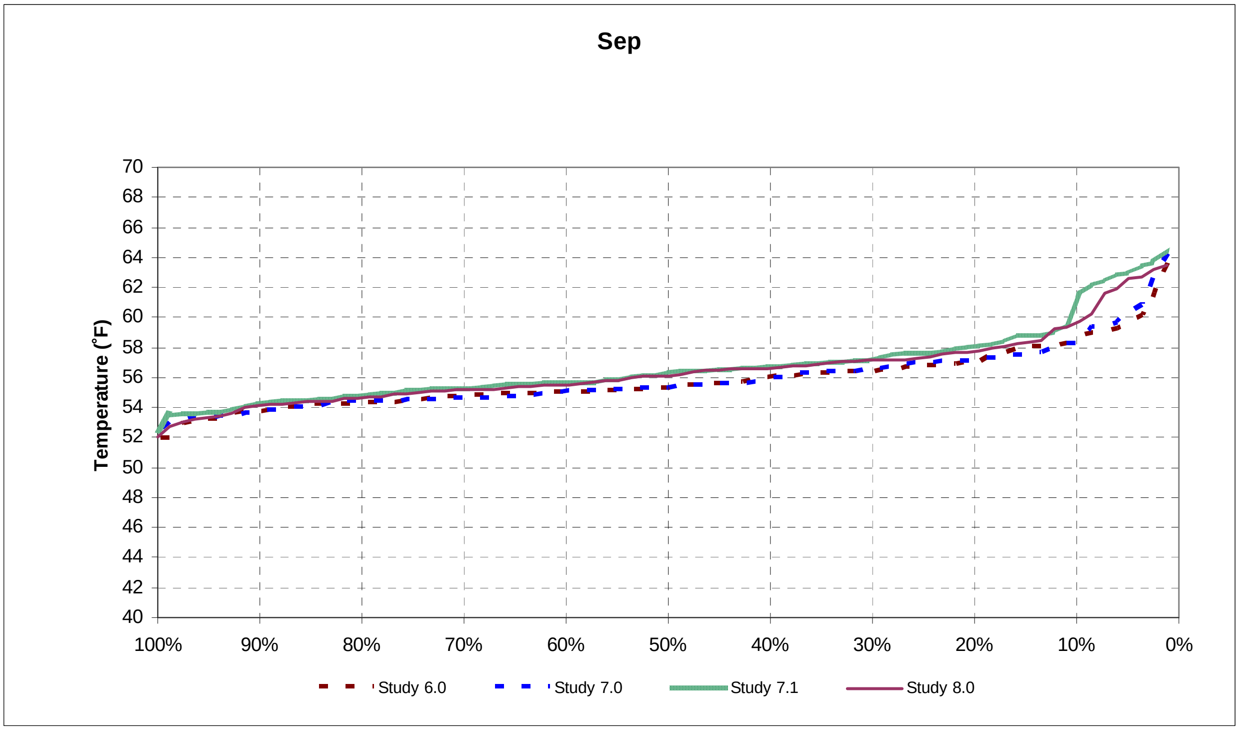


Figure 10-79 Balls Ferry End-of-September Exceedence

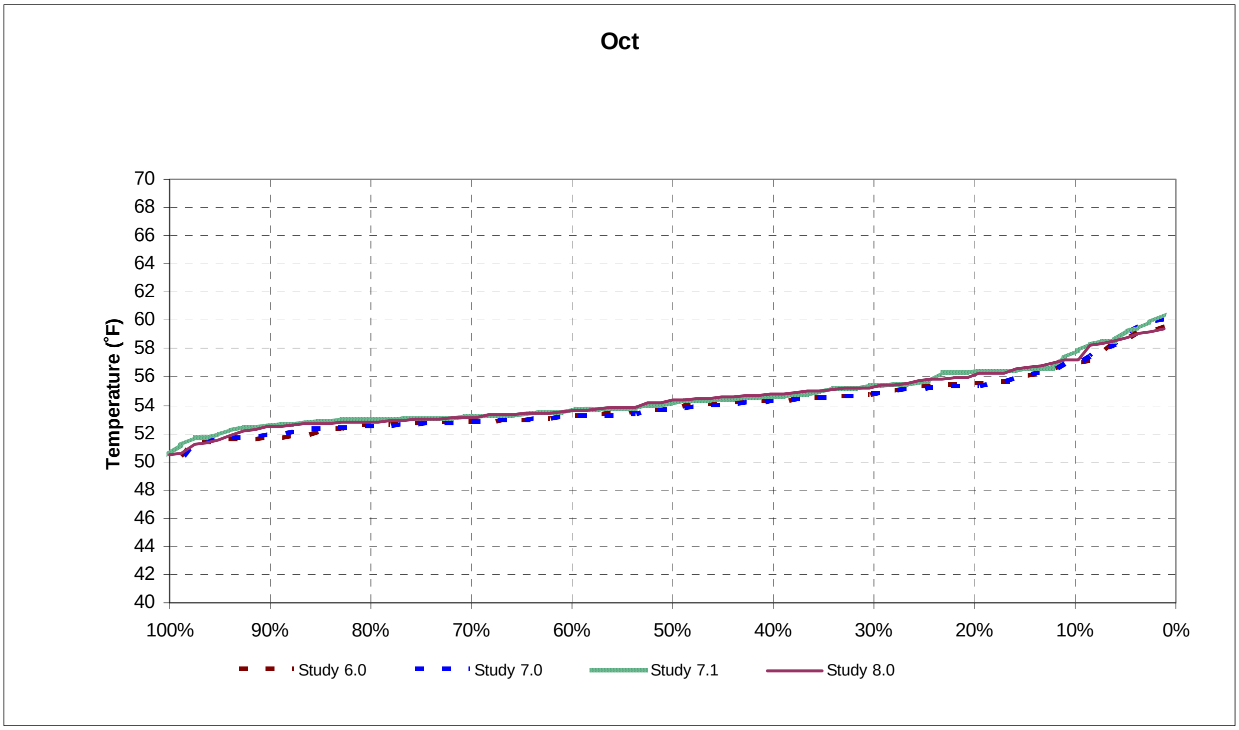


Figure 10-80 Balls Ferry End-of-October Exceedence

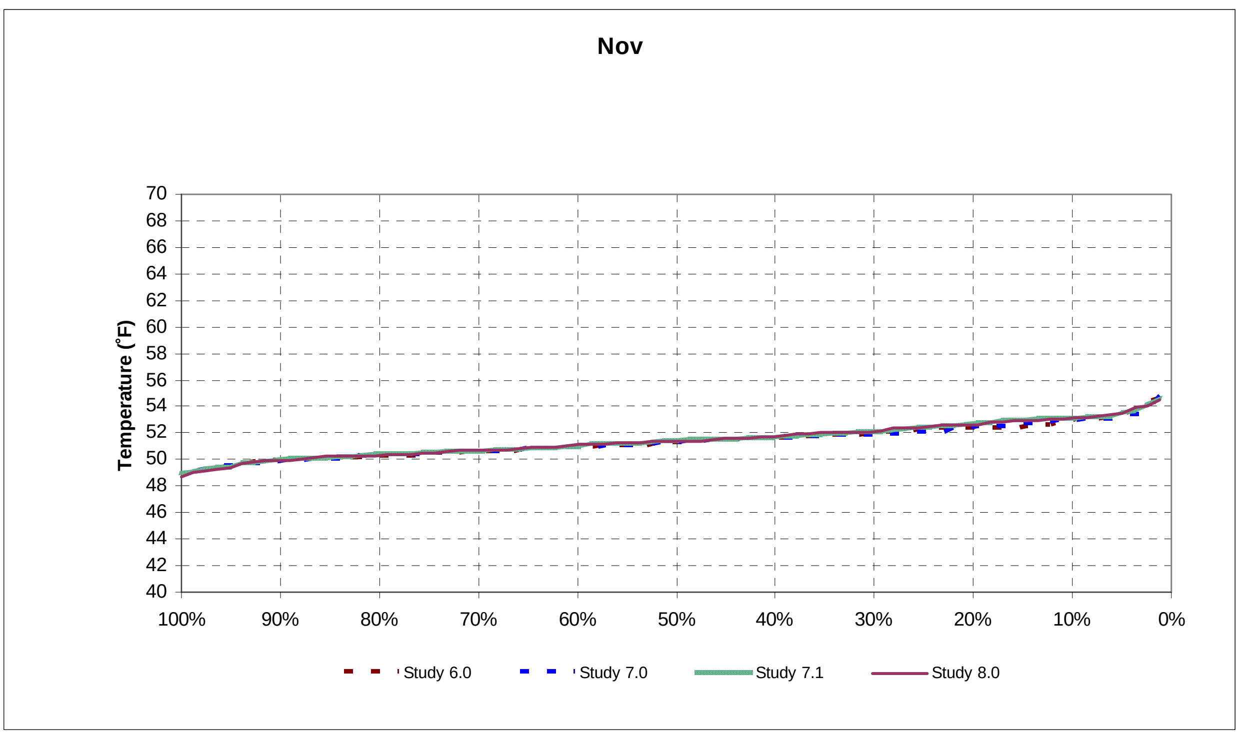


Figure 10-81 Balls Ferry End-of-November Exceedence

Bend Bridge Water Temperatures Seasonal Exceedence Plots

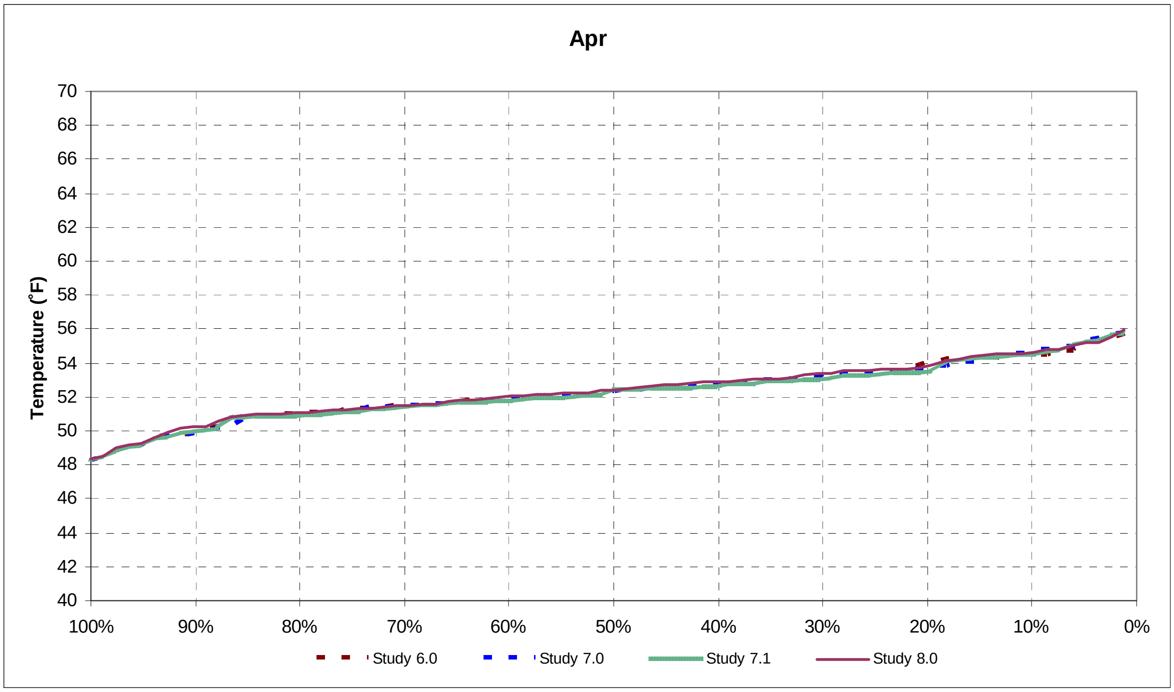


Figure 10-82 Bend Bridge End-of-April Exceedence

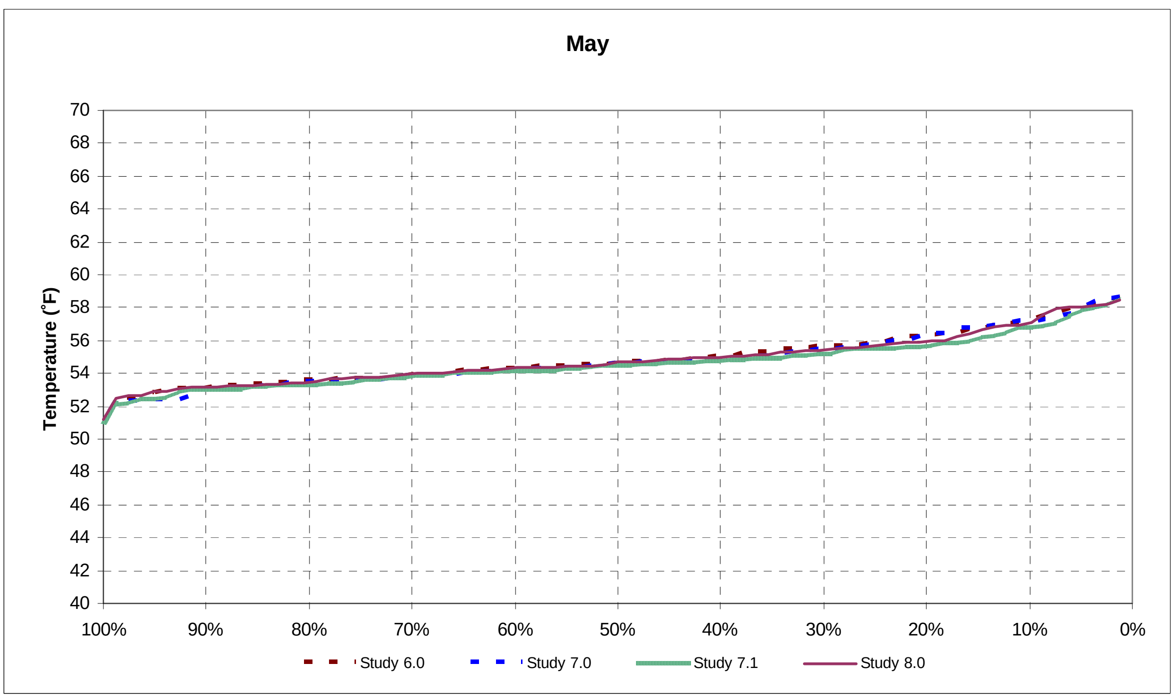


Figure 10-83 Bend Bridge End-of-May Exceedence

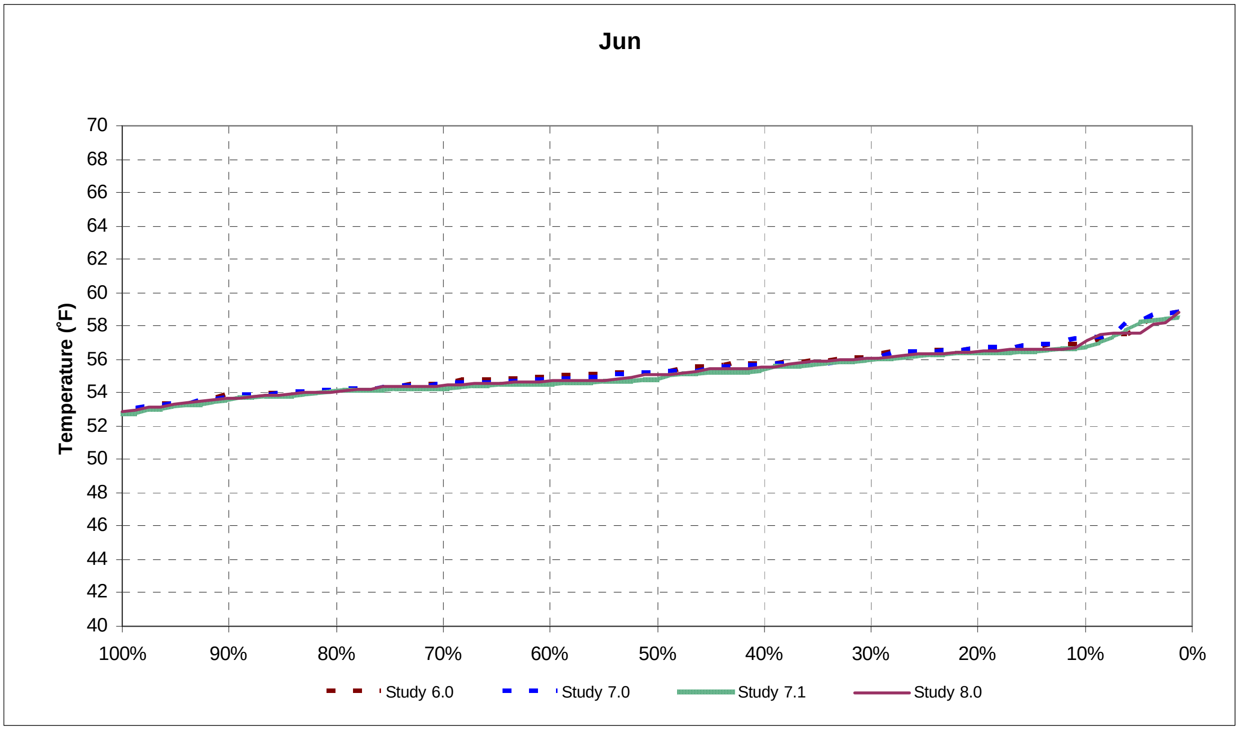


Figure 10-84 Bend Bridge End-of-June Exceedence

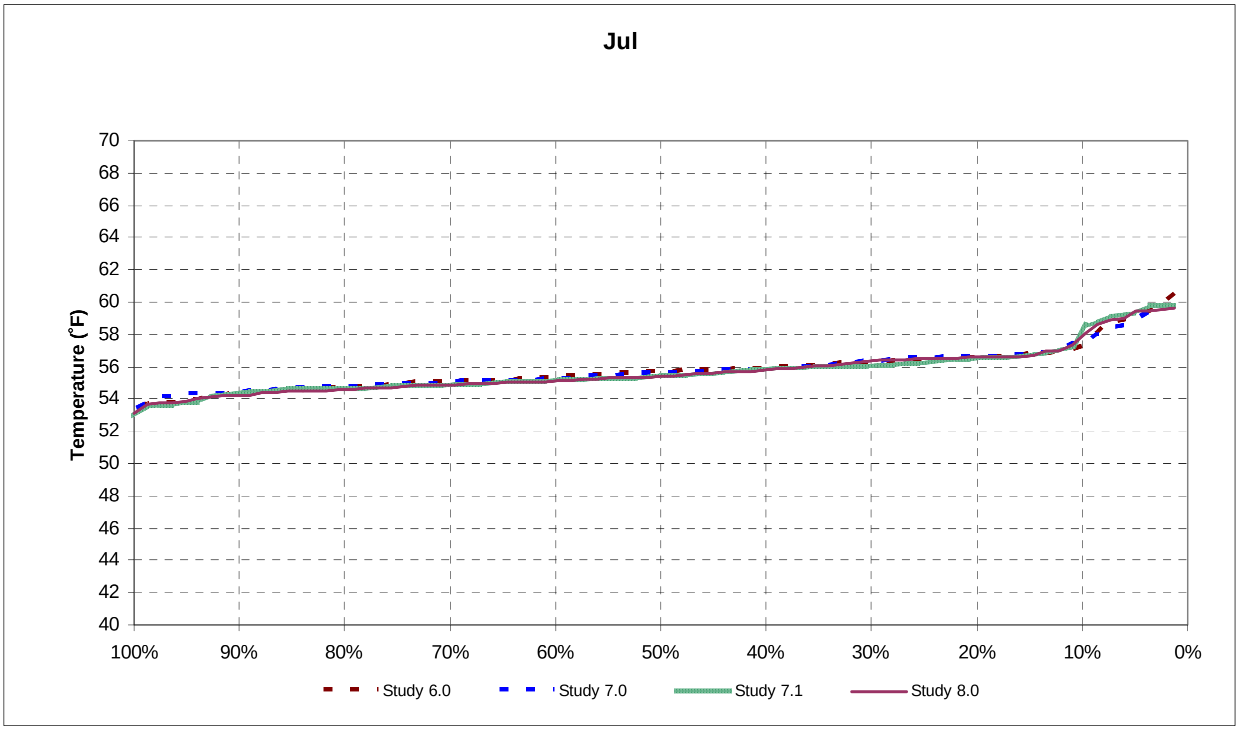


Figure 10-85 Bend Bridge End-of-July Exceedence

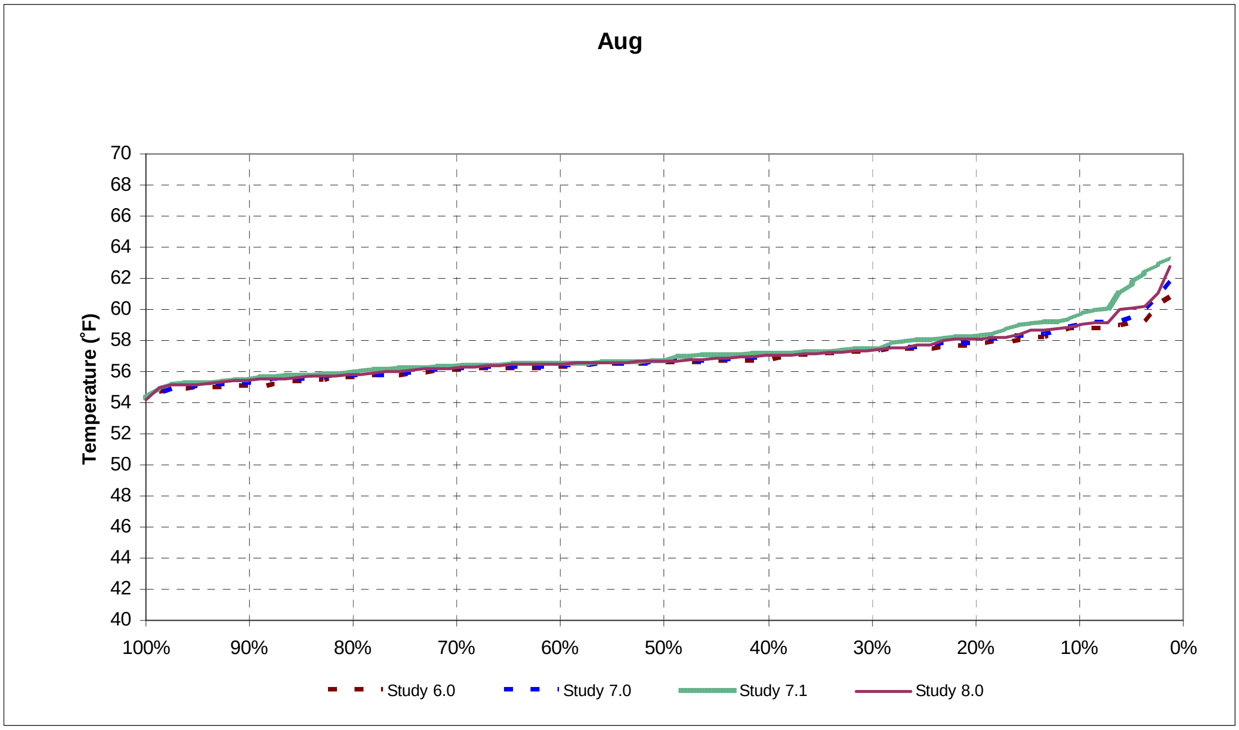


Figure 10-86 Bend Bridge End-of-August Exceedence

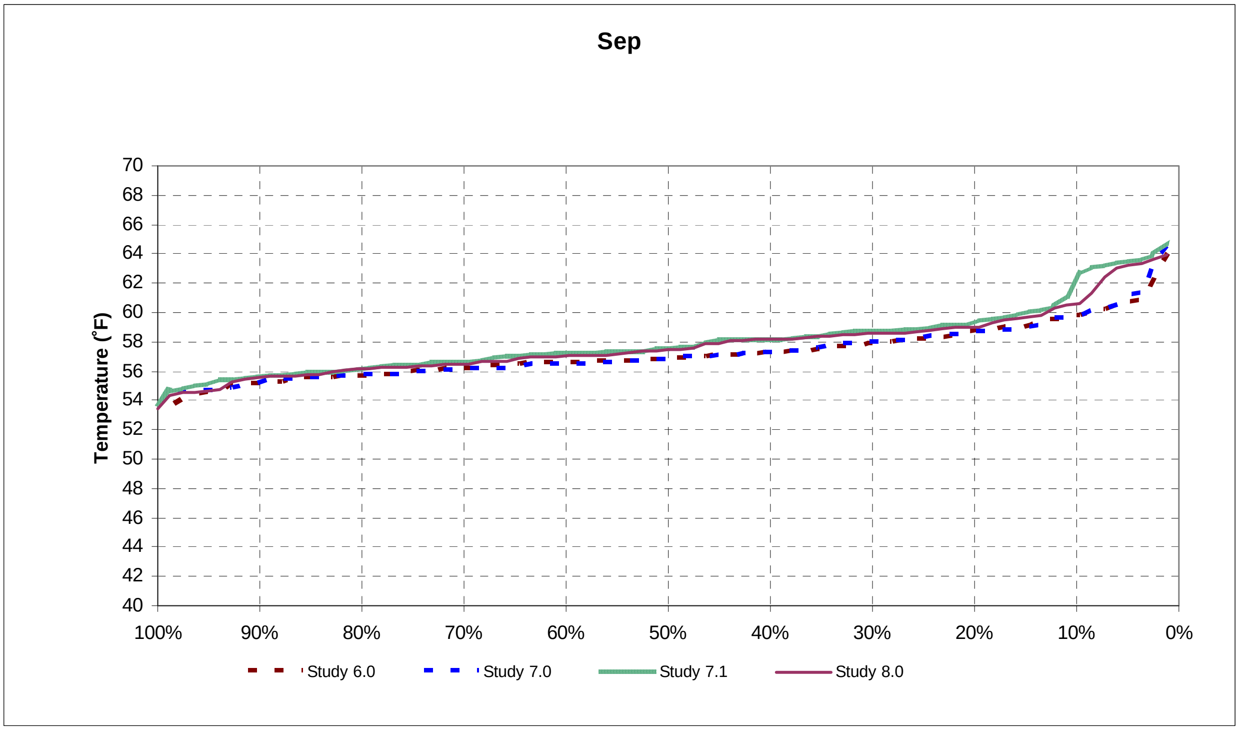


Figure 10-87 Bend Bridge End-of-September Exceedence

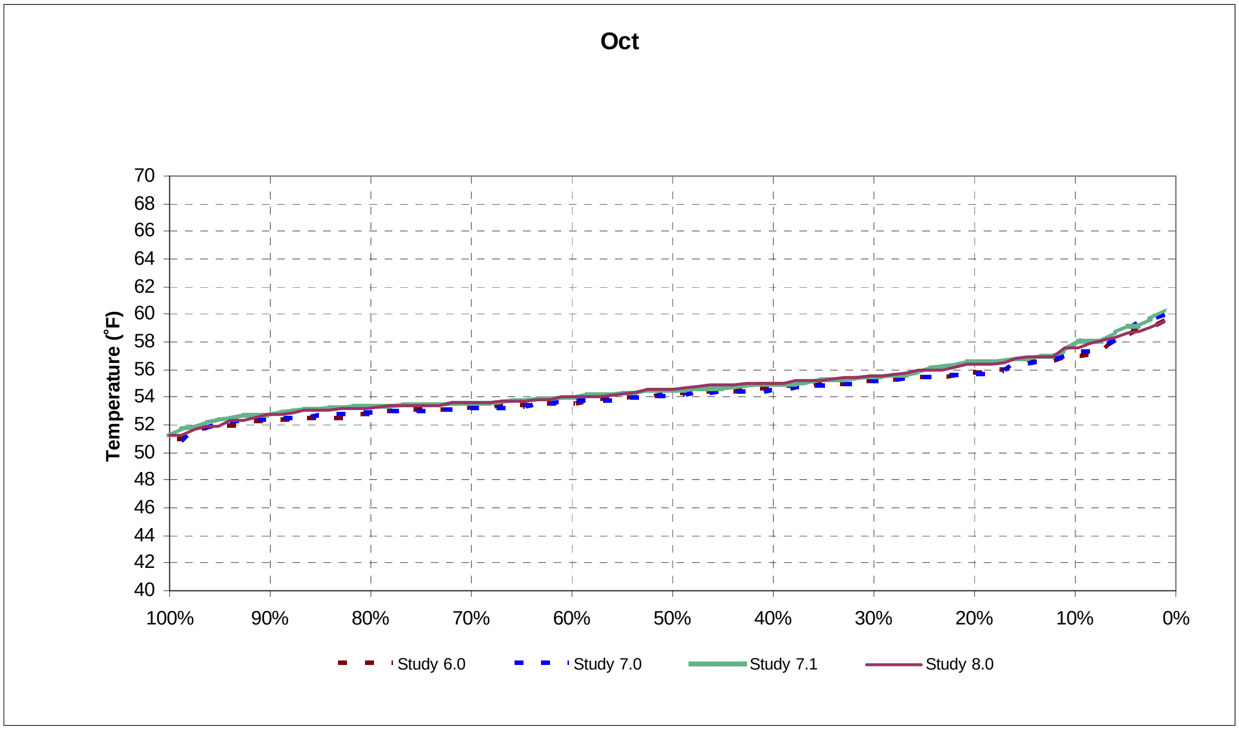


Figure 10-88 Bend Bridge End-of-October Exceedence

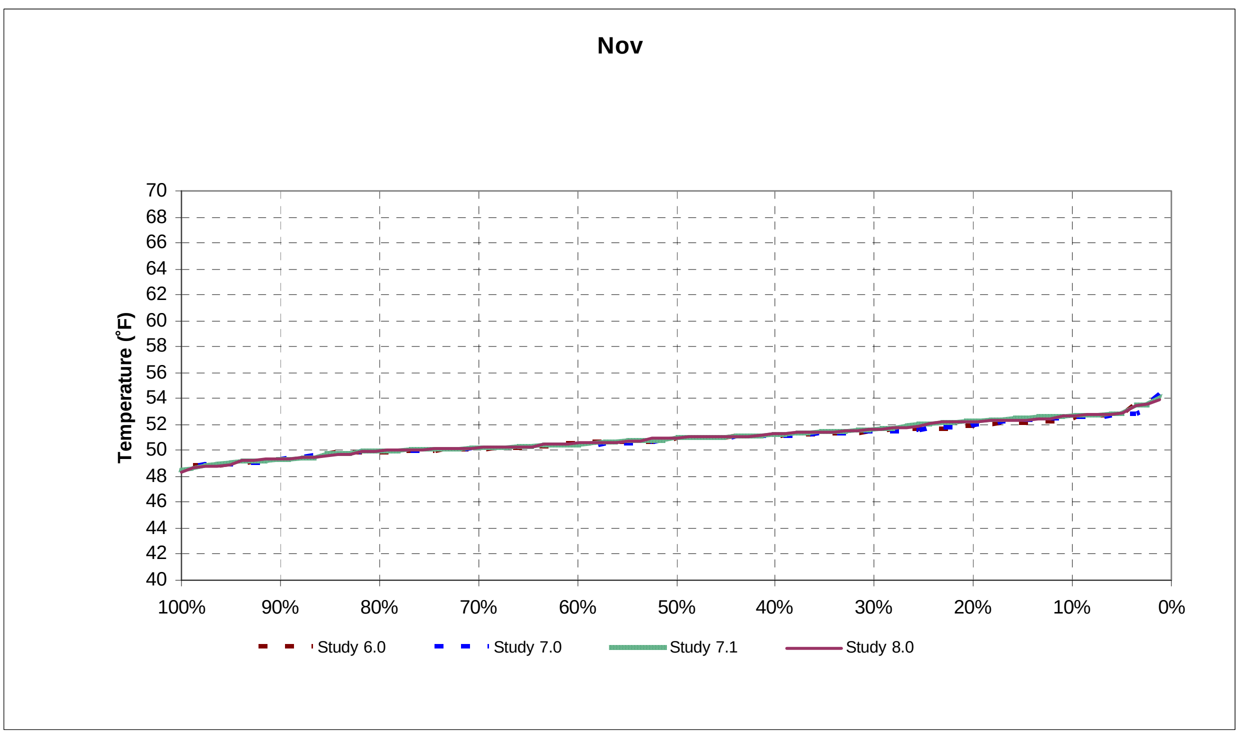


Figure 10-89 Bend Bridge End-of-November Exceedence

Feather River

Feather River operations of the Oroville Facilities are currently being covered under a separate Section 7 ESA consultation process for the Federal Energy Regulatory Commission (FERC) relicensing process (FERC BA). In addition, FERC prepared an Environmental Impact Statement (EIS) and DWR prepared an Environmental Impact Report (EIR) for the Relicensing of the Oroville Facilities. The draft National Marine Fisheries Service (NMFS) Biological Opinion (BO) for the Oroville Facilities is scheduled for release in late 2008. The discussion below compares the current OCAP BA models runs, or Studies, with the modeling conducted for the FERC Relicensing process and the various alternatives developed for the FERC BA and DEIR.

The Oroville Facilities Relicensing Draft Environmental Impact Report (DEIR) included evaluation of modeling output for three alternatives: the Existing Conditions, the No Project Alternative, and the Proposed Project Alternative. The Oroville Facilities Relicensing FERC BA included evaluation of Existing Conditions, a No-Action Alternative, and a Proposed Action Alternative. The DEIR Existing Conditions Alternative was based on the 2004 OCAP Study 3a, and the No Project and Proposed Project alternatives were based on the 2004 OCAP Study 4a.

Operations under OCAP Study 7.0 include the same flow and water temperature requirements as both of the Existing Conditions Alternatives in the FERC documents. While both the Proposed Action and Proposed Project alternatives evaluated conditions resulting from the March 2006 Settlement Agreement for Licensing of the Oroville Facilities (Settlement Agreement), as included in OCAP Study 7.1, evaluation of the Proposed Action Alternative focused on the effects of the flow and water temperature objectives, whereas analysis of the Proposed Project utilized a simulation including the flow and water temperature objectives to determine effects. Though no equivalent alternative was analyzed in either the FERC BA or DEIR, OCAP Study 8.0 would be similar to OCAP Study 7.1, with the exception of a facility modification to improve DWR's ability to manage Feather River water temperatures in OCAP Study 8.0. However, the specific configuration of a facility modification will be examined in a separate environmental process, so no water temperature modeling of a facility modification has been completed. Since the flow requirements and water temperature objectives for OCAP Studies 7.1 and 8.0 are the same, conditions under OCAP Study 8.0, at the two common water temperature compliance locations, the Feather River Fish Hatchery (FRFH) and Robinson Riffle, would be expected to be similar to OCAP Study 7.1 (and that of the Proposed Project and Proposed Action alternatives.).

Operational changes in simulation of OCAP Study 7.1, as compared to OCAP Study 4a and the FERC Proposed Project Alternative, include an increased emphasis on storing SWP water in San Luis rather than Oroville Reservoir. These operational changes would result in a general increase in releases from the Oroville Facilities in June through October and a resulting lower Oroville Reservoir storage for OCAP Study 7.1 as compared to OCAP Study 4a and the FERC Proposed Project Alternative. Lower storage would typically result in a decreased volume of cold water within Oroville Reservoir, and corresponding increases in temperature control actions (TCA) for the FRFH and Robinson Riffle. While storage conditions in Oroville Reservoir might be different in each alternative, OCAP Study 7.1, the Proposed Project Alternative, and the Proposed Action Alternative would each utilize TCA described in the Settlement Agreement. Since simulation of the Propose Project Alternative did not require the use of all available TCAs, water temperatures at the FRFH and Robinson Riffle under OCAP Study 7.1 and the Proposed Action Alternative would likely be similar to the Proposed Project Alternative. Table 10-4 shows the availability of TCAs from the Proposed Project Alternative modeling. If needed, OCAP Studies 7.1 and 8.0 would utilize temperature management actions not exhausted in modeling for the Proposed Project Alternative.

Table 10-4 Annual Availability of Oroville Facilities Temperature Management Actions in the Oroville Facilities Relicensing DEIR Proposed Project Alternative Simulation.

Temperature Management Action	Number of Years Utilized	Remaining Years of Availability
Pumpback curtailment[1]	74	0
Remove all shutters on the Hyatt Intake[2]	2	72
Increase LFC flow to 1,500 cfs[3]	10	64
Release 1,500 cfs from the river valve[4]	3	71

Source: Oroville Facilities Relicensing DEIR Proposed Project Simulation

Period of Record: 1922-1994

[1]Pumpback curtailed for at least a portion of the year

[2]All 13 shutters are removed from the Hyatt Intake

[3]For Robinson Riffle water temperature objective only

[4]For Feather River Fish Hatchery water temperature objective only

With all models there are assumptions and limitations that are inherent within. Please refer to Chapter 9 for a list of model limitations on which this analysis was based.

In conclusion, based on a comparison of OCAP Study 7.1 and OCAP Study 4a and the Proposed Project Alternative, modeling and environmental analysis of the Oroville Facilities conducted as part of the Oroville Facilities Relicensing DEIR and BA is still usable and applicable for use in the 2008 draft OCAP BA. While the TCA taken to achieve the water temperatures could be different under 2008 OCAP BA modeling, flows and water temperatures at Robinson Riffle and at the FRFH under the 2008 draft OCAP BA would generally be similar to the FERC Proposed Project.

American River

Modeling

When compared to modeling results provided from the 2004 OCAP BA, the most significant changes to the American River operations is the combination of increases in overall water demands from the 2005 to the 2030 Level of Development (LOD) and the implementation of higher minimum flows associated with the proposed Lower American River Flow Management Standard. The combination of these two factors have significant influence of how Folsom Reservoir is operated and ultimately how the integrated CVP overall is operated. In general, water demands for consumptive purposes are during the warm months of the year, late spring through summer. In addition, the higher minimum flow requirements from Nimbus Dam for fishery management objectives calls for higher flows during the fall and winter months than in previous studies.

Figure 10-90 shows the end-of-month Folsom Reservoir Storage for all three studies. Figure 10-91 and Figure 10-92 show the probability distribution for Folsom Reservoir Storage at the end-of-May and the end-of-September, generally the end of May is the high-point in storage at Folsom Reservoir. The end-of-May Folsom Reservoir storage shows some general differences between the studies in the 70% to 90% probability range. The differences appear to have a general magnitude of 50 TAF or less. The end-of-September Folsom Reservoir storage shows a much broader general difference between the studies in the 50% to 100% probability range. The differences have a general magnitude of 75 TAF to 100 TAF.

The differences between the end-of-May and the end-of-September probability plots can be explained by two general operations facts about the CVP reservoir system; 1) Folsom Reservoir has the highest refill probability in the CVP system – in most normal hydrologic or wetter hydrologic conditions Folsom Reservoir will need to release water for flood control purposes during the winter or spring months. Under this hydrologic scenario, the next year’s end-of-May Folsom Reservoir storage will likely be very similar. 2) If hydrologic conditions are not normal or better, and Folsom Reservoir storage conditions become stressed, water storage from the much larger storage Shasta-Trinity system is used to meet CVP water demands and objectives that can be met by either CVP water source. The integrated nature of CVP reservoir operations will spread a storage shortage from one year at Folsom Reservoir to the Shasta-Trinity System. The result is that by the following May, Folsom Reservoir storages are nearly similar.

Figure 10-93 shows the monthly percentile distribution values for Nimbus releases. This plot illustrates the CVP operations discussed above by showing the seasonal median releases through the year for each study. As the studies progress towards higher water use from the American Basin, either a median decrease occurs in another subsequent month (Shasta-Trinity integration) or the wintertime probability of higher flood releases is reduced. Figure 10-94 to Figure 10-99 show the average monthly Nimbus releases by long-term average and Sacramento River Basin 40-30-30 Water Year Classification.

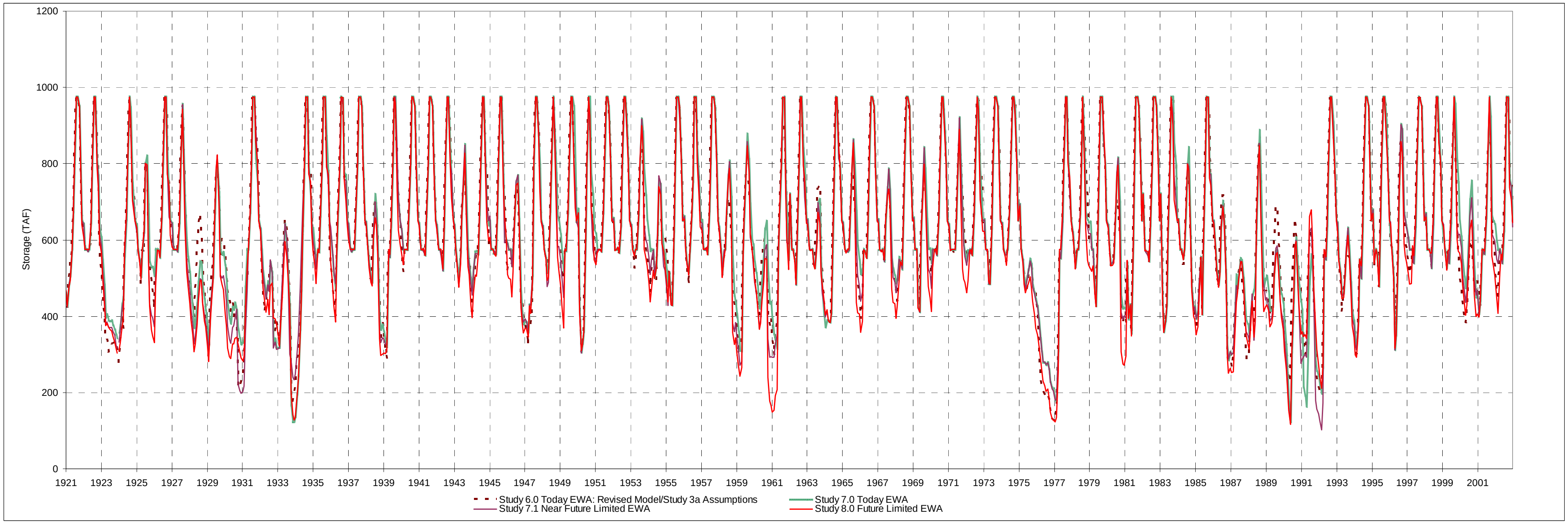


Figure 10-90. Chronology of Folsom Storage Water Years 1922 – 2003

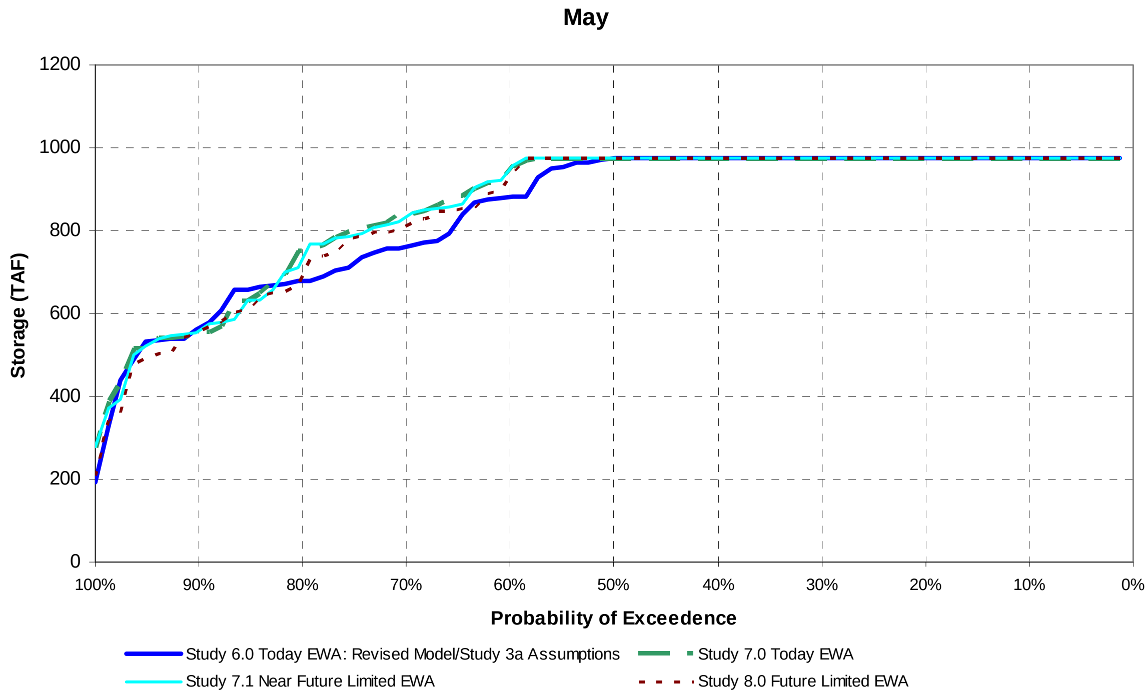


Figure 10-91 Folsom Reservoir End of May Exceedence

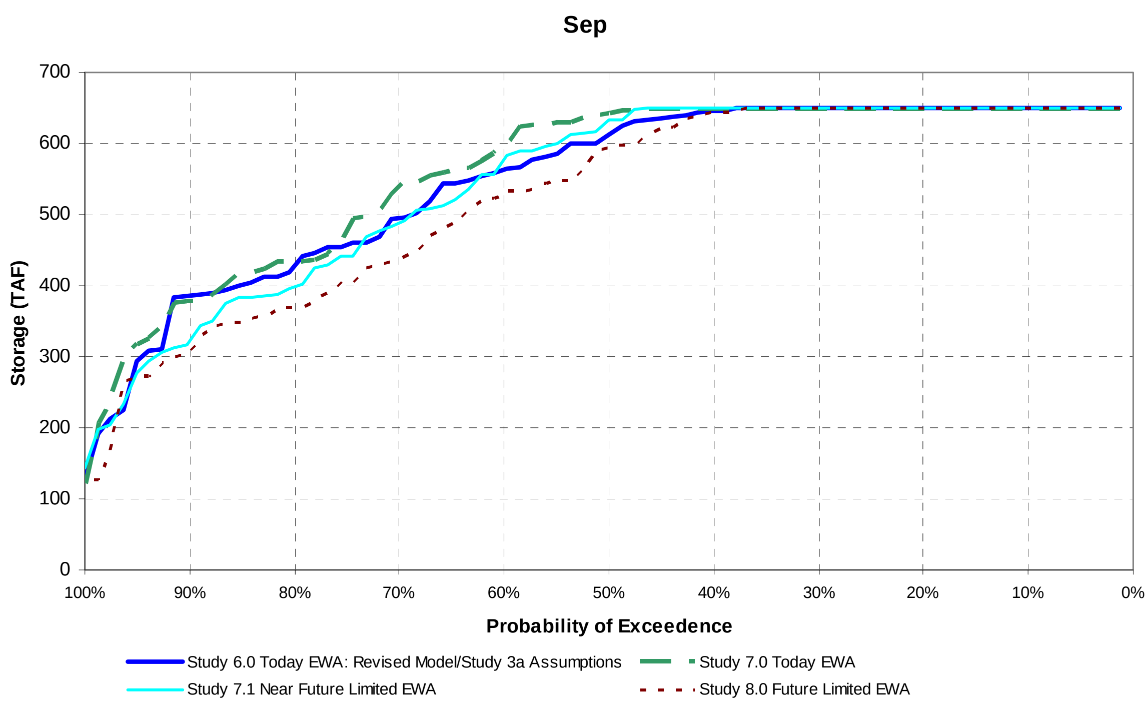


Figure 10-92 Folsom Reservoir End of September Exceedence

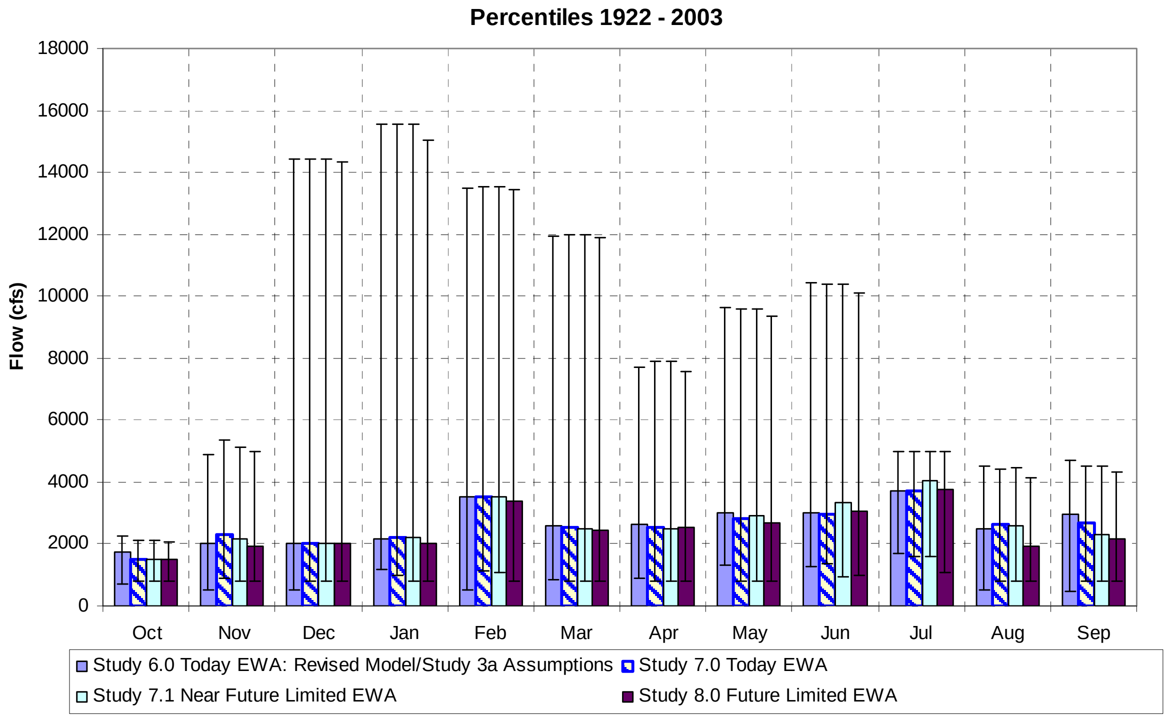


Figure 10-93 Nimbus Release 50th Percentile Monthly Releases with the 5th and 95th as the Bars

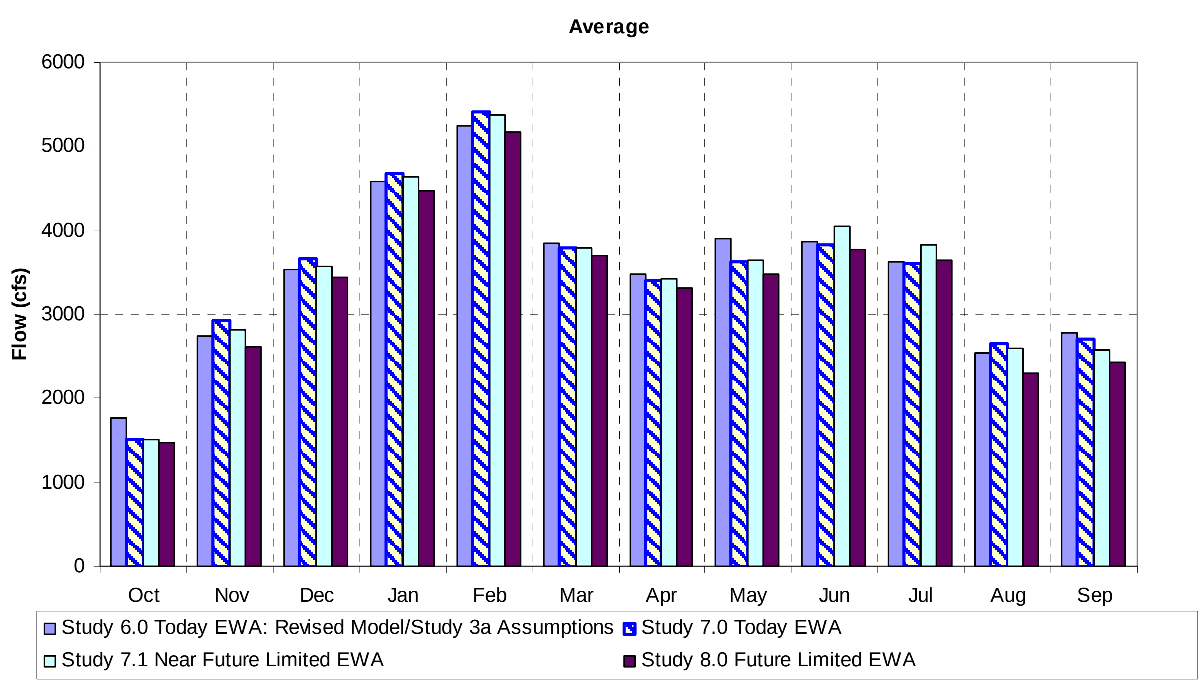


Figure 10-94 Average Monthly Nimbus Release

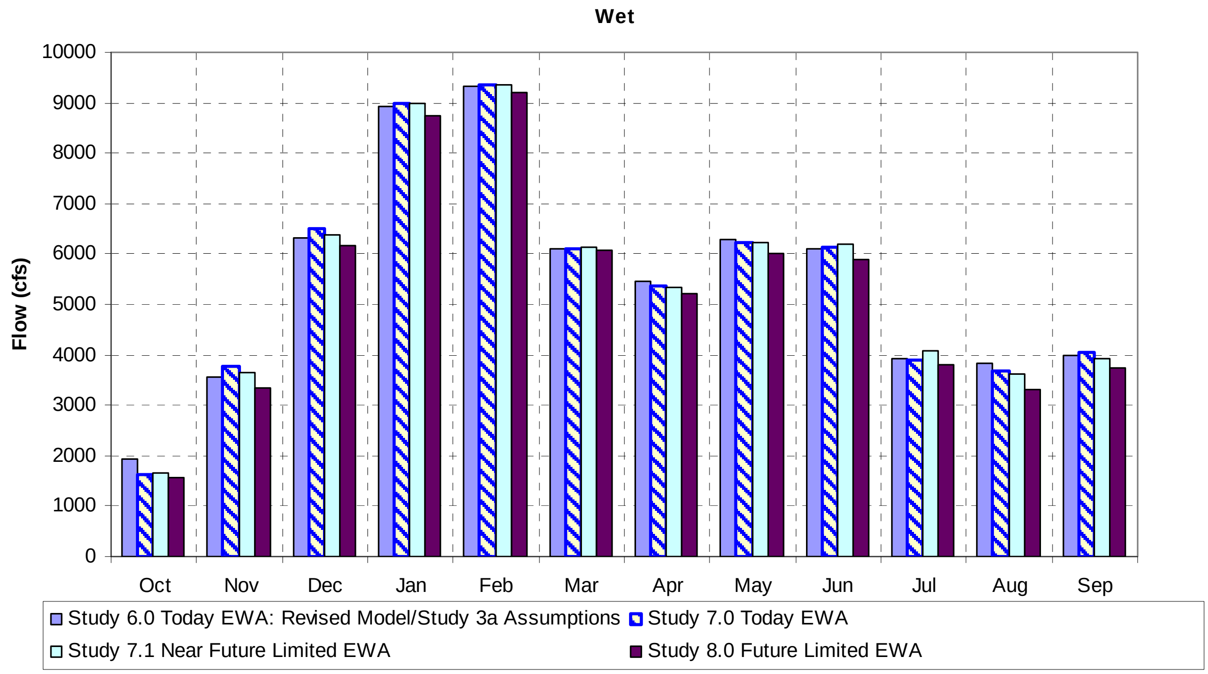


Figure 10-95 Average Wet Year (40-30-30 Classification) Monthly Nimbus Release

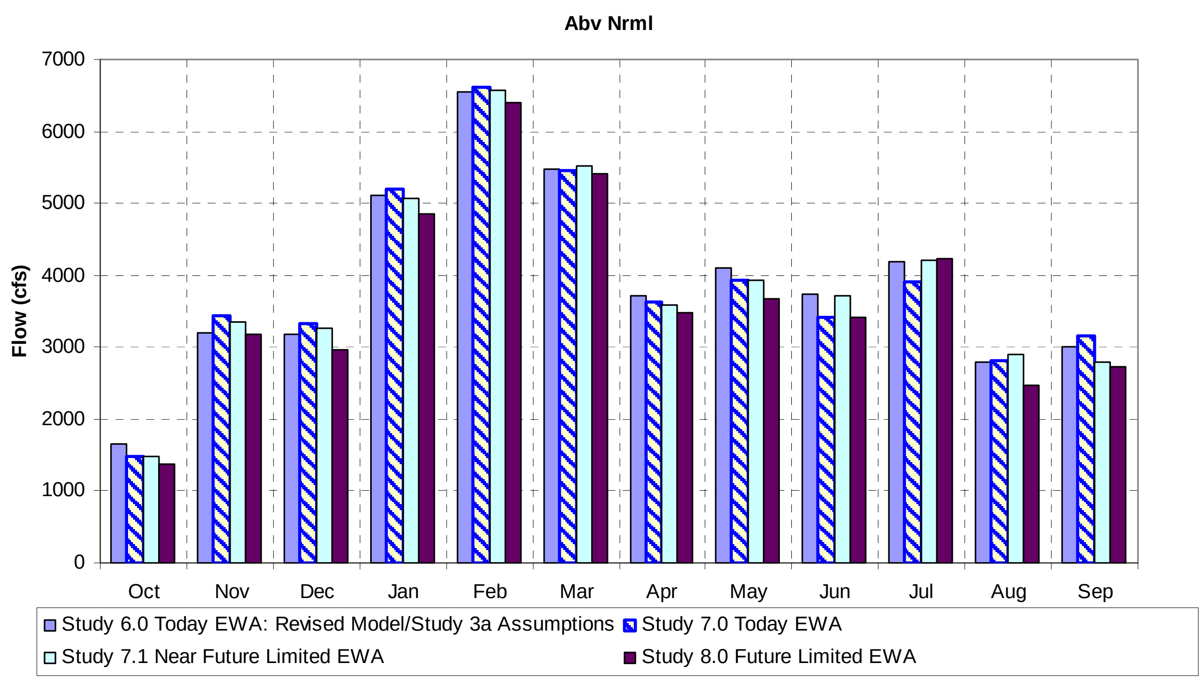


Figure 10-96 Average Above Normal Year (40-30-30 Classification) Monthly Nimbus Release

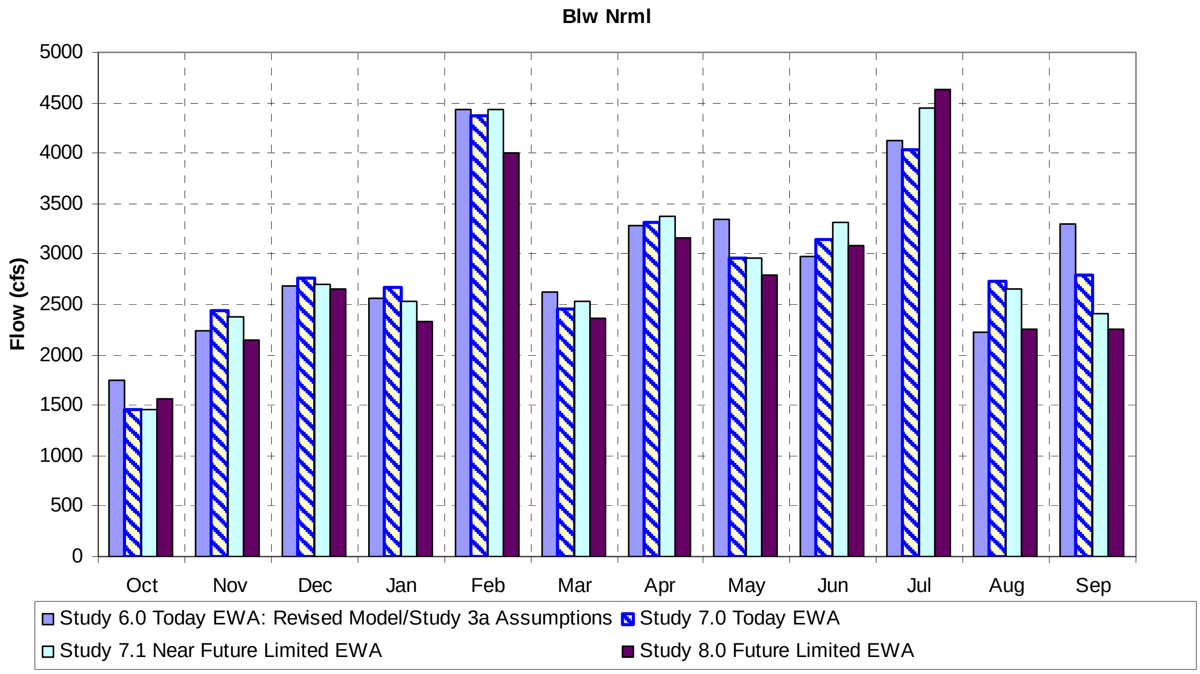


Figure 10-97 Average Below Normal Year (40-30-30 Classification) Monthly Nimbus Release

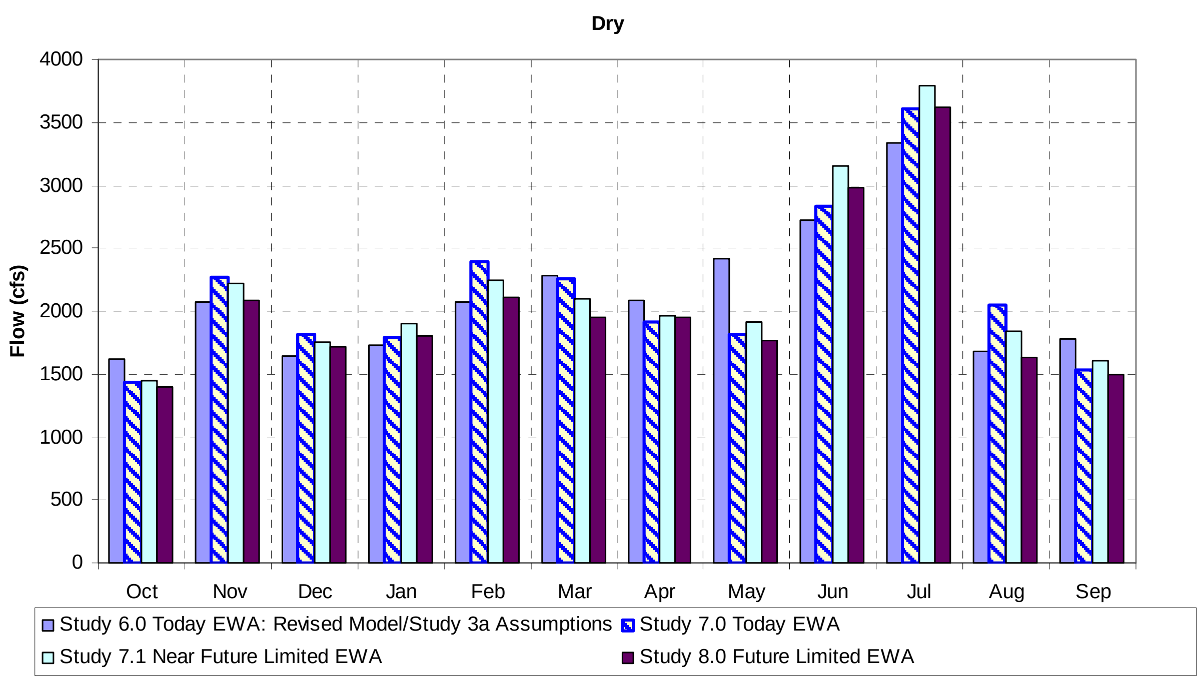


Figure 10-98 Average Dry Year (40-30-30 Classification) Monthly Nimbus Release

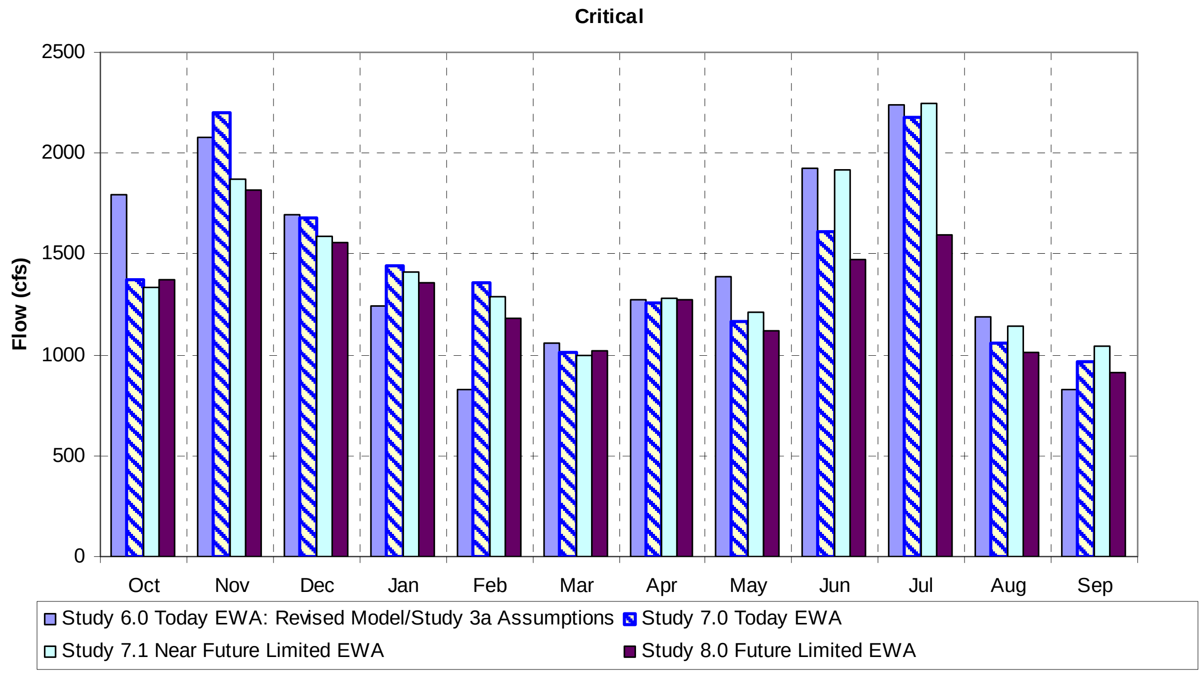


Figure 10-99 Average Critical Year (40-30-30 Classification) Monthly Nimbus Release

American River Temperature Analysis

Successful management of water temperatures to protect the fishery in any given year for the lower American River requires close coordination and analysis of several factors that influence water temperature. The general operational factors that will influence water temperature management are:

- Volume of coldwater availability in the spring
- Folsom Shutter operational flexibility
- Projected Nimbus Reservoir release rate over the temperature control season
    - Too low of release rates may require significantly colder source water to meet a target temperature leading to faster depletion of available coldwater.
    - Too high of release rates may deplete coldwater availability faster than anticipated and lead to faster depletion of available coldwater
- Water Purveyor withdrawal rates from Folsom Lake and lake elevation of these withdrawal.
- Designation of a compliance water temperature target at Watt Ave. that best integrates the above factors with water temperature habitat needs for sensitive lifestages of fish.

As described in Chapter 2, the American River Group (ARG) and B2IT evaluates all the above factors for any given year designate a compliance water temperature target at Watt Avenue that balances all the relevant information and factors into a seasonal strategy for water management. The adaptive management process updates and evaluates current information in order to make significant choices and tradeoffs for seasonal or inter-seasonal water temperature performance goals. Reclamation utilizes this adaptive management process in a very similar manner as the Sacramento River Temperature Task Group is utilized in order to comply with SWRCB 90-05 water temperature objectives in the upper Sacramento River environment.

The modeling results presented here cannot completely simulate the adaptive management process to designate a compliance water temperature target at Watt Avenue in any given year. The water temperature analysis presented here does demonstrate the generalized relationships of coldwater availability, generalized Folsom Shutter management and Nimbus Reservoir flow regimes associated with a specific set of assumptions for CVP operations. In this incremental sense, the modeled water temperature performance between different studies can be compared in a meaningful way to better understand the seasonal use of coldwater resources relative to each study framework. This water temperature analysis should not be construed as an absolute predictive analysis. The American River Group and B2IT use more detailed management tools to designate a reasonable water temperature target in any given year.

Coldwater Availability

The most significant influence on water temperature management is the volume of available cold water. The estimated volume of water colder than 58 ºF stored in Folsom Reservoir on or about June 1 is a very useful way to generally relate coldwater availability to potential seasonal compliance strategies. Generally, the larger the volume of 58 ºF water in Folsom Reservoir, the greater potential to designate a lower temperature target at Watt Ave., or the longer in time that a temperature target can be managed to over the temperature control season with a greater assurance of not over-extending the available coldwater resources.

Figure 10-100 illustrates the 58 ºF index of coldwater availability at Folsom Reservoir for all studies. All three studies show similar coldwater availability conditions from the 0% to 70% exceedence range. The shape of this coldwater availability index is not the same as Figure 10-101 which shows the exceedence shape of total Folsom Reservoir storage at the end-of-May. The reason is the accumulation of coldwater storage in the spring months is influenced by many factors beyond just total storage in Folsom Reservoir. Figure 10-100 illustrates that the 58 ºF index of coldwater availability in the drier 70% to 100% exceedence range is closely related to overall storage in Folsom Reservoir.

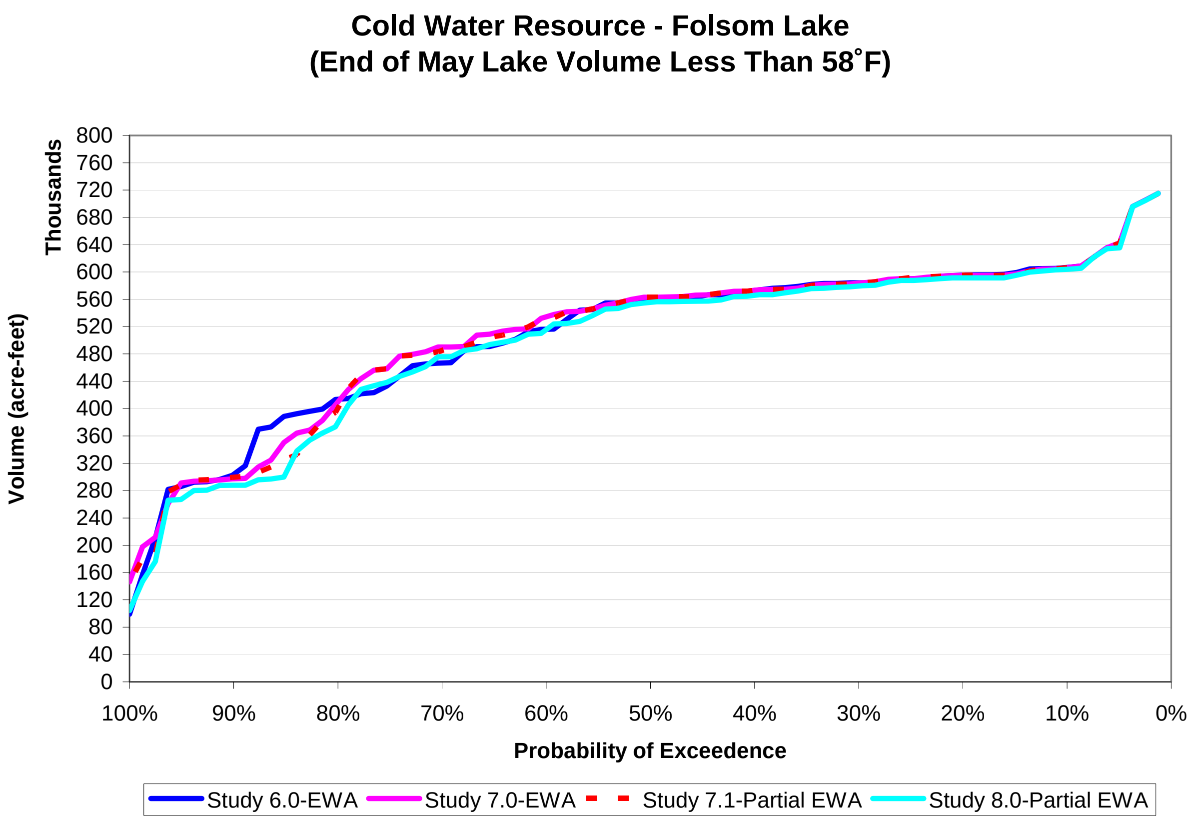


Figure 10-100 58ºF index of coldwater availability

Figure 10-101 to Figure 10-106 illustrate the potential seasonal coldwater patterns for the studies at the Folsom Reservoir tailbay location. Each of the studies has been modeled using the same Folsom Shutter target temperature logic. Since each study utilizes the same shutter operations logic to generate water temperature values, the results of this analysis will only characterize how the depletion of the annual coldwater resources at Folsom Reservoir is varies among the studies. Given that the water temperature analysis uses of the same shutter operations logic in each study, the model makes no attempt to adjust the water temperature target within the season based on the availability of coldwater. The American River Group would consider this kind of information and make choices as to how to manage the temporal distribution of coldwater resources differently than maybe portrayed with this water temperature analysis.

The usefulness of this analysis is to characterize the water temperature utilization between studies in order to evaluate general coldwater management and water temperature trends for each study framework, and should not be used as a predictive water temperature analysis.

The Folsom tailbay plots begin to show potential differences in the utilization of coldwater resources in May for approximately 10% of the years between study 6, study 7, study 7.1 and study 8. This is reflective of the lower coldwater availability under the very dry conditions for study 7.1 and study 8. By June the potential difference in the use of coldwater increases to approximately 40% of the years between the studies, again reflective of the lower coldwater availability differences for study 7.1 and study 8. By July, the potential differences in the use of coldwater resources for study 8, increased future demand in the American basin, reflect increased depletion of coldwater resources relative to all other studies. This trend persists for the remainder of the temperature control season.

Figure 10-107 to Figure 10-112 illustrate potential seasonal coldwater use patterns for the studies at Nimbus Reservoir. Nimbus Reservoir is the key management point to water temperature management operations for the lower American River because this is the location CVP operators have significant influence to the temperature of the water released on a daily basis before reaching the water temperature target at Watt Ave.

In realtime water temperature operations, CVP operators manage Nimbus release water temperatures by adjusting and balancing the following operational factors for water temperature purposes;

- Flow from Nimbus Dam
- Folsom shutter configuration
  - Shutter configuration changes are a one time event. Changes require a crane and are labor intensive. Changes must be scheduled and coordinated in advance of actual water temperature needs using forecast information.
- Daily “Blending” ratio of powerplant units when Folsom shutter are in an elevational stepped configuration.
  - When Folsom shutter are in a elevational stepped configuration, it is possible to schedule the daily releases at each Folsom powerplant unit to a desired water temperature blend and thereby conserve seasonal thermal resources.

This temperature analysis for Nimbus releases (Figure 10-107 to Figure 10-112) shows for all studies the same general water temperature seasonal patterns as the Folsom tailbay information. Study 8 shows the warmest Nimbus release patterns due to the lower initial coldwater availability and the increased water demand in the American basin. The temperature analysis shows Nimbus release temperatures in July to be consistently above 65 °F. The July water temperatures at Nimbus are a reflection of the internal model logic for Folsom shutter management and temporal water temperature choices for summer water temperatures and fall water temperatures. The American River Group may choose to manage the coldwater resources differently than how this model distributes the resource. If the American River Group chooses to provide less than 65 °F for Nimbus releases on a more frequent basis than this model portrayal, then the fall water temperatures would likely be warmer than this model portrayal.

This temperature analysis for Watt Avenue (Figure 10-113 to Figure 10-118) shows for all studies the same general water temperature seasonal patterns as the Nimbus release information.

Folsom Tailbay Exceedence Plots

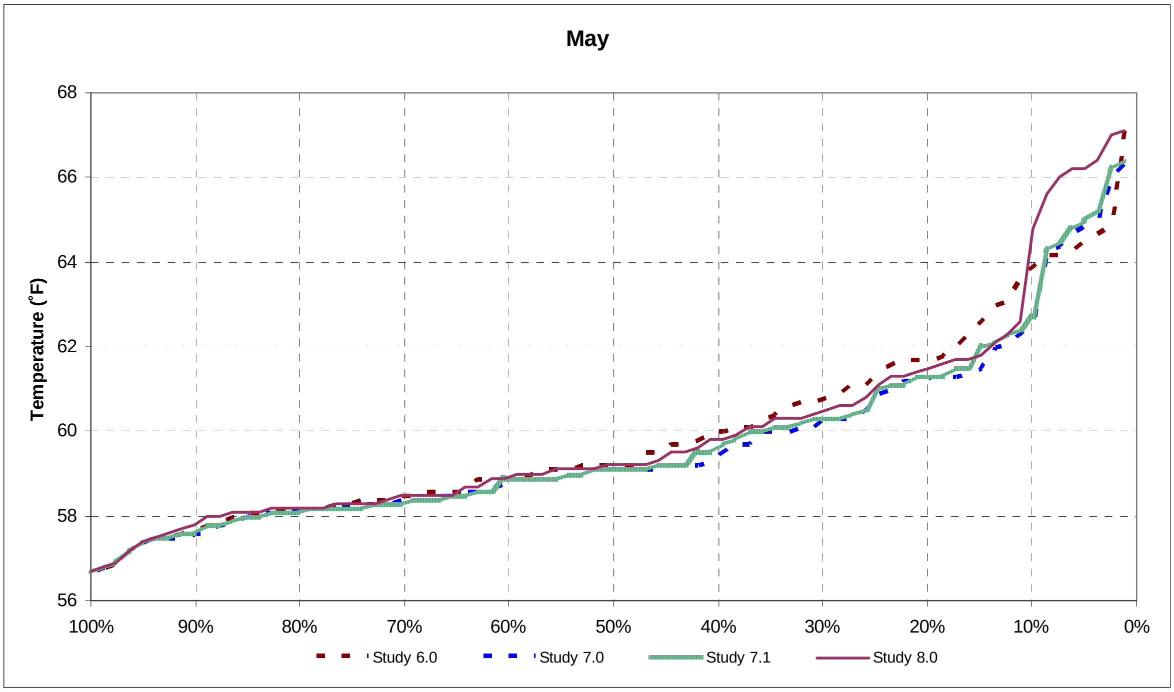


Figure 10-101 Folsom Tailbay End-of-May Exceedence

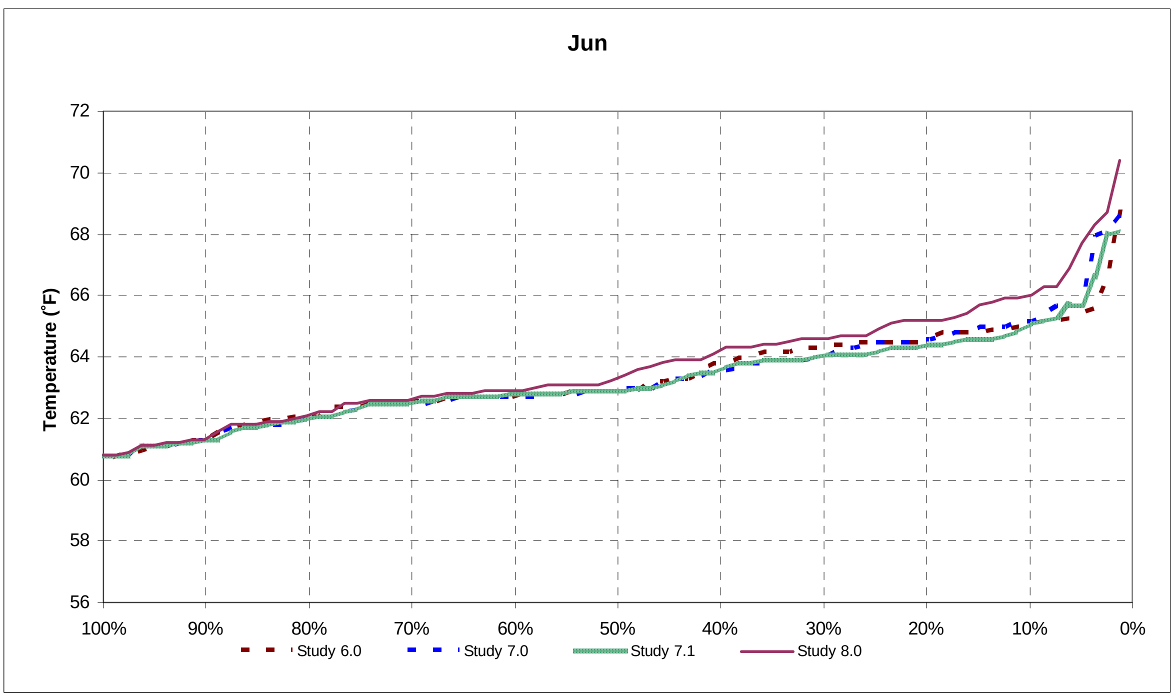


Figure 10-102 Folsom Tailbay End-of-June Exceedence

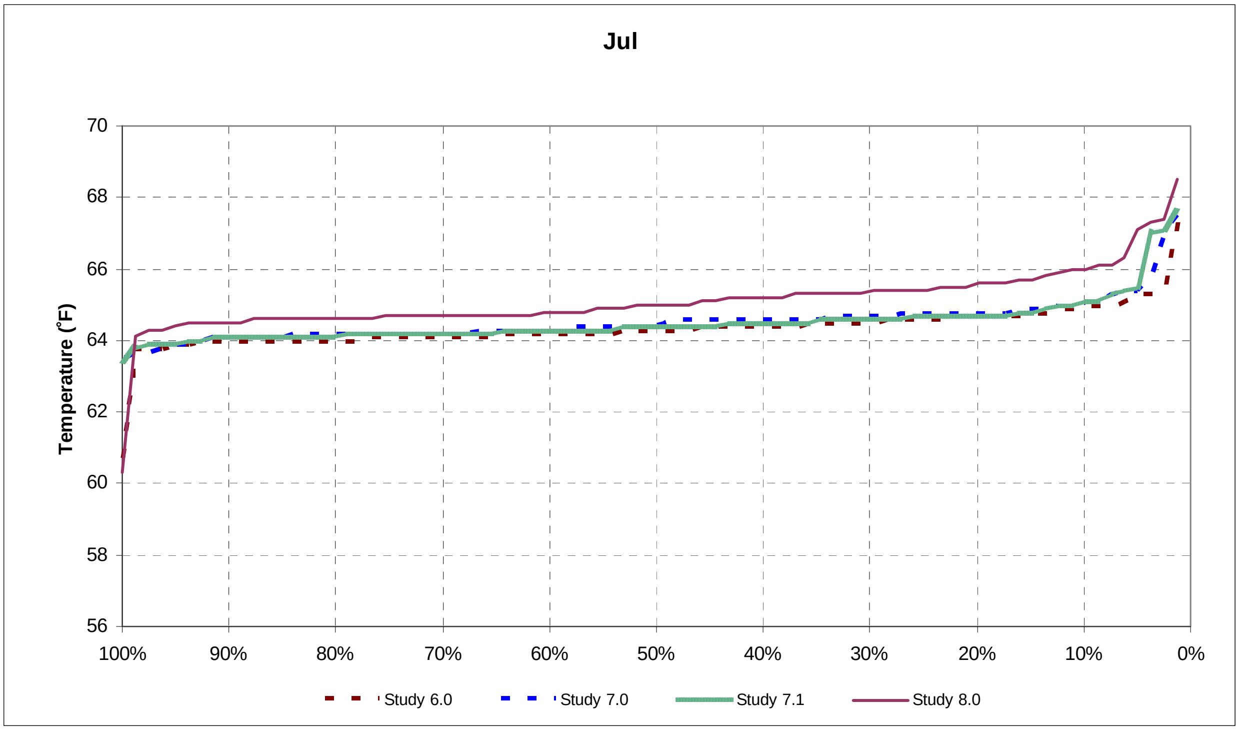


Figure 10-103 Folsom Tailbay End-of-July Exceedence

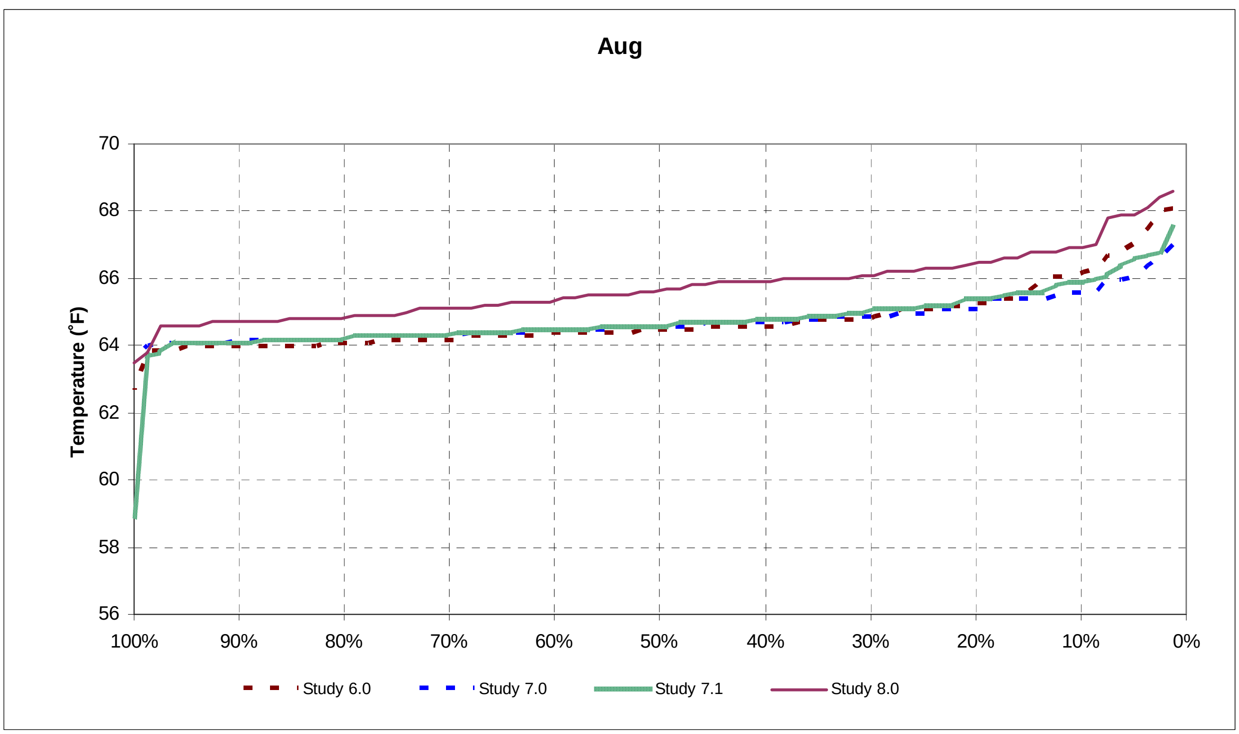


Figure 10-104 Folsom Tailbay End-of-August Exceedence

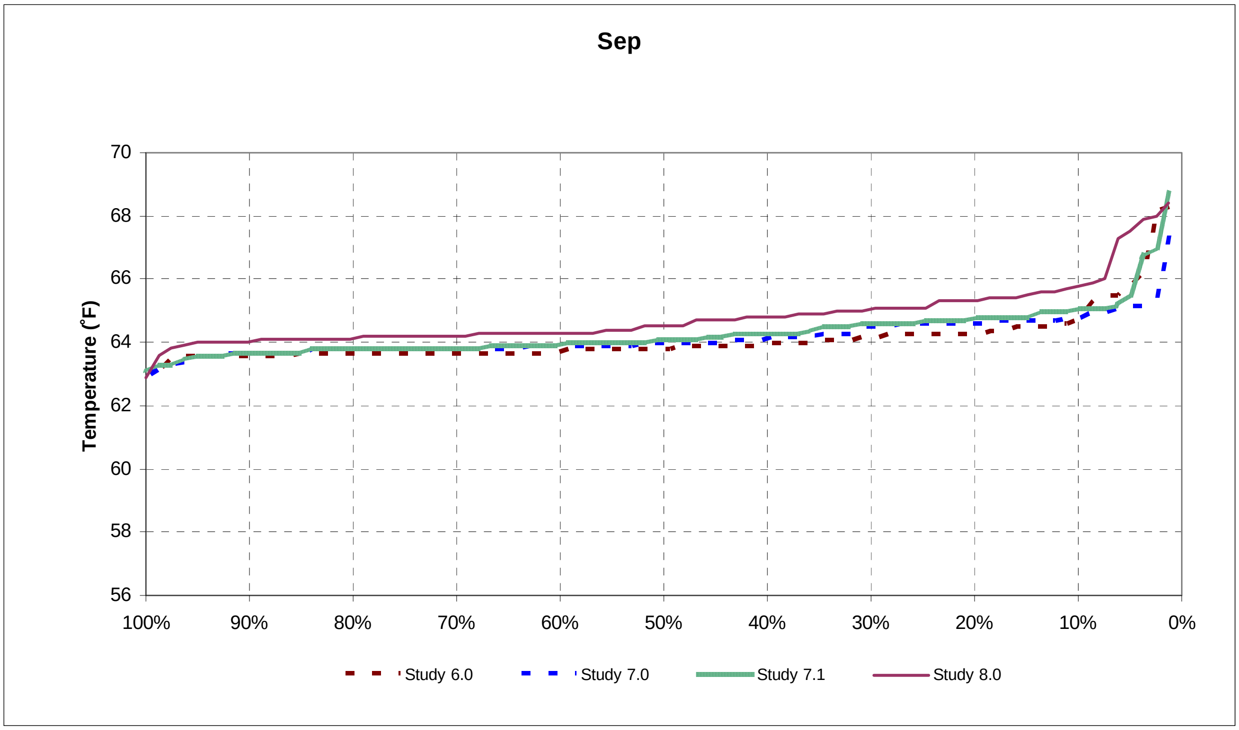


Figure 10-105 Folsom Tailbay End-of-September Exceedence

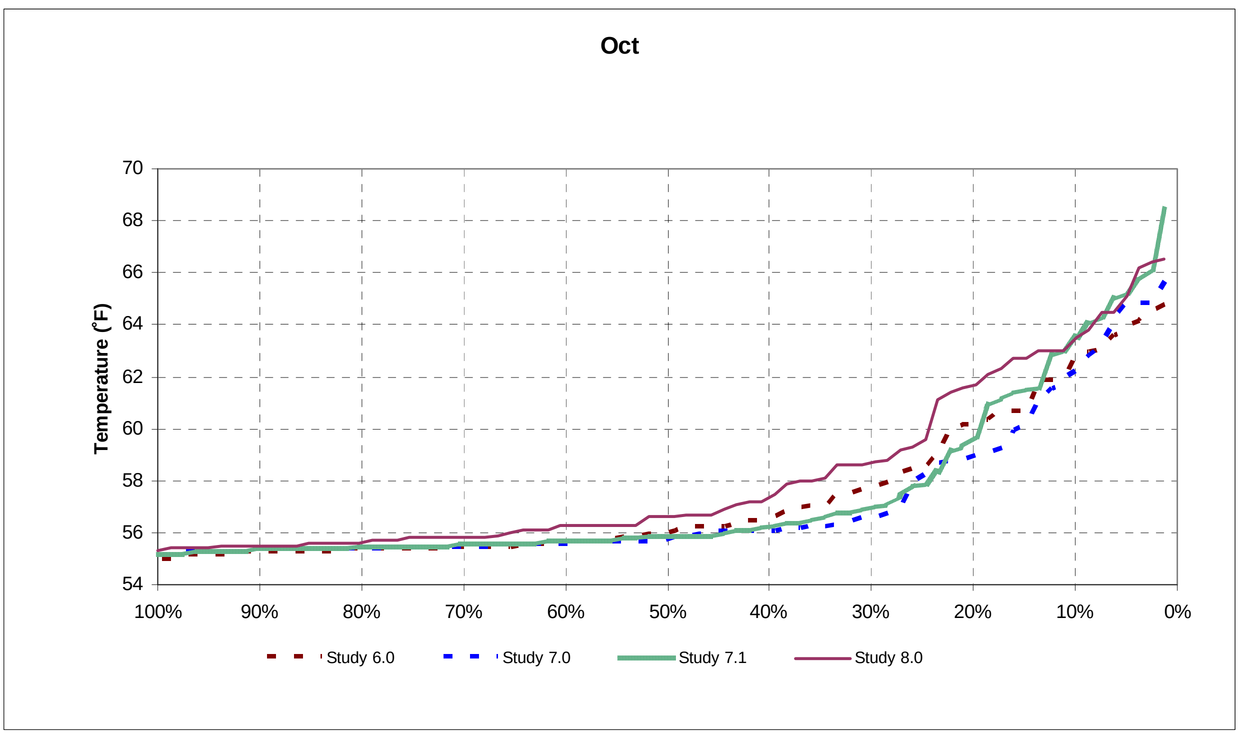


Figure 10-106 Folsom Tailbay End-of-October Exceedence

Nimbus Release Exceedence Plots

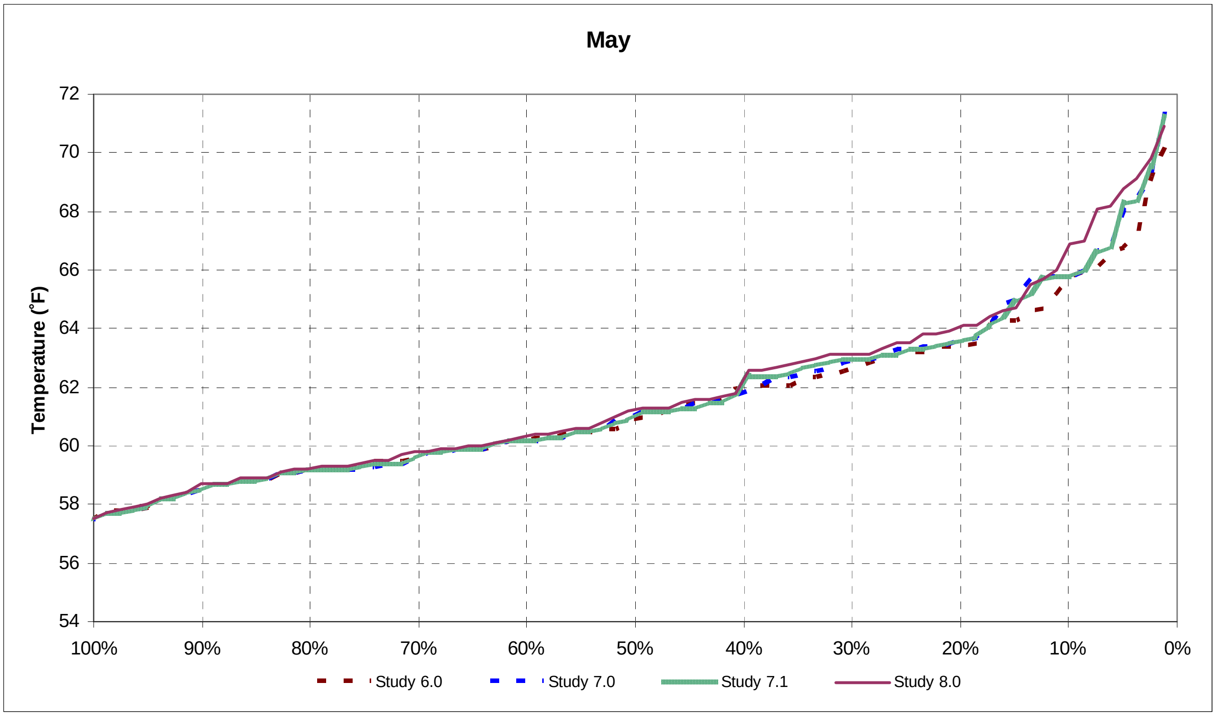


Figure 10-107 Nimbus End-of-May Exceedence

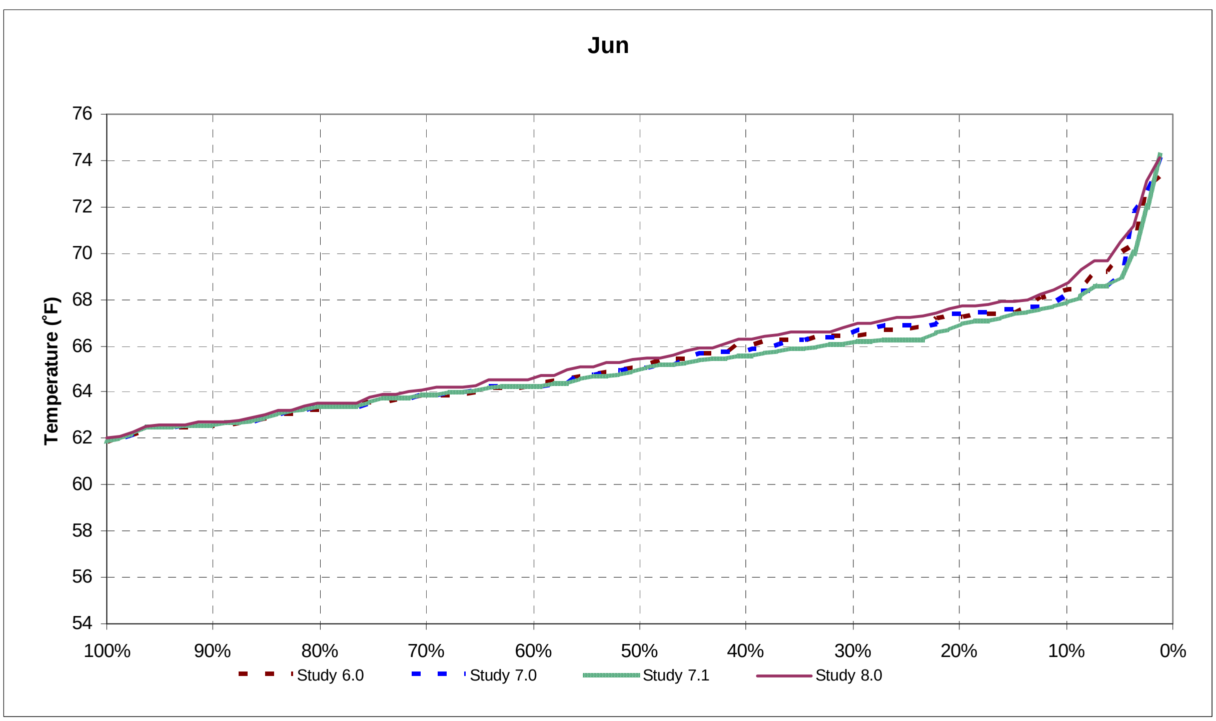


Figure 10-108 Nimbus End-of-June Exceedence

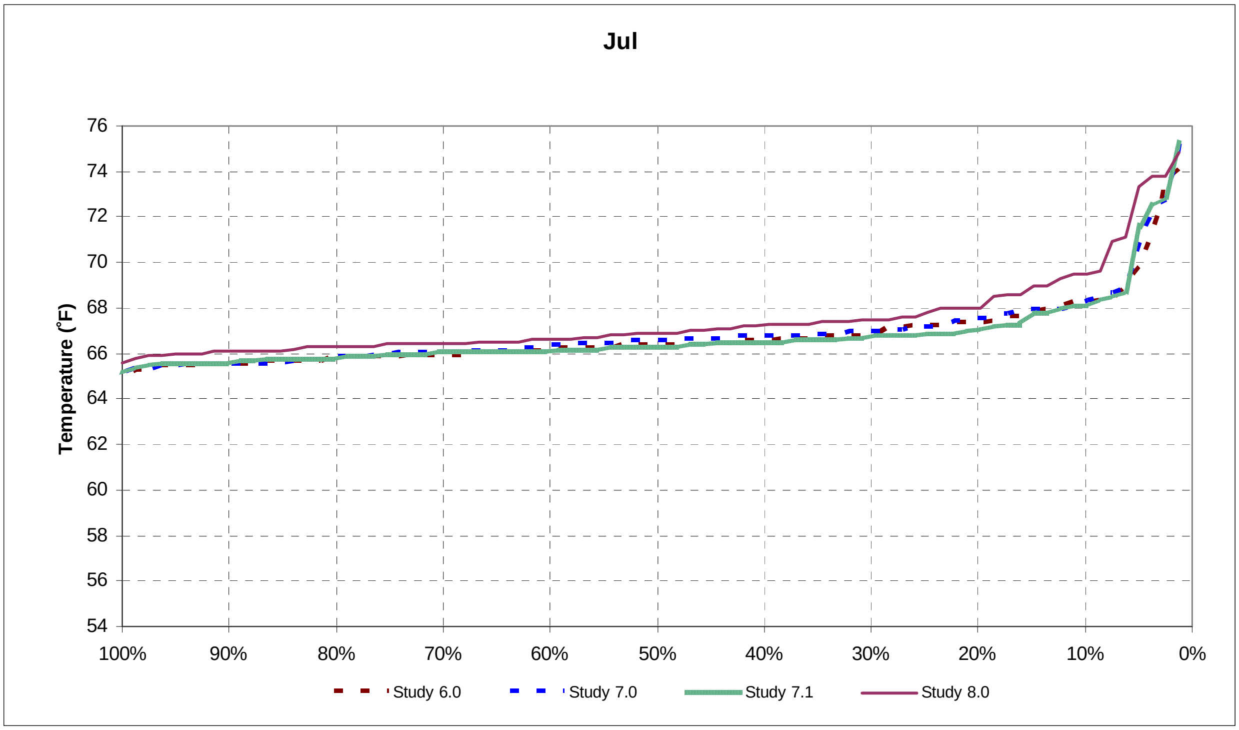


Figure 10-109 Nimbus End-of-July Exceedence

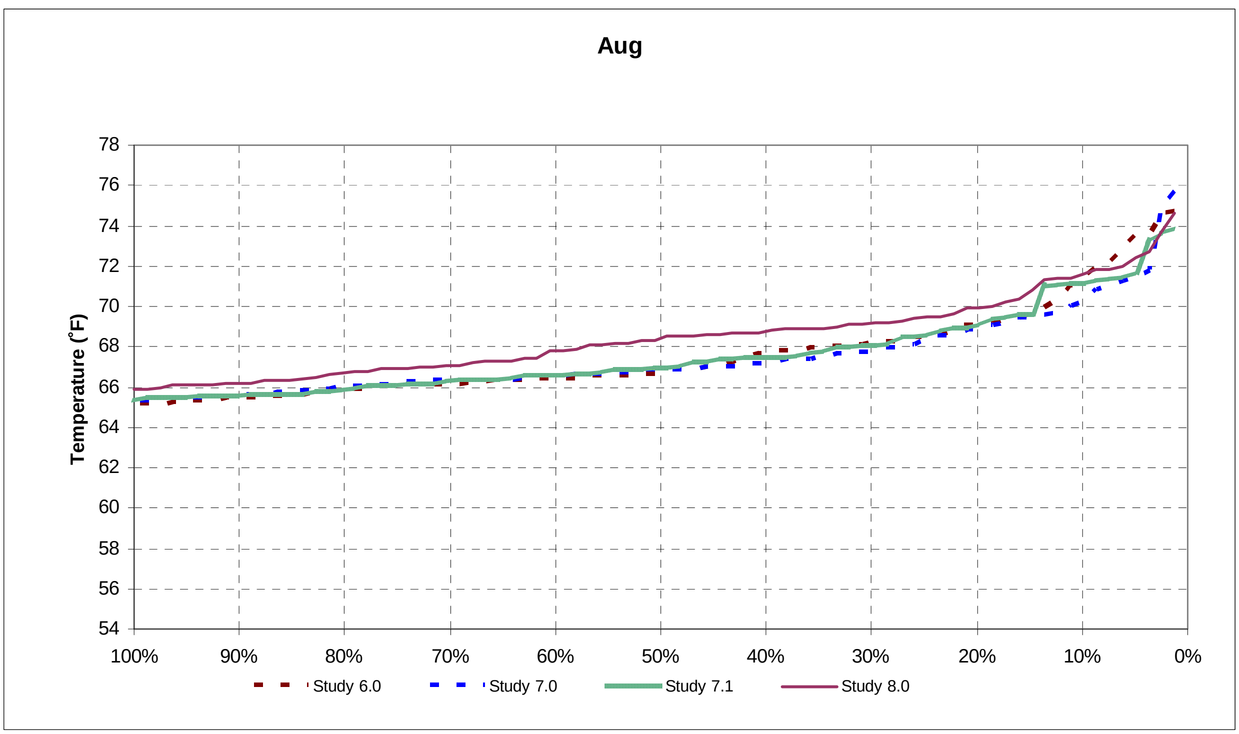


Figure 10-110 Nimbus End-of-August Exceedence

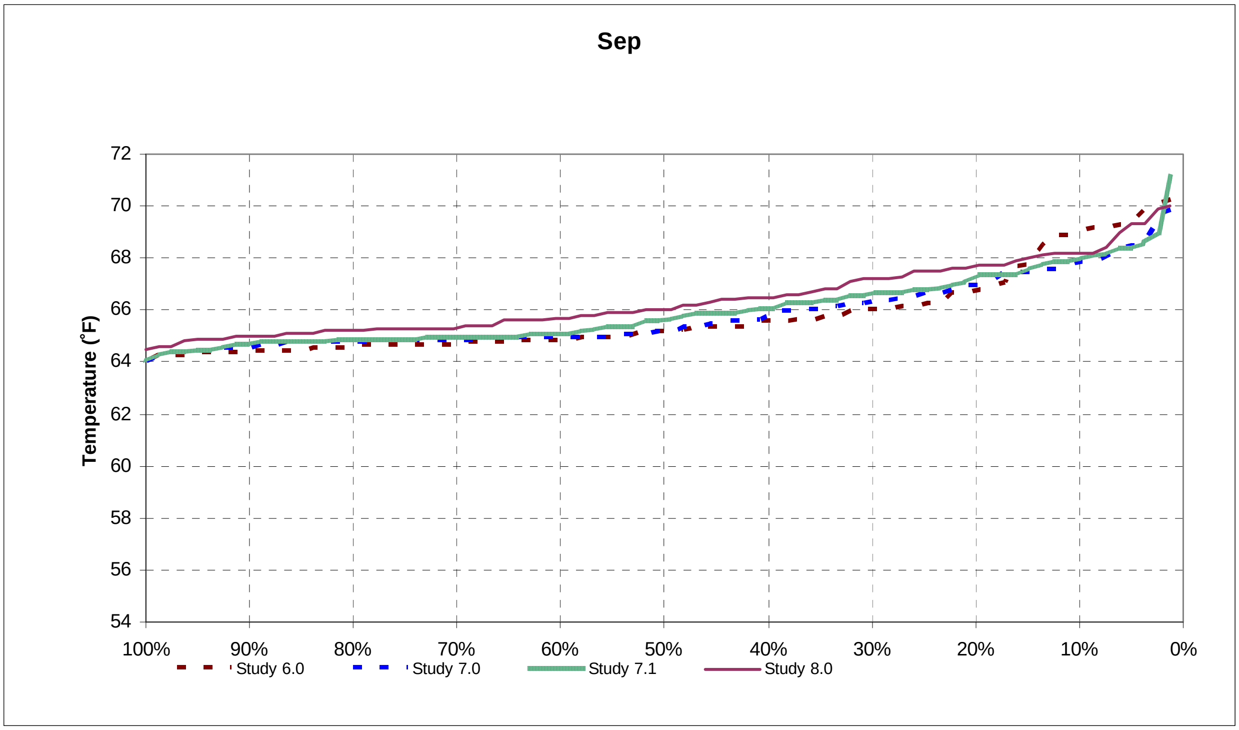


Figure 10-111 Nimbus End-of-September Exceedence

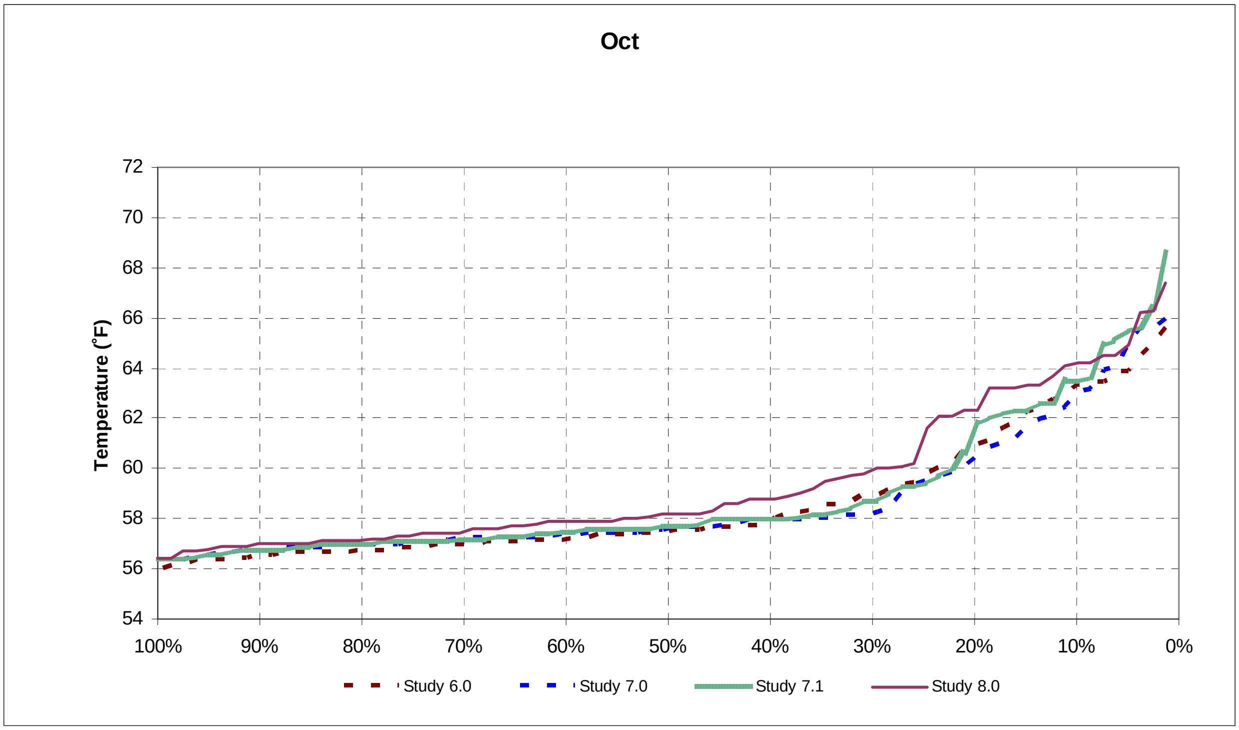


Figure 10-112 Nimbus End-of-October Exceedence

Watt Ave. Exceedence Plots

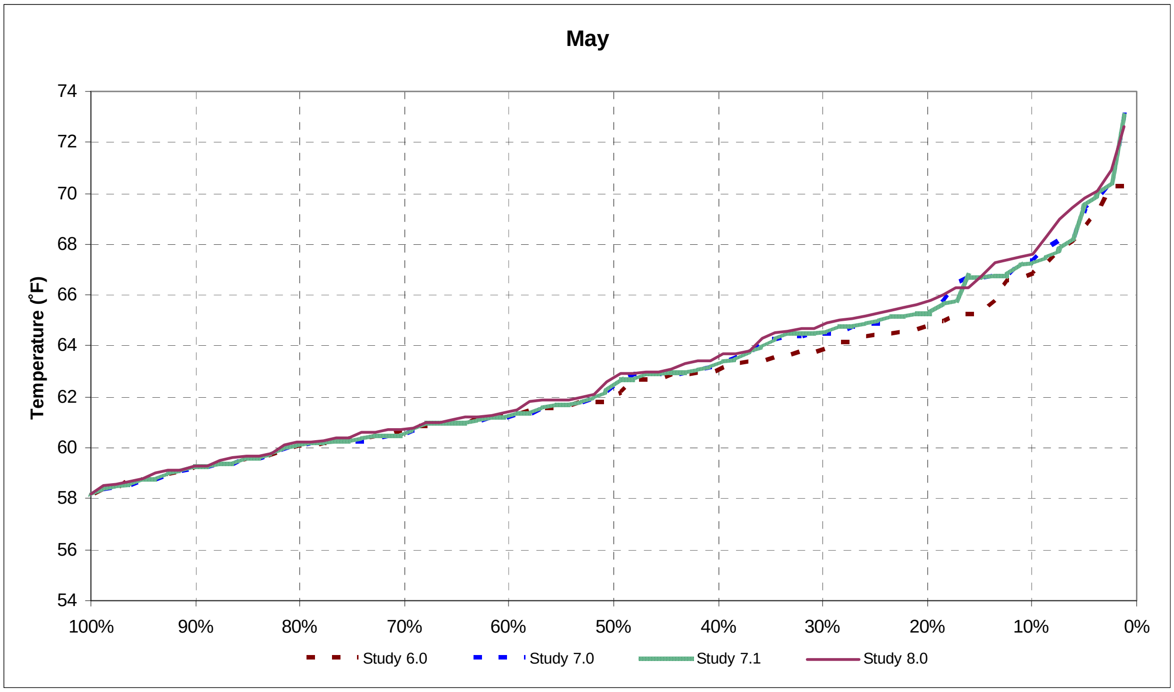


Figure 10-113 Watt Avenue End-of-May Exceedence

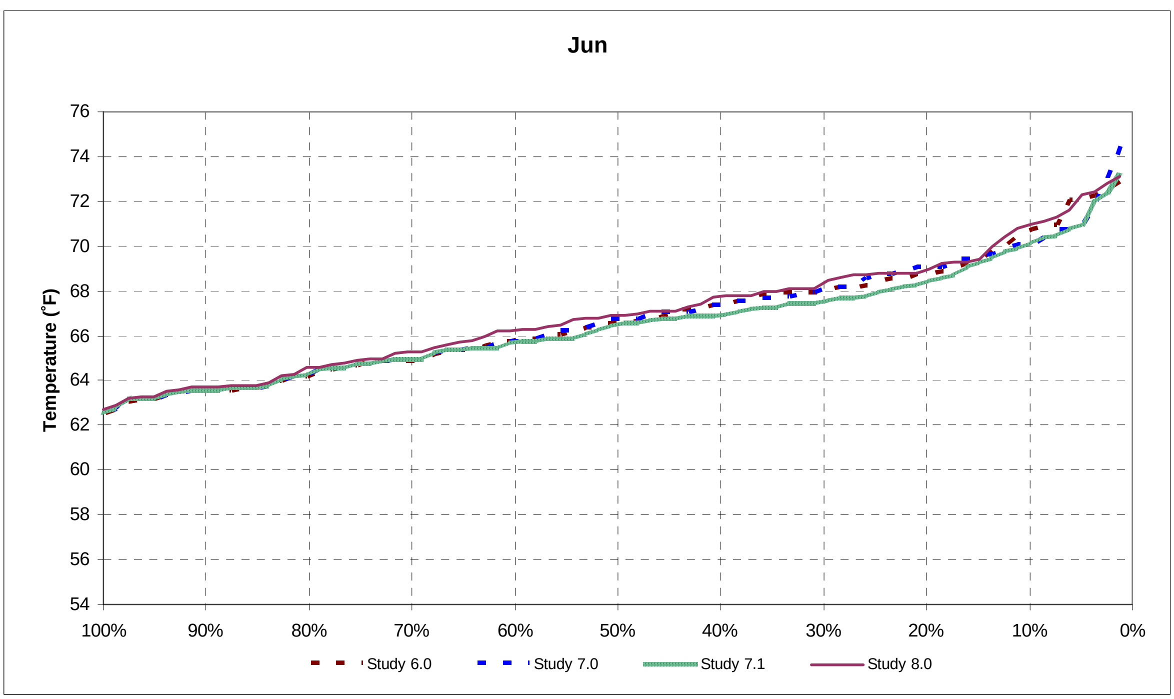


Figure 10-114 Watt Avenue End-of-June Exceedence

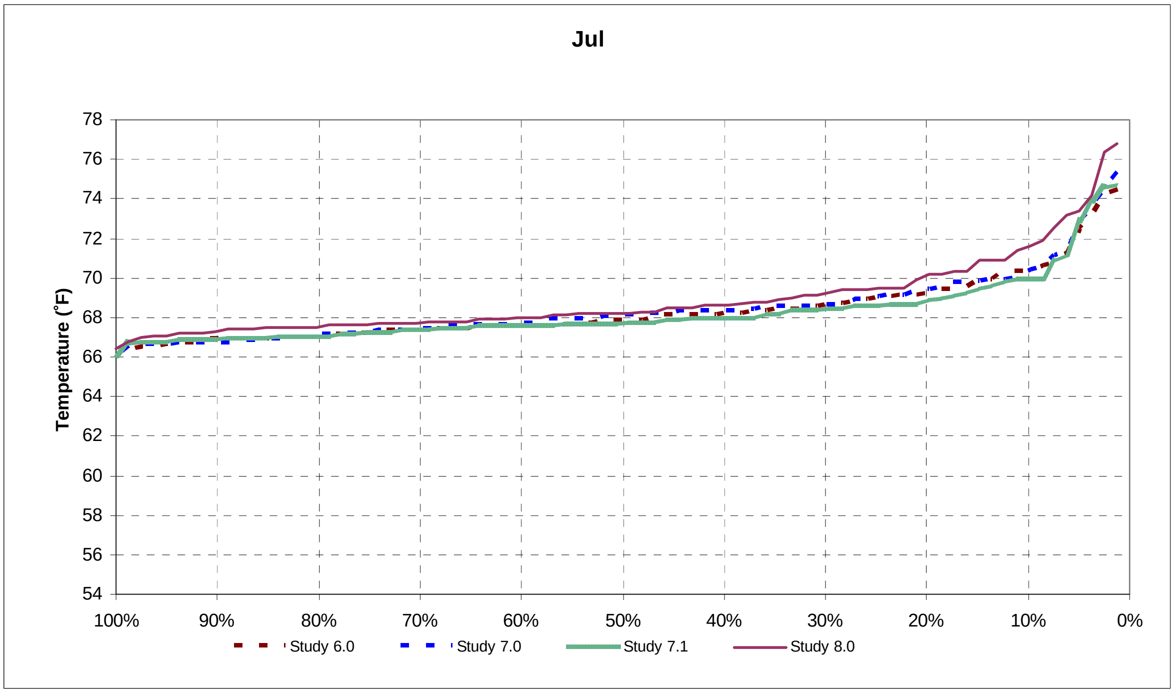


Figure 10-115 Watt Avenue End-of-July Exceedence

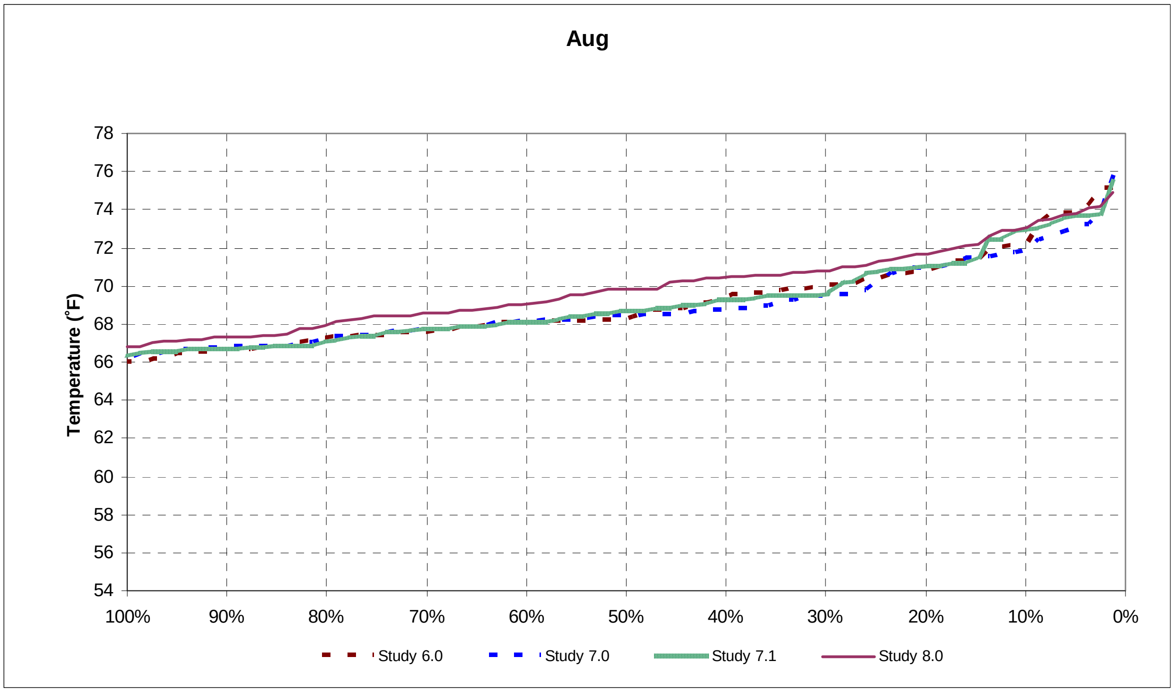


Figure 10-116 Watt Avenue End-of-August Exceedence

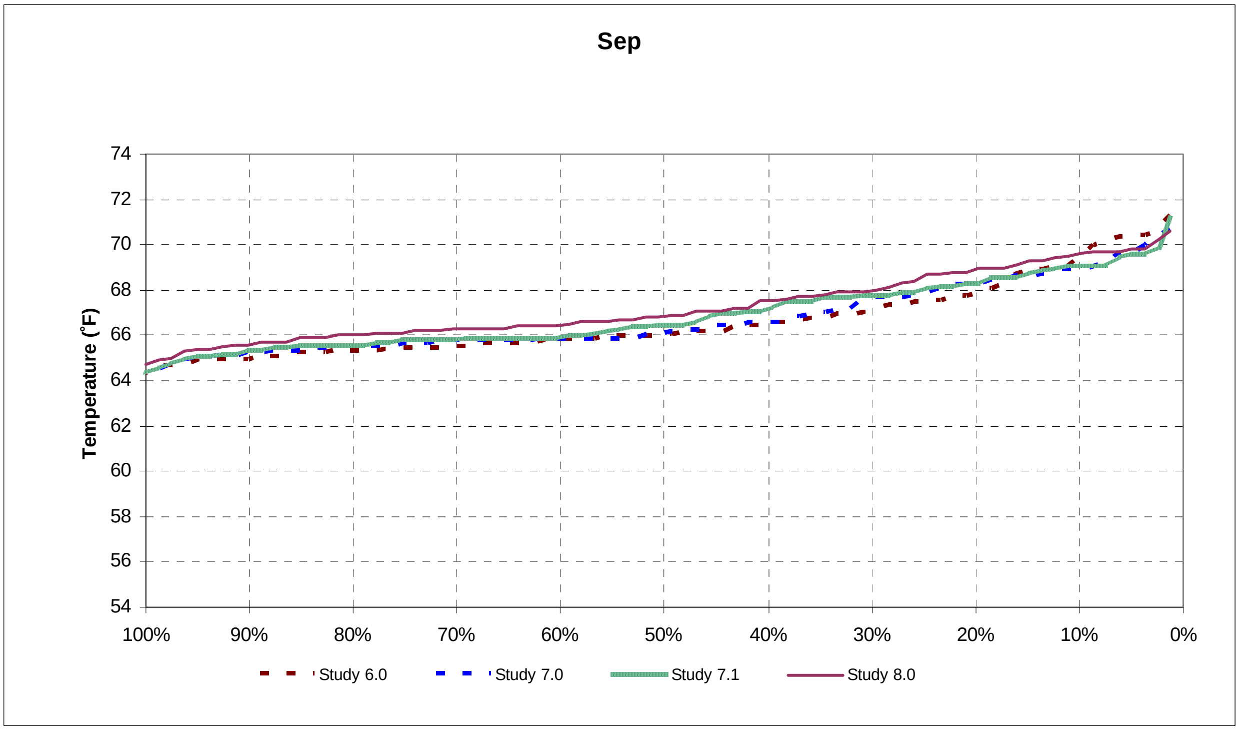


Figure 10-117 Watt Avenue End-of-September Exceedence

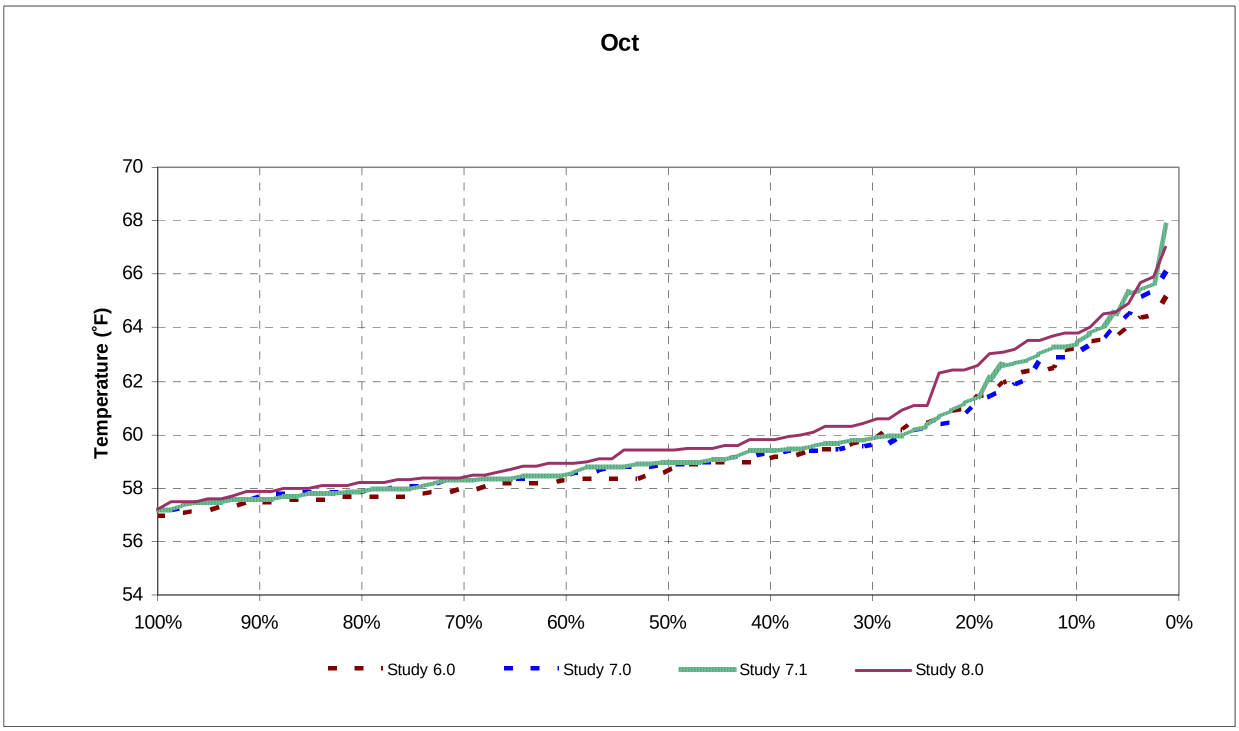


Figure 10-118 Watt Avenue End-of-October Exceedence

Stanislaus River

Modeling

Among the studies, long term annual averages show some change as a result of modified operations on the Stanislaus River and no significant effects of the previously mentioned CalSim-II modeling improvements on storage and release (Table 10-5). Figure 10-119 shows the chronology of New Melones. Figure 10-120 and Figure 10-121 and shows the end-of May and end-of-September exceedence plots. Both figures show that there are no significant differences in storage among the studies. Figure 10-122 shows the percentile values for the releases from Goodwin Reservoir, and Figure 10-123 to Figure 10-128 shows the monthly averages by 60-20-20 water-year types. The Goodwin release graphs also show no significant effect to operations among the three studies. Table 10-5 compares some of the annual average -impacts to Stanislaus River flows between the studies.

Table 10-5 Long-term Average Annual Impacts to Stanislaus River flows

Longterm Annual Average

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
New Melones End-of-September Storage	-1	39	31	-8
Annual Goodwin Release	19	6	0	-6

29- 34 Difference

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
New Melones End-of-September Storage	13	51	143	91
Annual Goodwin Release	142	46	10	-36

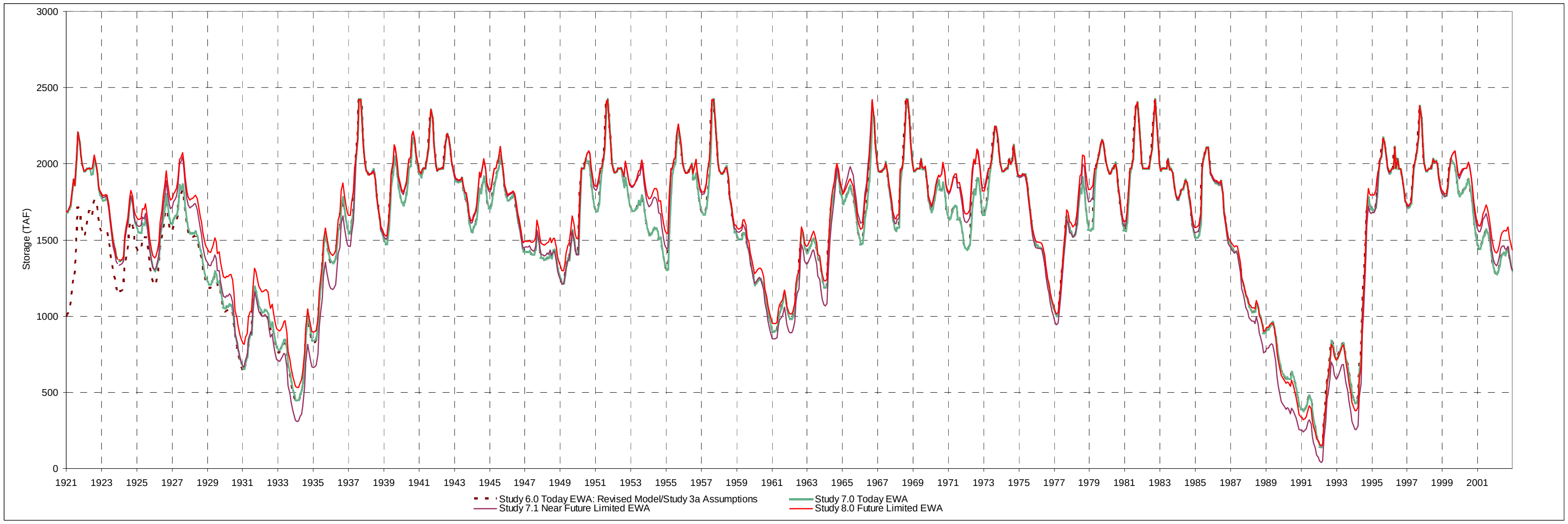


Figure 10-119 Chronology of New Melones Storage Water Years 1922 – 2003

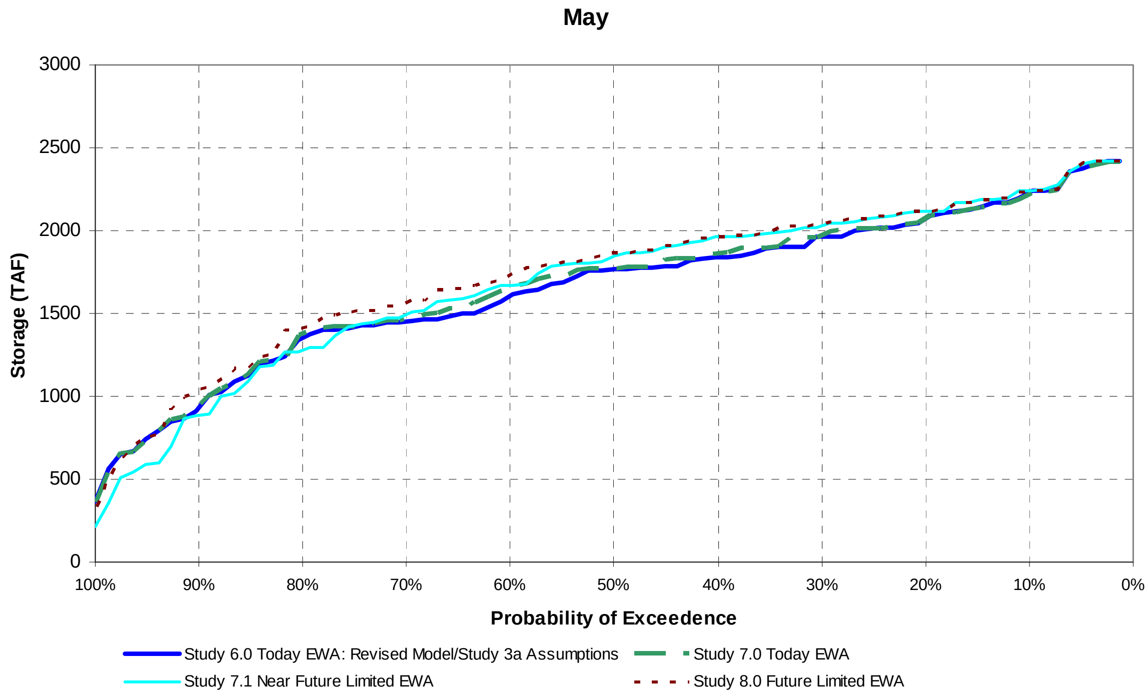


Figure 10-120 New Melones Reservoir End of May Exceedence

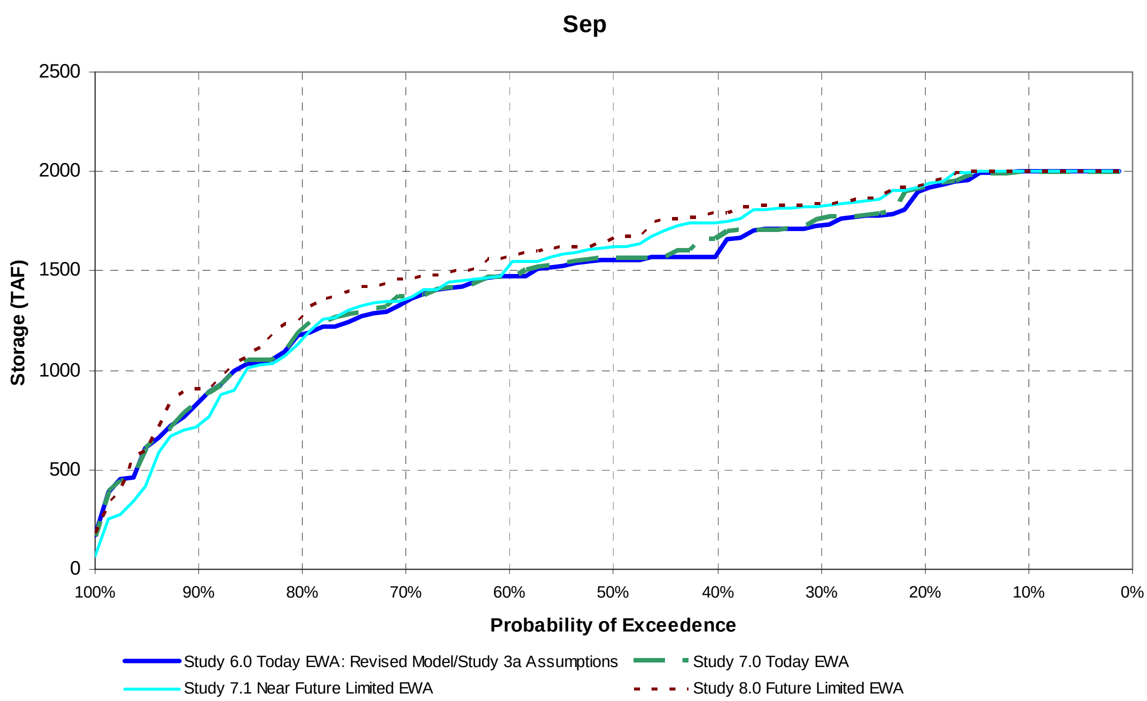


Figure 10-121 New Melones Reservoir End of September Exceedence

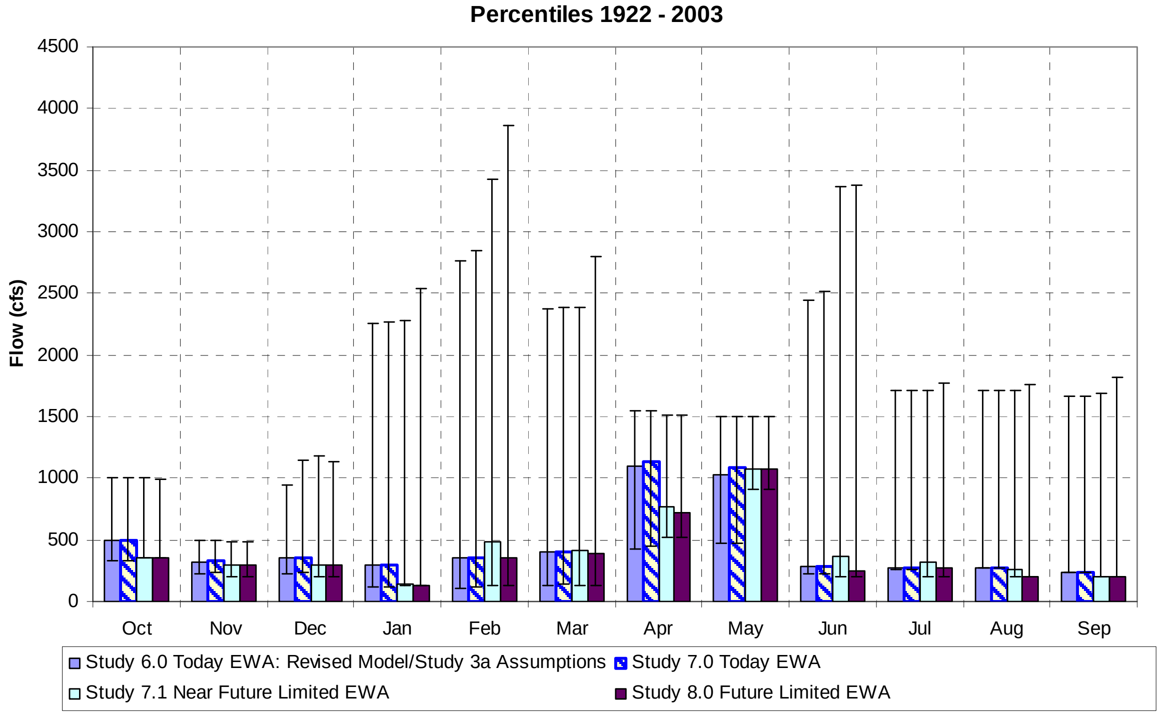


Figure 10-122 Goodwin Releases 50th Percentile Monthly Releases with the 5th and 95th as the Bars

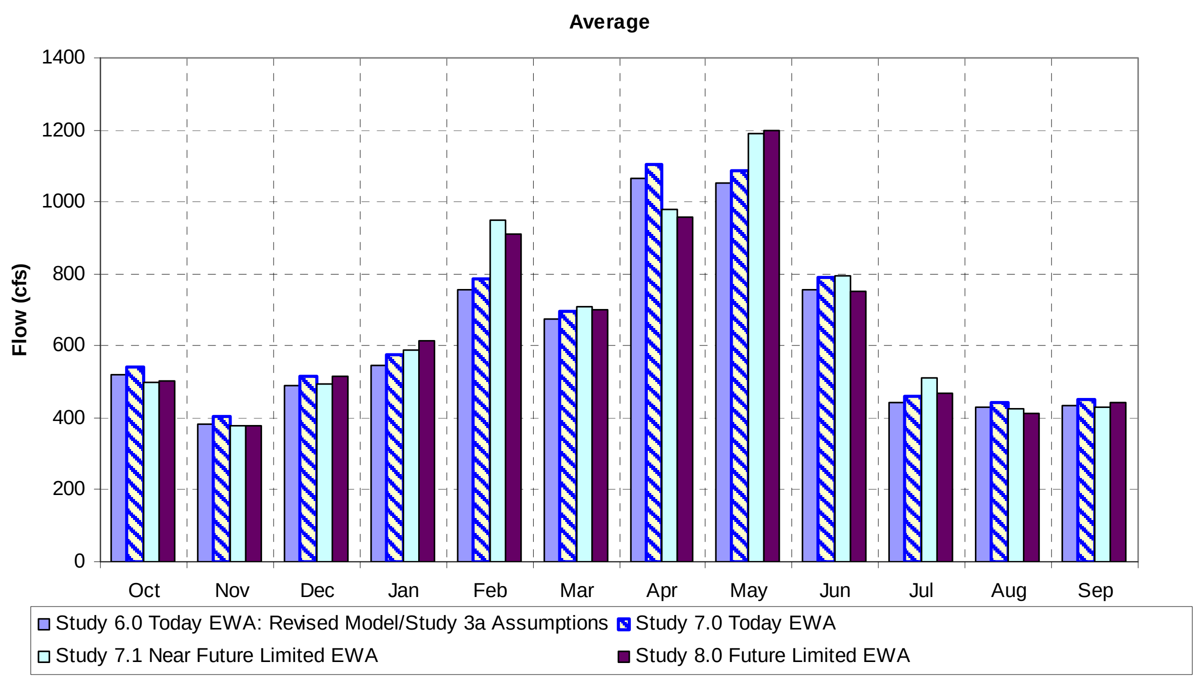


Figure 10-123 Average Monthly Goodwin Releases

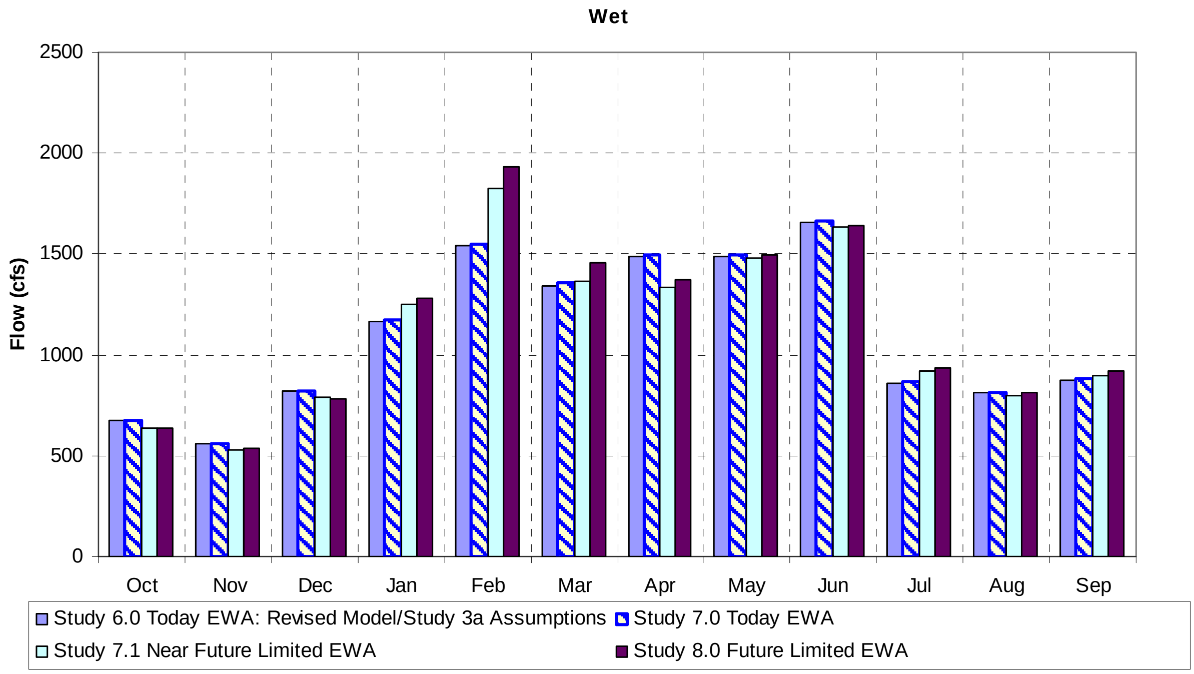


Figure 10-124 Average Wet Year (40-30-30 Classification) Monthly Goodwin Releases

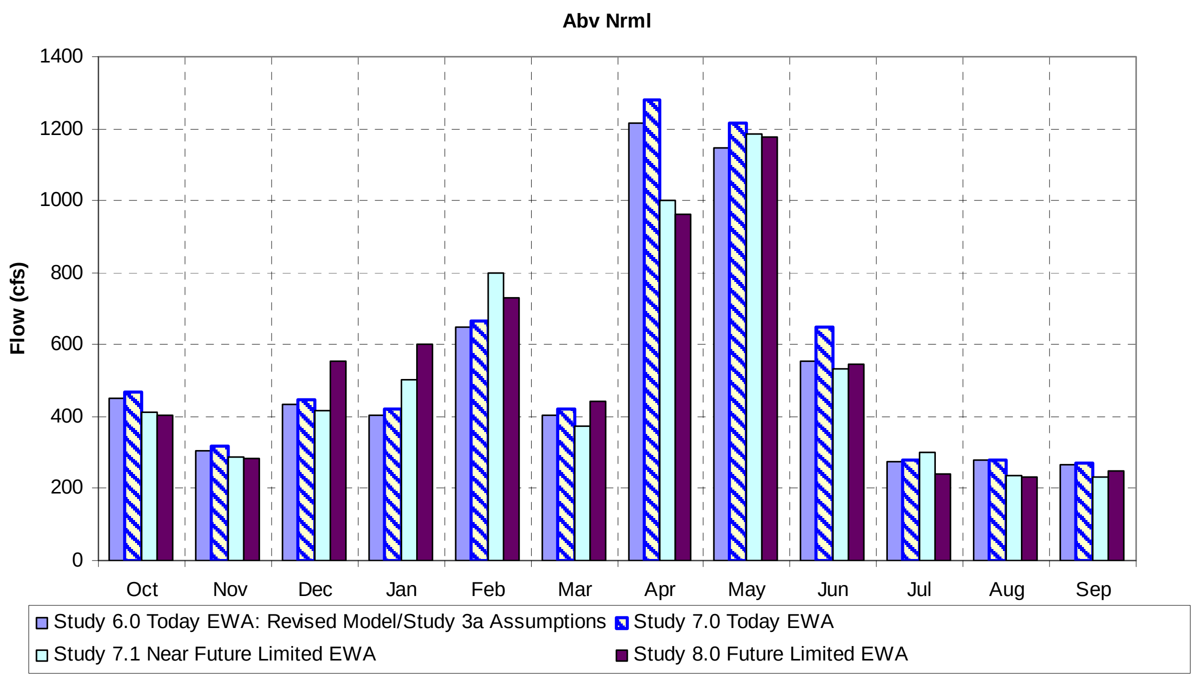


Figure 10-125 Average Above Normal Year (40-30-30 Classification) Monthly Goodwin Releases

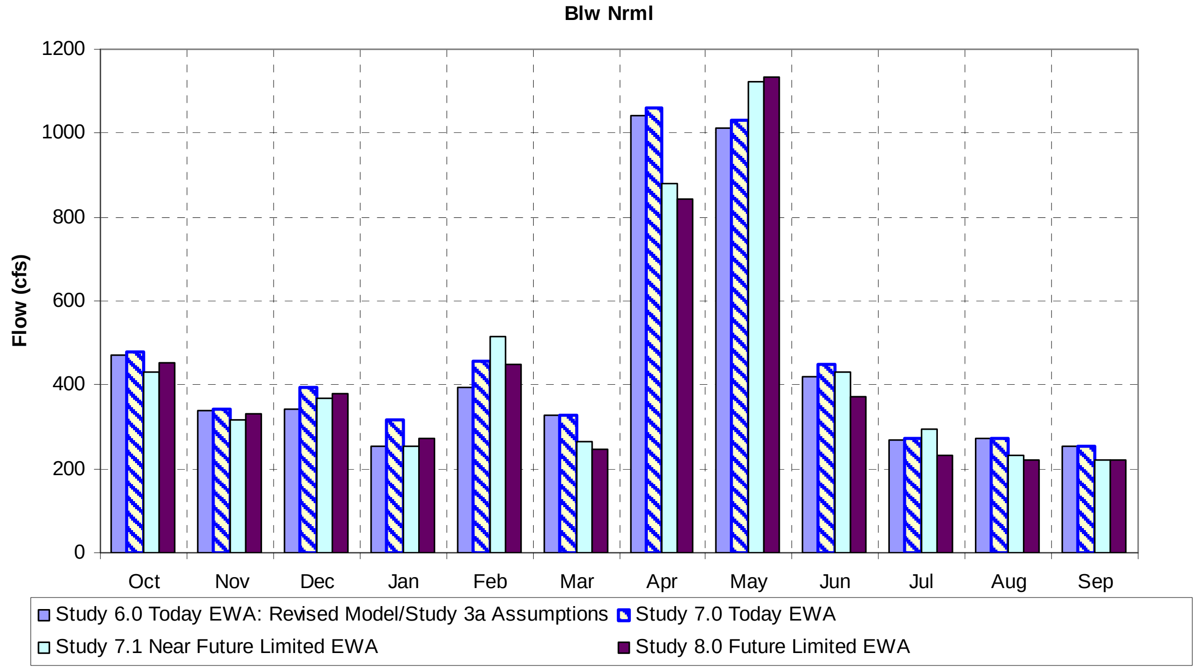


Figure 10-126 Average Below Normal Year (40-30-30 Classification) Monthly Goodwin Releases

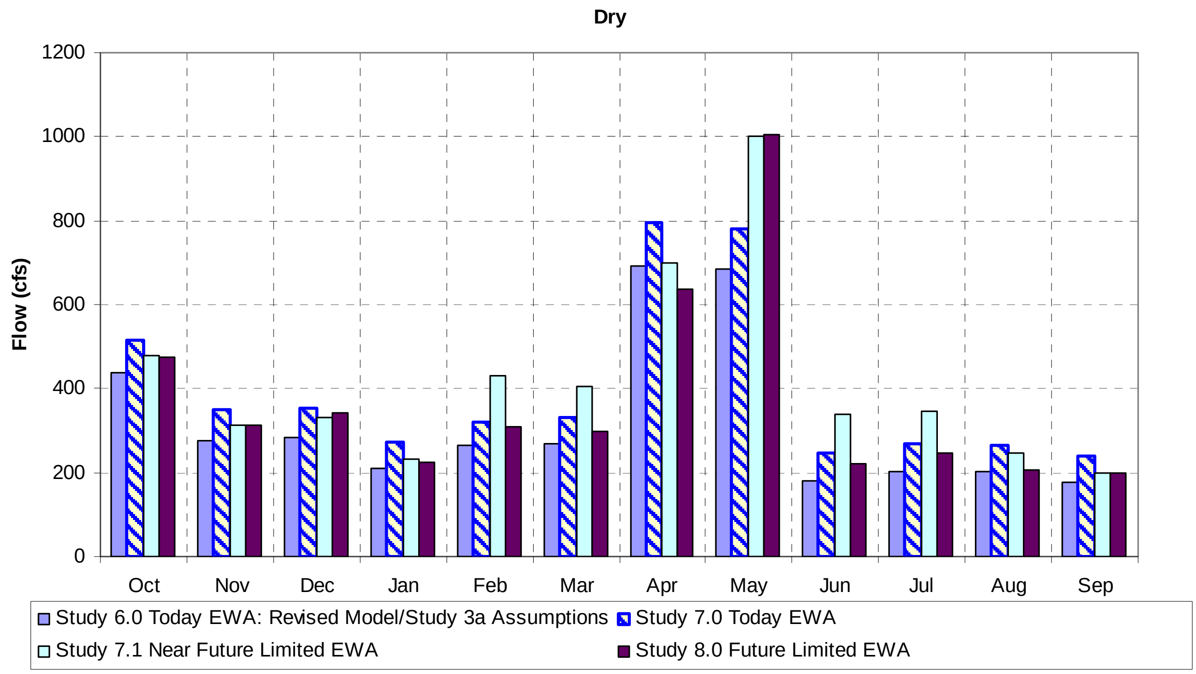


Figure 10-127 Average Dry Year (40-30-30 Classification) Monthly Goodwin Releases

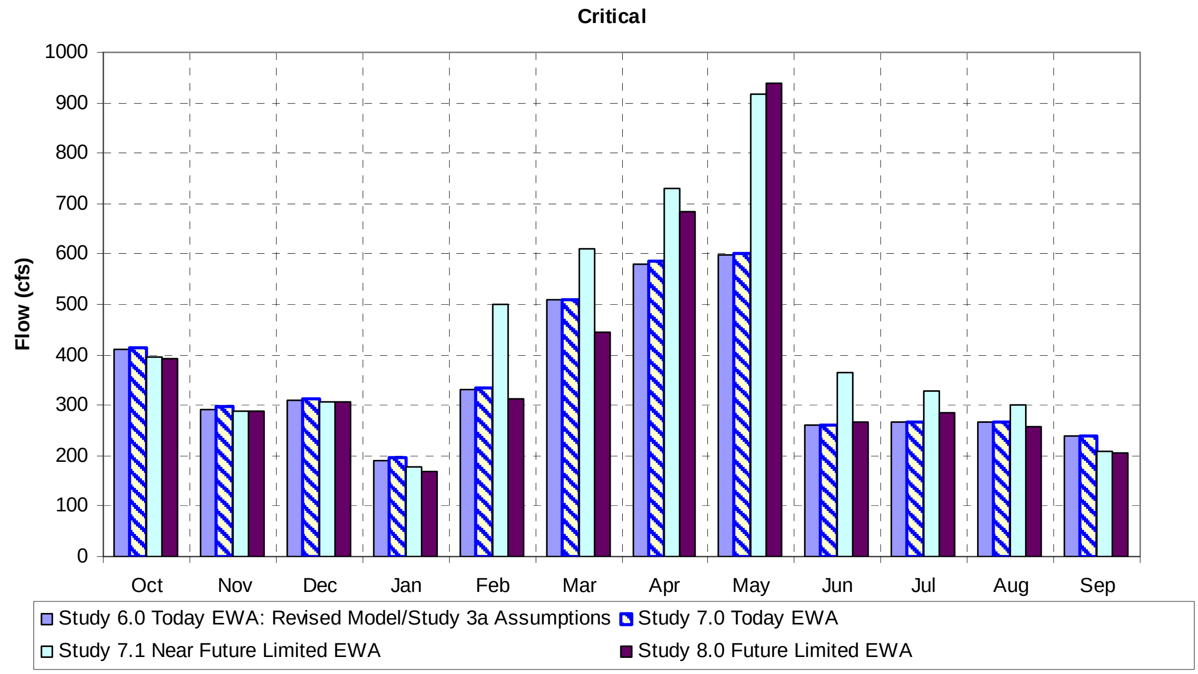


Figure 10-128 Average Critical Year (40-30-30 Classification) Monthly Goodwin Releases

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Chapter 11 Upstream Effects

This chapter focuses on the Central Valley Project (CVP) and State Water Project (SWP) project operations and how the operations affect flow and water temperature in river reaches downstream of project reservoirs. The following effects discussion refers to the reservoir release exceedance charts (monthly flow values) and water temperature exceedance charts (daily temperature model for Sacramento River and Clear Creek and monthly model for other rivers) found in Chapter 10. The amount and temperature of the water in the areas inhabited by the species are both elements of critical habitat that affect spawning, rearing, migration, and foraging. Recommended temperature ranges and flows for the species are compared to the exceedence charts. Modeling tools are used to help estimate effects on species and lifestages where available. Because the monthly model presents longer term trends, daily temperature measurements are presented herein to illustrate the potential range of variability within particular months. The modeling displays more of a net change by month and shows the general direction of change useful for comparing the water operations scenarios.

Three models, addressing portions of the Chinook salmon lifecycle, were used to evaluate the effects of operations on Chinook salmon in the Sacramento River. The Reclamation Mortality Model is used to compare the effects of water temperature on Chinook salmon egg mortality between scenarios for those rivers and salmonid runs for which the model has been developed. The model is only available for fall-run Chinook salmon on rivers other than the Sacramento. Past reviews of the effects analyses recommended additional quantitative assessment approaches to address lifestages beyond those addressed in the egg mortality model. The Salmod Model is being used to compare effects of water temperature and flow differences between scenarios on yearly juvenile winter-run and spring-run Chinook salmon production in the Upper Sacramento River. The Interactive Object-Oriented Salmon Simulation (IOS) Model (Appendix N) is used to compare the effects of the operational scenarios throughout the CVP/SWP system on the entire life cycle of winter-run Chinook salmon and provides an estimate of changes in escapement through time.

Water Temperature

Water temperature is critical to the populations of listed species, particularly Chinook salmon, coho salmon, and steelhead, present in the rivers considered in this consultation. Water temperature targets from the 2004 Operations Criteria and Plan (OCAP) Biological Opinion (BO) are shown in Table 11-1 and used in the analyses presented in this BA. The temperature targets vary from river to river based on the species and life stage needing protection. We are selecting the most temperature sensitive lifestage present in the river at a given time for analyses. The Upper Sacramento River has incubating winter-run Chinook eggs during the summer. Eggs have the coolest temperature needs and water temperatures naturally rise to the highest levels during the heat of summer, therefore the most stringent temperature targets are for eggs incubating during the summer in the Sacramento River. Steelhead rearing occurs in the Sacramento River, Clear Creek, Feather River, American River, and Stanislaus River. The generally accepted upper mean daily water temperature level for steelhead rearing in the Central Valley is 65 °F. Therefore, CVP/SWP water management tries to maintain 65 °F in the controllable reaches of the rivers where steelhead are present during the warmer months of the year. The American River is temperature limited in that the coldwater pool volume often cannot maintain the desired temperatures so the target recognizes this in an effort to spread the available coldwater out throughout the needed time period.

Table 11-1. Temperature targets from 2004 OCAP BO used as evaluation criteria in this BA. Temperature targets are mean daily. Target points in the Sacramento and American River are determined yearly with input from the Sacramento River temperature group and American River ops group.

River	Target Species and Lifestage	Temperature Target Point	Miles Below Dam	Date	Temperature Target	Comment
Sacramento	Winter run egg incubation	Balls Ferry	26	4/15 - 9/30	56	Location depends on coldwater availability
	Winter run egg incubation	Bend Bridge	44	4/15 - 9/30	56	Location depends on coldwater availability
	Spring run and winter run	Balls Ferry	26	10/1 - 10/31	60	Location depends on coldwater availability
	Spring run and winter run	Bend Bridge	44	10/1 - 10/31	60	Location depends on coldwater availability
Clear Creek	Spring run prespawn and steelhead rearing	Igo	7.5	6/1 - 9/15	60	
	Spring run spawning and steelhead rearing	Igo	7.5	9/15 - 10/31	56	
Feather River	steelhead rearing	Robinson's Riffle	6	6/1 - 9/30	65	
American River	steelhead rearing	Watt Avenue	13.4	plan May 1	68	Target based on yearly plan
Stanislaus River	steelhead rearing	Orange Blossom	12	6/1 - 11/30	65	

Historic Water Temperature Data Summary (Figures 11-1 through 11-25)

The figures listed below show the mean daily temperature at monitoring sites up and down the rivers. This shows the difference in water temperatures at different points in the river. These plots of actual measured data are presented to show the actual temperatures experienced by the species from day to day. The temperature gradient from upstream to downstream and the daily temperature fluctuations will likely stay about the same in the future, changing in the same trend (upward or downward) with the mean daily and mean monthly temperatures produced by the temperature models. These plots are a part of the baseline in that the conditions occurred under past operations, but they are presented here in the effects chapter because the finer details of daily temperature fluctuations and longitudinal temperature gradients under different flow conditions are more accurately represented by past real time data than predictive models.

- Figure 11-1 and Figure 11-2 - Sacramento River
- Figure 11-12 and Figure 11-13 - Clear Creek
- Figure 11-16 and Figure 11-17 - American River
- Figure 11-20 and Figure 11-21 - Stanislaus River
- Figure 11-26 and Figure 11-27 - Trinity River

Although the water temperature targets are based on mean daily temperatures, the fish respond to the temperature fluctuations that occur throughout the day. The figures listed below show past temperature data with daily maximum, minimum, and mean in selected dry and wet year types with available temperature data. Because temperatures become more flow dependent in intermediate distances below the dams, the flows are also displayed. Higher flows maintain water temperatures close to the reservoir release temperature for a longer distance downstream than do lower flows. Higher flows can also deplete the coldwater pool from reservoirs quicker in years when coldwater availability is a limiting factor for fish survival. Temperatures are generally more of an issue during the warmer months of the year, but can also be an issue into the fall and winter when reservoirs run out of cold water and maintain and release warm water built up during the summer.

- Figure 11-3, Figure 11-4, Figure 11-9, Figure 11-10, and Figure 11-11 - Sacramento River
- Figure 11-14 and Figure 11-15 - Clear Creek
- Figure 11-18 and Figure 11-19 - American River
- Figure 11-22, Figure 11-23, Figure 11-24 and Figure 11-25 - Stanislaus River and San Joaquin River
- Figure 11-26, Figure 11-27, Figure 11-28 and Figure 11-29 - Trinity River

Figure 11-5 and Figure 11-7 show the historical water temperature exceedences in the Sacramento River. Figure 11-6 and Figure 11-8 show water temperature exceedences through all years in the Sacramento River with modeling study 7.0, which approximates current operations (as described in Chapter 9).

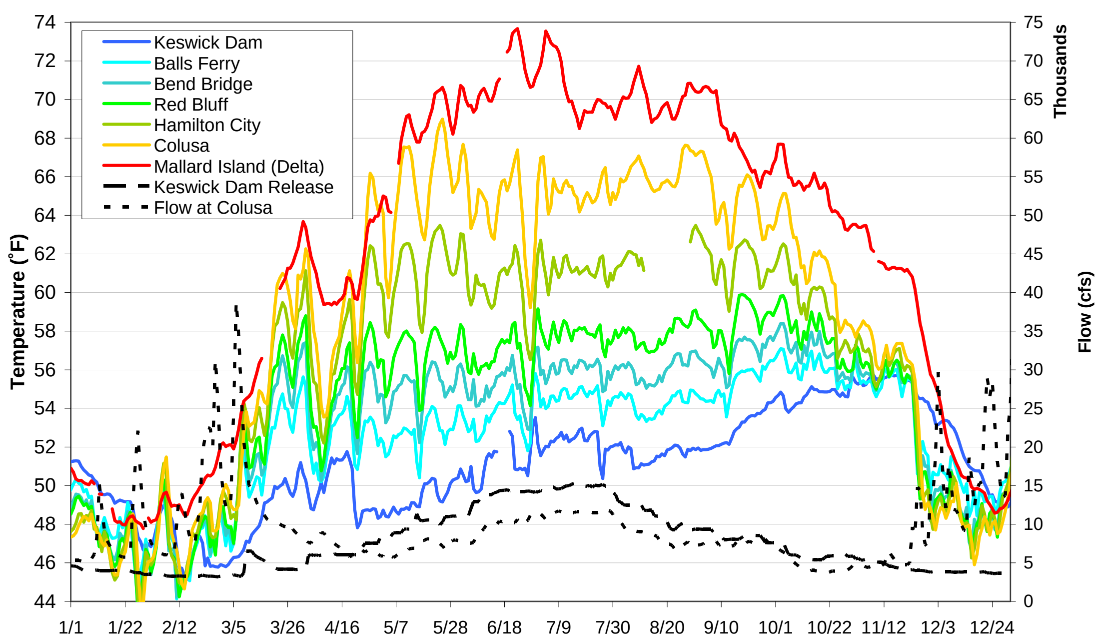

Figure 11-1. Sacramento River mean daily temperature and flow at selected locations in a dry water year, actual measured water temperatures (2001).

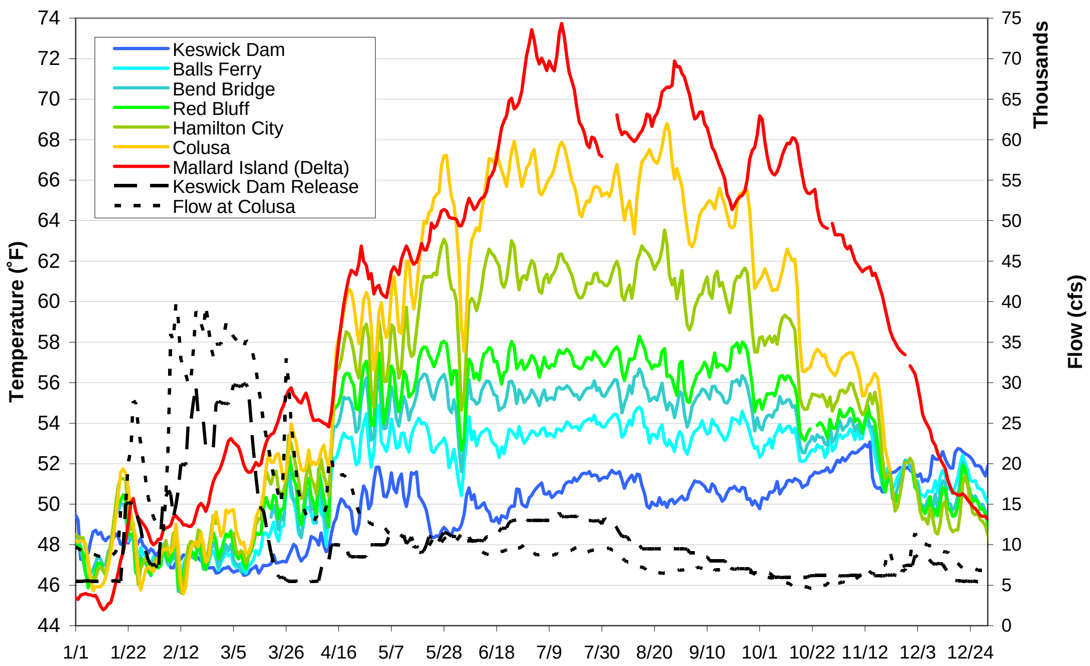

Figure 11-2. Sacramento River mean daily temperature and flow at selected locations in a wet water year, actual measured water temperatures (1999).

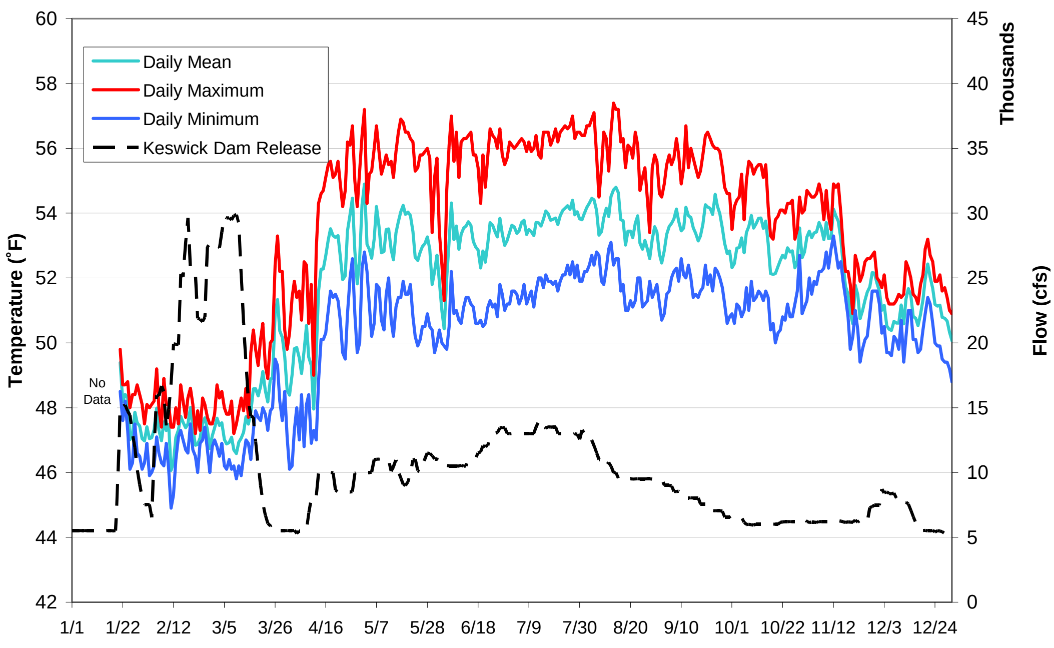

Figure 11-3. Sacramento River at Balls Ferry daily temperature range and flow in a wet water year, actual measured water temperatures (1999).

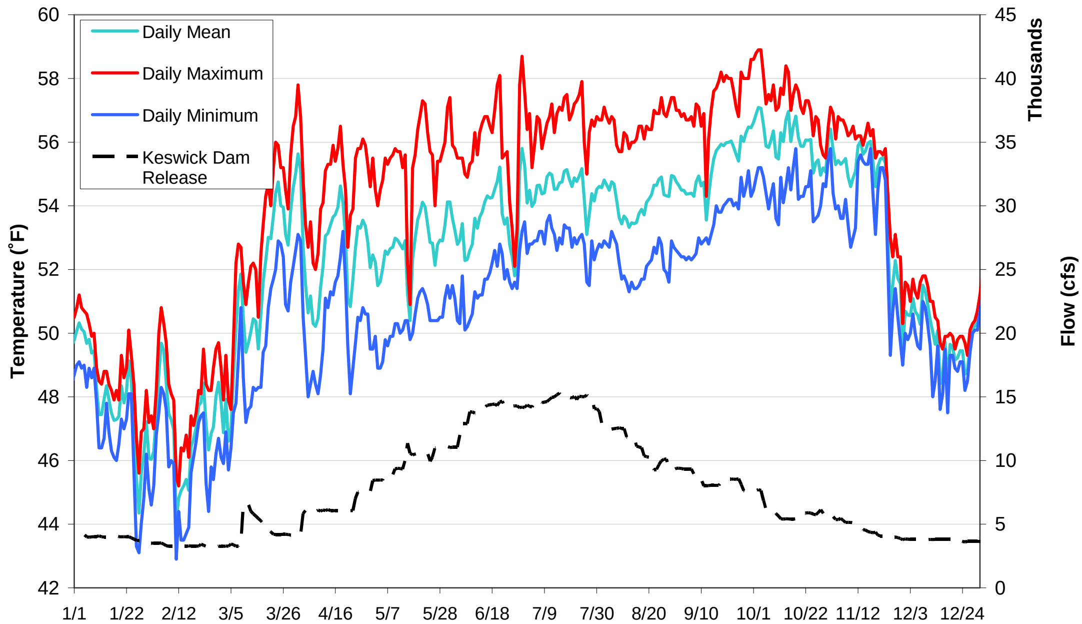

Figure 11-4. Sacramento River at Balls Ferry daily temperature range and flow in a dry water year, actual measured water temperatures (2001).

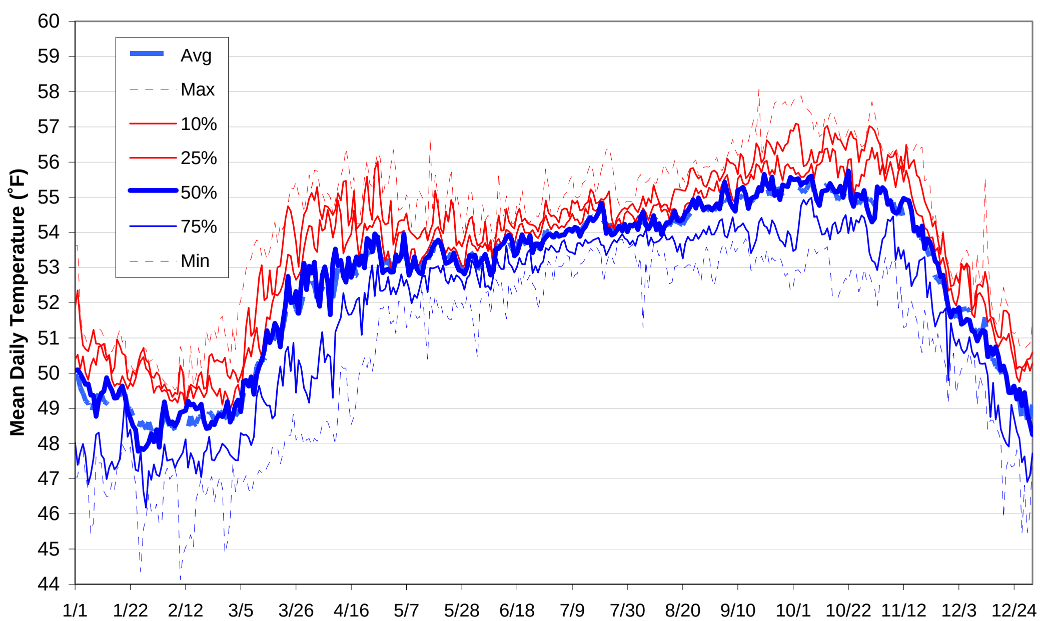

Figure 11-5. Sacramento River at Balls Ferry seasonal temperature exceedence, 1997-2007 (actual temperatures, not modeled).

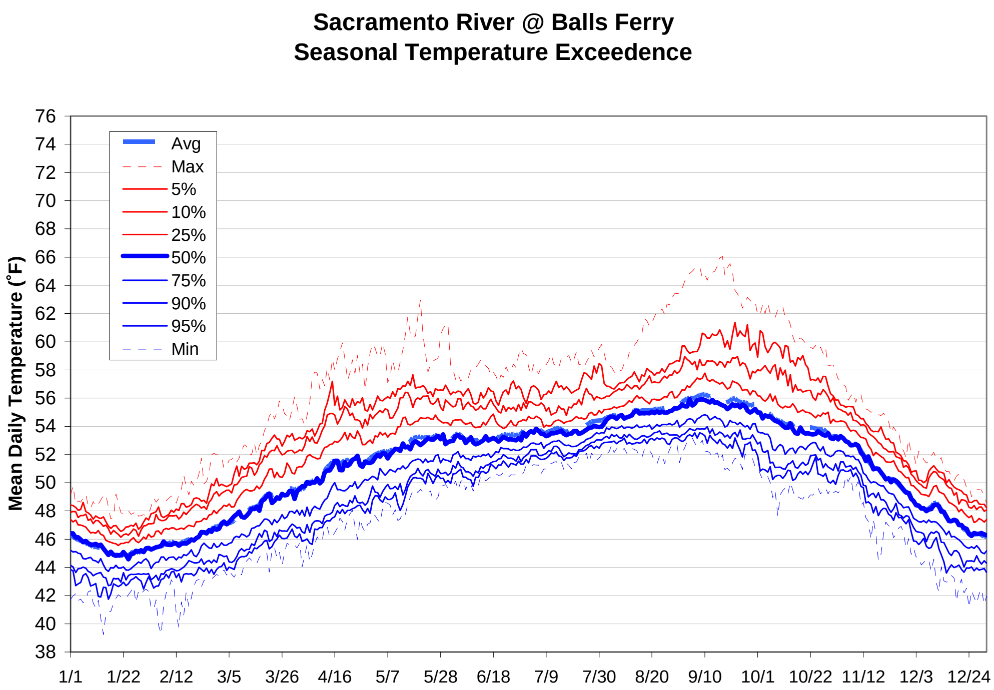

Figure 11-6. Sacramento River at Balls Ferry seasonal temperature exceedence in study 7.0 (modeled temperatures with current operations throughout the 82 year CalSim-II modeling period).

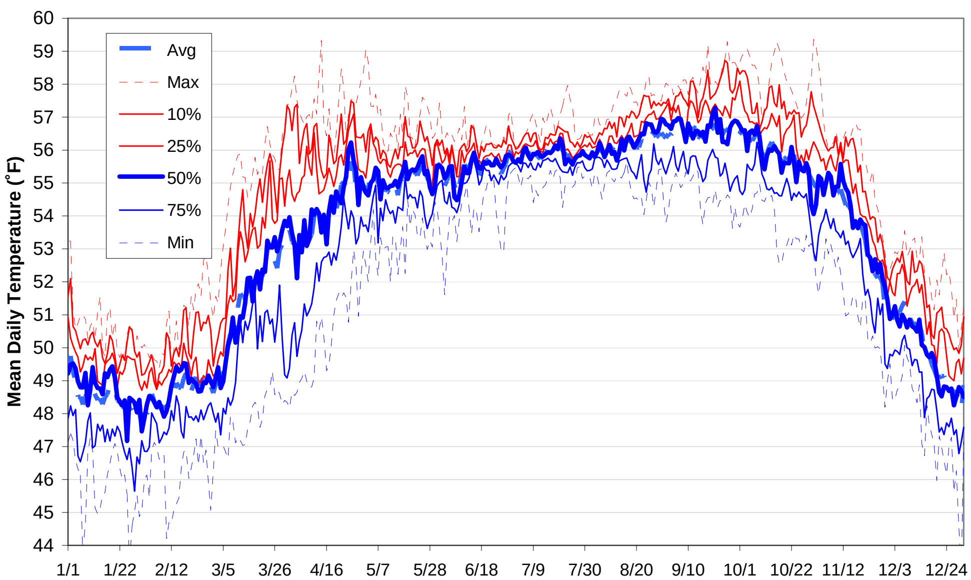

Figure 11-7. Sacramento River at Bend Bridge seasonal temperature exceedence, 1997-2007 (actual temperatures, not modeled).

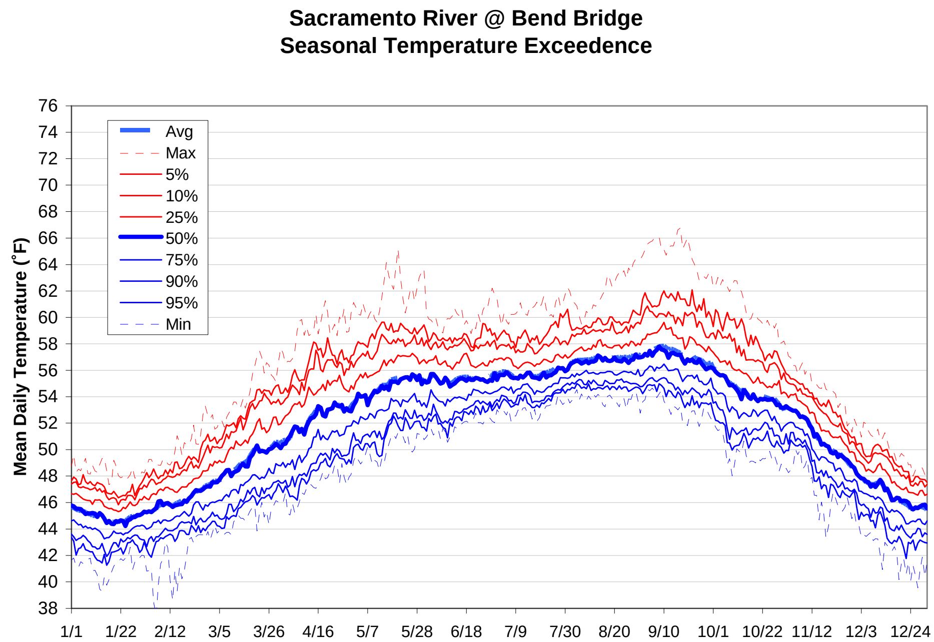

Figure 11-8. Sacramento River at Bend Bridge seasonal temperature exceedence in study 7.0 (modeled temperatures with current operations throughout the 82 year CalSim-II modeling period).

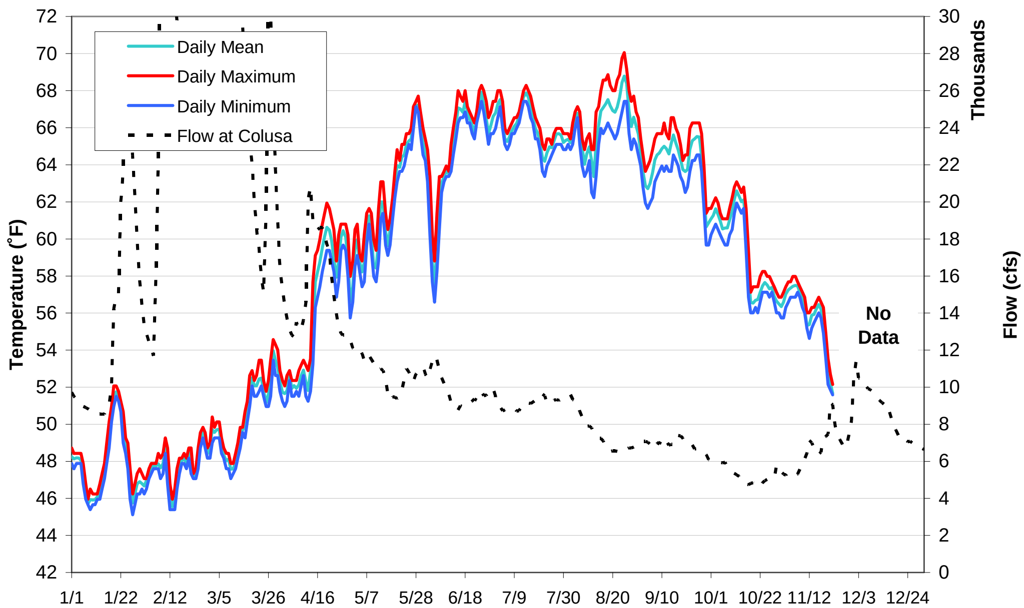

Figure 11-9. Sacramento River at Colusa daily temperature fluctuation and flow in a wet water year, actual measured water temperatures (1999).

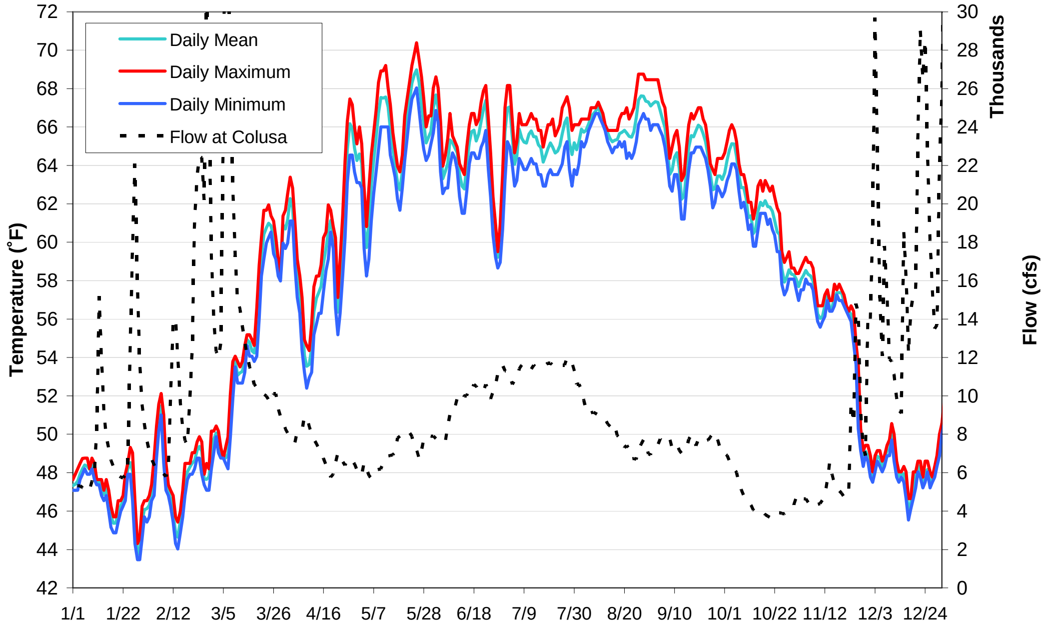

Figure 11-10. Sacramento River at Colusa daily temperature fluctuation and flow in a dry water year, actual measured water temperatures (2001).

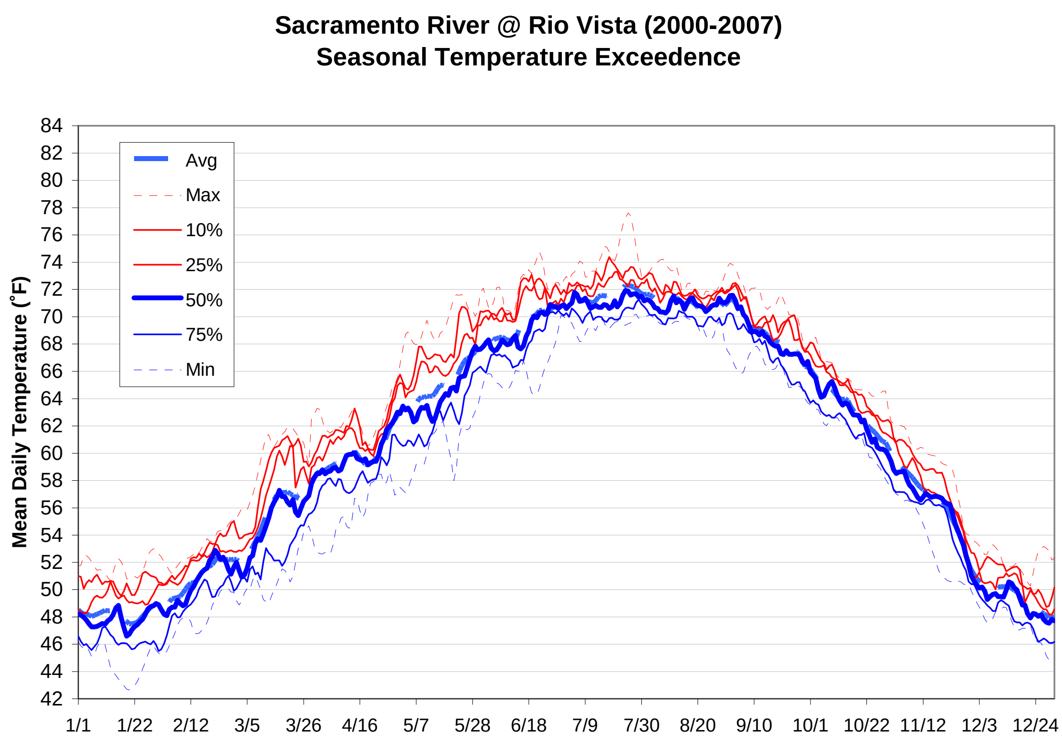

Figure 11-11. Sacramento River at Rio Vista water temperature exceedence for 2000 – 2007, actual measured temperatures.

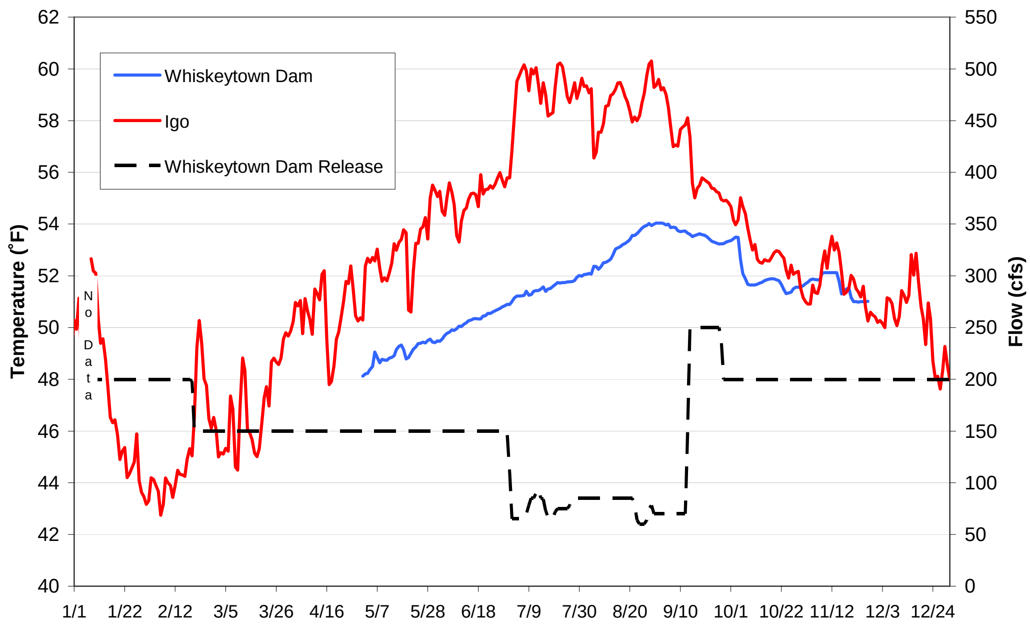

Figure 11-12. Clear Creek mean daily temperature at Whiskeytown Dam and Igo in a dry year, actual measured water temperatures (2002).

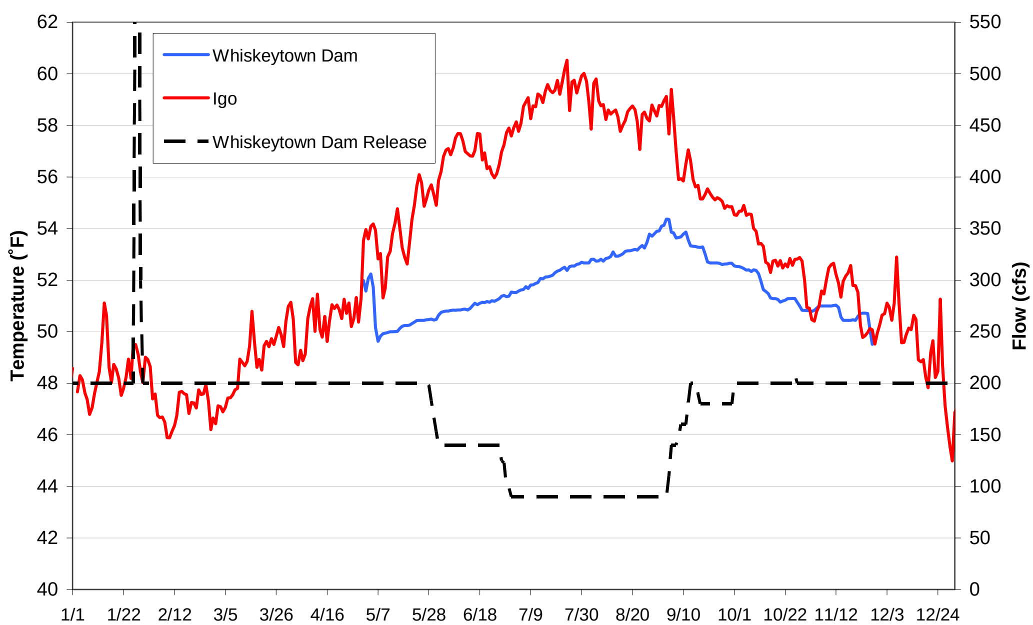

Figure 11-13. Clear Creek mean daily temperature at Whiskeytown Dam and Igo in an above normal water year, actual measured water temperatures (2003).

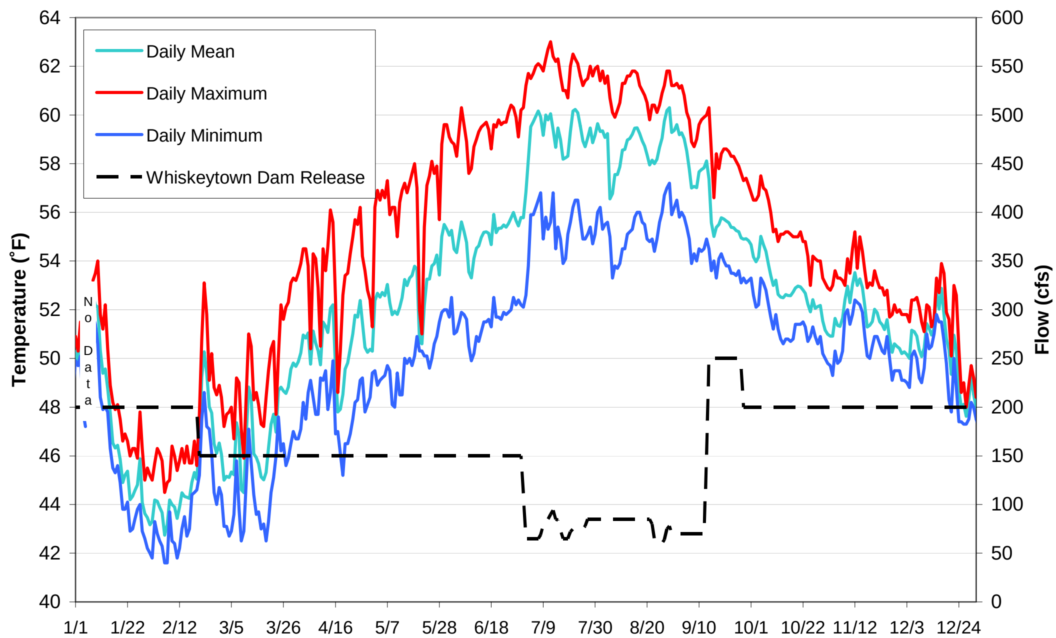

Figure 11-14. Clear Creek at Igo daily temperature fluctuation and flow in a dry water year, actual measured water temperatures (2002).

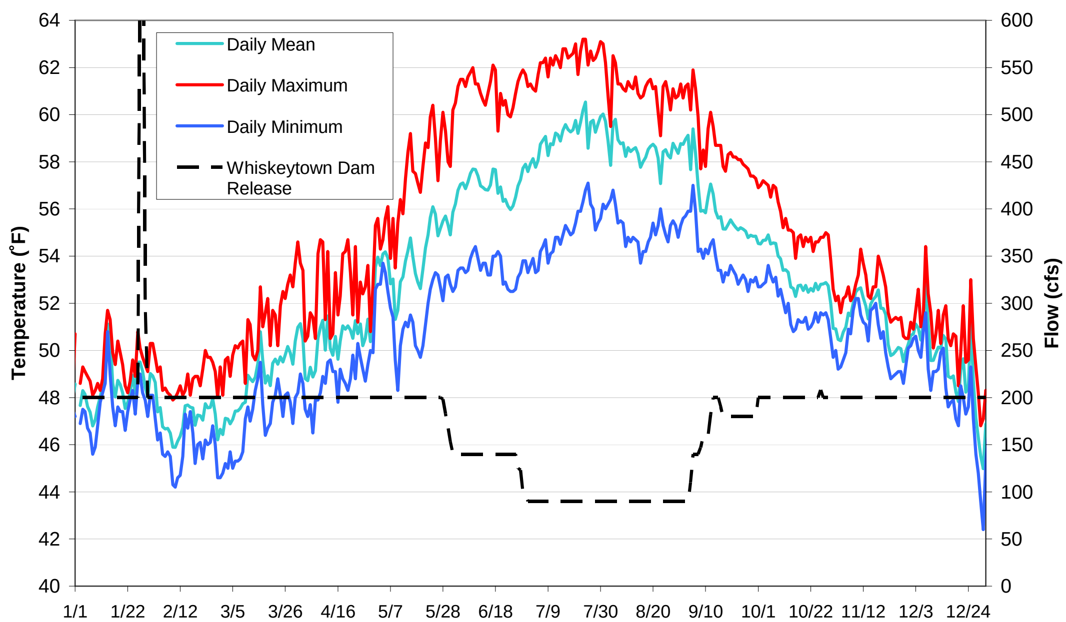

Figure 11-15 Clear Creek at Igo daily temperature fluctuation and flow in an above normal water year, actual measured water temperatures (2003).

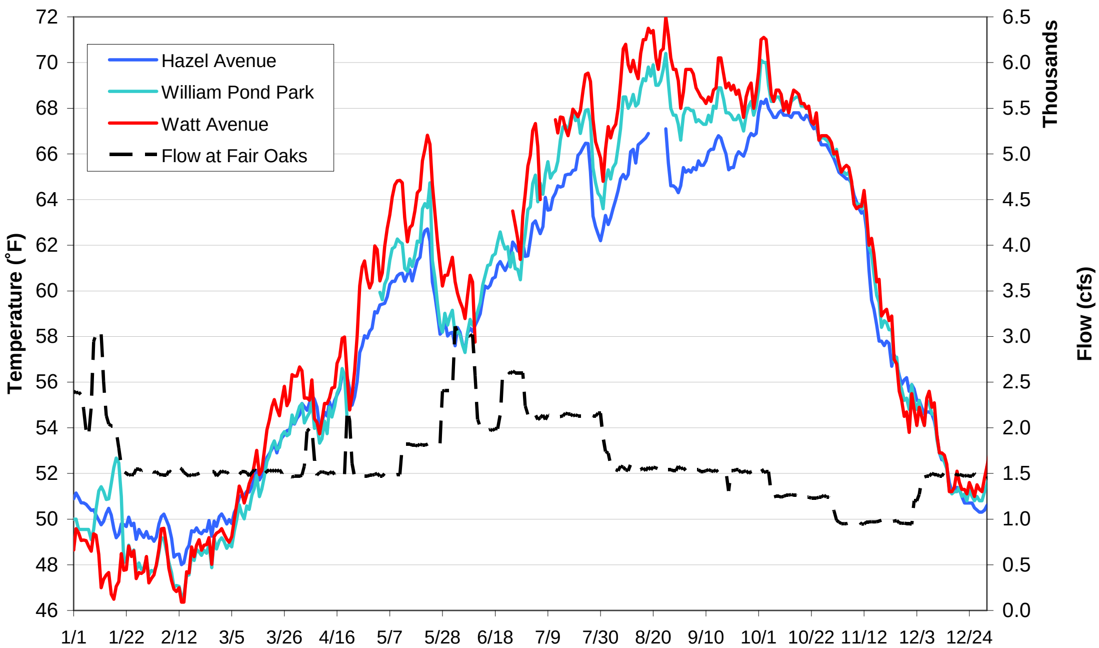

Figure 11-16. American River temperature and flow at monitoring sites in a dry year, actual measured water temperatures (2001).

There is a large "thermal lag" present in the American River downstream of Folsom Dam. The result is that fall temperatures in the river downstream of Folsom Dam are higher than they would be without the dam in place. The reservoir holds a summer's worth of thermal loading and as fall meteorological conditions cool, the reservoir's large thermal mass does not respond quickly – maintaining elevated temperatures. Note how Watt Avenue temperatures are cooler than Hazel Avenue – indicating cooling with distance downstream. Elevated fall temperatures may be a contributing factor to fisheries challenges in the American River. This is present in other systems too (like the Stanislaus), but occurs later in the year and not to the extreme that occurs on the American River.

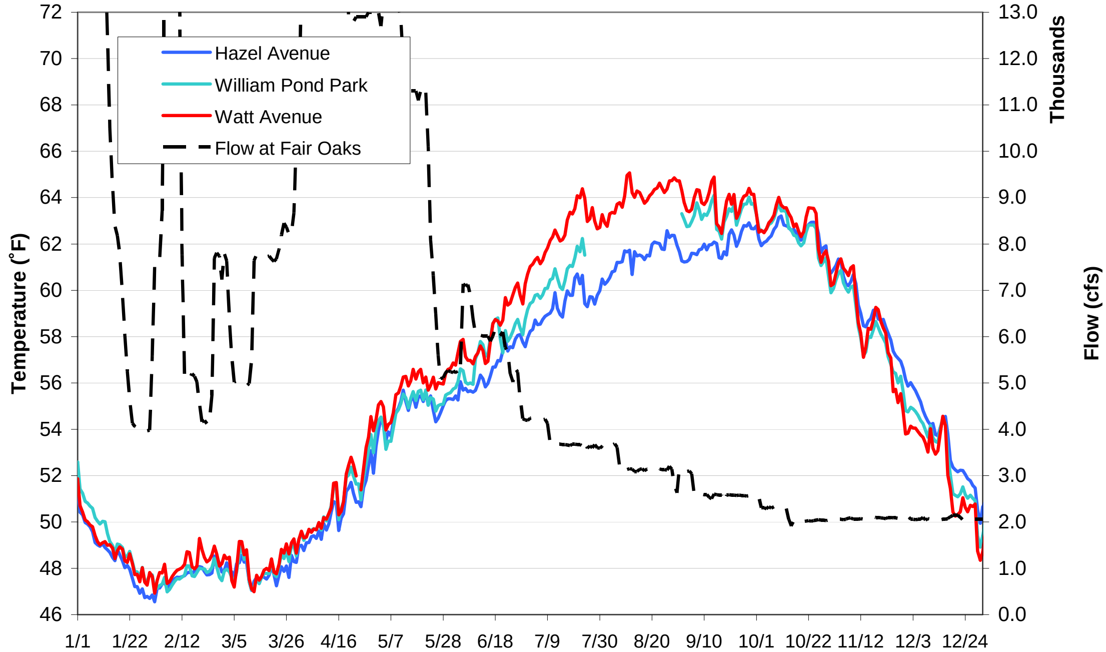

Figure 11-17. American River temperature and flow at monitoring sites in a wet year, actual measured water temperatures (2006).

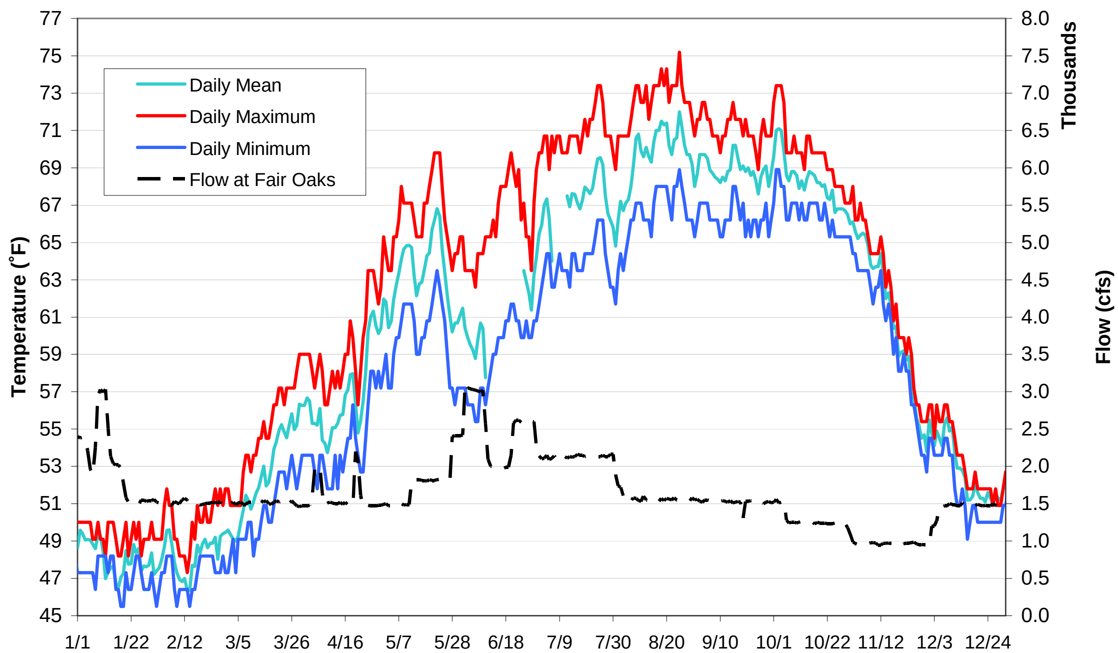

Figure 11-18. American River at Watt Avenue daily temperature fluctuation and flow in a dry year, actual measured water temperatures (2001).

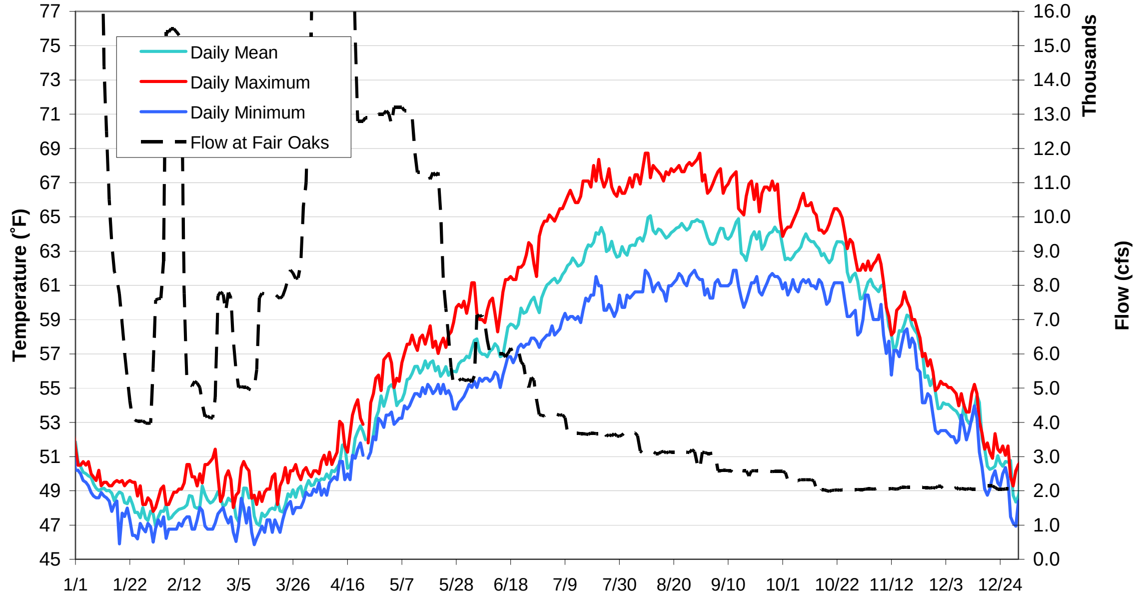

Figure 11-19. American River at Watt Avenue daily temperature fluctuation and flow in a wet year, actual measured water temperatures (2006).

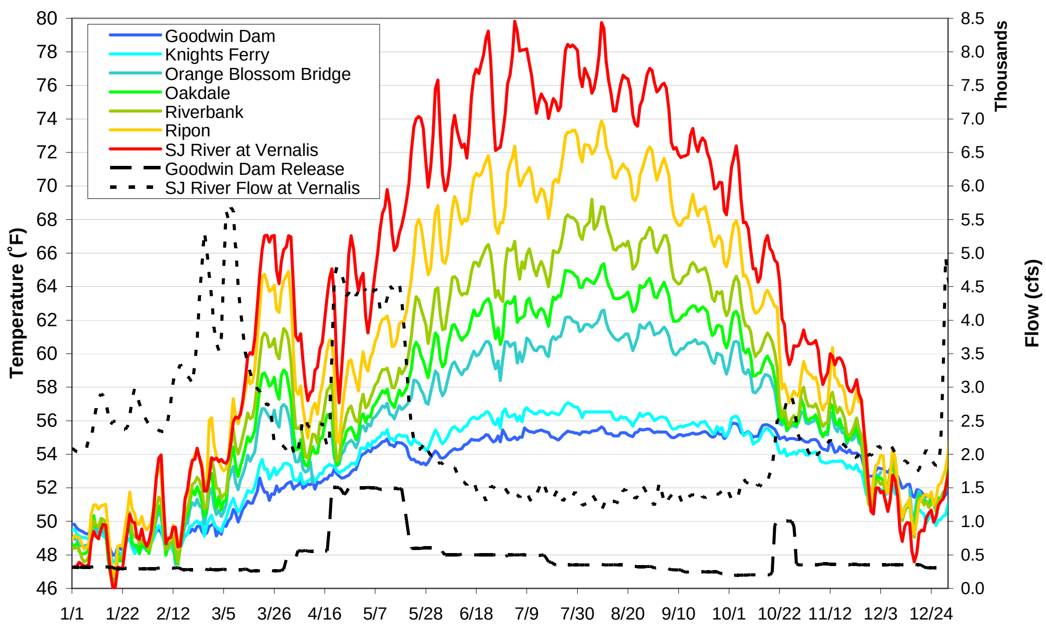

Figure 11-20. Stanislaus and San Joaquin River temperatures and flow at selected locations in a dry year, actual measured water temperatures (2001).

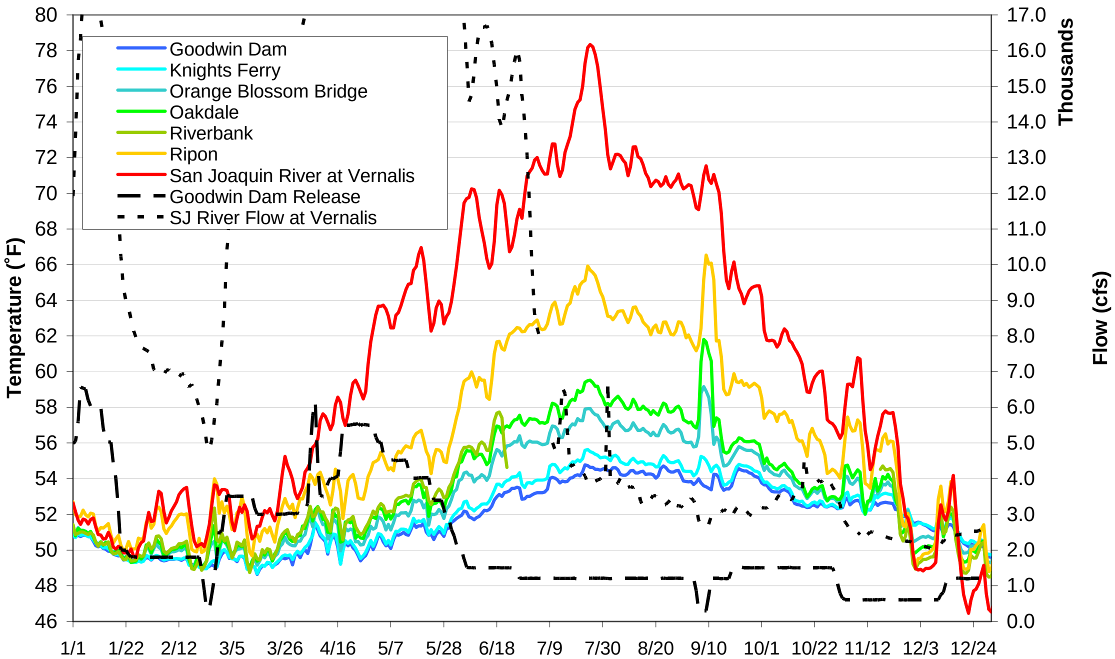

Figure 11-21. Stanislaus and San Joaquin River temperatures and flow at selected locations in a wet year, actual measured water temperatures (2006).

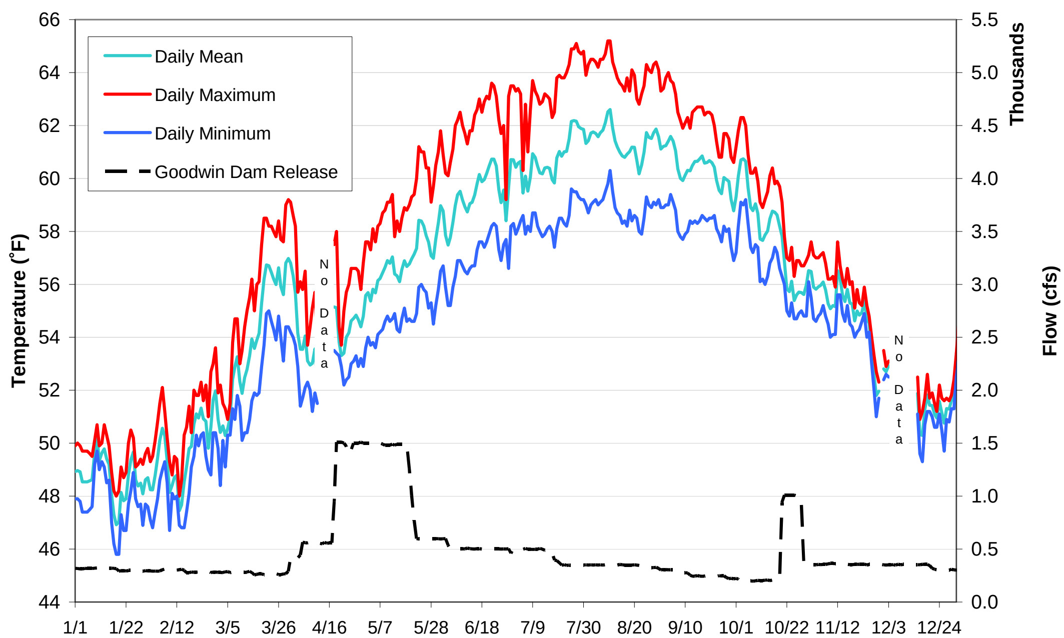

Figure 11-22. Stanislaus River at Orange Blossom Bridge daily temperature fluctuation and flow in a dry water year, actual measured water temperatures (2001).

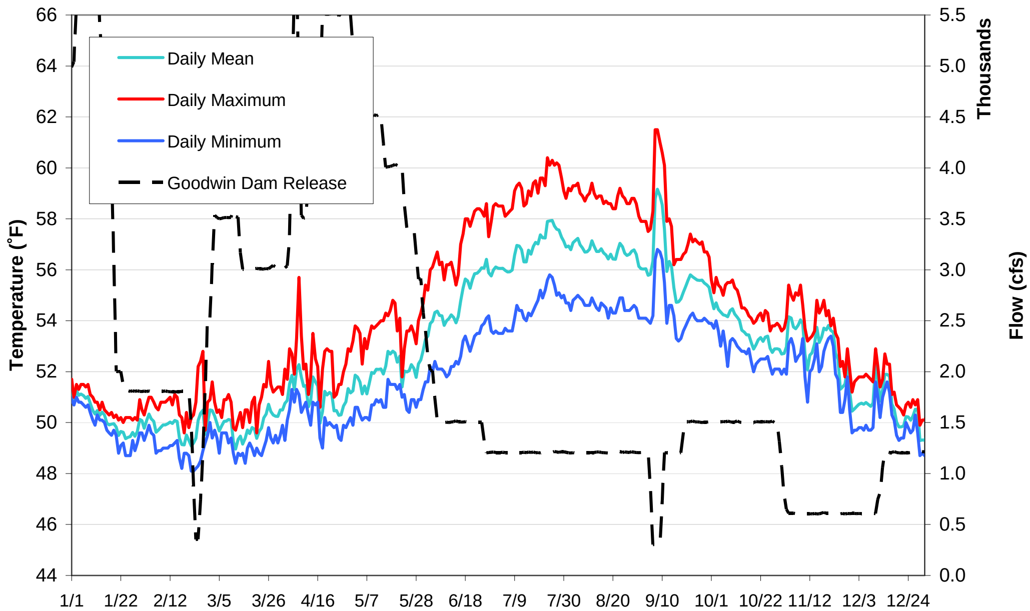

Figure 11-23. Stanislaus River at Orange Blossom Bridge daily temperature fluctuation and flow in a wet water year, actual measured water temperatures (2006).

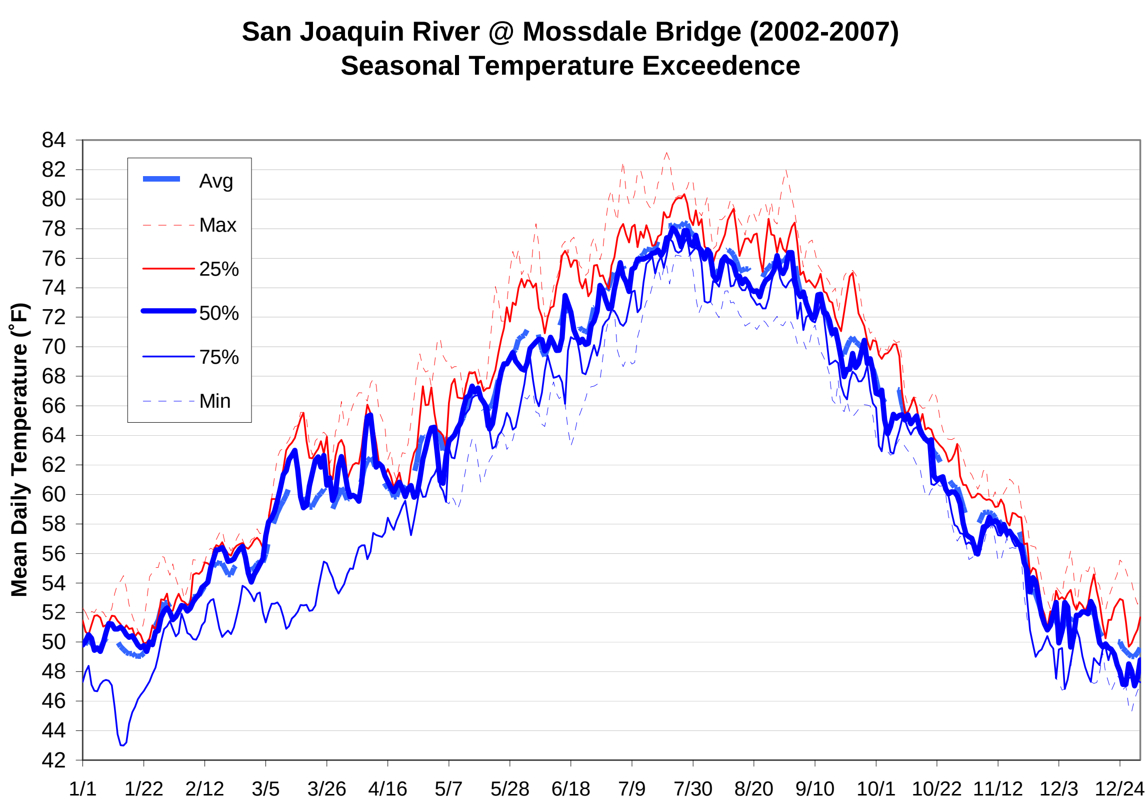

Figure 11-24. San Joaquin River at Mossdale Bridge water temperature exceedence for 2002 – 2007, actual measured water temperatures.

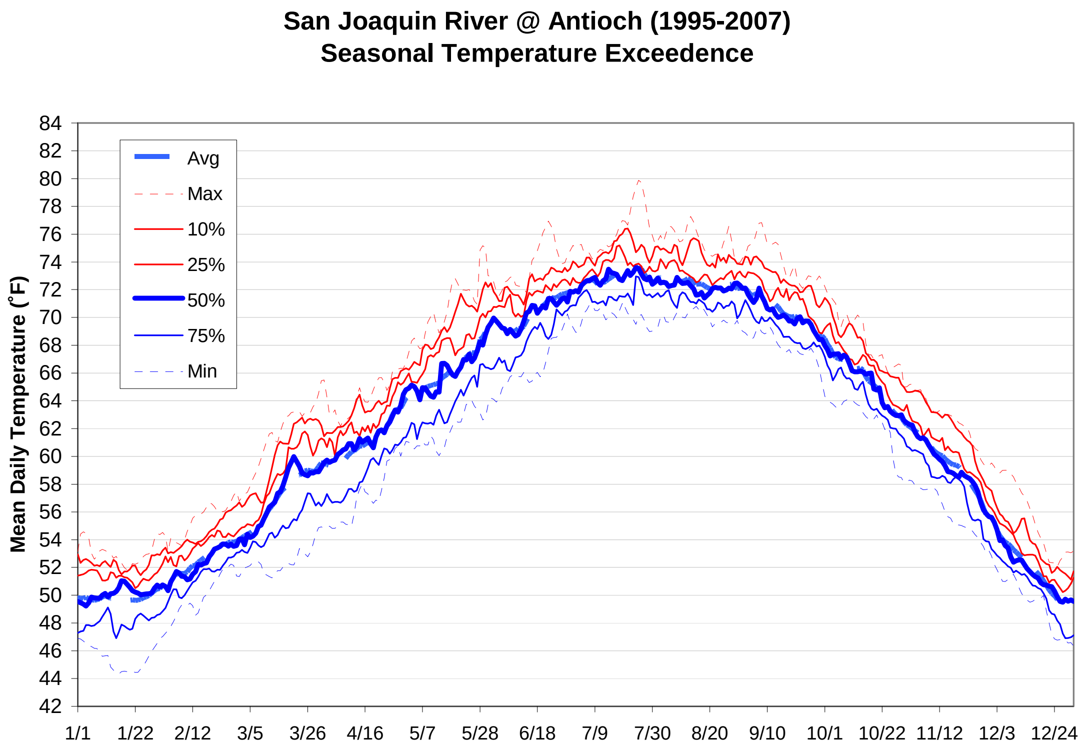

Figure 11-25. San Joaquin River at Antioch water temperature exceedence for 1995 – 2007, actual measured water temperatures.

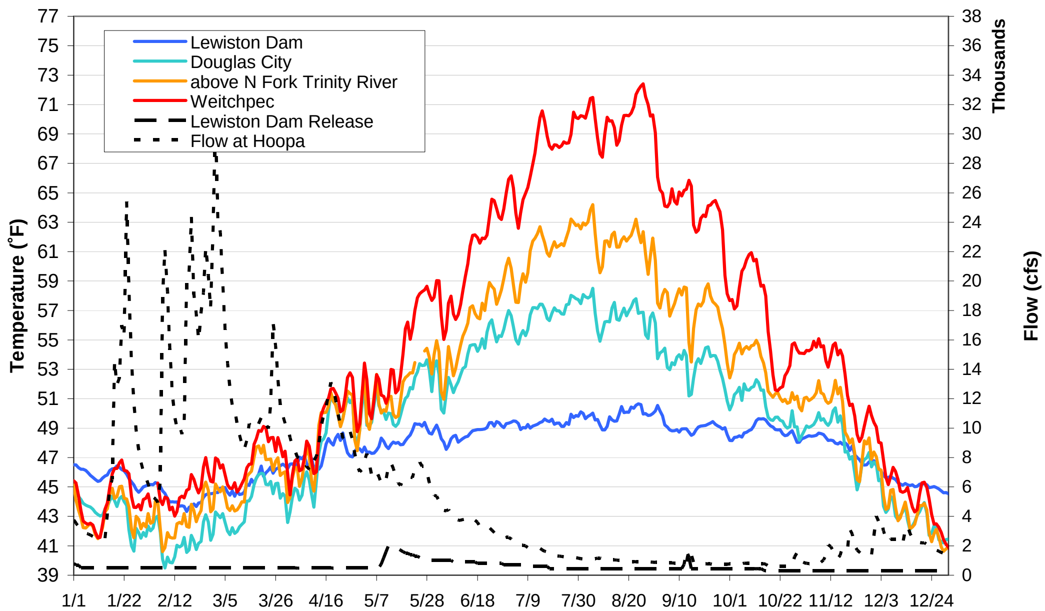

Figure 11-26. Trinity River water temperatures and flow at monitoring sites in a wet year type, actual measured water temperatures (1999).

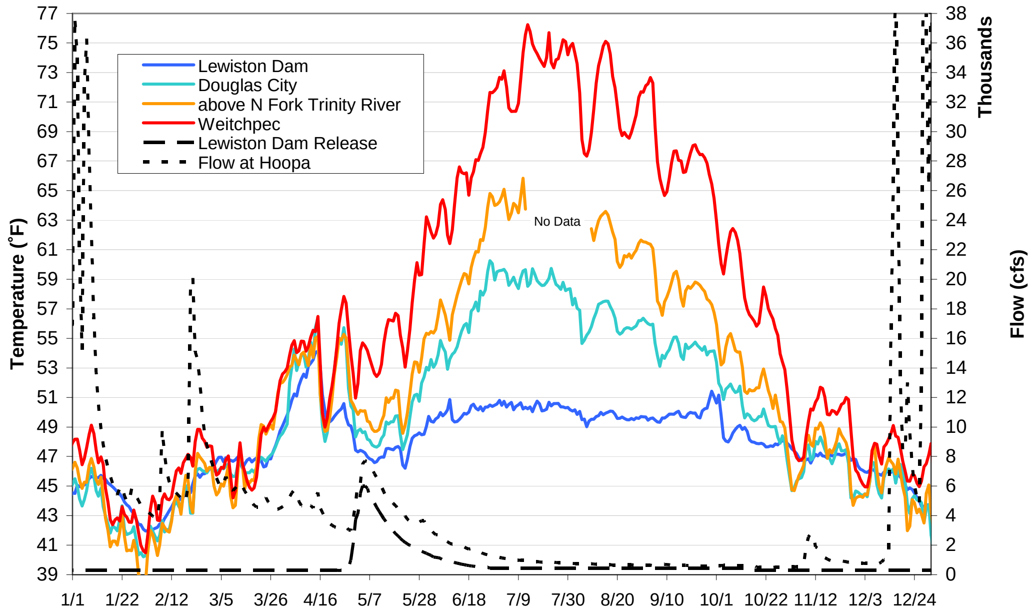

Figure 11-27. Trinity River water temperatures and flow at monitoring sites in a dry year type, actual measured water temperatures (2002).

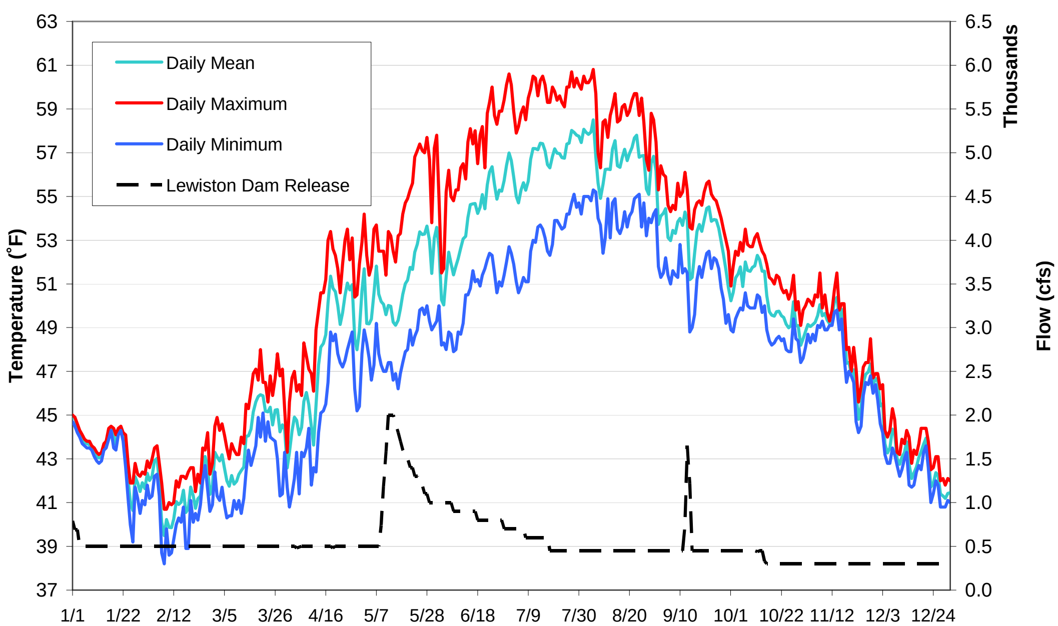

Figure 11-28. Trinity River at Douglas City daily temperature fluctuation and flow in a wet year, actual measured water temperatures (1999.

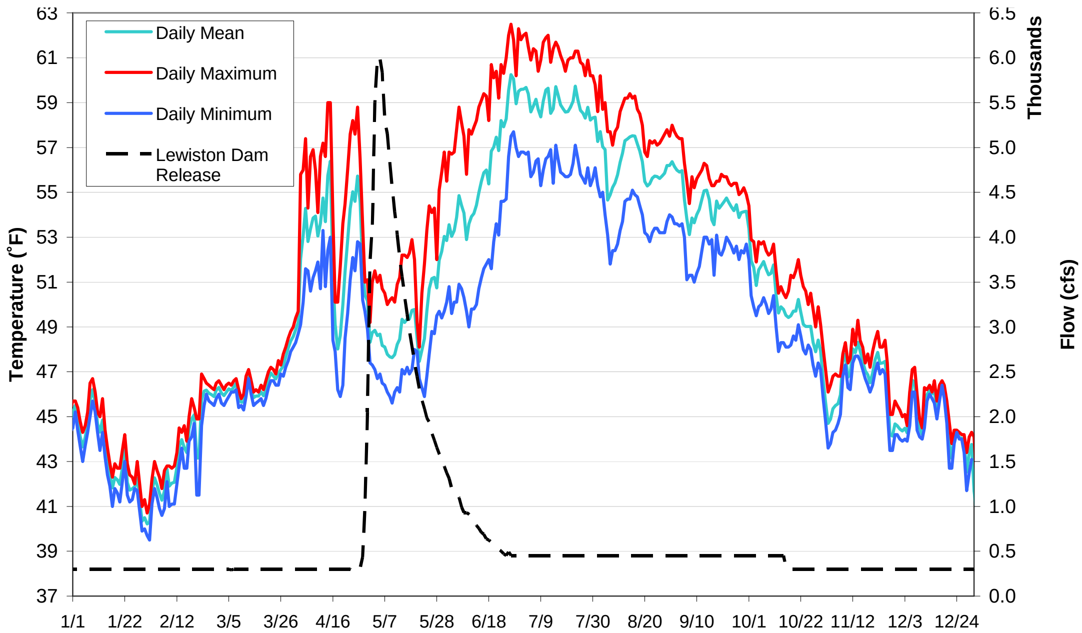

Figure 11-29. Trinity River at Douglas City daily temperature fluctuation and flow in a dry year, actual measured water temperatures (2002).

OCAP Modeling Studies

The modeling studies referenced in this chapter refer to the CalSim-II studies described in the project description (Chapter 2). Table 11-2 is a brief summary of differences between the studies.

Table 11-2. Summary of differences between the OCAP modeling studies.

	CVPIA 3406 (b)(2)	Level of Development	EWA	SDIP Stage 1	Freeport	Intertie	Climate and Sea Level Rise
Study 3a Today EWA	May 2003	2001	Full				
Study 6.0 Today EWA	May 2003	2005	Full				
Study 7.0 Today EWA	May 2003	2005	Full				
Study 7.1 Today Limited EWA	May 2003	2005	Limited	X	X	X	

	CVPIA 3406 (b)(2)	Level of Developm ent	EWA	SDIP Stage 1	Freeport	Intertie	Climate and Sea Level Rise
Study 8.0 Future Limited EWA	May 2003	2030	Limited	X	X	X	
Study 9.0 Future D1641 SA Climate Change		2030		X	X	X	No Sea Level Rise
Study 9.1 Future D-1641		2030		X	X	X	1ft Sea Level Rise and 4" amplitude
Study 9.2 Future D-1641		2030		X	X	X	Wetter, Less Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.3 Future D-1641		2030		X	X	X	Wetter, More Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.4 Future D-1641		2030		X	X	X	Drier, Less Warming Climate Change with 1ft Sea Level Rise and 4" amplitude
Study 9.5 D-1641 Future		2030		X	X	X	Drier, More Warming Climate Change with 1ft Sea Level Rise and 4" amplitude

Trinity River

Adult Coho Salmon Migration, Spawning, and Incubation

Adult coho typically enter the Klamath River and the mouth of the Trinity River starting in September with peak upstream migration occurring in October and November. Flows during this time would be a minimum of 450 cfs until October 15 in all year types and would not change between the current operations and future operations scenarios. Flows decrease to a 300 cfs spawning baseflow on October 15. Based on past observations of spawning salmonids in the Trinity River, it was concluded that this flow would provide adequate in stream conditions for the upstream migration and spawning of coho salmon.

For purposes of this assessment, water temperatures at or below 60 °F are assumed to provide suitable conditions for adult coho salmon migration. Water temperatures at or below 56 F are assumed to be suitable for egg incubation. Water temperatures early in the upstream migratory period, in September, would often be above preferred ranges near the mouth of the Trinity, but dam operations cannot efficiently control water temperature at the mouth, 110 miles below Lewiston Dam. Releases would always be 450 cfs in September. Temperatures were modeled down to the North Fork of the Trinity River. This is the reach where Trinity operations have the greatest temperature effect. Temperatures in September would be below 60 °F at Douglas City in September of about 95 percent of years and suitable for holding and migrating adult coho. During a few dry years temperatures could exceed 60 °F in September. Temperatures under future operations are projected to be slightly cooler. Between October and May mean monthly temperatures at Douglas City would always be maintained at or below 60 °F under all scenarios. During November when spawning initiates, average monthly temperatures would be almost always below 50 °F at Douglas City. Flows during spawning and incubation would be maintained at 300 cfs, which has been shown to provide suitable conditions for spawning and incubation of coho salmon. Most coho spawning in the mainstem occurs between Lewiston Dam and Douglas City with the greatest concentration in the first few miles below the dam. This distribution favoring upstream areas is probably influenced by the large hatchery component of the population. Based on these results we conclude that current and future operations are not likely to adversely affect coho salmon adult migration, spawning, egg incubation, or critical habitat in the Trinity River.

Coho Salmon Fry, Juveniles, and Smolts

The Trinity River supports young coho salmon rearing in the mainstem year round. Nearly all coho rearing during the summer occurs upstream of Douglas City, in the vicinity of the high density spawning. A critical seasonal period for juvenile coho rearing in California is generally June through September of dry years when water temperatures are at the high end of what is considered to be the optimal range for coho rearing. Water temperatures in the Trinity River between Lewiston and Douglas City are cooler than most coho streams in summer. Welsh et al. (2001) found coho in streams with mean weekly average temperatures of less than 62 °F. For purposes of this BA average monthly water temperatures of less than 62° F are assumed to support suitable juvenile coho rearing. Temperatures at Douglas City would be below 60 °F in over 95 percent of years but could rise above 62 °F (monthly average) in June through September in up to 5 percent of years. Temperatures between the studies are essentially unchanged. Based on these results we conclude that current and future oprations are not likely to affect coho salmon rearing or critical habitat in the Trinity River.

The spring high flows are provided to mimic the natural hydrograph during the snowmelt period (Figure 11-30). The flow schedule each year is determined through deliberations conducted by the Trinity River Restoration Program. These flows should increase survival of out-migrating coho smolts. The higher flows are intended to return more natural geomorphic processes to the Trinity River (USDI 2000). These flows should benefit coho salmon through the long-term habitat values provided. The flows are designed to discourage riparian vegetation establishment down to the edge of the lower flow channel margins and to scour the bed to maintain spawning and rearing habitat (USDI 2000). Off channel habitats out of the main river flow are important for sustaining juvenile coho salmon through the winter months when water is cooler. Off-channel habitats may potentially be created by the higher flows and are being created mechanically. Stranding of coho fry can occur when the flows are lowered following the restoration program prescribed flows (Chamberlain 2003). Flows are essentially unchanged between the studies and the spring pulse flows prescribed for the restoration program are the same under all scenarios. These flows along with physical habitat restoration projects are intended to increase the amount of fish habitat and increase fish production. Based on the potential stranding risk, we conclude that current and future operations may affect, but are not likely to adversely affect, juvenile coho.

High flows down the Trinity will occur during safety of dams releases during high runoff events, generally between December and May, to prevent overtopping of the dam. These safety of dams releases occur during about 10-20 percent of years depending on the month. Depending on timing of these releases, they can help or hurt juvenile coho. Additional rearing habitat is available during the higher releases but when the releases are subsequently lowered some stranding can occur where off-channel areas are isolated from the river. The higher releases make it easier for smolts to outmigrate from the river when the timing of the flows coincides with a period when fish are ready to outmigrate. Stranded fish tend to receive a lot of attention because they are visible and easy to count while benefits of the pulsed higher flows to the fish population are not as easily quantified. Based on the risk of stranding, we conclude that current and future operations may affect, but are not likely to adversely affect, juvenile coho salmon or their critical habitat.

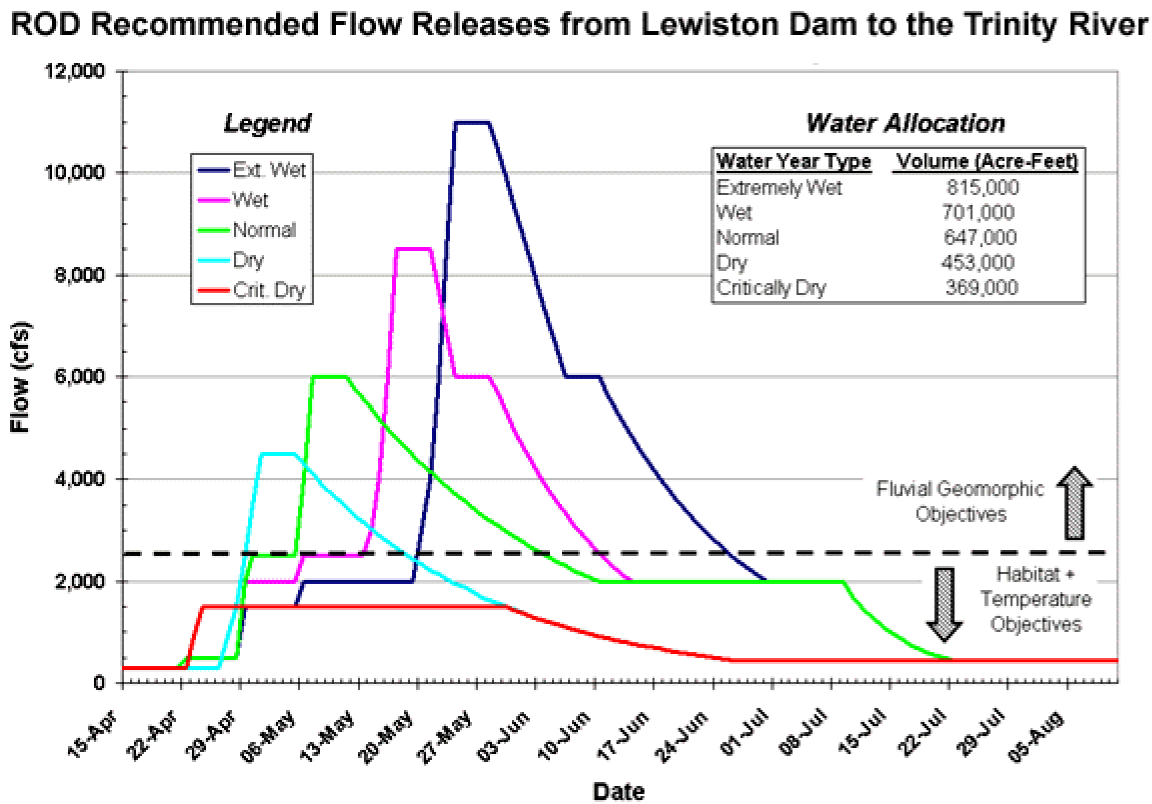

Figure 11-30. Trinity River Restoration Program recommended flow releases from Lewiston Dam to the Trinity River including functional performance ranges.

Clear Creek

Adult Salmon and Steelhead Migration, Spawning, and Incubation

There would be little, if any, difference in flows between current and future operations under all scenarios. Water temperature at Igo would be about the same in all years as well. No change in effect on steelhead or spring-run Chinook or critical habitat is anticipated. Salmonid populations in Clear Creek have been increasing under the current flow regime and physical channel restoration actions (DeStaso 2008) and depending on ocean conditions should have the capability to make continued increases to carrying capacity.

For purposes of this BA, suitable water temperatures for adult migration of both Chinook salmon and steelhead are assumed to be 60 F or less (Table 11-1). Suitable water temperatures for egg incubation are assumed to be 56 F or less (Table 11-1). Most steelhead adults are expected to migrate upstream in Clear Creek during December through March to spawn with spawning potentially stretching into April. Water temperatures between December and April are projected to be within the preferred range for steelhead spawning and incubation between Whiskeytown Dam and Igo (Figure 11-31 and Figure 11-32). Figure 11-31and Figure 11-32 show Study 7.0 only, but Studies 6.0, 7.1, and 8.0 are the same as Study 7.0 in Clear Creek. Flow releases from

Whiskeytown Dam into Clear Creek during upstream migration are expected to be 200 cfs in about 75 percent of the years during steelhead upstream migration in all scenarios. During the drier years releases are expected to be lower, as low as 30 cfs in the driest years in all scenarios. Optimal spawning flows were estimated to be 87 cfs upstream of the old Saeltzer Dam site and 250 cfs downstream of the old dam site (Denton 1986). Nearly all steelhead/rainbow spawning documented in redd surveys occurs close to Whiskeytown Dam (Jess Newton, personal communication, April 2003). During most years flows should be suitable for spawning in upstream areas but during dry years flows for attraction, holding, and upstream migration could be less than optimal. Tributary inflows downstream of Whiskeytown Dam provide some variation in the lower river hydrograph for increased attraction and migratory flows during rainfall events.

Spring–run Chinook salmon enter Clear Creek from April through September and spawn during August and September. Flow releases would be 200 cfs over 80 percent of the time in April, May, and June. Flows in July and August would always be 85 cfs in all years. September flows would be 150 cfs except during the driest 4 percent of years when they would be 30 cfs. These flows should provide adequate habitat for Chinook salmon upstream of the former Saeltzer Dam site. During the driest years the 30 cfs flows would not accommodate a large number of spawners so depending on run size more competition for spawning sites and superimposition may occur. Spring–run may benefit from a spawning attraction release during the late spring period to assist in upstream migration and passage through the bedrock chute area. This may be provided by CVPIA section 3406(b)(2) water. Flows during dry years could be as low as 30 cfs. These flows may be too low for spring–run to migrate upstream. Chinook may not be able to make it past the bedrock chute area at this flow. The area of Clear Creek upstream of the Clear Creek road bridge to Whiskeytown Dam is considered to be spring–run habitat (Jim DeStaso, personal communication). Denton (1986) estimated optimal flows for salmon in this reach would be 62 cfs for spawning and 75 cfs for rearing based on the IFIM study, provided suitable incubation and rearing temperatures were provided. Spring–run begin spawning in Clear Creek in September. The flows of 30 cfs in dry years would be below the optimum flow for Chinook spawning. Unless the spring–run population increases above present levels, spawning habitat availability should not be limiting, as long as the fish are able to migrate to the habitat at the lower flow levels. Water temperatures at Igo sometimes exceed optimal spawning and incubation temperatures of less than 56 °F. Most spring–run would likely spawn upstream closer to Whiskeytown Dam where optimal spawning and incubation temperatures can be provided year round. NOAA Fisheries (2003) states that the Denton (1986) flow recommendations are not applicable and that there are no applicable studies completed that can be used to describe the effect of operations on rearing, emigration, and spawning. Therefore use of the Denton (1986) recommendations may be somewhat subjective but in the absence of other on-the-ground recommendations we used Denton (1986). A new instream flow study is currently being conducted by the Fish and Wildlife Service and is scheduled for completion in 2010.

High flow events during the incubation period have the potential to scour redds and injure pre-emergent fry. High flow events in excess of 1,000 cfs often occur during heavy rain in the winter and spring (Figure 6-6). Whiskeytown Reservoir releases remain constant during all but the heaviest runoff periods when the reservoir overflows through the glory hole outlet. High flow events in Clear Creek are now smaller than those that occurred prior to flow regulation in the system. Clear Creek fishery studies found that spawning gravel in Clear Creek could be improved by adding spawning gravel below Whiskeytown Dam and allowing high flows to deposit it in downstream spawning areas. High flow events of approximately 3,000 cfs or greater, which occur infrequently, are needed to wash the artificially deposited gravel downstream (Table 11-3). Lansdslides deposited fine sediment into Clear Creek and may be affecting juvenile production (DeStaso 2008). The high flow events can be beneficial in washing the fine sediment downstream out of spawning areas.

Table 11-3. Estimated bed mobility flows for affected Central Valley Rivers.

River and reference	Bed load movement initiated, cfs	Bed mobility flow that may scour some redds, cfs
Sacramento River (Buer 1980 and pers. comm. 2003)	25,000	40,000 – 50,000
Clear Creek (McBain&Trush and Matthews 1999)	2,600 (up to 11 mm particles)	3,000 – 4,000 coarse sediment transport (32 mm)
Feather River		
American River (Ayres Associates 2001)	30,000 – 50,000	50,000
Stanislaus River (Kondolff et al 2001)	280 cfs for gravel placed in river near Goodwin Dam	5,000 – 8,000 to move D_{50}
Trinity River (USDI 2000)	6,000 cfs to move D_{84}	11,000 cfs to scour point bars

Steelhead fry are expected to emerge from redds from approximately mid-February through May. Release temperatures from Whiskeytown Dam are modeled to remain at optimal levels throughout this period. Most fry will likely remain in upstream areas near where they were spawned, at least through the early rearing period until early summer. Spring–run Chinook fry emerge from redds between December and February, depending on water temperature where they are spawned. Water temperatures during this period are optimal for survival of fry.

Salmon and Steelhead Fry, Juveniles, and Smolts

The freshwater life stages of steelhead and Chinook salmon could occupy Clear Creek throughout the year. For purposes of this BA, suitable water temperatures for junvenile salmon and steelhead rearing are assumed to be 60° F (Table 11-1). Mean monthly temperatures of Whiskeytown Reservoir releases are modeled to be in the preferred range for growth and development of steelhead (45 °F to 60 °F) and of Chinook salmon (50 °F to 60 °F) throughout the year under all hydrologic conditions. Whiskeytown releases are expected to be about the under current and future conditions for all months. The average monthly temperatures are always within the range that the species have been shown to survive and grow well with adequate food supplies (Myrick and Cech 2001). Based on observations of juvenile salmonids and their prey in streams further north, food availability does not appear to be a limiting factor to salmon or steelhead in the upstream rearing areas of any of the affected Central Valley streams.

Optimal rearing and emigration flows have not been estimated for Clear Creek. We expect that the modeled flows will be suitable for the rearing, smoltification, and emigration of steelhead and Chinook salmon during most years. During the driest years flows during summer and fall could be limiting for steelhead rearing and for spring–run Chinook that hold over in Clear Creek through the summer. During dry years, a source of somewhat higher flows for out migration could be provided by brief tributary inflows during rainfall events, but these would be dependent on the weather.

There would be no difference in flows between current and future operations under all scenarios. No change in effect on fish is anticipated. Water temperature below Igo would be about the same in all years as well. Based on results of these current and future conditions, we conclude that operations affecting habitat conditions in Clear Creek are likely to affect salmon and steelhead, but are not likely to adversely affect salmon and steelhead rearing in Clear Creek.

Stranding of fry and juvenile steelhead and Chinook salmon could occur following high flow events if river stages drop rapidly and isolate fish in stream margins that are not connected to the main channel. Whiskeytown Reservoir releases typically remain constant under the majority of flood events. If uncontrolled spills do occur, they are made through the “glory hole” at Whiskeytown Reservoir. The reservoir attenuates flood flows by spreading stage changes over the entire surface area and the glory hole naturally dampens the change in rate of flow along with the changes in reservoir water surface elevation. Rapid decreases in river stage following high flow events are typically the result of unimpaired flows from local and tributary inflows downstream from Whiskeytown Reservoir. Flow changes under proposed operations are less than those that occurred prior to flow regulation. Based on the risk of juvenile salmon and steelhead stranding with Clear Creek, we conclude from this assessment that operations are not likely to change stranding conditions.

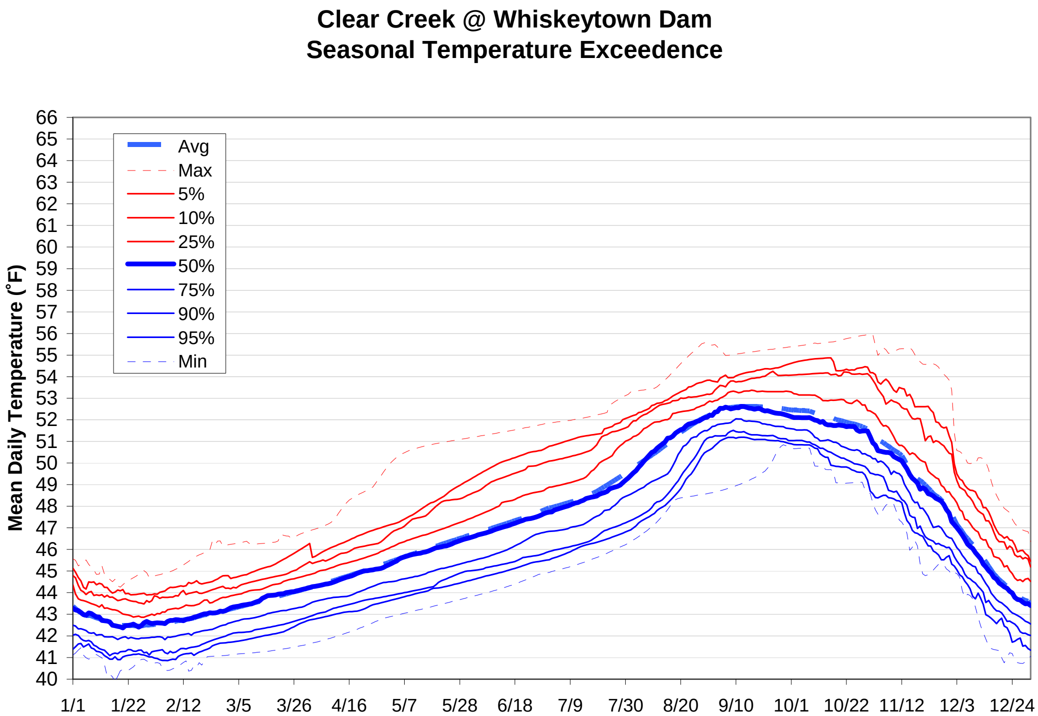

Figure 11-31. Water temperature exceedence in Clear Creek at Whiskeytown Dam in OCAP modeling study 7.0 in throughout the CalSim-II modeling hydrological record.

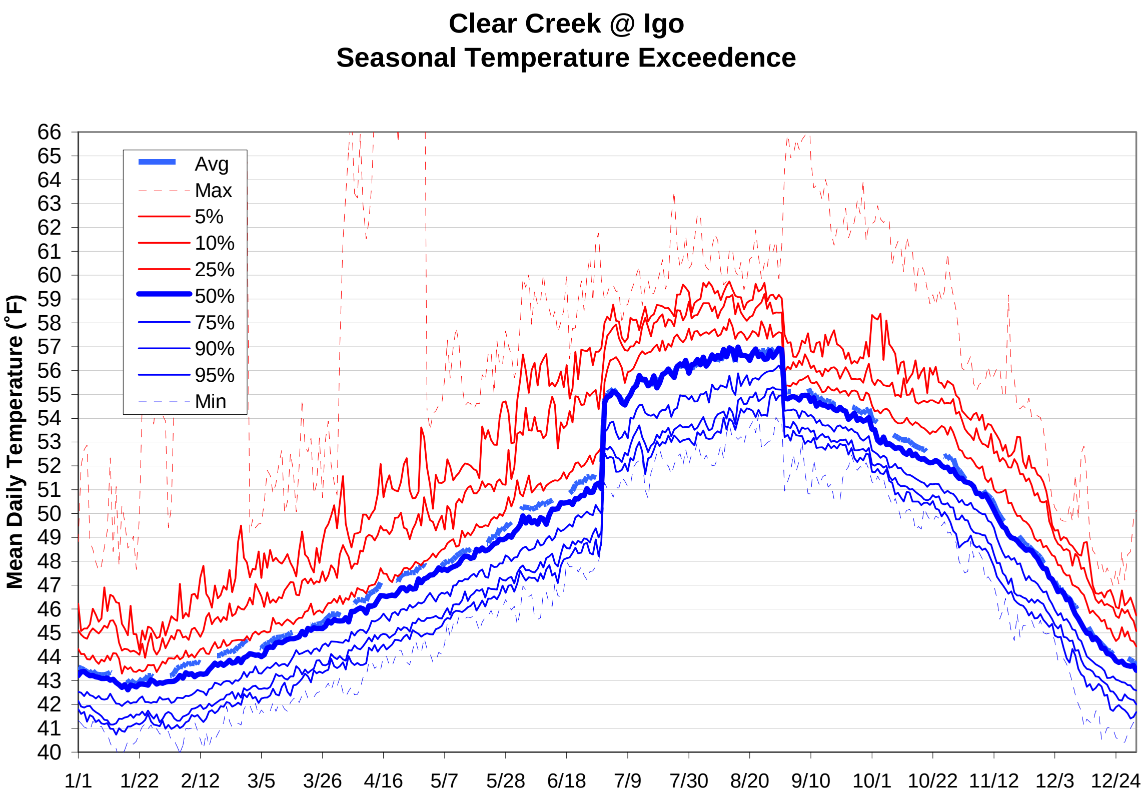

Figure 11-32. Water temperature exceedence in Clear Creek at Igo in OCAP modeling study 7.0 throughout the CalSim-II modeling hydrological record.

Implementation of the Trinity River Restoration Program Record of Decision increased flows in the lower Trinity River and decreased diversions into the Sacramento River Basin. Now less water passes through Whiskeytown Reservoir than prior to the Trinity decision (Table 11-4). Because less cool Trinity River water passes through Whiskeytown Reservoir there may be increased heating of the water as it passes through with the lower thermal mass. This appeared to result in a slightly warmer release into lower Clear Creek in 2005 than in prior years. The warmer temperatures occurred primarily during September and October (Figure 11-33 and Figure 11-34). This period coincides with the incubation period for spring run Chinook salmon when the target temperature is a mean daily average of 56 °F or below at Igo (NMFS 2004). The mean of the mean daily temperatures during the period June 1 through September 15 in 1996 through 2004 was 58.1 °F and in 2005 it was also 58.1 °F. The mean of the mean daily temperatures during the period September 15 through October 31 in 1996 through 2004 was 54.2 °F. The mean of the mean daily temperatures for this same period in 2005 was 56.7 °F. The warmer temperatures that occurred in the latter part of the temperature control season in 2005 are a tradeoff for the improved flow and temperature conditions being provided in the Trinity River.

The higher temperatures in 2005 occurred during the spring-run egg incubation period and on average exceeded the 56 °F target temperature by 0.7 °F. Chinook salmon eggs in other rivers (eg. American River) survive at high rates, at least in the hatchery, when spawned at 60 °F as long as the water temperature quickly declines to 56 °F or less. Temperatures in Clear Creek declined to 50 °F by the end of November in 2005. Therefore, effects of the slightly higher temperatures during early incubation for spring-run Chinook in 2005 were expected to be negligible. Similar temperature conditions will likely occur in future years.

A larger volume of water from the Trinity River goes to the Sacramento River through the Spring Creek tunnel than goes to Clear Creek. The Spring Creek tunnel water is used primarily to help cool the Sacramento River during the heat of the summer for winter run Chinook spawning and incubation. The higher volume going to the Sacramento River necessitates operating the system primarily for Sacramento River temperature targets. Clear Creek receives the same temperature water as what goes to the Sacramento River. This has generally provided suitable Clear Creek temperature conditions most of the time in the past. Daily temperature fluctuation in Clear Creek at Igo peaks in June and July when days are the longest at around 8 °F difference between the high and low temperature for the day (Figure 11-14 and Figure 11-15).

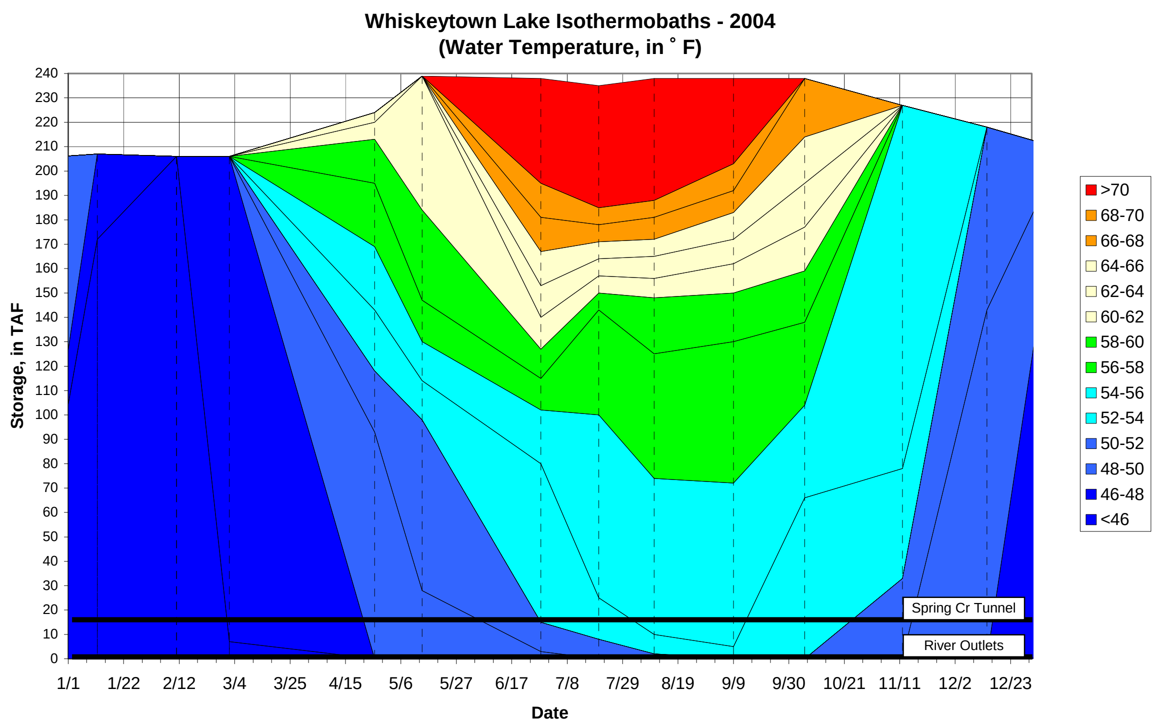

Figure 11-33. Whiskeytown Lake isothermobaths in 2004.

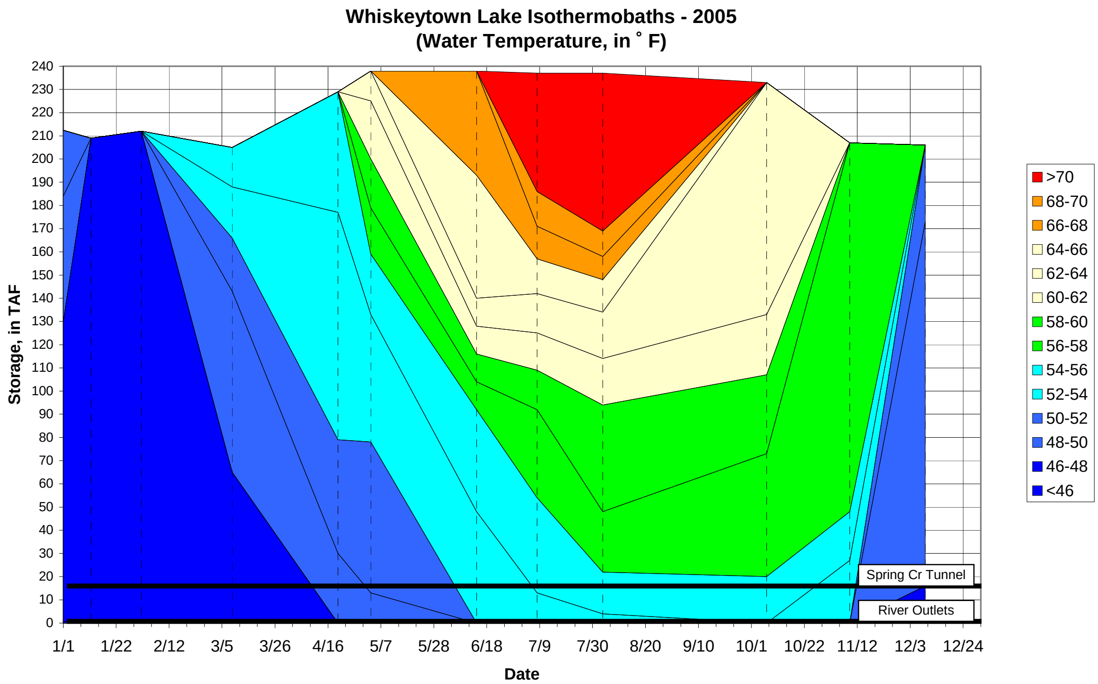

Figure 11-34. Whiskytown Lake isothermobaths in 2005. Water temperatures in degrees Fahrenheit.

Table 11-4. Spring Creek tunnel release volume, 1999-2004 compared to 2005.

Spring Creek Tunnel Volume (thousand acre feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2005	28.7	26.2	60.2	10.0	60.2	47.7	51.7	70.2	68.7	62.6	79.6	109.2	675
2004	54.4	111.7	202.6	123.8	19.4	89.0	133.6	89.8	95.0	156.3	8.7	26.3	1,111
2003	84.0	84.1	86.7	47.7	114.2	109.4	92.8	150.7	137.1	122.2	65.9	49.5	1,144
2002	71.1	27.6	23.2	7.2	41.1	103.8	131.2	131.0	57.8	80.8	16.4	84.0	775
2001	36.9	68.9	75.2	18.7	32.0	92.4	159.2	154.0	108.2	121.6	0.0	53.9	921
2000	83.3	178.2	148.9	122.3	158.7	167.6	193.8	203.4	117.5	31.6	5.4	16.8	1,428
1999	102.0	85.9	130.6	100.0	95.1	128.9	142.0	95.5	91.0	31.7	45.8	39.8	1,088
AVG 99-04 =	72.0	92.7	111.2	70.0	76.8	115.2	142.1	137.4	101.1	90.7	23.7	45.1	1,078
2005 % Diff	-60%	-72%	-46%	-86%	-22%	-59%	-64%	-49%	-32%	-31%	236%	142%	-37%

Based on results of the flow and temperature analysis for juvenile Chinook salmon and steelhead rearing in Clear Creek, we conclude that because operations in the base and future conditions will be the same there will be no change in effect to these species or their critical habitat in Clear Creek. Spring-run Chinook and steelhead populations should be maintained or increase.

Sacramento River

Adult Chinook Salmon and Steelhead Migration, Spawning, and Incubation

Adult steelhead are expected to migrate upstream past Red Bluff primarily from August through December and spawn in the Sacramento River from December through April with peak activity occurring from January through March (McEwan 2001). During the upstream migration time period flows are high during August as water deliveries are being made. Flows get gradually lower as water deliveries are reduced and weather cools so less water is needed for temperature control. Flows are expected to affect upstream migrating steelhead only to the extent that they affect water temperatures. The minimum Keswick release is 3,250 cfs. Steelhead spawning weighted usable area peaks at 3,250 cfs in the upper river reaches and peaks at about 13,000 cfs in the lower reach, forty miles further downstream, but with a low variability in availability (FWS 2003). Based on the results of the PHABSIM analysis there is no evidence that the 3,250 cfs flow level does not provide adequate physical habitat to meet the needs of all steelhead life stages in the Sacramento River. Flows during the summer greatly exceed this amount to meet temperature requirements for winter–run Chinook spawning. The winter–run Chinook temperature objectives during the summer and run-of-the-river temperatures the rest of the year result in water temperatures suitable for year-round rearing of steelhead in the upper Sacramento River. This reach of the Sacramento River provides the best steelhead habitat and greatest use. Therefore, we have concluded the current and future operations are not likely to adversely affect steelhead adults or their critical habitat in the upper Sacramento River.

Winter–run Chinook migrate upstream during December through June. Spring–run Chinook migrate from March into October, although the run is nearly complete by the end of June. Fall–run and late fall–run are migrating between about July and December so that Chinook salmon are migrating upstream in the Sacramento River during all months of the year (Figure 16-6). Winter–run spawning peaks in May through July and spring–run spawning peaks in August and September. Redd counts in recent years (2001 – 2007) showed no spawning peak in the Sacramento River during the expected spring–run Chinook salmon spawning period until October when the redds were considered fall–run redds (DFG aerial redd count survey data). Keswick average monthly releases between January and October range from a low of 3,250 cfs during dry years in all scenarios in January – April and October to a high of 54,000 cfs during flood control releases in the wettest years in January and February. The largest difference in flow between the current and future operations will be slightly higher releases in July and slightly lower releases in September, October, and June in the future. Flows at the low end of the range of projected flows (3,250 cfs) provide enough spawning area for approximately 14,000 winter–run Chinook (FWS 2003). Under higher levels of escapement spawning habitat at a minimum flow of 3,250 cfs may become limiting in the future. If escapement increases significantly to near recovery goals, the flow-versus-habitat relationships should be reassessed at the higher escapement levels. During the winter run spawning season flows would be high enough for temperature control to provide adequate spawning habitat within river reaches where winter-run spawn.

The lower flows in September and October would lower the amount of spring–run Chinook salmon spawning habitat. Spring–run spawning habitat was not estimated but is not limiting the population because few Chinook spawn in the mainstem Sacramento River during the spring–run spawning period, (i.e. there is plenty of space with suitable spawning habitat for the ones that are there).

During very wet years monthly flows as high as 53,000 cfs could occur during upstream migration for adult winter–run Chinook. During winter–run Chinook spawning, flood control peak flows above 50,000 cfs could occur and when combined with tributary inflow could potentially affect redd survival (Table 11-3). Attempts are made to spread flood control releases out when possible. When the high peaks occur egg-to-fry survival could decrease for a brood year due to redd scouring or entombment. Long-term habitat benefits from high flood control flows should include gravel recruitment from streamside sources enhancing spawning gravel, instream woody debris recruitment, and establishment of new cottonwood seedlings. The population effects should be maintained or better egg-to-smolt survival rates in the future. Flood control releases would rarely occur during winter-run Chinook spawning and they are the one run with the least exposure to redd scour risk.

Most of the winter–run Chinook spawning (98 percent) in recent years with better access to upstream habitat has occurred upstream of Balls Ferry (Figure 11-38). Water temperatures during winter–run spawning season can be maintained below 56 °F down to Balls Ferry in about 90 percent of years in May through August and 50 percent of years in September. Temperatures in the future modeling scenarios (7.1 and 8.0) would be slightly increased (1 – 2 °F) in the driest 10 percent of years with the greatest increase in September (Figure 11-35). Temperatures at Bend Bridge in about 20 percent of years in May, 30 percent of years in June, 40 percent of years in July, and 80 percent of years in August and September would exceed 56 °F (Figure 11-36). They would exceed 56 °F about 20 percent of years in October. The highest water temperatures of the year would occur in August through October during dry years as the cold-water pool is depleted. During the years when 56 °F cannot be maintained the cold-water pool storage in Shasta Reservoir would not be sufficient to maintain cool temperatures throughout the summer and decisions would have to be made as to how to allocate the available cool water throughout the warm weather period. Figure 11-37 shows that end of September storage would be reduced in the future compared to current operations in the drier 70% of years. End of September storage would be below 1.9 million acre feet in about 10% of years in the future.

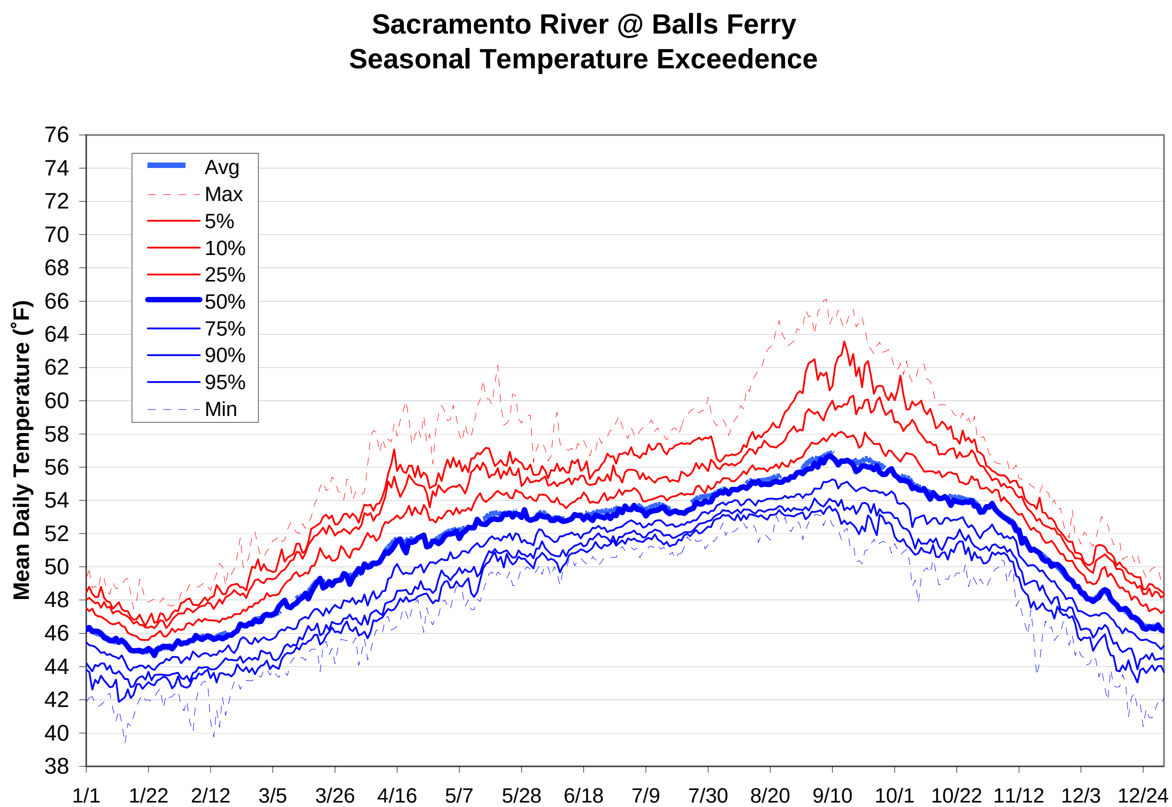

Figure 11-35. Water temperature exceedence at Balls Ferry under study 8.0 from CalSim-II and weekly temperature modeling results.

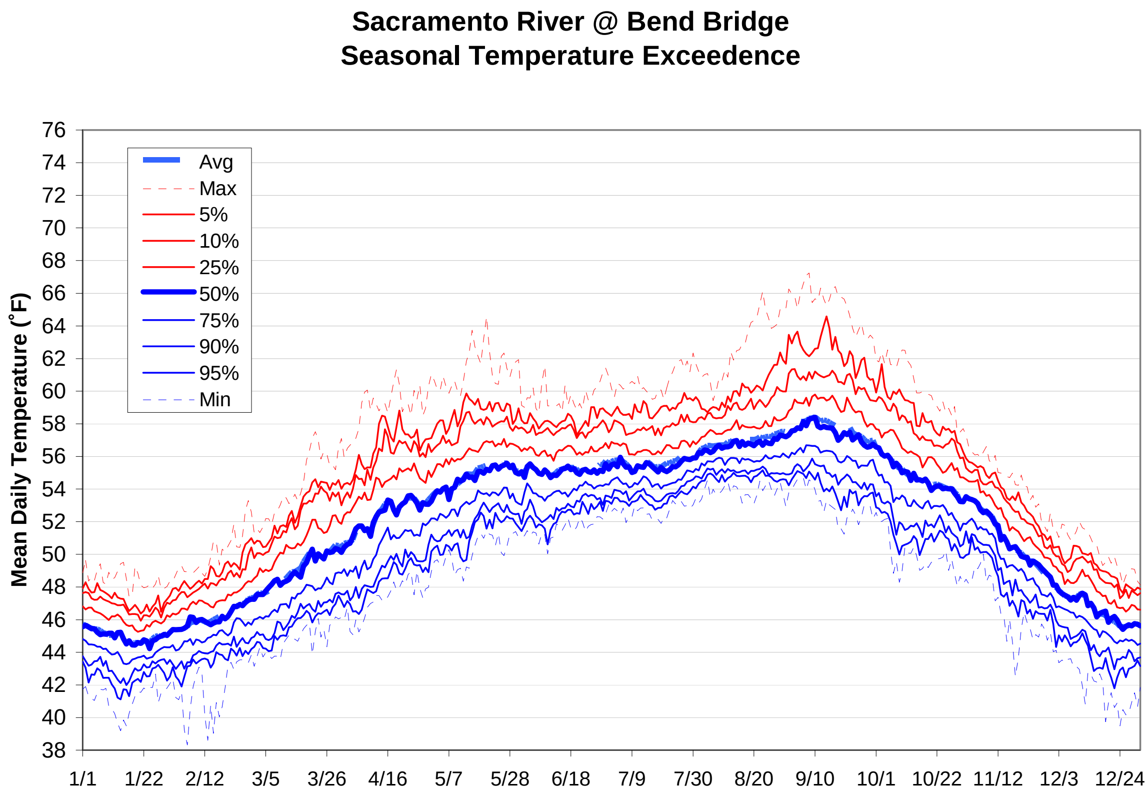

Figure 11-36. Water temperature exceedence at Bend Bridge under study 8.0 from CalSim-II flow and weekly temperature modeling results.

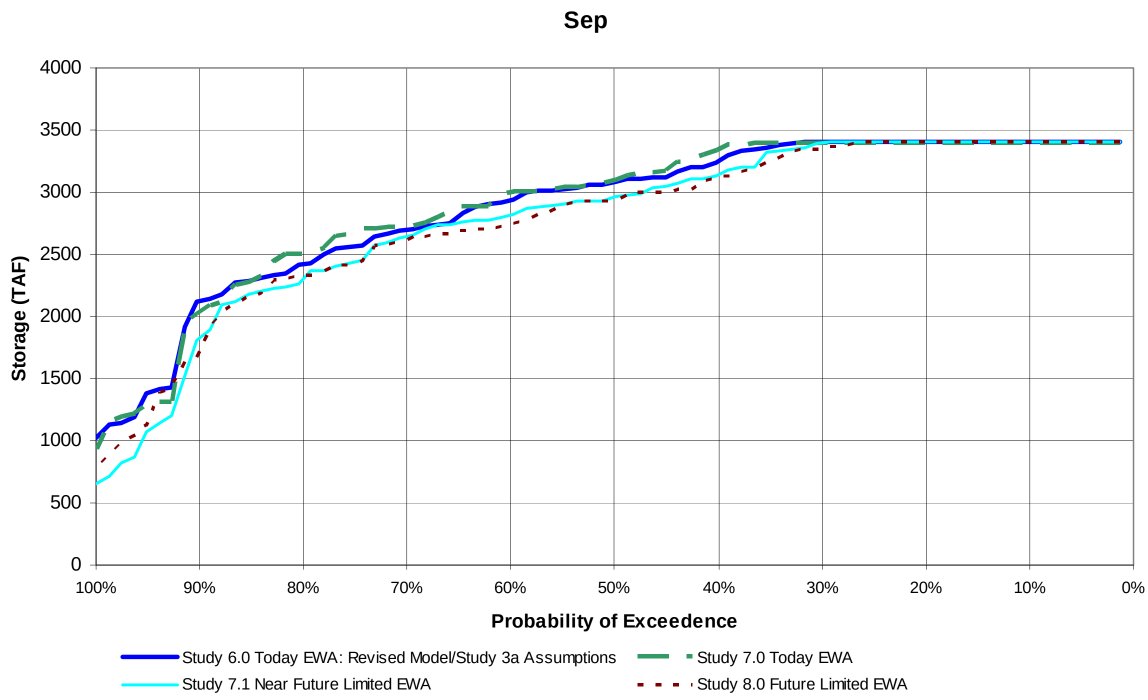

Figure 11-37. September storage in Shasta Reservoir. Study 6.0 represents 2004 operations, study 7.0 repesents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

Increased flows for the Trinity River restoration program have decreased the ability to maintain cool temperatures for winter-run Chinook and other species in the Sacramento River. The egg incubation lifestage requires the coolest water temperatures for Chinook salmon. Therefore, operations strive to provide temperatures suitable for successful egg to fry survival. Since temperature requirements are less stringent for later lifestages it is assumed that providing egg incubation temperatures in the controllable section of the Sacramento River will adequately protect the later lifestages. Effects of water temperature on egg incubation are evaluated using the Reclamation water temperature related egg mortality model. The model is described in Appendix L. Figure 11-43 shows the average percent mortality of Chinook salmon eggs and pre-emergent fry in the Sacramento River through all years modeled based on water temperature while eggs are in the gravel. The model projects that water temperature related mortality would be slightly higher for all runs in the future (study 7.1 and 8.0) than under current operations (study 7.0). The greatest change in mortality would occur in critical year types and is greatest for spring–run. Mortality would be higher under near future operations (Study 7.1) than under future operations (Study 8.0).

During dry years only about one percent of winter–run eggs are projected to suffer mortality but in critically dry years about 10 to 15 percent would suffer mortality on average (Figure 11-39). This is an increase from 7 percent under current operations. Mortality would occur primarily in six of the years used in the modeling (Figure 11-40). The hydrological period contains twelve critically dry years, which is 15 percent of the years used in modeling.

During dry years about a 18 percent of spring–run eggs could suffer mortality under current operations and 23 percent under future operations (Figure 11-41). During critically dry years about 49 percent mortality occurs for current operations (study 7.0) and about 65 percent in future scenarios.

Higher egg mortality occurs for spring-run than for winter-run because temperature management in the Sacramento River focuses on the winter run spawning and egg incubation period. Eight years in the hydrological record would have spring-run egg mortality of over 50 percent (Figure 11-42). Cold water is largely depleted by the end of the winter-run incubation period in these dry years, resulting in warmer water during spring-run Chinook egg incubation. A relatively small percentage of the total Central Valley spring–run population spawns in the mainstem Sacramento River. Therefore tradeoffs required to balance the cold water needs of winter-run Chinook and spring-run Chinook should continue to favor winter-run because the entire winter-run population spawns in the Sacramento River. The effects of changes in temperature patterns are of greater consequence to the winter-run population than to the spring-run population.

The Sacramento River exhibits a range of daily temperature fluctuation depending on distance downstream from the dam and whether water comes out of Keswick during day or at night. The effect at Colusa (Figure 11-9 and Figure 11-10) compared to Balls Ferry (Figure 11-3 and Figure 11-4) shows a greater daily temperature fluctuation upstream at Balls Ferry than downstream at Colusa.

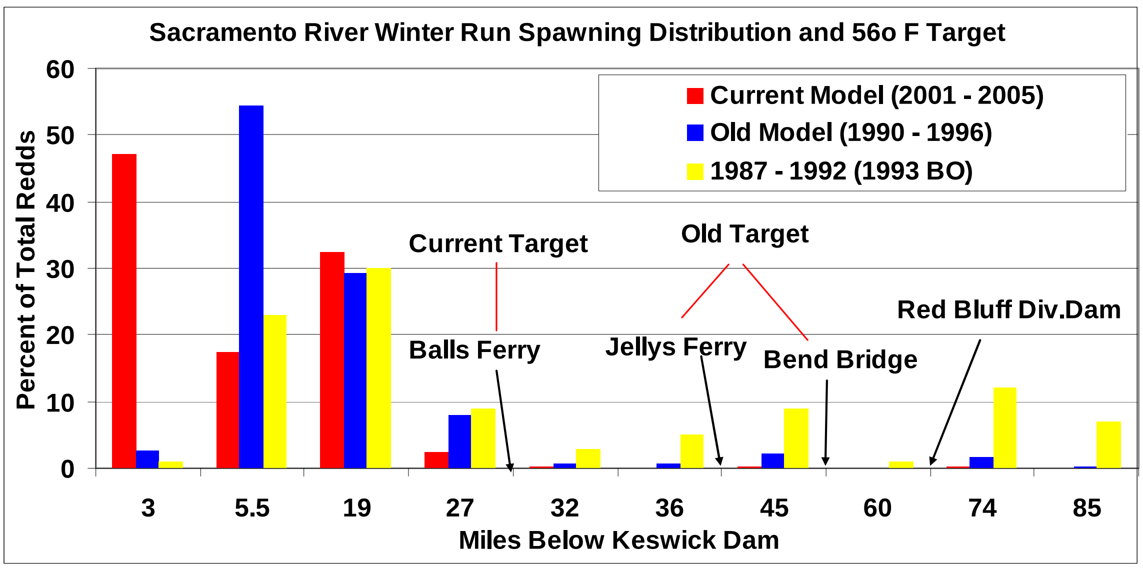

Figure 11-38. Winter-run Chinook salmon spawning distribution through time relative to water temperature targets.

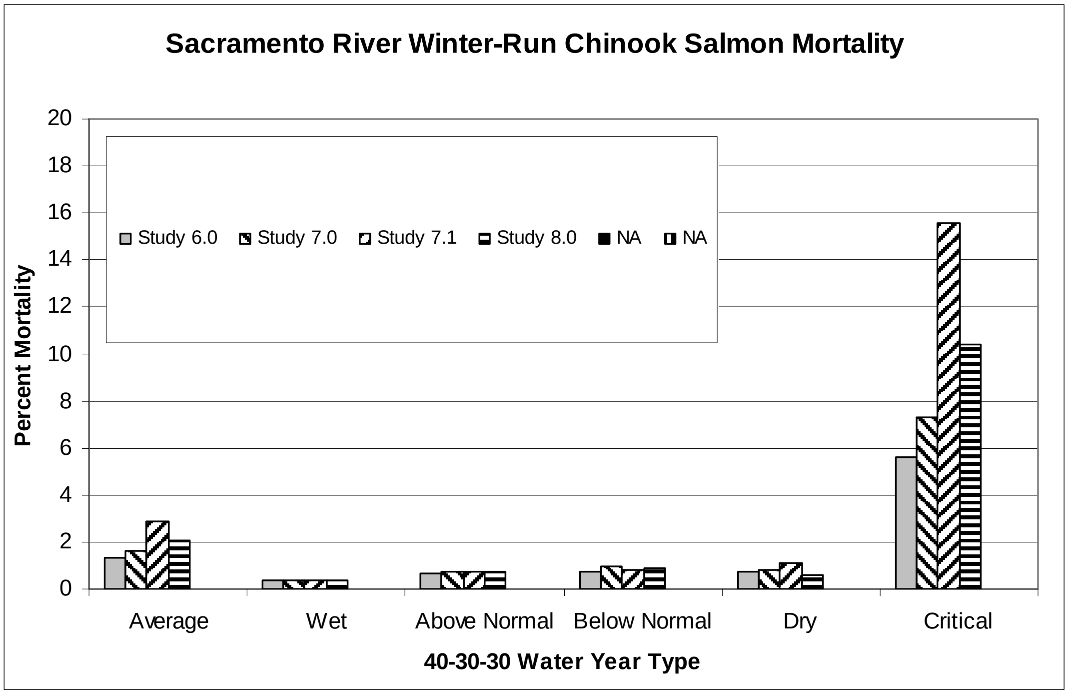

Figure 11-39. Winter run Chinook average egg mortality by water year type from Reclamation egg mortality model. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

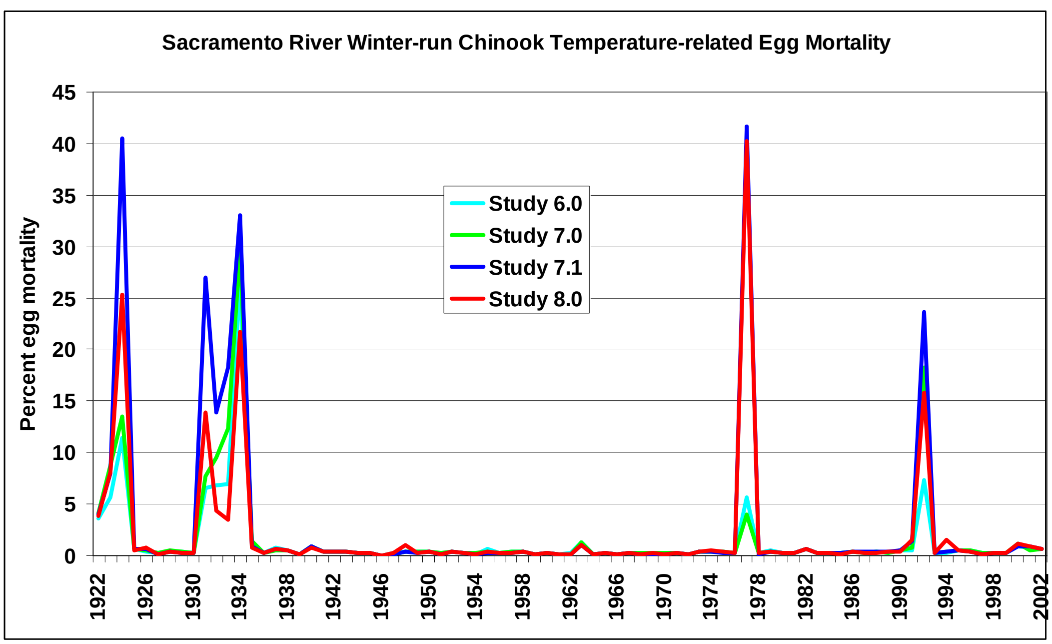

Figure 11-40. Winter run Chinook egg mortality from Reclamation egg mortality model by year in hydrological record. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

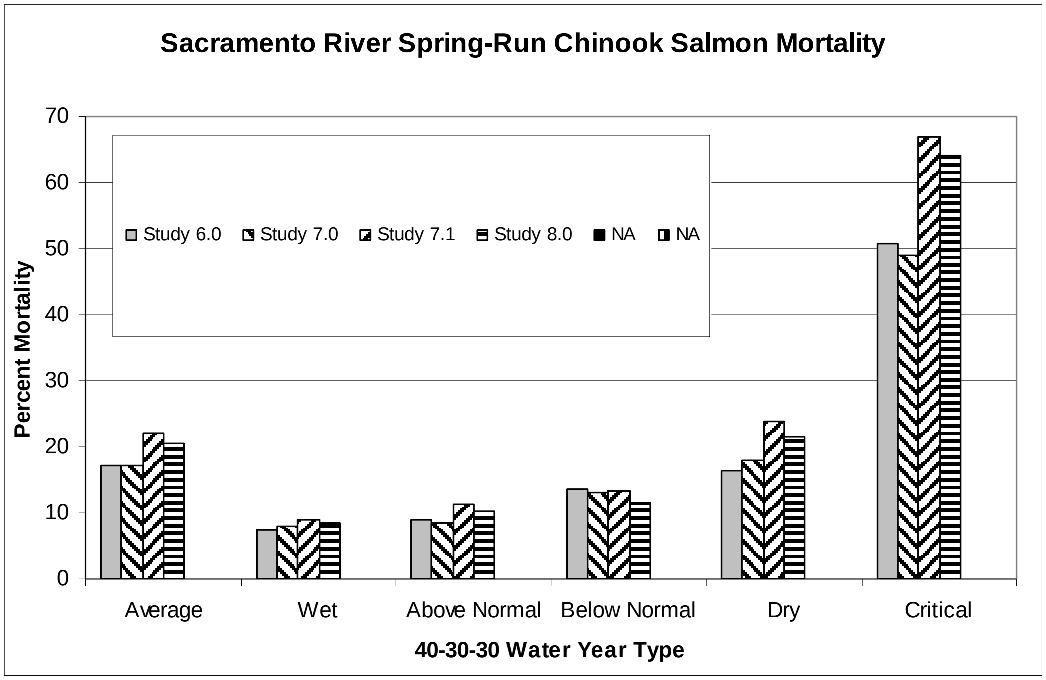

Figure 11-41. Spring run Chinook egg mortality from Reclamation egg mortality model by water year type. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

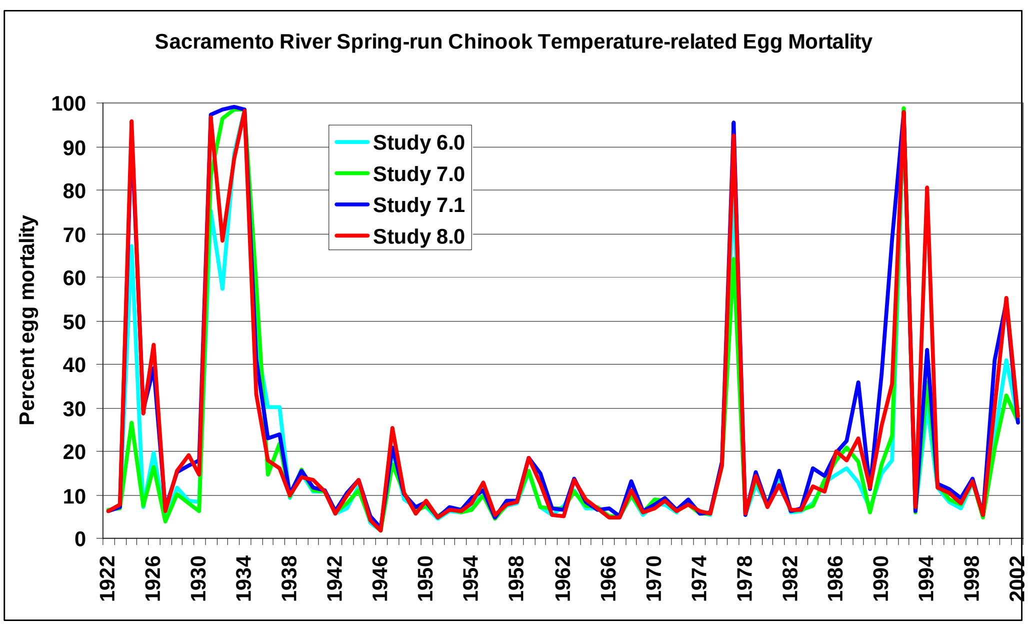

Figure 11-42. Spring-run Chinook egg mortality from Reclamation egg mortality model by year in hydrological record. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

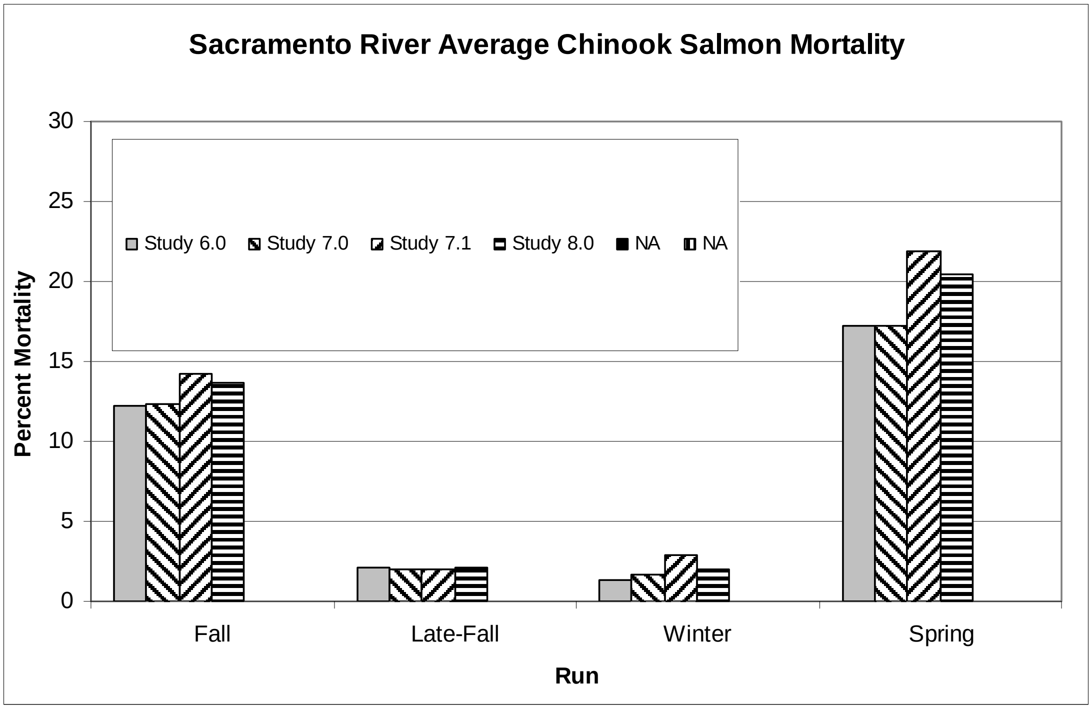

Figure 11-43. Average yearly egg mortality from Reclamation egg mortality model between studies for all four runs in the Sacramento River. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

Salmod Modeling Results (Sacramento River Only)

Salmod is a computer model that simulates the dynamics of freshwater salmonid populations. Salmod was applied to this project because previous reviews recommended a broader quantitative approach to the assessment than was provided by Reclamation's salmon egg mortality model. Model documentation is included in Appendix P. Salmod was developed for the Trinity River and has been adapted for use on the Sacramento River with fish and habitat data specific to the Sacramento River. A thorough review and update of model parameters and techniques on the Klamath River enabled a smooth transfer of relevant model parameters to the Sacramento River (Bartholow, 2003). Salmod was modified from the original for the Shasta Lake Water Resources Investigation in response to concerns posed by DFG, and from the original version used for the Sacramento River, which was set for Keswick Dam to Battle Creek. The study area for the Salmod analysis covers a 53-mile stretch of the Sacramento River from Keswick Dam to just above the Red Bluff Diversion Dam (RBDD). Keswick Dam forms the upstream boundary of anadromous fish migration in the Sacramento River, and the RBDD marks the current downstream limit of habitat that has been consistently classified by mesohabitat type and evaluated by the USFWS to estimate flow versus habitat availability relationships (data needed to run the model).

Results from SALMOD are best evaluated by examining the direction of change between operational scenarios rather than looking at absolute numbers of fish. Percent change from study 7.0 to study 6.0, 7.1 and 8.0 are presented as a representation of magnitude of potential change.

Salmod Inputs

Salmod was run using a spawning population of 8,591 winter run (the average escapement from 1999-2006) and 1,000 spring run (Table 11-5). Input variables, represented as weekly average values, include streamflow from CalSim-II modeling results, water temperature from the Sacramento River daily model, and number and distribution of adult spawners from DFG aerial redd survey data. The study area is divided into individual mesohabitats (i.e., pool, riffle, and run) categorized primarily by channel structure and hydraulic geometry, but modified by the distribution of features such as fish cover. Habitat quality in all computational units of a given mesohabitat type changes similarly in response to discharge variation.

Even though Salmod can simulate small numbers of fish, it is not prudent to do so. Because the model is deterministic, it relies on parameters that represent population means derived, or supported, by the "law of large numbers." When populations are low, mean responses are quickly affected by environmental stochasticity and individual variability, factors Salmod was not designed to address. The recent average escapement for spring run Chinook to the mainstem river was less than 500 adult spawners, which may be inappropriate because the number of spawners is low. The term "low" is arbitrary, but populations under 500 were identified as being too low for accurate results using Salmod. A starting adult population of 1,000 spring run was used.

Table 11-5. Number and Distribution of Spawning Fish (Adult Male and Female) Incorporated into Salmod Model.

Reach	Fall-Run	Late Fall-Run	Winter-Run	Spring-Run
California Department of Fish and Game (Grand Tab, 1999 – 2006 Average Escapement broken down into spawning distribution from redd surveys)				
Keswick to ACID	6,658	4,725	3,591	43
ACID to Highway 44 Bridge	4,011	2,096	1,761	188
Highway 44 Bridge to Airport Road Bridge	7,175	3,123	3,041	324
Airport Road Bridge to Balls Ferry Bridge	12,405	2,507	163	174
Balls Ferry Bridge to Battle Creek	8,337	767	9	106
Battle Creek to Jellys Ferry Bridge	12,146	282	9	150
Jellys Ferry Bridge to Bend Bridge	8,789	130	17	14
Bend Bridge to Red Bluff Inundation Zone	5,044	67	0	0
Total Adult Spawners	**64,565**	**13,697**	**8,591**	**1,000**
Potential Eggs	**154,955,000**	**32,865,000**	**12,369,000**	**2,400,000**

Salmod Results

Winter Run

The main output from Salmod is the number of juvenile Chinook emigrating past Red Bluff. It is more useful to examine the change in production between operational scenarios than to look at absolute fish numbers for evaluating effects of water operations. Figure 11-44 shows that there is not much change between current and future operations during most years but in a few critically dry years, when cold water is limited, production is decreased by about 10 to 40 percent. The greatest reductions occur in under near future operations. Starting with an escapement of 8,591, the number of juvenile winter Chinook emigrating remained relatively constant at around four million through most years. Years of low production were 1977, 1935, 1925, 1932, and 1992 (Figure 11-45). These are critically dry year types when egg mortality due to water temperature would be high (Figure 11-46 and Figure 11-47). Study 7.1 experienced the lowest production during each of these dry years and study 7.0 generally had the highest production. Winter-run fry mortality due to water temperature occurred in the same years as egg mortality (Figure 11-48). Mortality of winter-run fry and presmolts due to habitat availability (space) fluctuated slightly but there were no outstanding years or operational scenarios that would appear to have exceptional population level effects (Figure 11-49 and Figure 11-50).

Study 7.0 had higher presmolt mortalities in 1933 and 1978. The juvenile lifestage mortality was generally a small proportion of total passage past Red Bluff. There was little mortality of presmolts or immature smolts due to water temperature in any year under any of the scenarios.

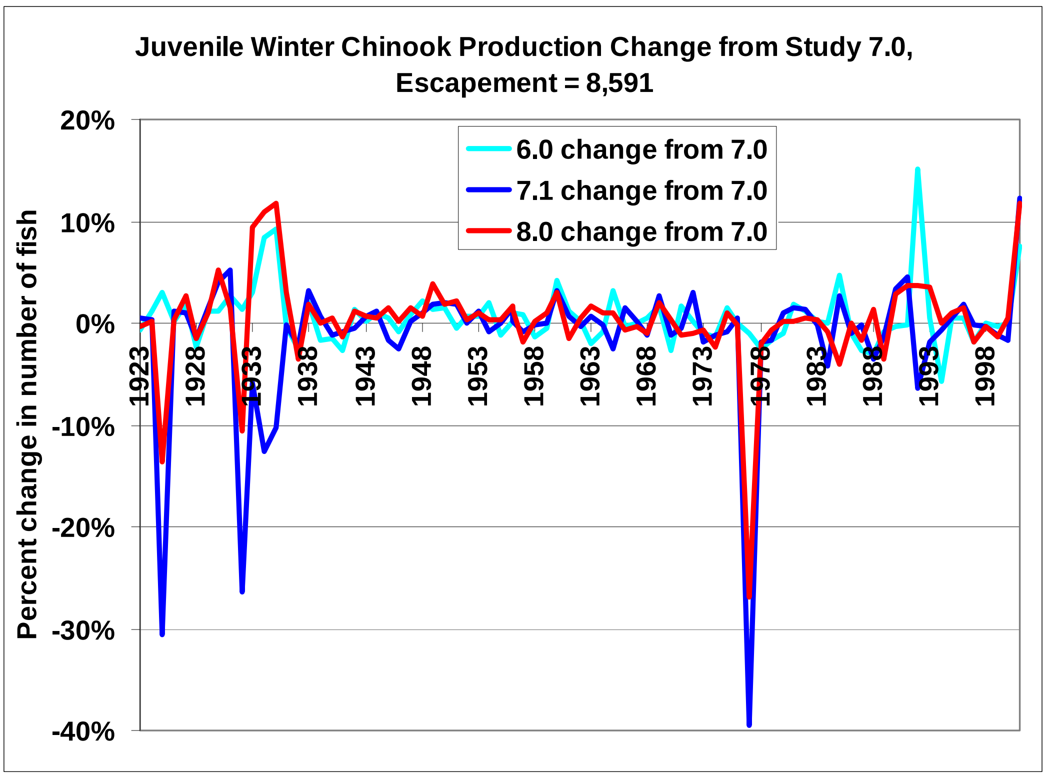

Figure 11-44. Percentage change in juvenile winter-run Chinook production past Red Bluff of operational scenarios compared with the current scenario from the SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations

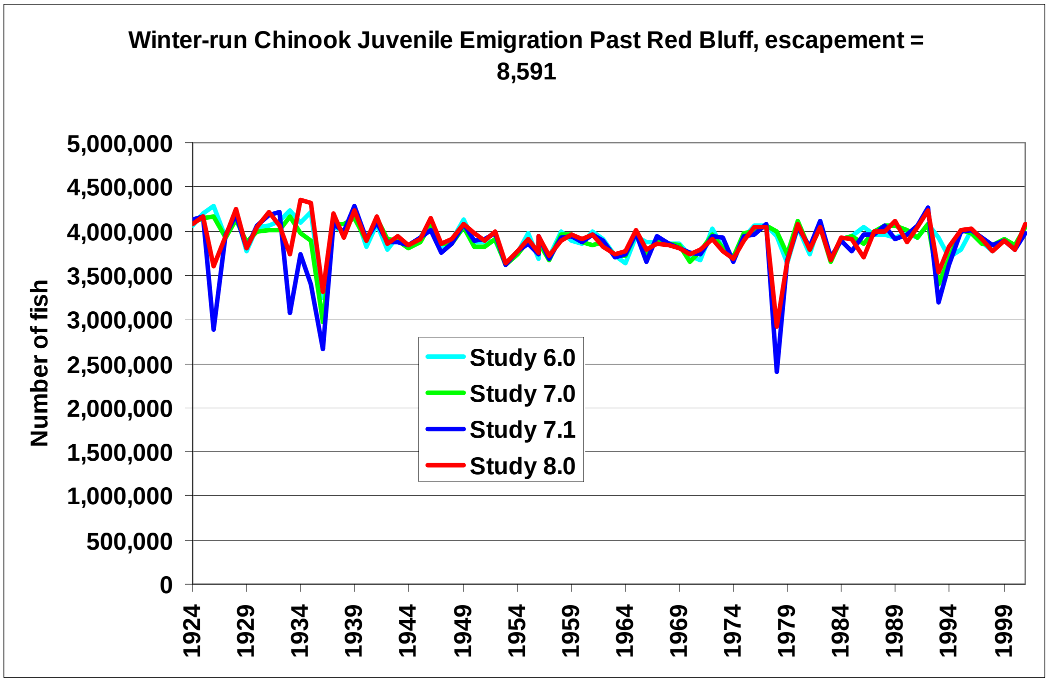

Figure 11-45. Winter-run Chinook juveniles emigrating past Red Bluff by operational scenario, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

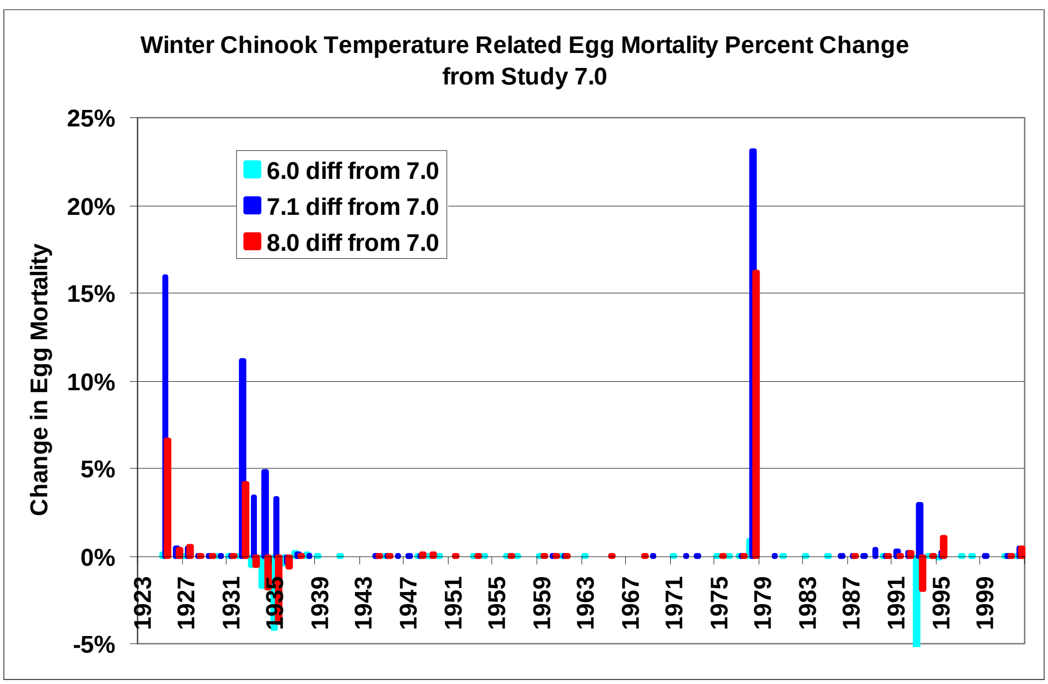

Figure 11-46. Percentage change in juvenile winter-run Chinook egg mortality in operational scenarios compared with the current scenario from the SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations

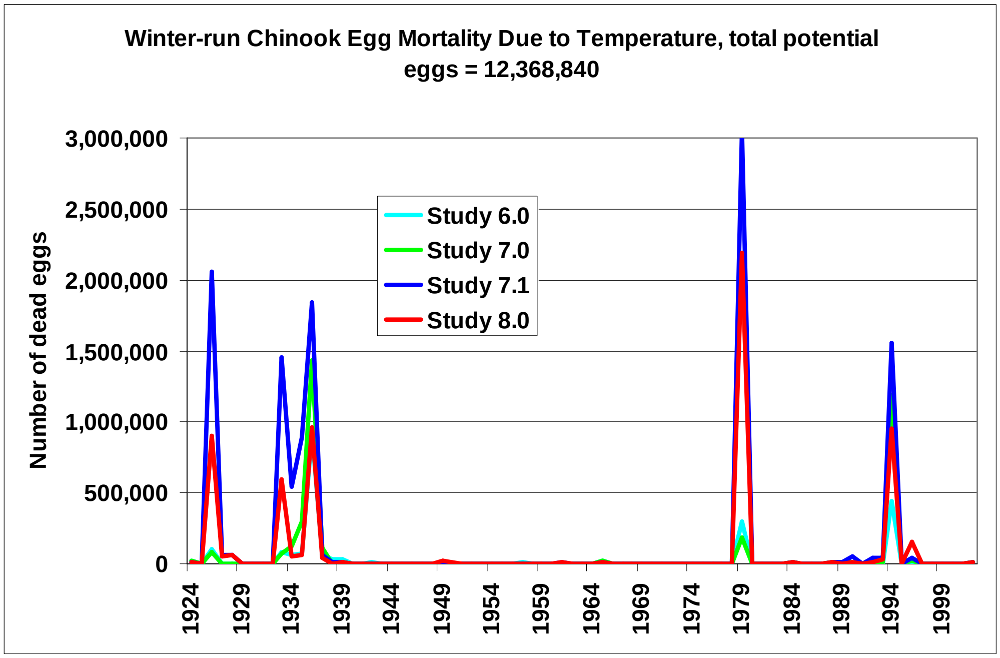

Figure 11-47. Winter-run egg mortality due to water temperature by operational scenario with 12,368,840 total potential eggs, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

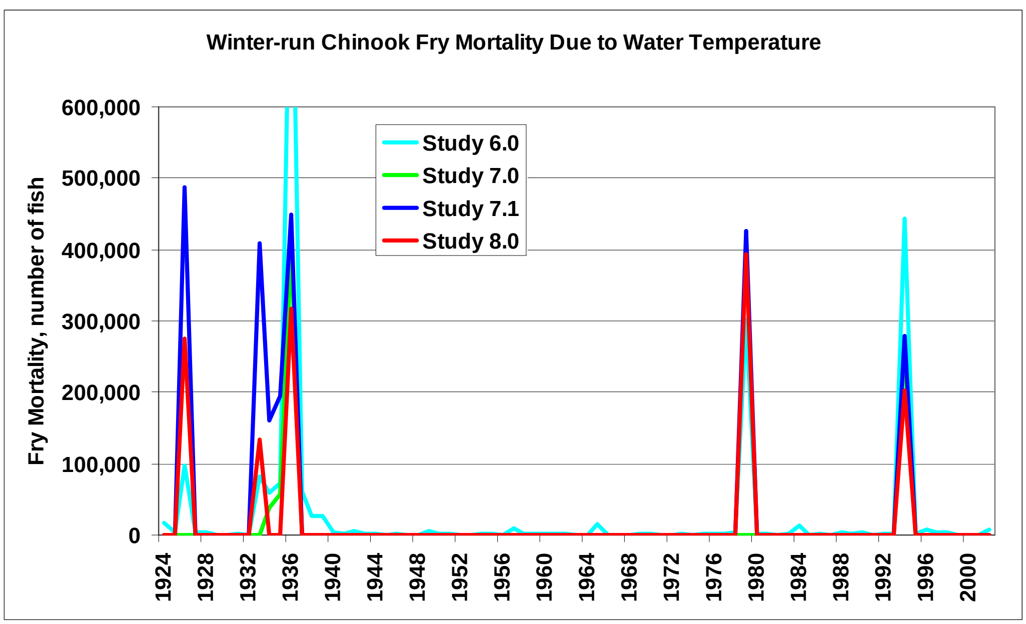

Figure 11-48. Winter-run Chinook fry mortality due to water temperature by operational scenario. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

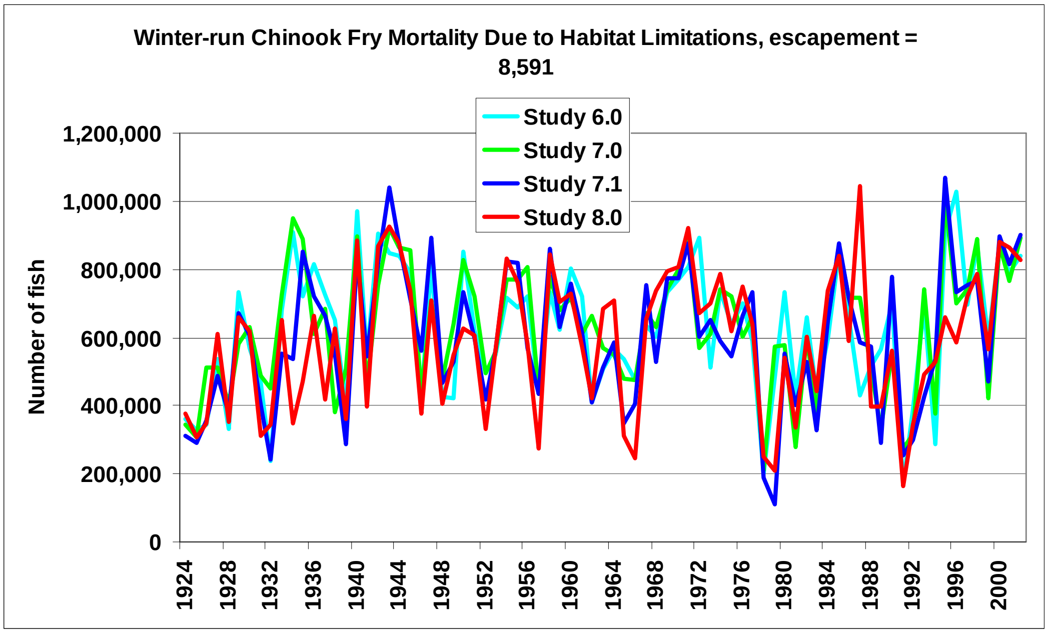

Figure 11-49. Winter-run Chinook salmon fry mortality due to habitat limitations by water operational scenario, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

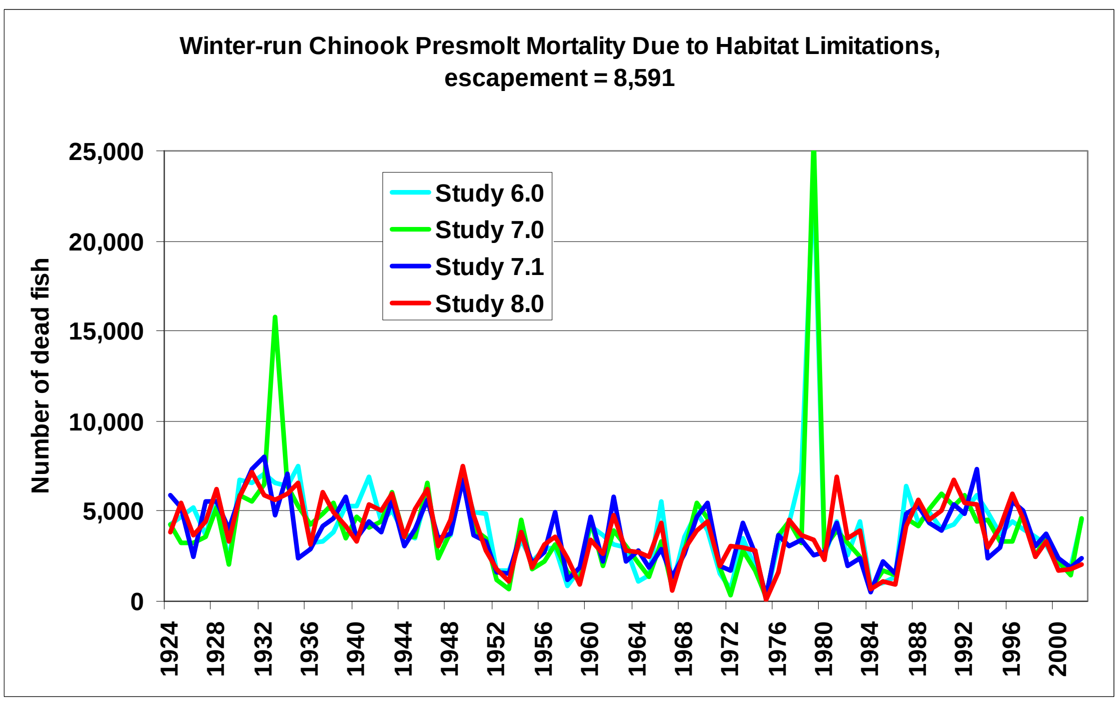

Figure 11-50. Winter-run Chinook presmolt mortality due to habitat limitations by operational scenario, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

Spring Run

Figure 11-51 shows the percent change in spring-run Chinook production for study 6.0, 7.1 and 8.0 compared with study 7.0. As with winter-run, the main differences are in the critically dry water years. The number of Sacramento River spring-run Chinook emigrating remained relatively constant at 800-900,000 through most years (Figure 11-52). Years of low production were 1932, 1935, 1934, 1925, 1978, 1993, 1933, 1927, and 2002 (Figure 11-51). These are critically dry year types when egg mortality due to water temperature would be high (Figure 11-53). There were not major differences in mortality among the studies. Study 7.0 had the highest mortality in some years and study 7.1 and 8.0 were highest in others. Mortality of spring-run fry due to habitat availability (space) fluctuated slightly but there were no outstanding years or operational scenarios that would appear to have exceptional population level effects (Figure 11-54). The years of very low fry mortality were the ones when most of the mortality occurred to the eggs from high water temperature. There was no mortality of presmolts or immature smolts due to habitat availability. There was no mortality of fry, presmolts, or immature smolts due to water temperature in any year under any of the scenarios.

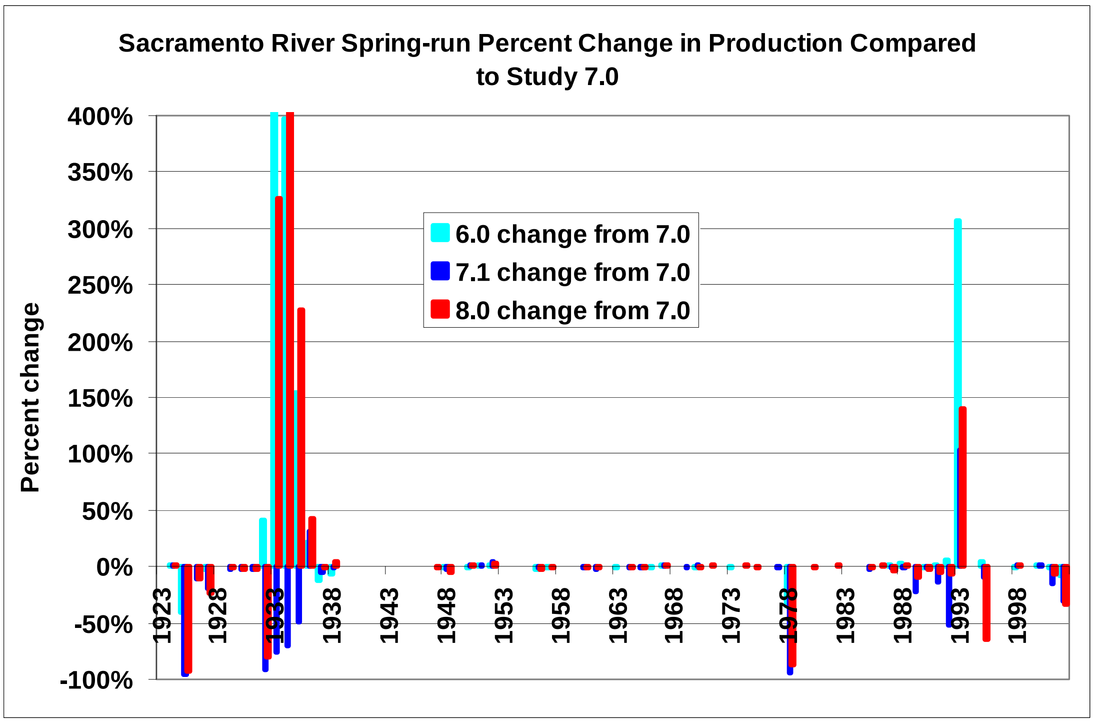

Figure 11-51. Percentage change in juvenile spring-run Chinook production past Red Bluff of future operational scenarios compared with the current scenario from the SALMOD model. Study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

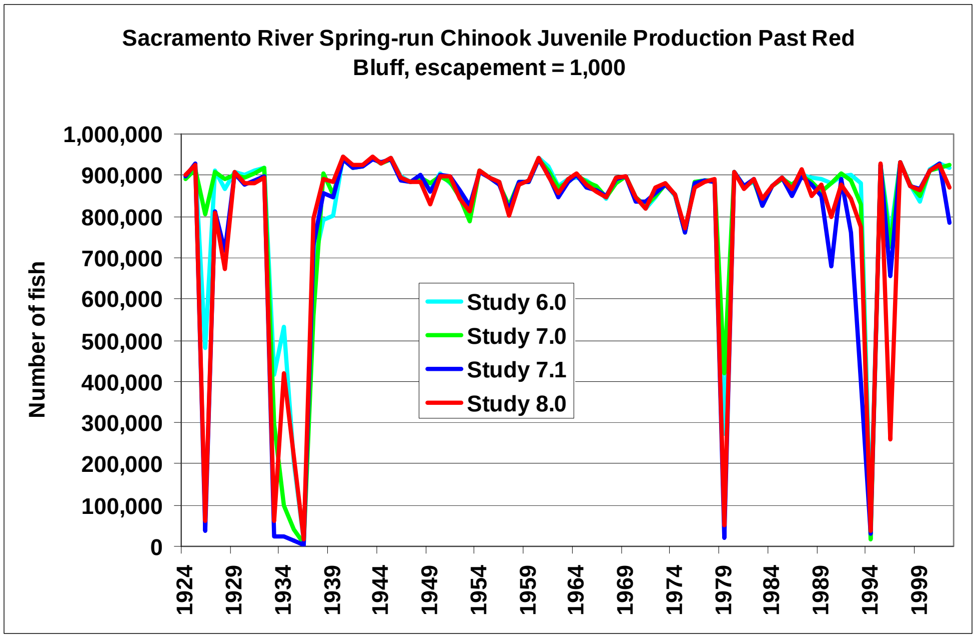

Figure 11-52. Juvenile Sacramento River Spring-run Chinook production emigrating past Red Bluff by operational scenario with 1,000 spawners, from Salmod model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

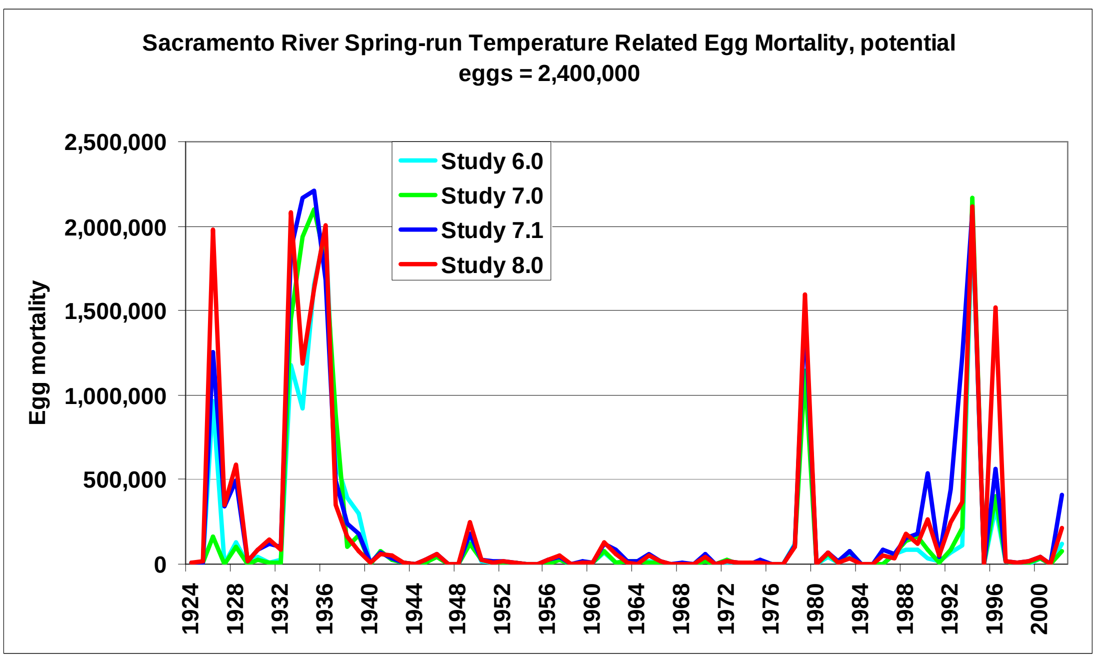

Figure 11-53. Sacramento River spring-run egg mortality due to water temperature by operational scenario with 2,400,000 total potential eggs, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

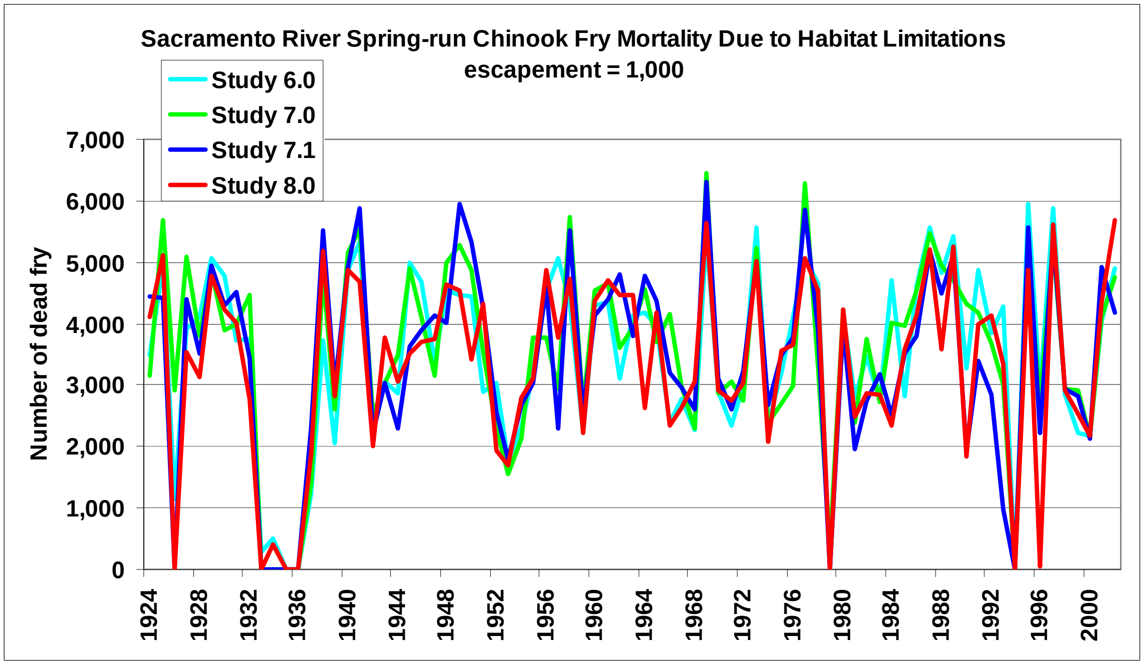

Figure 11-54. Spring-run Chinook salmon fry mortality due to habitat limitations by water operational scenario, 1923-2002 from SALMOD model. Study 6.0 represents 2004 operations, 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

Interactive Object-Oriented Salmon Simulation (IOS) Winter-Run Life Cycle Modeling Results

The IOS Winter-Run Life Cycle model was used to evaluate the influence of different Central Valley water operations on the life cycle of Sacramento River winter-run Chinook Salmon over an 80 year period using simulated historical flow and water temperature inputs. The model was used to provide a quantitative estimate of project effects to lifestages other than that provided by the Reclamation egg mortality model and to provide a feedback loop from one cohort to the next which is not available in Salmod. The IOS model was seeded with 5,000 spawners for the first four years then allowed to cycle through multiple generations during years 1923-2002. Four runs of the IOS model were completed, each under a different water operation scenario: 1) Study 7.0, 2) Study 6.0, 3) Study 7.1, and 4) Study 8.0.

The effect of different water operation scenarios on the Sacramento River winter-run Chinook salmon population was evaluated by comparing abundance and survival trends at various life stages among the three runs of the IOS Model. The annual abundance of returning spawners and juveniles out-migrating past RBDD were reported for each model run. Trends in survival through time at various life stages were examined to explain patterns seen in yearly escapement under each water operation scenario. Average differences in winter-run survival between water operation scenarios were translated into average differences in annual escapement to better evaluate the potential impact each water operation scenario has on the winter-run abundance in the Sacramento River. Finally, predicted monthly spatial distribution of juvenile salmon during model runs was reported.

Model Settings

Reach specific, daily CalSim-II discharge (CalSim-II monthly results disaggregated to daily) and daily HEC-5Q water temperature provided the basic inputs for model runs. In addition, monthly average Delta conditions (inflow, exports, DCC operations, temperature) were provided by CalSim-II. Most model settings and functional relationships were set as described in detailed IOS model documentation (http://www.fishsciences.net/projects/NODOS/winter_run_IOS_model_documentation.pdf). Other model settings were set specifically for this analysis and at constant values throughout the 80-year run of the IOS model. The use of constant values for parameters with little uncertainty or with lesser management significance is desirable because it simplifies the model and facilitates easier interpretation of results. The RBDD and ACID dams were set to be "open" to allow adult spawners access to upstream spawning reaches. Annual hatchery supplementation was set at zero. Adult harvest rates were set at approximate historical averages. Age-3 and age-4 ocean harvest rate was set at 0.3 and 0.5, respectively. In-river sport harvest was set at 0.10. The first four years of the model run were each seeded with 5,000 adult spawners.

Results

Measures of winter-run Chinook salmon abundance increased through time under water operation scenario 7.0; ultimately ending near 45,000 adult spawners in 2002 (Figure 11-55). Similarly, passage of juveniles past RBDD increased through time and ended around 14 million in 2002.

Even with large inter-annual variations in winter-run escapement and juvenile RBDD, winter-run abundance appears to show a strong increasing trend through time under water operation scenarios 6.0, 7.1, and 8.0 (Figure 11-55; Figure 11-56). Winter-run abundance increased at a similar rate for all three alternative water scenarios until the late 1970's when the escapement trend for study 6.0 continued to increase, while the escapement levels for studies 7.1 and 8.0 seemed to level off (Figure 11-55; Figure 11-56). For studies 7.1 and 8.0, winter-run abundance began at the initial spawner seeding level of 5,000 fish and slowly grew through time to end at approximately 35,000 fish in 2002 (Figure 11-55). For study 6.0, winter run abundance reached approximately 35,000 fish in the late 1970's and continued to increase to approximately 45,000 fish by 2002 (Figure 11-55).

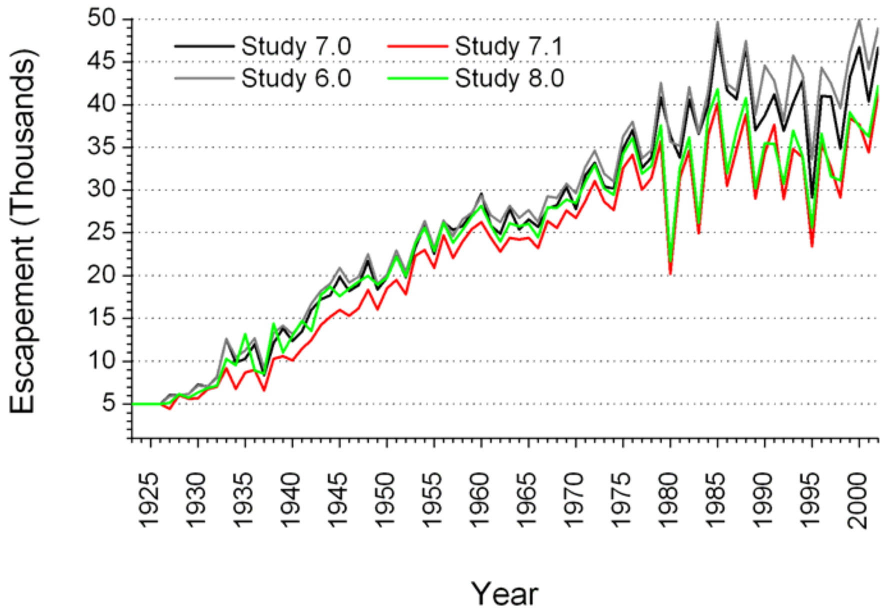

Figure 11-55. Annual winter-run Chinook salmon escapement under four OCAP water operation scenarios, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

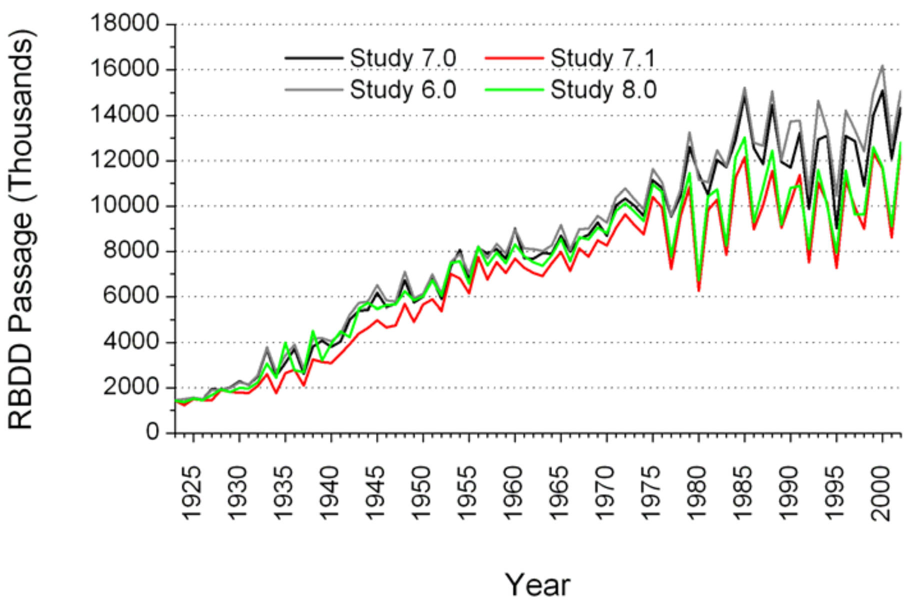

Figure 11-56. Annual Passage of winter-run Chinook Salmon juveniles past Red Bluff Diversion Dam (RBDD) under four OCAP water operation scenarios, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

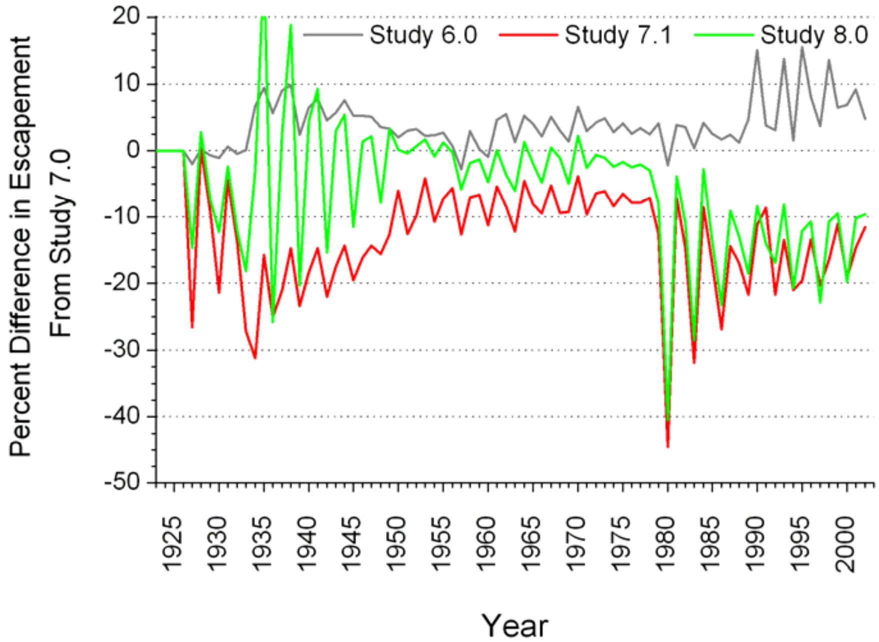

Figure 11-57. Annual percent difference in juvenile survival from emergence to RBDD from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

Annual differences in escapement from water operation scenario 7.0 follow different trends through time for each alternative water operation scenario (Figure 11-57). For study 6.0, the annual percent difference in escapement from study 7.0 increased from zero to near 10% in the late 1930's, then fluctuated near 3% until 1990 when the escapement difference from study 7.0 began fluctuating above 10% and continued through 2002 (Figure 11-57). For study 7.1, the annual percent difference in escapement from study 7.0 fluctuates wildly in the early years from -25% to +20%, stabilizes near 0% from 1948-1978, then decreases and fluctuates around -15% for the remainder of the model run (Figure 3). For study 8.0, the annual percent difference in escapement from study 7.0 decreases to -30% by 1935, then rebounds and fluctuates around -8% until a large decrease in 1980 and fluctuation around -15% for the remainder of the model run (Figure 11-57). The annual differences from study 7.0 for studies 7.1 and 8.0 appear almost identical for years 1980 to 2002 (Figure 11-57).

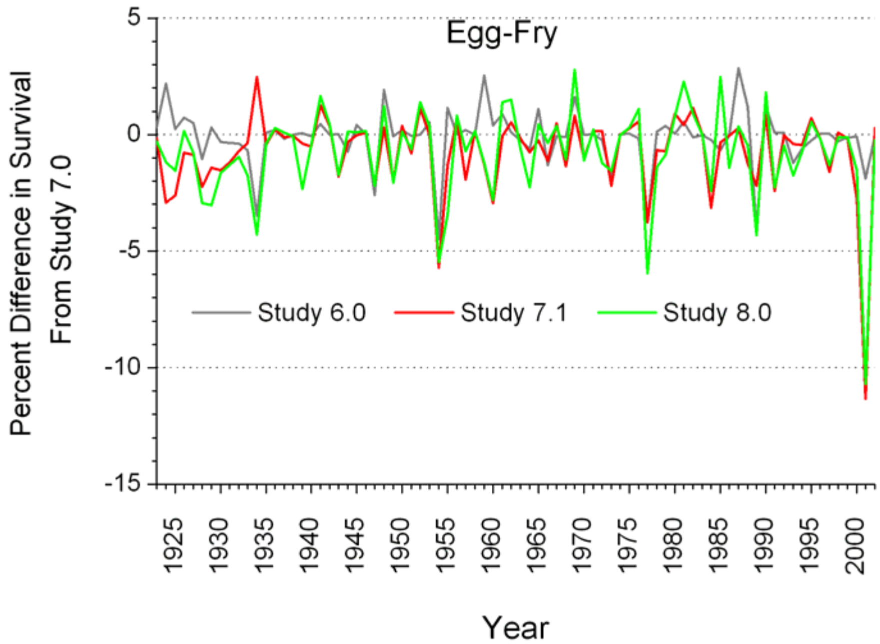

Figure 11-58. Annual percent difference in egg-fry survival from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

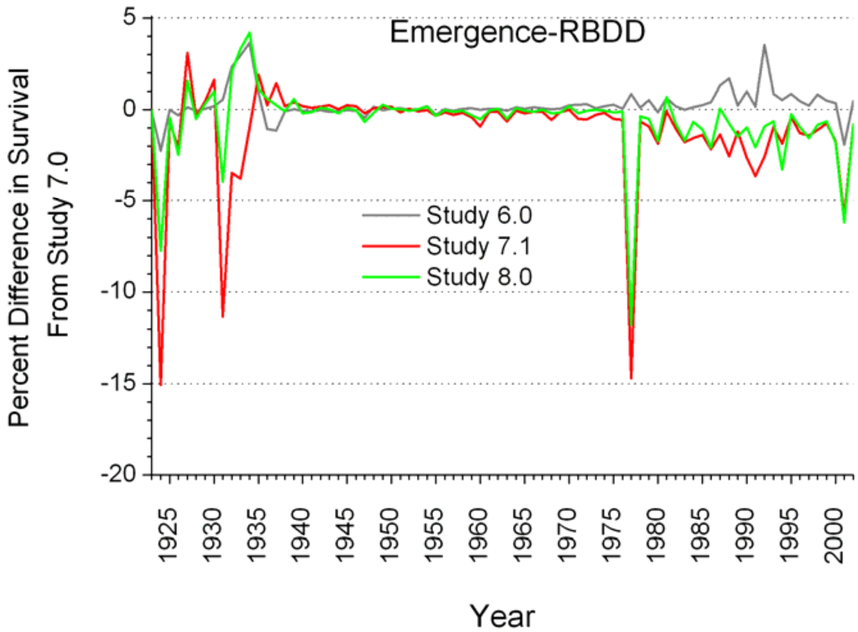

Figure 11-59. Annual percent difference in survival from emergence to RBDD from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

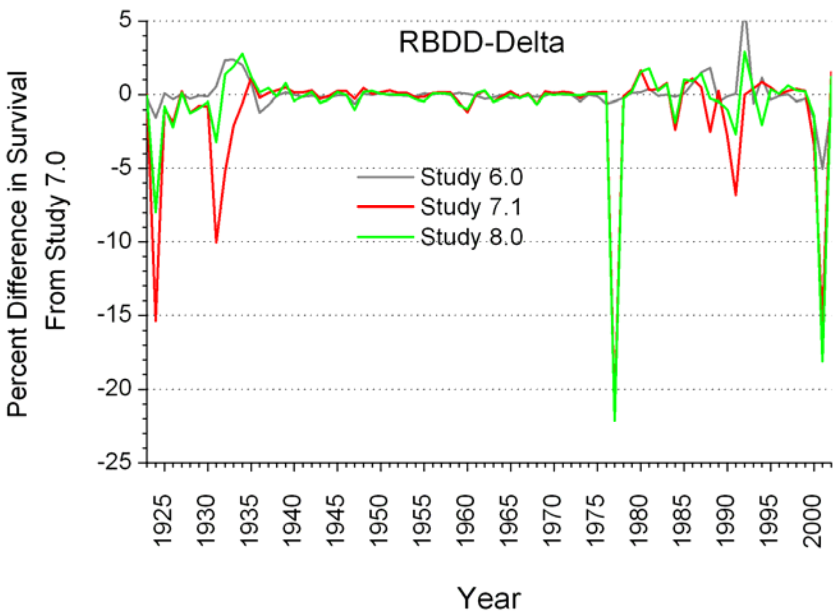

Figure 11-60. Annual percent difference in survival from RBDD to the Delta from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

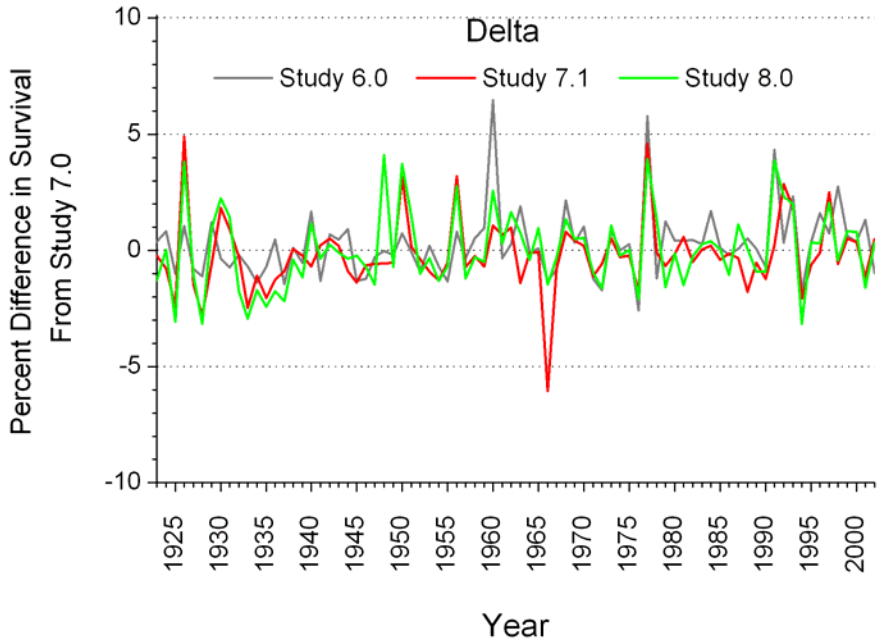

Figure 11-61. Annual percent difference in juvenile Delta survival from water operation scenario 7.0 for water operation scenarios 6.0, 7.1, and 8.0, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

The observed phases in differences in annual escapement from study 7.0 for study 6.0 during the 80-year model run as seen in Figure 3 may be a result of in-river survival trends of juveniles seen in Figure 11-59 andFigure 11-60. The percent difference in survival from study 7.0 for study 6.0 for fry emergence to RBDD passage and RBDD to Delta arrival show an increase in years 1932-1934 (Figure 11-59; Figure 11-60). Because 96 percent of returning spawners are age-3 it is likely that this increase in juvenile in-river survival resulted in the increased difference from study 7.0 observed in adult escapement in the late thirties. Likewise, the later increase in differences in juvenile in-river survival from study 7.0 from 1987 through the late nineties correspond to an increase in differences in adult escapement from study 7.0 for years 1990-2002 (Figure 11-57; Figure 11-59; Figure 11-60).

The two observed differences in annual escapement from study 7.0 for studies 7.1 and 8.0 during the 80-year model run as seen in Figure 11-57 also appear to be predominantly a function of in-river survival trends of juveniles seen in Figure 11-59 andFigure 11-60. The percent differences in survival from study 7.0 for studies 7.1 and 8.0 for fry emergence to RBDD passage and RBDD to Delta arrival show a sudden, dramatic decrease in 1977 (Figure 11-59; Figure 11-60). Because 96 percent of returning spawners are age-3 it is likely that this large difference in juvenile in-river survival resulted in the large difference observed in adult escapement in 1980 (Figure 11-57). Likewise, the long stable period in differences in juvenile in-river survival from study 7.0 prior to 1977 correspond to a period of increasing stabilization in differences in adult escapement from study 7.0 during a similar time period (Figure 11-57; Figure 11-59; Figure 11-60).

However, unlike in-river juvenile survival, egg-fry survival and Delta survival do not appear to contribute strongly to the trend seen in the observed phases in differences in annual escapement from study 7.0 for studies 6.0, 7.1, and 8.0 during the 80-year model run (Figure 11-57;Figure 11-58;Figure 11-61). Despite large inter-annual variation, the percent differences in survival from study 7.0 for studies 6.0, 7.1, and 8.0 for egg-fry survival and Delta survival show no distinct trend through time (Figure 11-58; Figure 11-61).

Table 11-6. Average survival proportions under four OCAP water operation scenarios and percent difference in average survival from study 7.0 for studies 6.0, 7.1, and 8.0, 1923-2002 fro IOS model. . Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

	Study 7.0	Study 6.0		Study 7.1		Study 8.0	
Survival	Avg. Survival	Avg. Survival	% Diff.	Avg. Survival	% Diff.	Avg. Survival	% Diff.
Egg-Fry	0.273	0.2731	-0.1	0.2713	-0.8	0.2712	-0.8
Emergence-RBDD	0.546	0.5472	0.3	0.5397	-1.1	0.5426	-0.6
RBDD-Delta Arrival	0.3288	0.3289	0.0	0.3256	-1.0	0.3269	-0.6
Delta	0.709	0.7104	0.3	0.7073	-0.2	0.7088	0.0
Overall	**0.0491**	**0.0492**	**0.1**	**0.0478**	**-2.7**	**0.0482**	**-1.8**

For study 6.0, the average survival values across all life stages and spatial locations were very similar to study 7.0 during the 80-year model run (Table 11-6). The overall average survival (egg deposition to Bay arrival) was 0.1% higher for study 6.0 than study 7.0 (Table 11-6). Studies 7.1 and 8.0 had slightly lower average survival values across all life stages and spatial locations than study 7.0 (except Delta survival for study 8.0) during the 80-year model run (Table 11-6).

We translated differences in average survival between study 7.0 and studies 6.0, 7.1 and 8.0 into average differences in the number of smolts entering the ocean and number of adult spawners to better evaluate the impact each water operation scenario may have on winter-run abundance in the Sacramento River. We found that study 6.0 produced on average 87,000 more smolts entering the ocean and ultimately 1,800 more adult spawners annually than study 7.0. Study 7.1 produced on average 300,000 fewer smolts entering the ocean and ultimately 6,200 fewer adult spawners annually than study 7.0. Study 8.0 produced on average 176,000 fewer smolts entering the ocean and ultimately 3,600 fewer adult spawners annually than study 7.0.

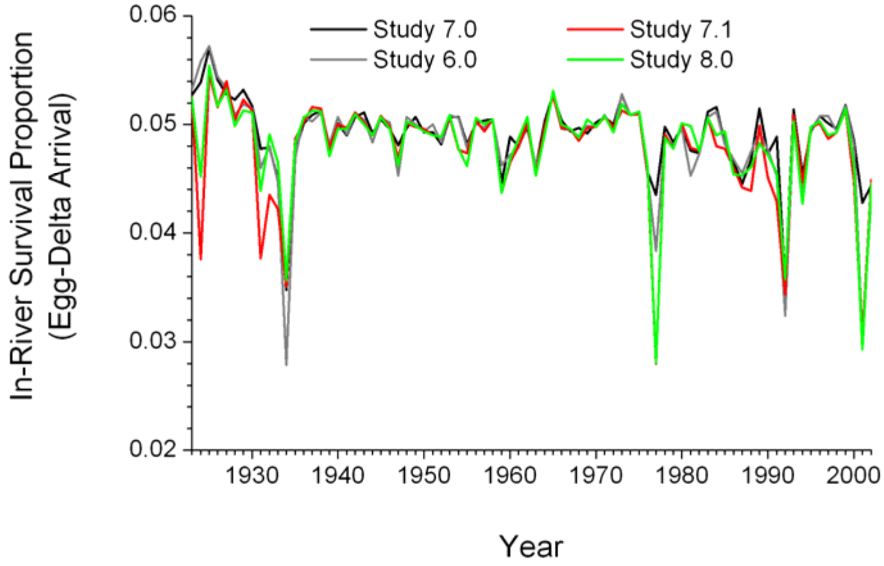

Figure 11-62. Annual winter-run Chinook salmon in-river survival (egg-Delta arrival) under four OCAP water operation scenarios, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

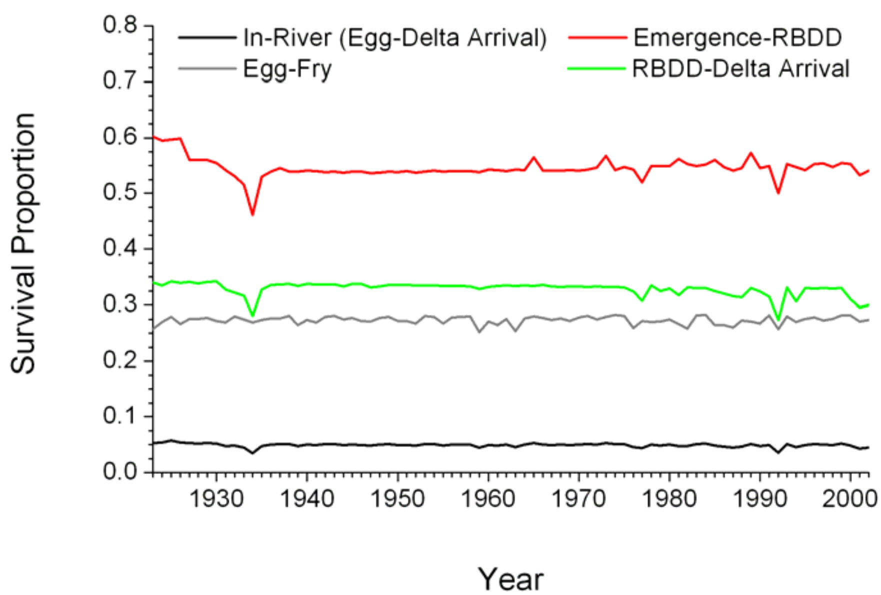

Figure 11-63. Annual winter-run Chinook salmon in-river survival (egg-Delta arrival) for water operation scenario 7.0 and its three components: 1) egg to fry, 2) fry emergence to RBDD, and 3) RBDD to Delta arrival, 1923-2002 from IOS model.

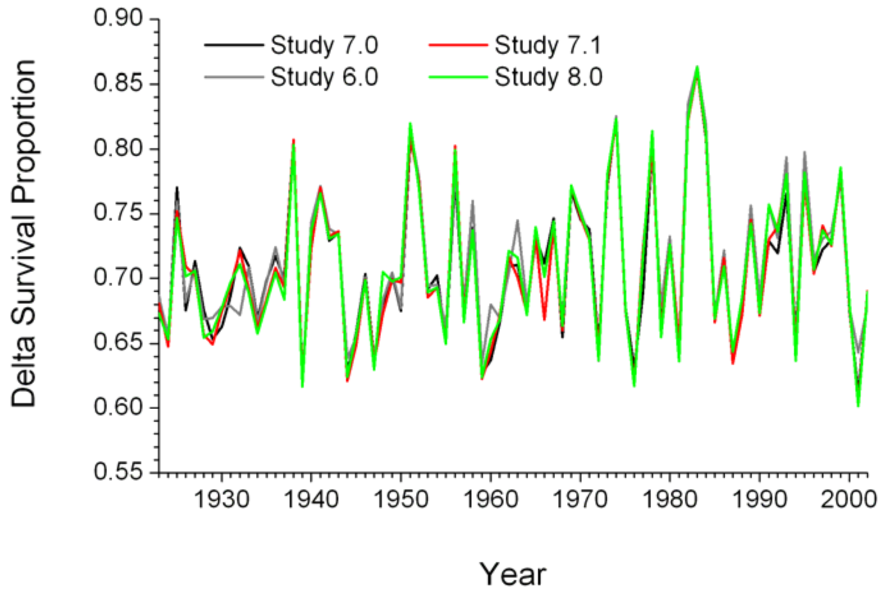

Figure 11-64. Annual winter-run Chinook salmon Delta survival under four OCAP operation scenarios, 1923-2002 from IOS model. Study 7.0 represents current operations, 6.0 represents 2004 operations, 7.1 represents near future operations, and 8.0 represents future operations.

PRE-SMOLTS

	Location													
Name	RM Start	RM End	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Segment 1	302	271.3	■	■	■	■								
Segment 2	271.3	243		■	■	■	■							
Segment 3	243	220.4		■	■	■	■	■						
Segment 4	220.4	171		■	■	■	■	■	■					
Segment 5	171	46.5			■	■	■	■	■	■				
Delta	N/A	N/A			■	■	■	■	■	■	■	■		

SMOLTS

	Location													
Name	RM Start	RM End	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Segment 1	302	271.3												
Segment 2	271.3	243												
Segment 3	243	220.4						■	■					
Segment 4	220.4	171						■	■	■	■			
Segment 5	171	46.5						■	■	■	■			
Delta	N/A	N/A						■	■	■	■	■		
Ocean Entry	N/A	N/A						■	■	■	■	■	■	

Figure 11-65. Monthly spatial distribution of winter-run Chinook salmon pre-smolts and smolts in the IOS Winter-Run Life Cycle Model during OCAP Biological Assesment model runs from IOS model.

Discussion

We observed an increasing trend in winter-run escapement through time for all four water operation scenarios. Although trends in escapement were similar for all studies, by the end of the 80-year model run escapement was higher for studies 7.0 and 6.0 than studies 7.1 and 8.0. It should be noted that escapement trends are sensitive to factors external to OCAP related environmental conditions. For example, increased harvest rate or loss of winter run hatchery contribution could easily lead to a different population trajectory. In evaluating effects of the proposed actions, differences between the four studies rather than absolute trends should be examined.

We found that study 6.0 produced on average 87,000 more smolts entering the ocean annually than study 7.0. Increased smolt production led to an average annual escapement increase of approximately 1,800 adult winter-run Chinook in years 1923-2002 for study 6.0. While studies 7.1 and 8.0 annually produced on average 300,000 and 176,000 fewer smolts than study 7.0, respectively. For studies 7.1 and 8.0, reduced smolt production led to an average annual escapement reduction of approximately 6,200 and 3,600 adult spawners, respectively.

Study 6.0 survival proportions across all life stages and spatial locations were almost identical to those observed in study 7.0. Increased abundance of smolts and spawning adults in Study 6.0 apparently results from slightly improved in-river juvenile survival. Unlike studies 7.1 and 8.0 (discussed below), water year type doesn’t appear to be driving the differences in survival between study 6.0 and 7.0.

Differences between study 7.0, and studies 7.1 and 8.0 appears to be driven largely by decreased in-river survival among juveniles during critically dry water years. The year with the largest difference in juvenile in-river survival between 7.0 and studies 7.1 and 8.0 was 1977. Adult escapement in 1980, 3 years later, exhibits the largest difference in adult abundance between study 7.0 and studies 7.1 and 8.0. 1977 is the most critically dry water year during the 80-year period of 1923-2002 (Table of Water Year Type). Our results suggest that winter-run abundance may exhibit a greater sensitivity to critically dry water years under water studies 7.1 and 8.0 relative to 7.0.

Conclusion

The IOS model was designed to serve as a quantitative framework for estimating the long-term response of Sacramento River Chinook populations to changing environmental conditions (e.g. river discharge, temperature, habitat quality at a reach scale). Life cycle models are well-suited for such evaluations because they integrate survival changes at various life stages, across multiple habitats, and through many years.

In applying the IOS winter run Chinook model to predicted environmental conditions under four alternative operational scenarios, we found that escapement increased for all four studies. Escapement for study 6.0 was similar to study 7.0 throughout the 80-year model run, with average annual escapement slightly higher for study 6.0 (Figure 11-57). However, escapement for studies 7.1 and 8.0 was typically lower than study 7.0 by approximately 15 percent (Figure 11-57). Winter-run Chinook salmon abundance demonstrated considerable sensitivity to critically dry water years for studies 7.1 and 8.0 relative to study 7.0. The primary mechanism for this observed difference appears to have been reduced survival of juvenile winter-run during critically dry water years for studies 7.1 and 8.0.

While differences in survival between operational scenarios were seemingly minimal, (e.g. seeTable 11-6), the IOS model effectively integrates these incremental effects over many salmon generations. This long-term, life cycle approach indicates that episodic reduction in juvenile survival (particularly in critically dry years) leads to an average annual reduction of 6,200 adult spawners for 7.1 and 3,600 for 8.0 (relative to study 7.0). The effect of this reduced escapement through an 80-year period of simulation is sensitive to effects external to the proposed action. For example, increased harvest rate or loss of winter run hatchery supplementation would exacerbate the effects reported here.

In evaluating effects of the proposed actions, differences between the four studies should be favored over analysis of absolute trends. It should also be noted that IOS model results reported here do not include confidence intervals or other measures of uncertainty. As such, quantitative results should be interpreted cautiously, with preference given to general trends rather than specific, numeric values.

Red Bluff Diversion Dam

Reclamation plans to continue the current May 15-September 15, gates lowered period at RBDD under current and near future operations and extend to a ten month gates out period under future operations. The gates will be in a closed position during the tail end of the winter–run upstream migration and during much of the upstream migration season for spring–run. Approximately 15 percent of winter–run and 70 percent of spring–run that attempt to migrate upstream past RBDD may encounter the closed gates (TCCA and Reclamation 2002). This is based on run timing at the fish ladders (ie. after the delay in migration has occurred) when the gates were lowered year round so a delay is built into the run timing estimate. The percentage, especially for winter-run Chinook is likely lower than 15 percent. Over 90 percent of the spring–run population spawns in tributaries downstream of RBDD. Most of the spring–run that do pass RBDD pass before May 15. The downstream tributary runs never encounter the gates. When the gates are closed, upstream migrating Chinook salmon have to use the fish ladders to get past RBDD. Vogel et al (1988) found the average time of delay for fish passing through RBDD was three to13 days depending on the run. Spring–run had the highest average delay but that mean value was influenced by a single fish that stayed downstream of the dam for 50 days. Recent radio tagging data indicate an average delay of 21 days (TCCA and Reclamation 2002). Winter-run consistendly experienced the greatest delays, likely due to the higher winter discharge rates making fish ladder entrances harder to find. Delay for spring-run Chinook was influenced by the fact that the area below RBDD is a suitable over-summering habitat in normal and wetter years. Spring-run tend to “hole up” and hang out for long periods of time during the pre-spawning season in the summer months. Although studies have shown that fish do not immediately pass the fish ladders, the extent that delayed passage affects ultimate spawning success is unknown. Some Chinook immediately pass RBDD when they arrive. For example, in 2008, 18, 36, and 14 Chinook salmon passed the fish ladders on May 15, 16, and 17 respectively, after the gates were lowered on May 15. The five year average is passage of 219 Chinook on those days (Red Bluff Fish and Wildlife Office fish passage monitoring data).

Average monthly water temperatures at Red Bluff would be maintained at suitable levels for upstream migrating and holding Chinook through July of all years (Figure 11-66). Fish delayed by

RBDD should not suffer high mortality due to high temperatures unless warmer than average air temperatures warm the water significantly above the monthly average temperatures predicted by the model. Average monthly water temperatures during August and September could be greater than 60 °F in about 10 percent of years. Study 7.1 shows the highest temperature in these 10% of years. During these years delays at RBDD would be more likely to result in mortality or cause sufficient delay to prevent migration into tributaries. The lower reaches of small tributaries can become too warm for salmon passage in mid-summer of some years. Effects to fish from warmer temperatures later in the summer when they are delayed below the dam would affect primarily fall–run fish. This is much less of a problem since the installation of the Shasta temperature control device. Elevated temperatures downstream of RBDD were the big problem for delayed fish prior to improvements in temperature control capability. The proportion of the spring–run and winter–run populations that encounter closed gates is small so effects of delays at RBDD during these dry years would not be as great as the population effect of higher than optimal spawning and incubation temperatures in critically dry years.

The ten month gates out period under future operations would extend from Labor Day to July 1 with a seven day closure over Memorial Day. This period would eliminate the potential migratory delay to upstream migrating spring-run Chinook salmon and winter-run Chinook salmon, improving migratory conditions for a small proportion of the adult winter-run population and the proportion of the spring-run population that utilizes habitats upstream of RBDD (about 10% of the Central Valley spring-run population).

The spring–run population upstream of RBDD has not exhibited patterns of abundance similar to the tributaries from what appears to have been a down cycle that should have ended shortly after the by-passes at Shasta Dam for temperature control began (1987) and shortly before the full eight months gates out operation began (1995). During this same period, spring–run downstream of the RBDD have increased about 20 fold, suggesting that some upstream event other than the RBDD operations have caused the decline in the spring–run population (TCCA and Reclamation 2002). This may be an artifact of a change in sampling protocols, but remains an unknown. It is also possible that some spring-run destined for the upper Sacramento River get delayed at RBDD so head back downstream and enter tributaries to spawn.

Early migrating steelhead encounter the lowered gates at RBDD. Approximately 84 percent of adult steelhead immigrants pass RBDD during the gates-out period based on average run timing at RBDD. Although the historical counts of juvenile steelhead passing RBDD do not differentiate steelhead from resident rainbow trout, approximately 95 percent of steelhead/rainbow trout juvenile emigrants pass during the gates-out period based on historical emigration patterns at RBDD (DFG 1993, as summarized in FWS 1998). Effects of RBDD operation on steelhead run timing would be unchanged from the current condition. About 16 percent of steelhead would still be delayed until the future gate operations are implemented when the gates would come out a week or two earlier. Because this is the early part of the steelhead run, well before the spawning period, and temperatures are generally suitable for holding below RBDD we believe that steelhead that do not use the ladders hold successfully until the gates are raised and the continue their upstream migration. No mortality to adult steelhead is expected to occur due to gate operations.

Fry, juveniles, and smolts that pass RBDD when the gates are lowered are more susceptible to predation below the gates because pike minnows and striped bass congregate there. The predation situation at RBDD has improved since gate operations were changed so that not as many predator species now stop at RBDD during their upstream migrations (CH2M Hill 2002). The predation situation as it is now would likely continue through near future operations but under the 10 month gates out period the amount of time predators would be attracted to the gates in place situation would be reduced by 58 percent.

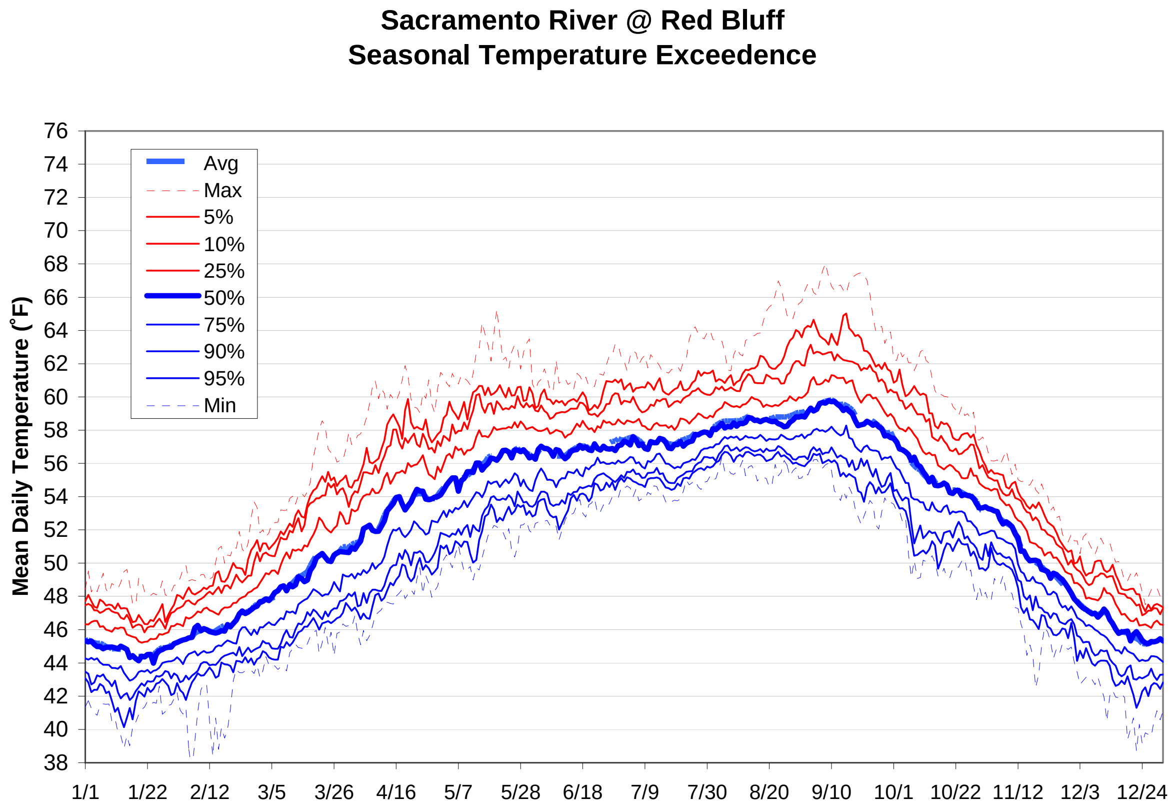

Figure 11-66. Water temperature exceedence at Red Bluff under study 8.0 from CalSim-II and weekly temperature modeling results.

Green Sturgeon

The Sacramento River provides spawning, adult holding, foraging, and juvenile rearing habitat for green sturgeon. Specific spawning areas have not been identified but some do spawn upstream of Red Bluff Diversion Dam as evidenced by catches of green sturgeon in rotary screw traps at RBDD. Acoustically tagged green sturgeon were detected upstream of RBDD in 2007. Green sturgeon water temperature requirements are less stringent than winter-run Chinook salmon. Water temperatures greater than 63 ºF can increase mortality of sturgeon eggs and larvae (PSMFC 1992). Effects to green sturgeon life stages in the Sacramento River are believed to be covered by operating to target water temperatures for winter-run Chinook. During the green sturgeon incubation period, temperatures at Hamilton City, about 100 miles below Keswick Dam, would be maintained below 63 °F. Water temperatures are not likely to adversely affect green sturgeon in the reaches of the river where temperature control operations are most effective.

Green sturgeon upstream spawning migrations occur near the time the Red Bluff gates are lowered for the summer irrigation season on May 15. The gates of the dam are lowered during the last third of the spawning period. Most sturgeon make it past before gate closure but some do get blocked and congregate downstream of the dam as occurred in May of 2007 and 2008. During an emergency closure to meet high irrigation demands, ten green sturgeon carcasses were found downstream of RBDD between May 18 and early June in 2007. These sturgeon may have been killed when they attempted to pass downstream past the dam but were lodged in gate openings of a smaller height than the depth of their bodies. Reclamation worked with other agencies to review the gate operation protocol to reduce this type of effect. The new protocol is for all gates in operation to be open to a minimum height of 12 inches to reduce the possibility of injury should adult green sturgeon pass beneath the gates. There would still be turbulence below the gates after passage that could injure sturgeon, but the chance for impingement in the gates when sturgeon are swept under by high velocities is reduced. The gates would still pose a barrier to upstream migrating green sturgeon because velocities under the gates are too high for sturgeon passage. White sturgeon passage through fish ladders on the Columbia River has been documented (Parsley et al 2007) but none has been documented at the Red Bluff ladders. Sturgeon that are blocked would need to spawn in habitats downstream of the dam. Green sturgeon have been documented holding and spawning in large pools downstream of RBDD. Reclamation tracked acoustically tagged green sturgeon during 2007 and identified three that passed the gates during the gates closed period (Table 11-7). This was prior to the time the new 12-inch minimum gate opening protocol was developed. The new protocol should reduce the chance of injury to adult green sturgeon in the future. The chance of injury would be reduced because the body depth of green sturgeon is less than 12 inches. They may be swept under the gates in the high velocity water but should not become stuck due to gate opening height being too small. Monitoring is underway to better quantify effects of RBDD on adult green sturgeon. Numerous adult green sturgeon were present in the river during 2008 monitoring and no gate related mortality has been detected to at least the end of July. We conclude the new protocol will reduce adverse effects on adult green sturgeon.

The ten month gates out period in the future will remove the barrier to upstream migrating green sturgeon and remove the potential for injury to a majority the downstream migrating adult green sturgeon.

Table 11-7. Acoustic tagged adult green sturgeon that passed downstream under the RBDD gates in 2007 and height of opening under gates in feet.

GS #	Date of Passage	Gate Opening (feet)										
		No. 1	**No. 2**	**No. 3**	**No. 4**	**No. 5**	**No. 6**	**No. 7**	**No. 8**	**No. 9**	**No. 10**	**No. 11**
#3	May 18	1.2	0.2	1.1	0.2	0.2	0.2	0.1	0.3	1.2	0.4	1.2
#2	May 21	1.1	0.3	1.1	0.3	0.3	0.3	0.2	0.2	1.2	0.5	1.5
#1	June 10	1.1	0.8	0.9	0.7	0.0	0.0	0.0	0.9	0.9	0.9	1.7

Red Bluff Research Pumping Plant

The Red Bluff Research Pumping Plant will continue to be operated to supply water to the Tehama-Colusa and Corning Canals when the RBDD gates are raised. Reclamation monitors fish entrainment at the downstream side of three of the four pumps in operation. The fourth pump which was installed in the spring of 2006 has no infrastructure for monitoring entrainment. We used this entrainment data for the three previous existing pumps to estimate total entrainment since operation and monitoring of the pumps began in 1997. Data on amount of pumping time for all four pumps and amount of time entrainment monitoring occurred was summed each year to determine the proportion of the time entrainment was monitored. The sum of fish entrained was divided by proportion of pumping time that monitoring occurred to estimate total entrainment each year. Table 11-8, Table 11-9, and Table 11-10 show the estimates of entrainment and mortality of winter-run, spring-run, and steelhead respectively. Chinook were assigned to runs based on size at age data. Borthwick and Corwin (2001) found that the average mortality of Chinook salmon entrained through the pumps was 0.9 percent during short trials so this percentage was used to estimate mortality for each year. Higher mortality occurs when entrainment is monitored for longer periods of time (eg 24 hours) but this is due to the presence of sampling gear and the entrainment of debris in the holding tanks which does not occur during normal pumping operations. Future pumping operations with all four pumps will be similar so we expect a similar range of fish entrainment and mortality as occurred in 1997 through 2007. Entrainment will vary with the population of fish in the river. Fish that pass through the pumps return to the river through the same passage used by fish diverted from the canal when RBDD gates are lowered.

Four juvenile sturgeon have been captured since monitoring began. These occurred in May and June of 1997 (2 sturgeon), 1998, and 1999. These were all captured alive. Due to the low number captured no estimate of total sturgeon entrainment was made. Future impacts of the pumps to green sturgeon are likely to be similarly low.

It should be noted that during the initial years of pump evaluations the pumps were run during the winter when water is generally not being diverted to supply the water needs of the Tehama-Colusa and Corning canals. Pumps will generally not be run during times of the year when water is not needed to supply the canals. They would only be run to conduct additional effects evaluations but none are currently planned.

Borthwick and Corwin (2001) estimated the proportion of fish in the river that were diverted compared to the proportion of water diverted. The proportion of fish diverted was consistently less than the proportion of river flow diverted and was similar to the results of Hanson (2001). This is likely due to the location of the pump intakes which are near the bottom of the river.

Table 11-8. Estimated entrainment and mortality of winter-run sized Chinook salmon at Red Bluff Pumping Plant pumps.

Winter Run sized fish

Month

	1	2	4	7	8	9	10	11	12	Total	Mortality
1997	0	2	0	0	0	400	304	149	6	862	8
1998	0	0	2	25	161	753	227	17	0	1,186	11
1999	0	0	0	0	0	330	295	5	0	630	6
2000	0	0	0	0	0	144	148	0	0	292	3
2001	7	0	0	0	0	751	731	0	0	1,488	13
2002	0	0	0	0	0	544	719	0	0	1,262	11
2003	0	0	0	0	0	1,558	981	0	0	2,539	23
2004	0	0	0	0	0	2,886	232	0	0	3,119	28
2005	0	0	0	0	0	2,123	1,381	0	0	3,504	32
2006	0	0	0	0	29	2,984	1,809	0	23	4,845	44
2007	0	0	0	0	0	329	105	22	0	456	4
Total	7	2	2	25	190	12,803	6,931	194	30	20,184	182

Table 11-9. Estimated entrainment and mortality of spring-run sized Chinook salmon at Red Bluff Pumping Plant pumps.

Spring Run sized fish

Month

	1	2	3	4	5	10	11	12	Total	Mortality
1997	0	2	4	243	0	0	115	290	654	6
1998	2	0	21	2	0	6	25	0	57	1
1999	5	0	5	0	0	3	0	0	13	0
2000	117	0	19	47	4	0	0	0	187	2
2001	0	0	0	75	0	0	0	0	75	1
2002	0	0	0	87	0	0	0	0	87	1
2003	0	0	0	6	0	112	0	0	118	1
2004	0	0	0	70	0	0	0	0	70	1
2005	0	0	0	271	15	5	0	0	291	3
2006	0	0	0	0	0	12	0	17	29	0
2007	7	22	37	247	15	7	150	0	486	4
Total	133	27	90	1,052	38	155	301	319	2,115	19

Table 11-10. Estimated entrainment and mortality of steelhead at Red Bluff Pumping Plant pumps.

Steelhead
Month

	1	2	3	4	5	6	7	8	9	10	11	Total	Mortality
1997	0	11	0	4	4	6	2	4	9	2	15	57	**1**
1998	47	0	6	0	2	4	2	13	4	2	0	81	**1**
1999	0	3	5	0	8	3	3	0	33	0	0	54	**0**
2000	171	0	4	4	0	0	0	0	0	0	0	179	**2**
2001	0	0	0	41	48	0	0	0	0	7	0	96	**1**
2002	0	0	0	40	0	0	0	0	0	7	0	47	**0**
2003	0	0	0	12	12	0	0	0	12	12	0	50	**0**
2004	0	0	0	19	0	0	0	0	14	5	0	37	**0**
2005	0	0	0	24	73	0	0	0	0	0	0	97	**1**
2006	0	0	0	0	151	0	0	6	12	0	0	169	**2**
2007	0	52	0	30	15	0	0	0	7	0	7	112	**1**
Total	**218**	**66**	**15**	**175**	**313**	**13**	**7**	**23**	**92**	**35**	**22**	**978**	**9**

It is concluded that future operation of the pumps will continue to have the same level of effect on entrainment.

Estimated Loss from Unscreened Diversions on the Sacramento River

Hansen (2001) studied juvenile Chinook salmon (mean length = 102 mm) entrainment at unscreened diversions during June at the Princeton Pumping Plant (river mile 164.4) and at the Wilkins Slough Diversion (river mile 117.8). The Princeton Pumping Plant has a peak diversion capacity of 290 cfs through four 36 inch diameter pipes and one 30 inch diameter pipe. Maintenance flows are typically 120 to 180 cfs. He found that the percent of the released hatchery Chinook salmon entrained was 0.05 to 0.07 times the percent of the Sacramento River flow diverted for the two sites respectively. We use an average of percent of juveniles diverted to be 0.06 times the percentage of the Sacramento River flow diverted for calculating entrainment into unscreened diversions. We used the average juvenile Chinook salmon (for each run) and rainbow trout (resident and anadromous forms not differentiated) passage past Red Bluff Diversion Dam (Martin et al 2001 and Gaines and Martin 2002) for the brood years 1995 through 1999 as the number and timing of winter run present in the Sacramento River. All of the 123 unscreened diversions (not counting those in the process of being screened) are downstream of Red Bluff Diversion Dam (RBDD). Average Sacramento River flow at Red Bluff from CalSim-II modeling study number eight was used for the river flow past the diversions. We did not calculate a separate estimate for each study because the calculation is not precise enough to logically separate out differences in number of fish diverted from the similar Sacramento River flows between studies. Many diversions on the Sacramento River are located over 100 miles downstream of Red Bluff Diversion Dam. There is some unquantified mortality that occurs within this reach and a timing delay between the time fish pass RBDD and when they reach the diversions. This unquantified mortality and timing delay was not factored into this anlaysis.

Timing and quantity of diversions was based on the monthly average of historic diversions from Sacramento River contractors with currently unscreened diversions, 1964 through 2003 (Table 11-11).

Table 11-11. Timing and quantity of diversions based on past averages.*

Sacramento Diversion Timing						
		Project			Base	
	Percent	amount, acre-ft	cfs	Percent	amount, acre-ft	cfs
April	0.0%	20	0	11.9%	40,475	680
May	0.0%	3	0	27.0%	91,460	1,487
June	8.8%	11,264	189	26.9%	91,252	1,534
July	34.7%	44,310	721	18.6%	63,030	1,025
August	44.5%	56,845	924	11.0%	37,348	607
September	11.7%	14,922	251	2.2%	7,450	125
October	0.3%	364	6	2.4%	8,124	132

*Project diversions are the amounts of water diverted under contract with Reclamation. Base diversions are water rights diversions not associated with Reclamation.

Average summer water temperatures may be somewhat suitable down to Butte City. They are projected to average about 67 °F in June through August. Seventeen diversions are between RBDD and Butte City and probably pose the highest risk to winter-run based on location and timing of diversions.

Juvenile salmonid passage by run past RBDD is in Table 11-12 below.

Table 11-12. Timing and passage of juvenile salmonids past Red Bluff Diversion Dam. The line "% of year total" refers to the percent of the fish for the entire year that pass RBDD during that month.

Juvenile Emigration Data, Sacramento River at RBDD

Numbers of winter-run Chinook salmon passing RBDD by month, Martin et al 2001.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 95	236	0	0	751	81,804	1,147,684	299,047	1,529,522
BY 96	1,378	272	0	903	18,836	228,197	24,226	273,812
BY 97	732	0	0	18,584	134,165	925,284	410,781	1,489,546
BY 98	1,754	262	0	184,896	1,540,408	2,128,386	404,275	4,259,981
BY 99	1,092	375	0	8,186	91,836	404,378	163,482	669,349
Average	**1,038**	**182**	**0**	**42,664**	**373,410**	**966,786**	**260,362**	**1,644,442**
% of year total	0.1%	0.0%	0.0%	2.2%	19.5%	50.4%	13.6%	85.7%

Numbers of fall-run Chinook salmon passing RBDD by month, Gaines and Martin 2002.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 94	4,172,651	672,926	194,843	42,564	21,463	12,976	2,125	5,119,548
BY 95	692,012	340,490	143,832	82,885	19,634	3,906	721	1,283,480
BY 96	600,977	198,705	264,400	111,830	41,309	6,287	385	1,223,893
BY 97	2,667,508	200,945	588,586	265,092	97,305	5,958	0	3,825,394
BY 98	471,158	826,624	767,144	613,884	181,162	49,401	683	2,910,056
Average	**1,720,861**	**447,938**	**391,761**	**223,251**	**72,175**	**15,706**	**783**	**2,872,474**
% of year total	8.8%	2.3%	2.0%	1.1%	0.4%	0.1%	0.0%	14.7%

Numbers of late fall-run Chinook salmon passing RBDD by month, Gaines and Martin 2002.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 94								
BY 95	65,895	15,975	1,688	1,974	5,213	10,061	7,295	108,101
BY 96	13,698	3,450	1,283	2,390	2,762	4,445	5,133	33,161
BY 97	19,909	8,071	14,037	29,711	47,684	32,880	12,632	164,924
BY 98	241,824	59,444	34,077	32,281	94,981	47,958	20,998	531,563
BY 99	131,113	63,611	16,968	56,119	110,316	79,303	49,215	506,645
Average	**94,488**	**30,110**	**13,611**	**24,495**	**52,191**	**34,929**	**19,055**	**268,879**

Numbers of spring-run Chinook salmon passing RBDD by month, Gaines and Martin 2002.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 94								
BY 95	49,304	6,105	0	0	0	0	9,056	64,465
BY 96	136,766	3,889	404	99	0	0	491	141,649
BY 97	70,874	10,762	482	0	0	0	1,207	83,325
BY 98	20,608	3,004	110	129	0	0	26,394	50,245
BY 99	281,808	19,374	466				20,414	322,062
Average	**111,872**	**8,627**	**292**	**57**	**0**	**0**	**11,512**	**132,349**
% of year total	21.7%	1.7%	0.1%	0.0%	0.0%	0.0%	2.2%	25.7%

Numbers of O.mykiss passing RBDD by month, Gaines and Martin 2002.

Brood Year	April	May	June	July	Aug	Sep	Oct	Total
BY 94								
BY 95	5,626	39,102	2,541	2,230	22,418	34,485	1,400	107,802
BY 96	2,524	4,412	3,098	1,342	8,012	34,164	3,109	56,661
BY 97	8,183	6,796	4,951	3,686	5,282	1,758	632	31,288
BY 98	5,083	11,632	4,777	3,647	12,889	10,432	1,156	49,616
BY 99	1,571	8,040	4,465	5,092	12,810	11,605	1,146	44,729
Average	**4,597**	**13,996**	**3,966**	**3,199**	**12,282**	**18,489**	**1,489**	**58,019**

Number of fish diverted was calculated for each of the 123 unscreened diversions and then the fish numbers summed for an overall entrainment estimate. No specific information on the configuration of the diversion points relative to fish habitat was used in the entrainment estimates. Only the amount of water diverted by month was used. Entrainment separated out between project water supply diversions and base water supply diversions. The project water diversions are the ones under contract with Reclamation. Base supply is water rights water. Entrainment for the diversions upstream of Butte City is estimated to be 86 winter run from the project supply and 23 winter run from the base supply. This is the primary area where pumping occurs when winter run are likely to be present in the vicinity of the pumps because water temperatures are suitable. Water temperatures at the diversion sites may be warm for salmonids (Figure 11-67) during the summer months but this was not figured into the analysis. Past water temperature information at the sites was not available.

O. mykiss use slightly different habitats than Chinook so the past entrainment monitoring of Chinook is probably not that representative of O. mykiss, but we used it in the absence of other data. We expect that steelhead would be diverted at a lower rate than Chinook salmon because diversions are often in slack water areas where steelhead are less inclined to inhabit than Chinook.

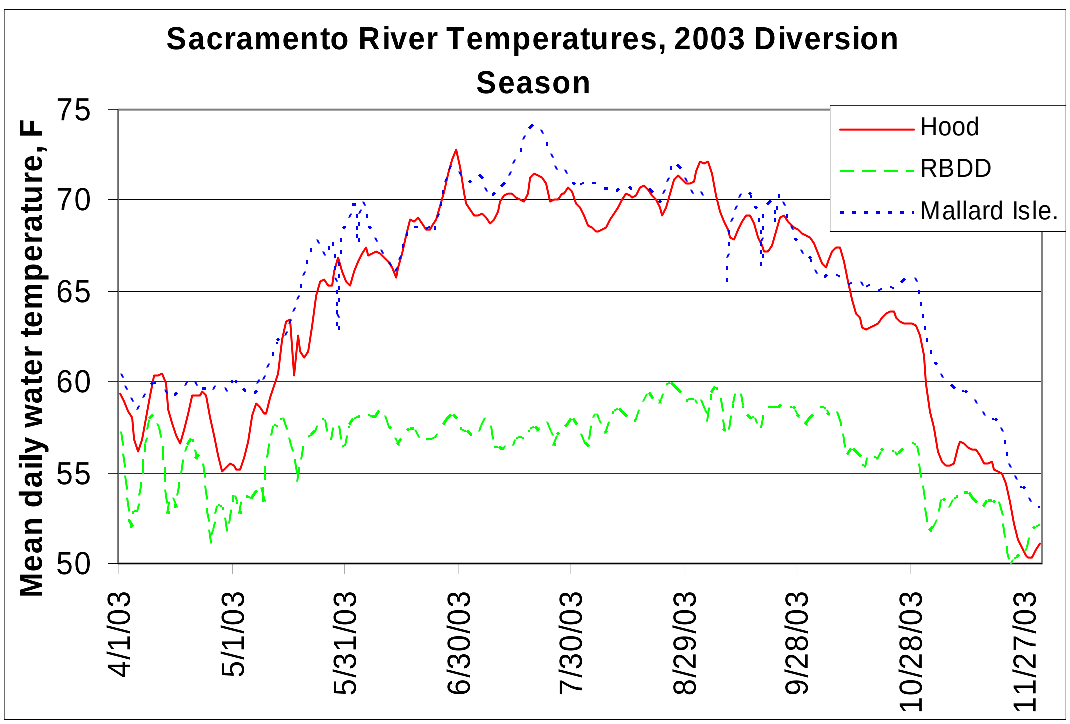

Figure 11-67. Water temperatures at Sacramento River temperature monitoring stations.

Total winter run entrainment for all diversions assuming timing of fish presence is the same in the lower river as at RBDD is estimated to be 4,455 from project pumping and 2,985 from base supply pumping, for a total of 7,440 winter run (Table 11-13). This is very likely an over estimate because the lower river is too warm through much of the summer for juvenile salmon rearing. The estimated entrainment contains six older juveniles (April through June), all from base water deliveries. The rest are fry entrained during July through October. One diversion at approximately river mile 88 accounted for 65 percent of the entrainment estimate.

The total estimated entrainment into unscreened diversions represents 0.37 percent of the estimated winter run juvenile passage past RBDD.

Spring run entrainment for all diversions is estimated to be 537 individuals with one from project water diversions and 536 from base diversions. 98 percent of the spring run diverted are estimated to be older juveniles occurring in April, May, and June.

An estimated 393 of O.mykiss would be entrained with 32 percent of them from project supply.

Table 11-13. Estimated entrainment of salmonids in unscreened diversions in the Sacramento River. Project water refers to water supplied by Reclamation and base water is water rights water.

Sac Flow @ Red Bluff, cf	10,404	9,435	11,110	13,082	9,683	6,730	7,013	
Project Water	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**Total**
% of flow diverted	0.0%	0.0%	1.7%	5.5%	9.5%	3.7%	0.1%	
% of fish diverted	0.0%	0.0%	0.1%	0.3%	0.6%	0.2%	0.0%	
Number of Fish Entrained								
Winter Run	0	0	0	141	2,139	2,162	13	4,455
Spring Run	0	0	0	0	0	0	1	1
O. mykiss	0	0	4	11	70	41	0	126
Fall Run	3	0	400	738	413	35	0	1,590
Late Fall Run	0	0	14	81	299	78	1	473
Base Water								
	April	May	June	July	August	September	October	
% of flow diverted	6.5%	15.8%	13.8%	7.8%	6.3%	1.9%	1.9%	
% of fish diverted	0.4%	0.9%	0.8%	0.5%	0.4%	0.1%	0.1%	
Number of Fish Entrained								
Winter Run	4	2	0	201	1,405	1,079	294	2,985
Spring Run	439	82	2	0	0	0	13	536
O. mykiss	18	132	33	15	46	21	2	267
Fall Run	6,750	4,237	3,245	1,050	272	18	1	15,572
Late Fall Run	371	285	113	115	196	39	22	1,140
Total (Project + Base)								
	April	May	June	July	August	September	October	
% of flow diverted	6.5%	15.8%	15.5%	13.3%	15.8%	5.6%	2.0%	
% of fish diverted	0.4%	0.9%	0.9%	0.8%	0.9%	0.3%	0.1%	
Number of Fish Entrained								
Winter Run	4	2	0	342	3,545	3,241	308	7,440
Spring Run	439	82	3	0	0	0	14	537
O. mykiss	18	132	37	26	117	62	2	393
Fall Run	6,754	4,237	3,645	1,788	685	53	1	17,162
Late Fall Run	371	285	127	196	495	117	23	1,613

Green Sturgeon at Sacramento River Sites

We estimated potential take of green sturgeon by examining screw trap catches of sturgeon at GCID and RBDD (Table 11-14, Table 11-15, and Figure 11-68). Most of the sturgeon captured in these traps are young of the year and too small to identify to species. Based on a sample of these sturgeon that have been raised to an identifiable size they appear to be mostly green sturgeon. White sturgeon spawn mostly downstream of GCID. The GCID screw trap at river mile 205 is the closest to many of the diversions so the catches from that trap were used to estimate potential entrainment. This screw trap has not been calibrated for expanding catch to total passage. We used an efficiency of 0.5 percent at the GCID screw trap for green sturgeon.

The total estimated entrainment of green sturgeon is 199 green sturgeon (Table 11-16). We used 0.06 times the percentage of the Sacramento River flow diverted (same as for Chinook) as the percentage of the green sturgeon that would be entrained when passing the monitored diversion sites. This estimate is largely dependent on an unknown screw trap efficiency and percentage of sturgeon diverted relative to flow diverted.

Table 11-14. Rotary screw trap catches of sturgeon at GCID, 1994-2005.

					Sturgeon in CDF&G Screw Trap at GCID										
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average	Median	Std Dev
January	0	0	0	0	0	0	0	1	0	0	0	0	0.1	0.0	0.3
February	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
March	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
April	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
May	0	0	113	27	0	0	1	3	8	0	1	0	12.8	0.5	32.5
June	12	20	10	126	0	23	13	13	1	4	3	5	19.2	11.0	34.4
July	6	205	180	52	0	214	18	16	0	3	1	23	59.8	17.0	85.9
August	0	77	109	24	0	52	2	1	0	1	0	4	22.5	1.5	37.0
September	1	4	2	3	0	1	0	0	0	1	0	1	1.1	1.0	1.3
October	0	0	1	4	0	1	1	0	0	0	1	0	0.7	0.0	1.2
November	2	0	0	1	0	0	0	0	0	0	0	0	0.3	0.0	0.6
December	2	1	5	0	0	0	0	0	0	0	0	0	0.7	0.0	1.5
Total	23	307	420	237	0	291	35	34	9	9	6	33	117.0	33.5	151.2

Table 11-15. Sturgeon captured at RBDD rotary screw traps

Sturgeon Captured at RBDD Screw Traps

Year	Months Captured	# of Sturgeon
1995	June - August	1364
1996	May - August	410
1997	May - July	354
1998	July - August	302
1999	Feb - Oct	80
2000	May - June	98
2001	No sampling	
2002	May - July	35
2003	June - November	360
2004	May - July	643
2005	May - August	271
2006	June - August	191

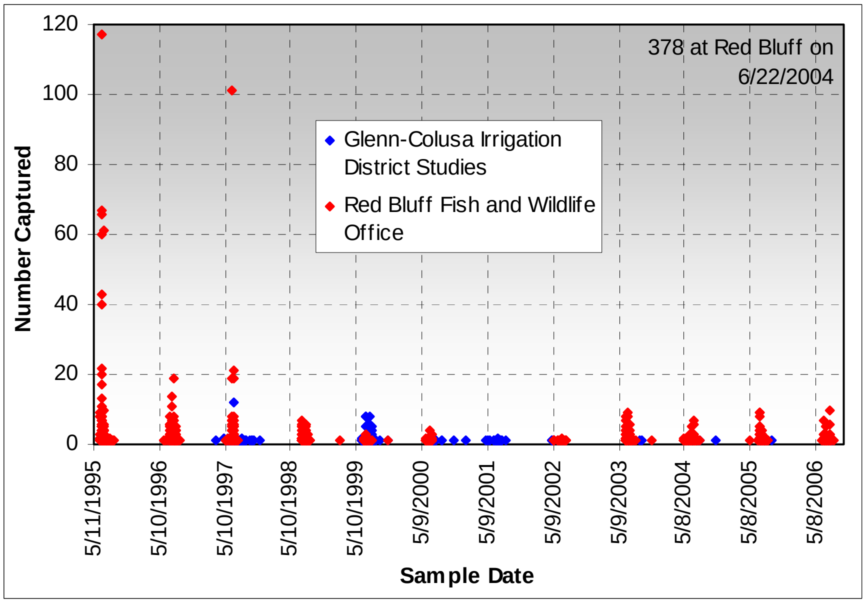

Figure 11-68. Sturgeon captured at RBDD and GCID (BDAT 8/29/2006).
***Note*: All Sturgeon, N=4,767 (green=296, white=18, unidentified=4,453)**

Table 11-16. Estimated entrainment of green sturgeon at unscreened diversions in the Sacramento River.

	April	May	June	July	August	September	October	Total
Sturgeon catch (average 94-2005	0.0	12.8	19.2	59.8	22.5	1.1	0.7	116
Total Sturgeon at 0.5% efficienc	0	2,550	3,833	11,967	4,500	217	133	23,200
Flow at RBDD	10,404	9,435	11,110	13,082	9,683	6,730	7,013	
% of flow diverted	6.5%	15.8%	15.5%	13.3%	15.8%	5.6%	2.0%	
% of fish diverted	0.4%	0.9%	0.9%	0.8%	0.9%	0.3%	0.1%	
Number of Sturgeon Diverted	0	24	36	96	43	1	0	199

Effect of Cool Summer Time Dam Releases on Steelhead Critical Habitat

The Sacramento River below Keswick Dam is managed for cool water during the summer to protect winter-run Chinook. This area was historically warmer prior to the dam and therefore was not as suitable for juvenile steelhead during the summer. Prior to dam construction most trout probably reared further upstream, above the Shasta Lake area. The cool water provided over the summer downstream of Shasta Dam for winter run Chinook has been implicated in potentially decreasing the steelhead population due to an increase in the resident trout population and predation mortality on juvenile steelhead (Cramer 2006). A similar situation occurs in the Stanislaus River downstream of Goodwin Dam and Clear Creek downstream of Whiskeytown Dam where cool water releases are maintained throughout the summer and resident rainbow trout populations are high. The larger resident trout populations may potentially compete with juvenile steelhead, reducing the juvenile steelhead population. The Cantara chemical spill occurred July 14, 1991, in the upper Sacramento River five miles upstream of the city of Dunsmuir. An estimated 309,000 trout were killed by the spill in an approximately thirty mile reach of the river, upstream of Shasta Lake (Hankin and McCanne 2000). Scale analysis and genetic analysis indicated 83-96 percent of these fish were wild (non-hatchery produced) trout. This population size amounts to 10,300 trout per mile (two trout per linear foot of river). This may be the best estimate of trout population size in any part of the Sacramento River. The population has since recovered to a similar density of trout in this reach. Water temperatures in this reach of the river are expected to be similar (or potentially higher due to Lake Siskiyou) compared to historic temperatures. The high trout population in this reach is probably similar to what existed in the upper Sacramento River historically in the presence of steelhead. Therefore we expect that the high resident trout population supported by cool water downstream of Central Valley Dams such as Keswick, Goodwin, and Whiskeytown is not a major factor in decreasing the anadromous populations in those systems. In any event the resident fish do produce anadromous individuals and maintain a supply of fish for the anadromous population. Fish from upstream do survive passage downstream during flood control operations and adults have been documented surviving downstream passage through turbines.

Zimmerman et al (2008) found that in a sample of 964 of O. mykiss otoliths from Central Valley rivers 224 were from fish who were the progeny of anadromous rainbow trout (i.e., steelhead) females and 740 were the progeny of non-anadromous rainbow trout females. This indicates relatively higher reproduction from resident trout than from the anadromous form, however because many samples were from fish in a size range not exhibited in anadromous trout in freshwater, sampling may have been biased towards resident fish.

Feather River

The operations on the Feather River for the Oroville Facilities are currently being covered under a separate Section 7 ESA consultation process for the Federal Energy Regulatory Commission (FERC) hydroelectric relicensing process. The draft NMFS BO is scheduled for release in late May 2008. Under the 2008 OCAP BA, DWR would continue to operate the Oroville Facilities to meet the same water temperature objectives at the Feather River Hatchery and Robinson Riffle under the current FERC license until the new license is issued. While simulated storage conditions in Oroville Reservoir might be different under the 2008 OCAP BA, temperature management actions would follow the procedures described in the 2006 Settlement Agreement for Licensing of the Oroville Facilities (Settlement Agreement) and in Appendix J (Feather River Temp appendix). Therefore, affects to the listed fish species under Studies 7.1 and 8.0 are expected to be the same as what is described in the Section 7 consultation document for the Oroville Relicensing Project. A brief summary of the changes affecting Chinook salmon, steelhead and green sturgeon resulting from the project are outlined below.

Under Studies 7.1 and 8.0, both of which include conditions established under the Settlement Agreement, from April 1 to September 8, DWR would release a minimum flow of 700 cfs into the Low Flow Channel (LFC) to improve habitat conditions for Central Valley spring-run Chinook salmon adult immigration and holding and juvenile rearing and emigration. From September 9 to March 31 of each year, the minimum flow in the LFC would be 800 cfs to accommodate adult spawning for spring-run Chinook salmon and steelhead. Prior to the facilities modifications included in Study 8.0, if DWR does not achieve the applicable temperatures upon release of the specified minimum flow, DWR would singularly, or in combination (a) curtail pump-back operation, (b) remove shutters on Hyatt Intake, and (c) increase flow releases in the LFC up to a maximum of 1500 cfs, or up to the total facilities releases, whichever is less. Increased flows are anticipated to decrease water temperature and thereby increase holding-habitat area, decrease egg mortality in holding adults, enhance adult spawning and egg survival, and improve rearing habitat conditions in the LFC.

Accordingly, water temperatures in Studies 7.1 and 8.0 would likely be decreased relative to Study 7.0, improving conditions for Federally listed anadromous salmonids. It is anticipated that changes in water temperature under Studies 7.1 and 8.0 would result in an overall benefit to spring-run Chinook salmon and steelhead adult immigration and holding, adult spawning and embryo incubation, and/or juvenile rearing and emigration. Increasing flows and decreasing water temperatures in the LFC would likely result in a beneficial change to green sturgeon habitat as well (DWR 2007).

American River

Adult Steelhead Migration, Spawning, and Incubation

Flows in the future would be similar to the baseline condition in all months except July through September. During July flows would be slightly higher and in August and September they would be slightly lower than under present conditions. The American River flow standard is being implemented to provide for operations consistent with the lifecycle needs of steelhead and fall-run Chinook salmon. Management for both species requires tradeoffs that benefit one species while making conditions less favorable to the other, especially regarding temperature management. The flow standard is integrated in with the CalSim-II modeling results.

The American River supports a steelhead run but no spring–run or winter–run Chinook salmon. Adult steelhead migration in the American River typically occurs from November through April and peaks in December through March (McEwan and Jackson 1996; SWRI 1997). Spawning occurs in late December to early April with the peak in late February to early March (Hannon and Deason 2007). Predicted flows could drop as low as 500 cfs in up to 10 percent of years and be as high as 33,000 cfs as a monthly average. Flows in the future will be lower in these months. Steelhead spawning habitat area peaks at 2,400 cfs (Table 4–2) but shows very little variability in spawning habitat area between 1,000 and 4,000 cfs. Flows during the spawning period would be below 2,400 cfs in about 30 to 60 percent of years, depending on the month. Average monthly flows could range up over 30,000 cfs in the wettest years with instantaneous flows likely over 100,000 cfs for flood control. The flows over about 50,000 cfs could scour some redds (Ayres Associates 2001), but will provide needed reconfiguration of the channel for long-term maintenance of good spawning and rearing habitat. At the 90 percent exceedance level flows could average as low as 500 cfs (driest years). Spawning habitat area was not predicted for flows below 1,000 cfs but spawning habitat would certainly be less and important side channel spawning habitat would be nearly absent. The steelhead population in the American River does not appear to be ultimately limited by spawning habitat availability, but by factors following fry emergence such as summer water temperatures and predation. The majority of steelhead enter the hatchery instead of spawning in the river. Efforts are underway to provide habitats such as improved spawning gravel in upstream areas and additional side channel areas to entice more steelhead to spawn in the river. The number of juvenile steelhead in the river drops quickly at the beginning of the summer, possibly due to predation. Predators likely take more steelhead when the water is warmer. Flow conditions are expected to provide suitable depths and velocities for upstream passage of adults to spawning areas within the lower American River. No migration barriers exist below Nimbus Dam, except when the hatchery picket weir is in operation.

Steelhead prefer 46 °F to 52 °F water for upstream migration. Temperatures of 52 °F or lower are best for steelhead egg incubation. However temperatures less than 56 F are considered suitable. Average temperatures at Watt Avenue are generally within this range much of the time between December and March. During dry years temperatures in November, March, April, and May would be higher than preferred and could be as high as 71 °F in May of warm dry years (Figure 11-69 and Figure 11-70). Over 90 percent of the steelhead spawning activity occurs during late December through March when temperatures are generally within an acceptable range for spawning (Hannon and Deason 2007). Steelhead eggs are in the gravel from December until mid-May. Temperatures from March through May could be above the preferred range for egg incubation at Watt Avenue in about 50 percent of years during March, and in all years in April and May. Fish surveys identify newly emerged steelhead in the American through May indicating that eggs do survive at temperatures above the preferred range. Temperatures are relatively unchanged between all modeling runs during the steelhead spawning and incubation period so there is no change in effect.

Meeting temperature objectives for steelhead during the summer and for Chinook in the fall involves trade-offs between whether to use more cool water during the summer for steelhead rearing or saving some amount of cool water until fall to increase Chinook spawning success. Reclamation manages the cold-water pool in Folsom reservoir with regular input from the American River Operations Group. Temperature shutters on each of the power penstocks are raised throughout the summer and fall when needed to provide cool water in the lower American River for steelhead and Chinook. The shutters allow releases to be made from four different levels of the reservoir, depending on the desired water temperature in the lower river.

Flood flows that are not reflected in the operations forecasts have the potential to scour steelhead redds resulting in injury and mortality of steelhead eggs and sac-fry. Frequency and magnitude of flood operations will be the same between the baseline and future scenarios. Most flood control operations are not expected to result in flow conditions that are likely to create scour (>50,000 cfs). Flow reductions following flood control releases have the potential to dewater redds constructed during the higher flow period. Higher flood control releases over a one or two-day period rather than lower releases over an extended period would preclude steelhead spawning in areas that will be later dewatered. The American River Operations Group considers the risk of redd dewatering when choosing options for flood control releases. Planning for the normal operations of Folsom Reservoir during this period considers the potential for high flood control releases during the steelhead spawning and egg incubation period. Non-flood control operations are typically designed to avoid large changes in flow that may create stranding problems. Because Folsom Reservoir is the closest water source to the Delta, releases from Folsom can be needed to maintain Delta water quality requirements when delta water quality deterioration occurs (chapter 2). Once water quality requirements are met or increased flows from other reservoirs make it to the Delta Folsom releases can be reduced to conserve storage, sometimes affecting fish or redds in the river. CVPIA section

3406(b)(2) water may be used during this period to support higher flows or avoid reductions that otherwise would be made. Dewatered steelhead redds likely lowered the number of steelhead fry produced in 2003. The limiting period to in-river steelhead production seems to occur after fry emergence. Therefore changes in operational effects on spawning and egg incubation are not expected to affect the steelhead population in the American River. It is hoped that spawning gravel introductions will improve the condition of spawning and rearing critical habitat in the American River.

Steelhead Fry, Juveniles, and Smolts

The freshwater life stages of steelhead occupy the American River throughout the year. Most literature has indicated that rearing fry and juvenile steelhead prefer water temperatures between 45 °F and 60 °F (Reiser and Bjorn 1979; Bovee 1978; Bell 1986). However, Myrick (1998) found the preferred temperatures for Mokelumne River Hatchery steelhead placed into thermal gradients were between 62.6 °F and 68 °F. NMFS generally uses a daily average temperature of 65 °F at Watt Avenue as a temperature objective for steelhead rearing in the American River and then adjusts the temperature objective and point depending on Folsom cold-water pool each year. Temperatures could exceed a monthly average of 65 °F at times between May and October with the highest temperatures of up to 75 °F in occurring in July and August of years with a low cold-water pool storage in Folsom. Temperatures are modeled to be almost always higher than 65 °F at Nimbus Dam in July through September with not much difference between the current and future scenarios (Figure 11-71 and Figure 11-72). Temperatures would exceed 70 °F during July in 20 percent of years and in August in 50 percent of years at Watt Avenue. These high summer temperatures are likely what limits the naturally spawned steelhead population in the American River by providing conditions conducive to predatory fish. Monitoring during 2001 and 2002 indicated that steelhead did not appear to be finding water cooler than that found in the thalweg and they persisted below Watt Avenue in water with a daily average temperature of 72 °F and a daily maximum over 74 °F. Water temperature in the future runs is predicted to be approximately 1 °F warmer from July to October. Temperatures the rest of the year will be relatively unchanged. The increased temperatures will put additional temperature stress on rearing steelhead during summer and adult Chinook holding and spawning. Due to the high temperatures the steelhead run in the American River will likely require continued support by the hatchery. This is an adverse effect to steelhead.

Juvenile salmon emigration studies using rotary screw traps in the lower American River at Watt Avenue generally capture steelhead fry from March through June while steelhead yearlings and smolts emigrate from late December till May, with most captured in January (Snider and Titus 2000). Specific flow needs for emigration in the American River have not been determined. Steelhead emigrate at a relatively large size so are good swimmers and presumably do not need large pulses to emigrate effectively from the American River as long as temperatures are suitable through the lower river and in the Sacramento River. Modeled flows are expected to provide suitable depth and velocity conditions for emigration during most years. Flows could drop below 1,000 cfs between December and May in about 5 to 15 percent of years depending on month. Low flows would occur slightly more often in the future than under current operations. This would probably affect juvenile salmon more than juvenile steelhead due to the high salmonid densities. The habitat is generally not fully seeded with steelhead fry. December through March forecast mean monthly temperatures are expected to be generally within the optimum smoltification and emigration range (44 °F to 52 °F) during most years but temperatures may exceed 52 °F in February in about 10 percent of years and in about 70 percent of years in March. No change in temperatures between current and future operations during December through March is expected to occur.

Rearing steelhead fry and juveniles can be exposed to stranding and isolation from main channel flows when high flows are required for flood control or Delta outflow requirements results in short duration flow increases which are subsequently reduced after the requirement subsides. After high flow events when rearing steelhead fry and juveniles issues are a concern, Reclamation coordinates flow reduction rates utilizing the B2IT and American River Operation Group adaptive management processes to minimize the stranding and isolation concerns versus current hydrologic conditions and future hydrologic projections to Folsom cold-water management. Reclamation attempts to avoid flow fluctuations during non-flood control events that raise flows above 4,000 cfs and then drop them back below 4,000 cfs as recommended by Snider et al (2002). Flow fluctuations are sometimes difficult to avoid with competing standards to meet in the Delta and upstream so some stranding will continue to occur at about the same level as under the baseline.

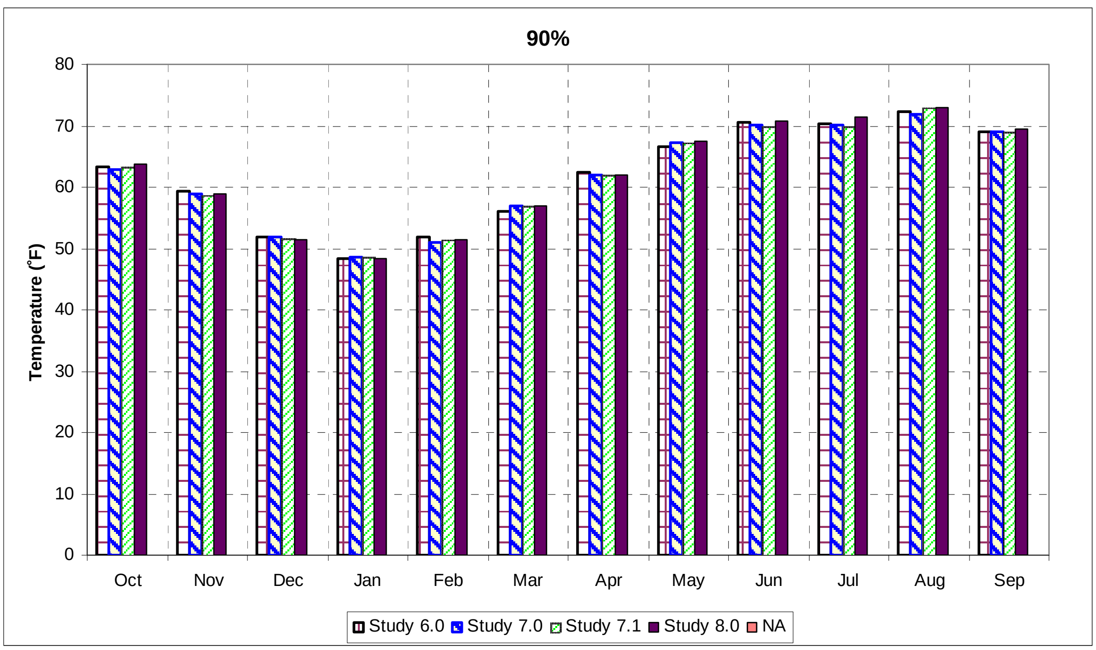

Figure 11-69. 90% exceedence level monthly water temperatures at Watt Avenue for the four OCAP scenarios (dry conditions).

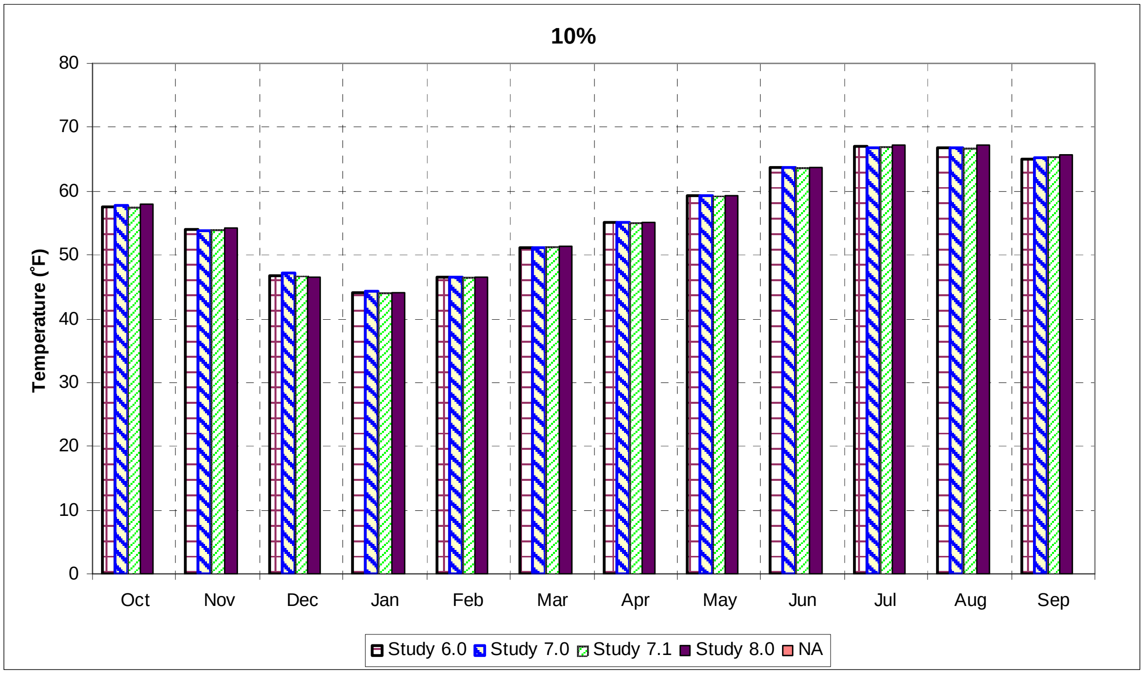

Figure 11-70. 10% exceedence level monthly water temperatures at Watt Avenue for the four OCAP scenarios (wet conditions).

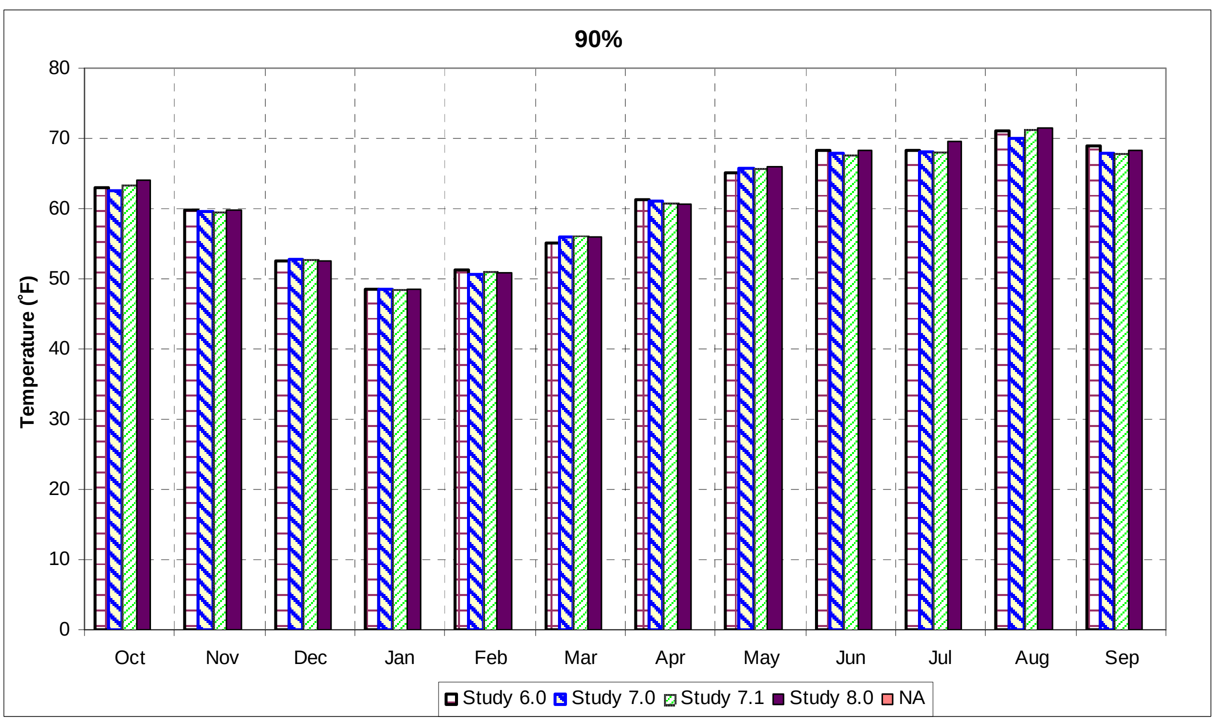

Figure 11-71. 90% exceedence level monthly water temperatures at Nimbus Dam for the four OCAP scenarios (dry conditions).

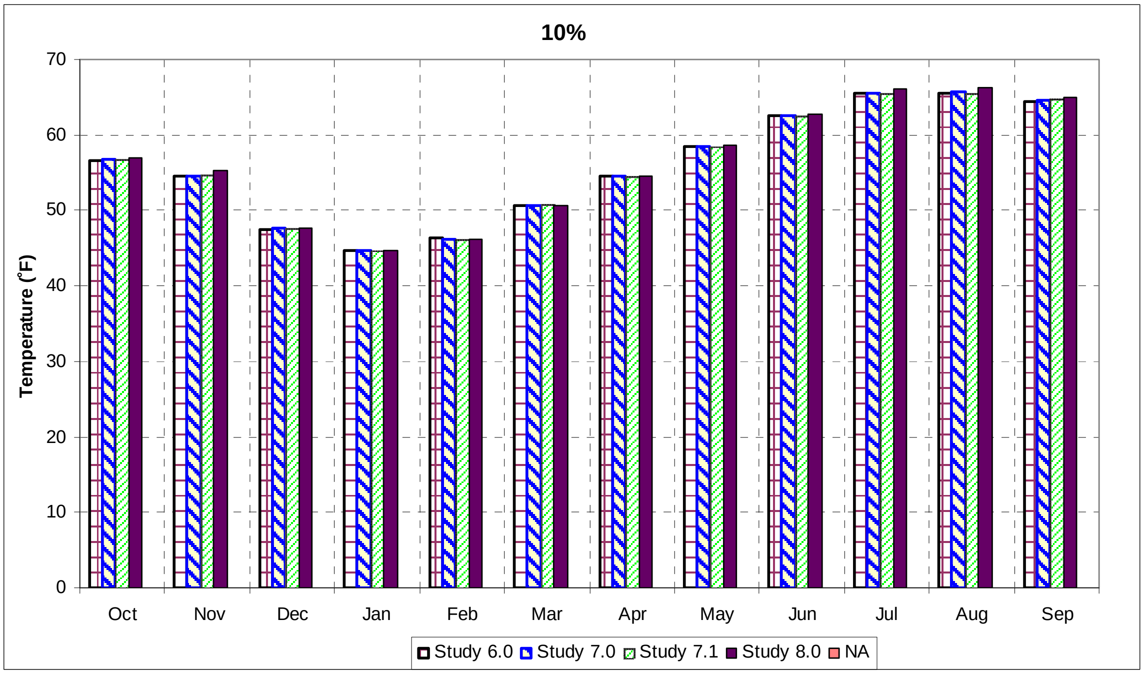

Figure 11-72. 10% exceedence level monthly water temperatures at Nimbus Dam for the four OCAP scenarios (wet conditions).

Gas Bubble Disease and IHN (effects of high releases on critical habitat)

Gas bubble disease was detected in fall-run Chinook salmon in Nimbus Hatchery during flood control releases in 2006. It likely occurred in the river as well. All salmonids are susceptible. An outbreak of infectious hematopoietic necrosis (IHN) also occurred in Nimbus and was implicated to be caused by the stress from the gas bubble disease. High mortality of the hatchery Chinook occurred from the IHN. It is not known whether wild fish in the American River also suffered mortality from IHN. Juvenile Chinook salmon from Nimbus Hatchery are stocked in Folsom Reservoir as a put and take fishery. This upstream stocking could possibly be a source of the IHN, carried into the hatchery by the water supply. The IHN virus isolated from Sacramento River and Feather River Chinook salmon causes high mortalities in Chinook salmon in California but does not readily kill steelhead (Leong 1984). Gas bubble disease can occur below the dams when high flows are released. Supersaturation of the water with dissolved gasses occurs when the water cascades down over dam spillways into the pools below with high force causing higher than normal levels of dissolved gasses in the water. Under the high flows the water quickly flows down through the reregulating reservoir (eg. Lake Natoma on the American) before the extra gasses have time to be released into the atmosphere. When the water reaches the anadromous habitat it is used by the fish and comes out of saturation inside the fish forming gas bubbles. This situation occurs during high runoff years.

Beeman and Maule (2006) studied gas supersaturation effects on migrating steelhead and Chinook during spills at Columbia River dams. They found dissolved gas levels below the dams were high enough to cause gas bubble disease. The levels decreased with increasing distance downstream of the dams. They concluded that hydrostatic compensation, through depth of the fish in the water column, along with short exposure time in the areas of highest dissolved gas levels reduced the effects of gas supersaturation exposure below those generally shown to elicit gas bubble disease signs or mortality.

Frequency of occurrence for flood control releases from the dams is illustrated in Figures 6-6 through 6-11 and Figure 6-13. This approximates the frequency with which supersaturation of water with dissolved gasses in the critical habitat near the dams can be expected to occur. The frequency and duration is expected to be about the same in the future.

Stanislaus River

Adult Steelhead Migration, Spawning, and Incubation

Steelhead life history patterns in the Stanislaus River and the rest of the San Joaquin River system are only partially understood, but studies are underway to determine steelhead populations, extent of anadromy, and run timing. Resident rainbow trout are abundant in the first 10 miles downstream from Goodwin Dam. Anglers report catches of adults that appear to them to be steelhead based on large size and coloration. Rotary screw traps at Oakdale and Caswell catch downstream migrating steelhead with smolting characteristics each year. The Stanislaus River weir has captured a few adult steelhead, mostly during the years it was operated past the first of the year (Figure 11-73). Three of these steelhead captured at the weir were identified as steelhead based on scale samples. The Stanislaus River receives the highest year-round flows during most years and has the coolest water of the three major San Joaquin tributaries. A high population of resident trout in the roughly ten river miles below Goodwin Dam in the Stanislaus River indicates critical habitat conditions are favorable year round for steelhead rearing in the Stanislaus River.

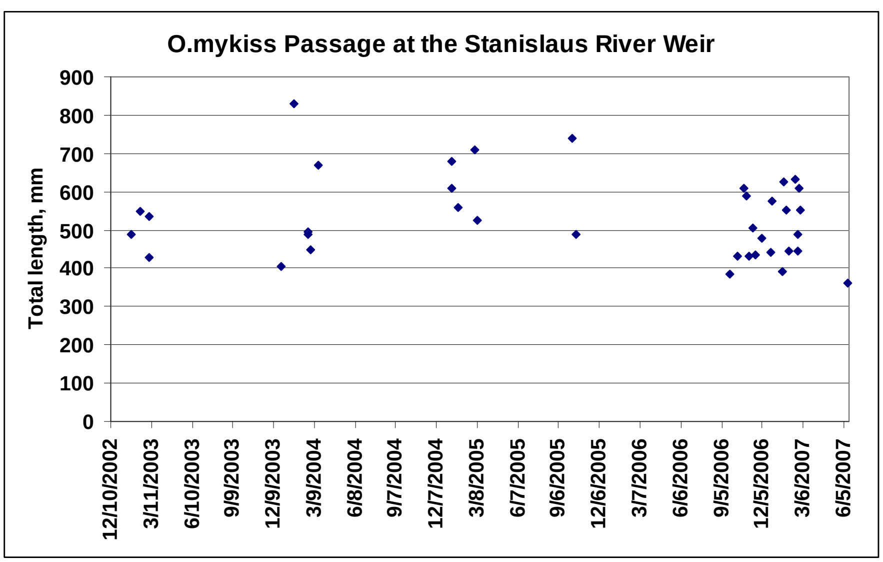

Figure 11-73. O. mykiss passage through the Stanislaus River weir.

River releases from Goodwin Dam are relatively unchanged between the three studies. Steelhead in Sacramento River tributaries migrate upstream to spawn primarily between December and March. Spawning occurs during this period and may extend through April. Based on trout fry observations in Stanislaus snorkel surveys, spawning timing appears to be about the same in the Stanislaus as in the Sacramento River tributaries. Goodwin Dam releases during this period would be mostly from 200 to 500 cfs in December and 125 to 500 cfs in January through March. Flows in April and May would be between 400 and 1,500 cfs. Steelhead spawning flows were estimated to be maximized at 200 cfs and in stream habitat for adult migration and rearing was estimated to be maximized at 500 cfs (Table 4–4). Spawning or holding habitat for adult steelhead is not likely limiting in the Stanislaus because the anadromous component of the population is not abundant. Monthly mean flows as high as 5,000 cfs and as low as 125 cfs could occur throughout the range of precipitation regimes. Flows above about 5,000 cfs could affect egg survival in redds or scour some redds (Table 11-3). Spawning occurs on a number of gravel addition sites. Bed mobility flows are likely lower at these sites until the initial high flows distribute the gravel in a more natural manner. The flows as low as 125 cfs in 90 percent exceedance years and dryer would still provide some spawning habitat for steelhead. The recommended spawning flows for rainbow trout were 100 cfs (Table 4–4). Low flows for upstream migration and attraction during dry years may result in fewer steelhead reaching the spawning areas. During years when flows are low in the Stanislaus they would likely be low in other rivers so that Stanislaus flows should still be a similar proportion of total San Joaquin River flow and Delta outflow.

During low flows from the San Joaquin River dissolved oxygen sometimes reaches lethal levels in the Stockton deep-water ship channel. The low DO can cause a barrier to upstream migrating steelhead and Chinook so that they are delayed or migrate up the Sacramento River or other tributary instead. This generally occurs prior to the time steelhead are migrating up to the Stanislaus. Flows from the Stanislaus help to address the low DO problem by meeting the Vernalis flow standard when possible, although there is not always enough water available from New Melones to meet the flow standard at all times.

Little change in Stanislaus River temperatures at Goodwin Dam is projected to occur (Figure 11-74 and Figure 11-75). Temperatures at Orange Blossom Bridge would be 52 °F or below most of the time from December to February. In March and April temperatures would exceed 52 °F in about 45-60 percent of years and in May in 90 percent of years. Because these temperatures are about the same as in past operations and the Stanislaus River supports a large trout population year round with these temperatures, these temperatures appear to provide sufficient cold water in the critical spawning habitat for the current steelhead population and there is space for additional anadromous individuals.

Steelhead Fry, Juveniles, and Smolts

Most literature has indicated that rearing fry and juvenile steelhead prefer water temperatures between 45 °F and 60 °F (Reiser and Bjorn 1979; Bovee 1978; Bell 1986). However, Myrick (1998) found the preferred temperatures for Mokelumne River Hatchery steelhead placed into thermal gradients were between 62.6 °F and 68 °F.

Snorkel surveys (Kennedy and Cannon 2002) identified trout fry starting in April in 2000 and 2001, with the first fry observed in upstream areas each year. During 2003, a few trout fry were identified as early as January but most did not appear until April as in 2000 and 2001. Rotary screw traps operated at Oakdale and Caswell capture rainbow trout/steelhead that appear to exhibit smolting characteristics (Demko and others 2000). These apparent smolts are typically captured from January to mid-April, and are 175 to 300 mm fork length. Because steelhead smolts are generally large (>200 mm) and strong swimmers, predicted Goodwin Dam releases are expected to provide adequate depth and velocity conditions for emigration at all times. Spring storms that generally occur during this period provide pulse flows from tributaries below Goodwin Dam that will stimulate and assist in out migration. The lowest flows predicted between January and April would be 125 cfs. Flows would pick up in mid-April for the VAMP period and provide an out migration pulse for any steelhead smolts still in the river that late.

Smolts are thought to migrate through the lower reaches rather quickly so should be able to withstand the few days of warmer temperatures when migrating to the estuary or ocean. The current temperature compliance point is 65 °F at Orange Blossom Bridge June 1 to November 30. Most of the steelhead spawning and rearing habitat extends from near Orange Blossom Bridge up to Goodwin Dam. This is the area with higher gradients producing riffles used by steelhead for rearing, food production, and spawning. Gradients below the vicinity of Orange Blossom Bridge are flatter with sand substrates more prevalent as you get further downstream. These habitats are less suitable for steelhead rearing. Temperatures would be below 65 °F through June in 95 precent of years (Figure 11-76 and Figure 11-77). About 5 percent of years in July, could be above 65 °F. In August and September, temperatures could exceed 65 °F at Orange Blossom in about 15 percent of years. Temperatures during summer would be about the same under future scenarios in the summer at Orange Blossom. Year round temperatures for steelhead in the upper river above Orange Blossom Bridge are suitable for steelhead rearing (Figure 11-74 and Figure 11-75).

Although Stanislaus River operation assumptions changed between scenarios, results show there are only slight changes (annual average) to flows and temperatures. Effects of the project on steelhead and their critical habitat in the Stanislaus River are expected to be about the same between the OCAP scenarios. Migratory conditions through the delta may be the most significant factor affecting the proportion of O.mykiss in the Stanislaus River that assume an anadromous lifecycle.

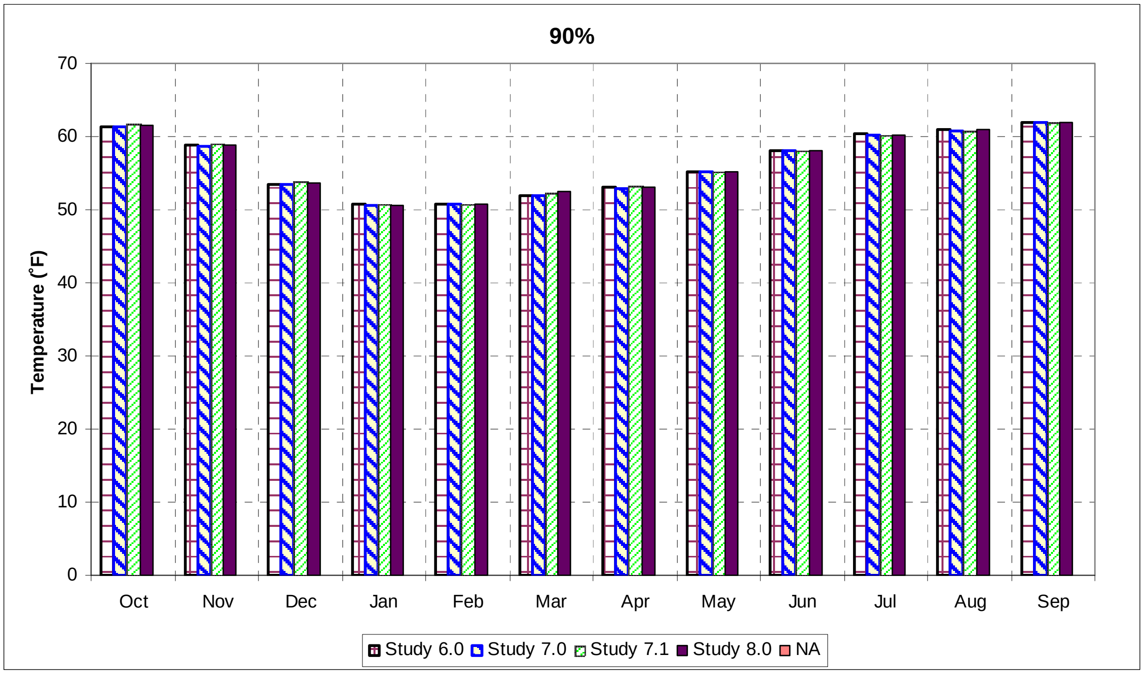

Figure 11-74. Stanislaus River at Goodwin Dam modeled water temperatures for the four studies at the 90% exceedence level (dry conditions).

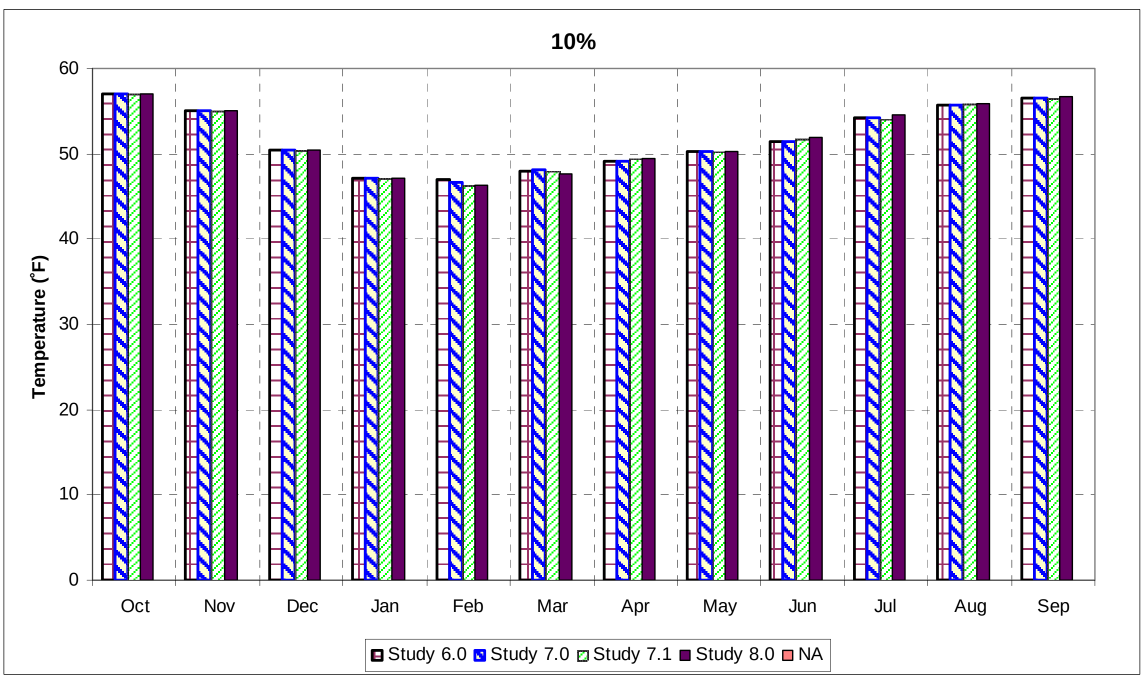

Figure 11-75. Stanislaus River at Goodwin Dam modeled water temperatures for the four studies at the 10% exceedence level (wet conditions).

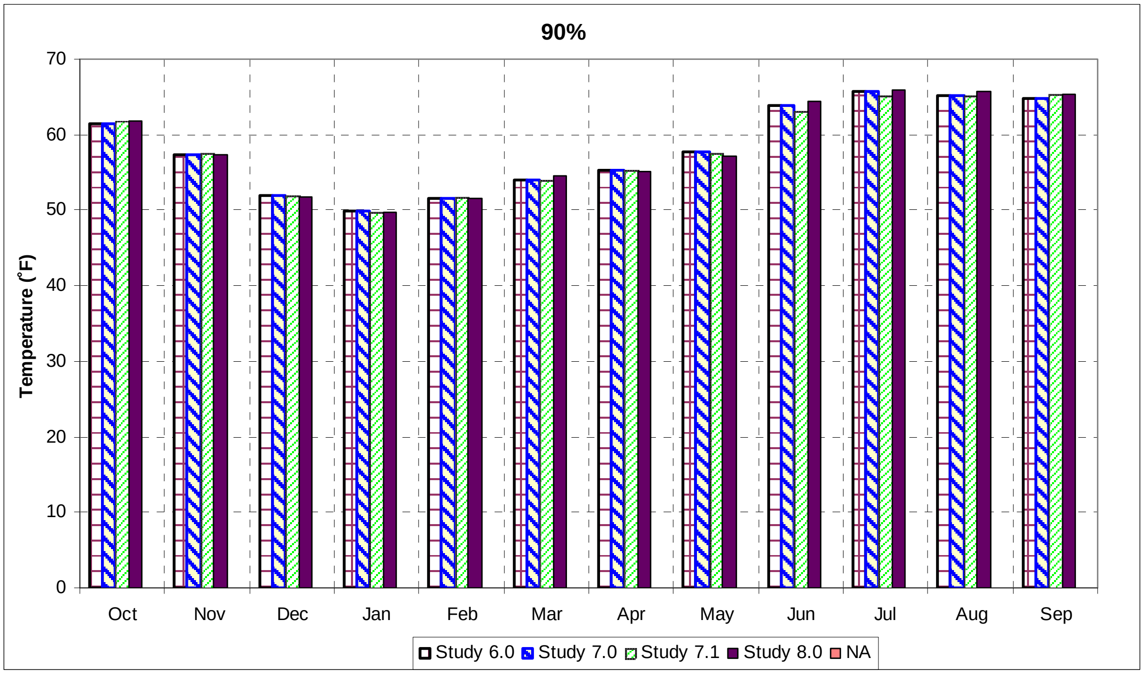

Figure 11-76. Stanislaus River at Orange Blossom Bridge modeled water temperatures for the four studies at the 90% exceedence level (dry conditions).

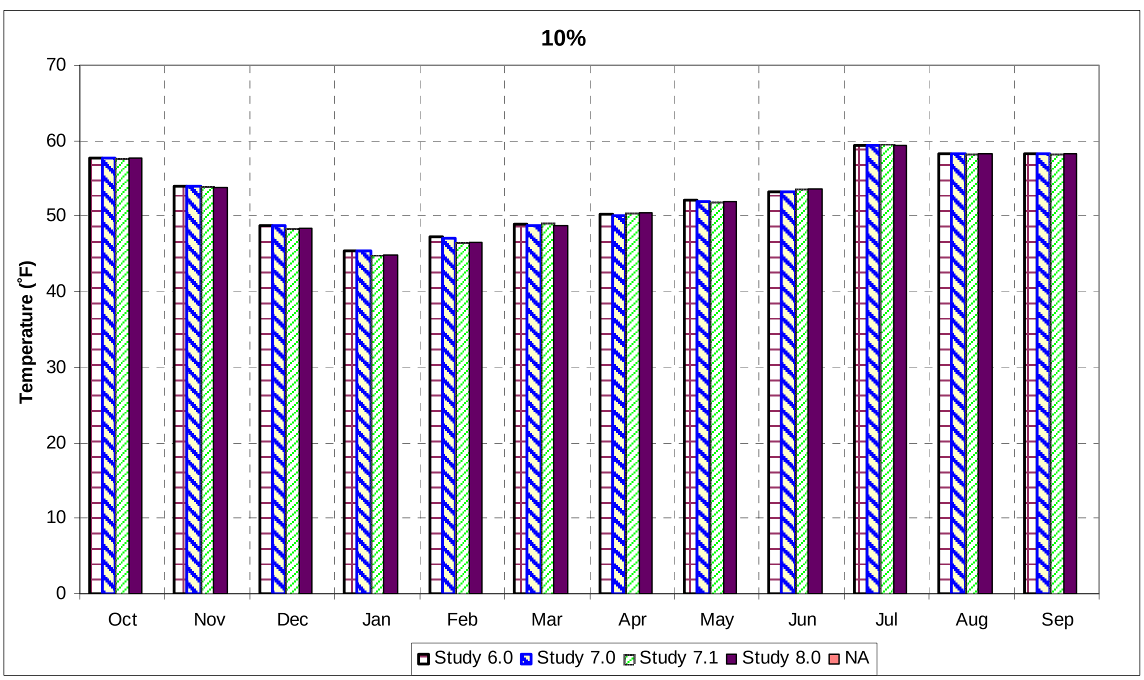

Figure 11-77. Stanislaus River at Orange Blossom Bridge water temperatures for the four studies at the 10% exceedence level (wet conditions).

San Joaquin River

Adult Steelhead Migration, Spawning, and Incubation

The modeling shows essentially no difference in flows in the San Joaquin River between the current and future modeled scenarios. Steelhead life history patterns in the San Joaquin River system are only partially understood, but studies are underway to determine steelhead populations, extent of anadromy, and run timing. Steelhead/rainbow populations exist in the San Joaquin tributaries and smolt-sized fish get captured by trawling in the lower river near Mossdale (Figure 3-17). Adult steelhead are assumed to migrate up the San Joaquin River in late fall and winter, after temperatures and dissolved oxygen conditions become suitable for migrations to occur. Spawning, although not well documented, likely occurs in the tributaries primarily from January through March. No steelhead spawning or incubation occurs in the mainstem San Joaquin River because habitat conditions (gravel and higher gradient) is not suitable in the lower river.

Supplemental water released in the Stanislaus River for Chinook salmon in October will generally provide conditions (attraction flow, lower temperature, and higher dissolved oxygen) in the lower San Joaquin River and through the Stockton Deep-water Ship Channel suitable for upstream migrating steelhead. During November and through the rest of the upstream migratory period ambient cooling generally provides suitable conditions for migrations up through the San Joaquin. Prior to the October pulse, conditions in the lower San Joaquin and Stockton Deepwater Ship Channel are sometimes unsuitable for migrating steelhead (Lee 2003). Early returning fish could be delayed or stray to the Sacramento River tributaries when San Joaquin River conditions are unsuitable. During pre-dam days temperatures were likely higher and flows in the lower San Joaquin were likely lower than what occurs currently (although dissolved oxygen was probably not as much of an issue then) so there were not likely historically steelhead returning to the San Joaquin during late summer and fall before ambient cooling and seasonally increased flows occurred.

Steelhead Fry, Juveniles, and Smolts

San Joaquin River flow and habitat conditions are not predicted to change under the future scenarios. Habitat conditions in the San Joaquin River do not appear well suited to young steelhead rearing because there are no riffles or gravel for invertebrate production and temperatures are often too high. Fry and juvenile steelhead rearing for long periods in the San Joaquin River is not likely a common occurrence. The river likely serves primarily as a migratory corridor for smolts heading to saltwater. Out migration from the San Joaquin tributaries to saltwater probably occurs from November through May. The lowest flows during this period would be about 1,200 cfs in January of 1 percent of years. The 50th percentile flows range from about 2,100 cfs in December to about 5,000 cfs in April. The larger size of steelhead smolts makes them stronger swimmers than juvenile salmon so they should be better able to out-migrate during the low water velocity years when flows are lower. Conditions in the critical habitat in the San Joaquin River during the summer and fall are not conducive to successful out migration or habitation because water is warmer and dissolved oxygen sags occur.

San Joaquin River flows from the Merced River downstream are managed for one life history type of Chinook salmon. Flows are managed for fall run Chinook salmon to enter the river in October, spawn in November, and incubate and rear in the river until late spring. A month long increased flow pulse is provided each year generally mid April to mid May to aid emigration of the large (~75-100 mm) Chinook salmon juveniles out of the river and through the Delta to the estuary. Flows prior to April 15 are managed for in-river rearing of Chinook and steelhead with no pulses, other than that provided by brief tributary inflows, to aid emigration of yearling Chinook, Chinook fry, or steelhead from the system. Little data on steelhead in the San Joaquin system exists so it is assumed that the flows that are managed for fall run Chinook will adequately support the steelhead life history. Data from the Stanislaus River weir shows that the adult steelhead population in the Stanislaus is very low compared to the large resident rainbow trout population that is evident when snorkeling the river.

Climate Change

Details on climate change sensitivity analyses are presented in Appendix R. Temperatures in California are projected to increase several degrees centigrade (°C) by the end of this century as a result of climate change. One expected consequence of this is further reduction in the State's annual snowpack with more precipitation falling as rain, and earlier melting of snow. Warming and reduction to the State's snowpack will affect the operation of most major multipurpose reservoirs at low and mid-elevations in the Sierra including all of those included in this consultation.

Climate change could also affect the intensity, duration, and timing of precipitation events in California as well as the spatial distribution and temporal variability of precipitation. Significant changes in one or more of these factors would present major challenges for water supply management, and therefore have an effect on future water demand patterns. However, many other factors such as population, land development and economic conditions that are not directly related to climate change will also affect future demand.

Predicting effects of climate change on Chinook salmon, steelhead, and green sturgeon is difficult due to the uncertainty of future changes. According to the DWR climate change report, Sierra watersheds with snowpack are predicted to get less snow and more rain, more winter and less spring and summer runoff, and warmer runoff. Increased water temperatures pose a threat to aquatic species that are sensitive to elevated water temperature, including anadromous fish. Increased water temperatures would decrease dissolved oxygen concentrations in water and would likely increase production of algae and some aquatic weeds. (DWR 2006)

In many low- and middle-elevation streams in California today, summer temperatures often come close to or exceed the upper tolerance limits for salmon and steelhead. Thus, anticipated climate change that raises air temperatures a few degrees celsius may be enough to raise water temperatures above the tolerance of salmon and trout in many streams, favoring instead non-native fishes such as carp and sunfish. Chinook salmon and steelhead trout that migrate upriver early in the year, spending the summer in deep, cold pools, and spawning in the summer or fall (Chinook salmon) or winter (steelhead) depend on the availability of cold water for survival over the summer months. Climate change could reduce the volume of cold water in storage in reservoirs and groundwater upwelling/springs, and tributaries since they would receive less snowmelt and have reduced carryover storage. Runoff would occur earlier in the year and require earlier releases for flood control, reducing coldwater pools for summer. Thus, the availability of cold water volumes needed to maintain releases of cold water to support salmonid and sturgeon spawning and rearing below the dams may decline. Due to the combination of anticipated warmer and shallower streams and rivers, climate change may diminish most summer habitat for steelhead and winter-run Chinook and potentially all such habitat now used by spring-run Chinook salmon (DWR, 2006).

Study 9.0 is considered the baseline for climate change scenario comparisons. Study 9.0 is the same as study 8.0 except it does not include EWA and b2. Study 9.1 is the same as 9.0 except that study 9.1 includes a one foot sea level rise. Studies 9.2, 9.3, 9.4, and 9.5 all include the one foot sea level rise and the various changes in precipitation and temperature. Figure 11-78 and Figure 11-79 show the effect of climate change scenarios on winter-run Chinook egg mortality. Results in all year types show increased mortality in studies other than the wetter, less warming scenario, when mortality would be reduced. Four years show near 100% egg mortality in the dryer, more warming scenario. Figure 11-80 and Figure 11-81 show that spring-run Chinook egg mortality in the Sacramento River would also be increased in all year types except for under the wetter, less warming scenario. Figure 11-82 shows the average egg mortality for all four runs increases in all except the wetter, less warming scenario. Figure 11-83 shows effects of the scenarios on coldwater pool volume in Shasta Reservoir. Figure 11-84 through Figure 11-89 show Chinook salmon egg mortality in the Trinity, Feather, American, and Stanislaus Rivers under the climate change scenarios. These results are for fall-run Chinook but show the likely trend for the other runs and species as well. Effects on egg incubation in coho salmon in the Trinity River would be less than for Chinook because coho spawn during the coolest time of year. Effects in the Feather River shownot much change in the wetter and less warming scenario but increased mortality for the other scenarios. Effects in the American River would likely be greater for Chinook than for steelhead but the general trend would be increased mortality under most conditions with climate change. Figure 11-88 shows effects on coldwater pool volume in Folsom Reservoir. Stanislaus River steelhead egg mortality would be less than for Chinook. The Stanislaus River shows much greater effect due to climate change scenarios than due to changes in water operations under the regular studies.

The mortality model shows projections of egg incubation success due to water temperature changes between the climate change scenarios. Additional effects to eggs could occur due to higher high flows under the increased precipitation and temperature scenarios. This could result in scouring eggs from the gravel or entombment of eggs due to additional deposition on top of redds. Effects to Chinook and steelhead adults in the rivers include a reduction in the quality and amount of holding habitat prior to spawning. These effects would be greatest for spring run Chinook because they hold over all summer in the rivers before spawning in the fall. Increasing water temperatures can increase the rate of development of eggs and result in earlier emergence timing and smaller fry. If the entire freshwater lifestages are condensed into a shorter period of time then Chinook salmon could reach the ocean earlier, potentially prior to the time of greatest productivity in the spring. If many fish enter the ocean at an earlier time then food could be limiting for the juvenile fish in the ocean. Salmonids have evolved with peak ocean entry times to coincide with periods of plankton blooms and high juvenile food availability in the ocean. The climate change scenarios could alter this pattern so that fish become out of balance with their food supply in the ocean.

Increased water temperature in the rivers under climate change scenarios would improve conditions for predatory fish such as bass. As shown in Figure 11-90 and Figure 11-91 water temperatures at Balls Ferry and at Freeport would increase. The 50% Freeport temperatures could increase by up to as much as three degrees as a monthly average in the summer. Over-summer rearing conditions for steelhead in rivers would be degraded with warmer temperatures. This would occur particularly in the American River. Conditions for over-summer rearing of juvenile steelhead in Nimbus Hatchery would be degraded. Steelhead would likely need to be moved to other hatcheries more often to be reared over the summer. Although these steelhead are not considered to be a part of the DPS, they play a large role in producing the in-river spawners. Salmonids could become more susceptible to diseases such as IHN under increased water temperatures. Salmon and steelhead would be more confined to areas closer to the dams where water is coolest during warm weather and predators would have increased food requirements in the warmer water.

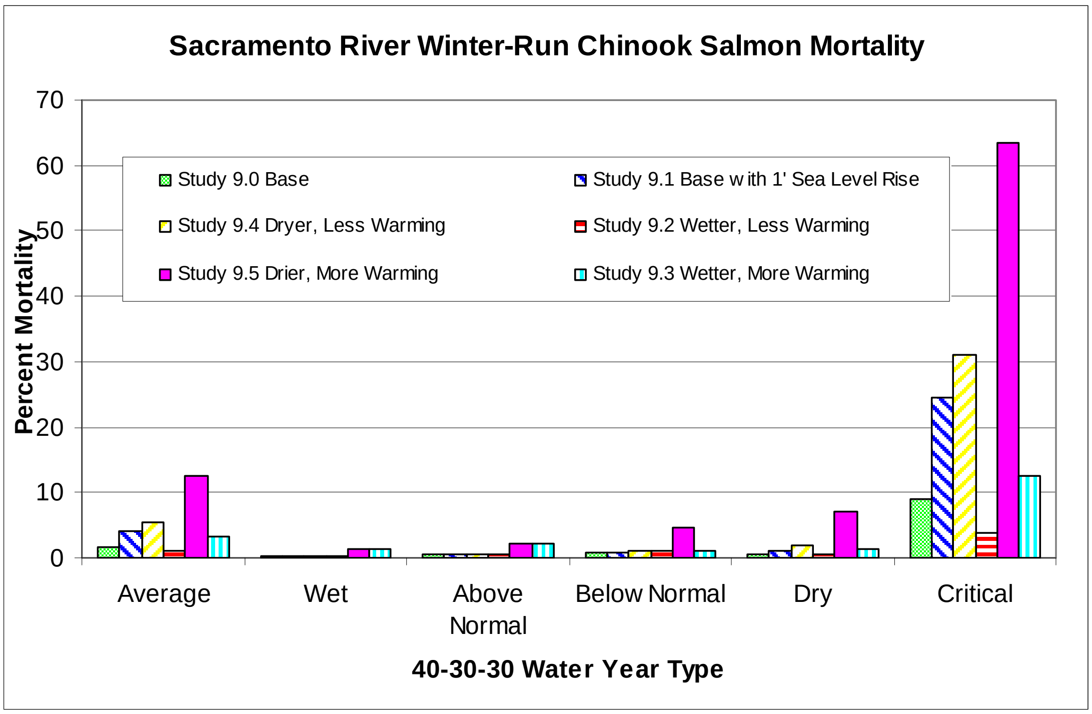

Figure 11-78. Sacramento River winter-run Chinook egg mortality with climate change scenarios from Reclamation egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

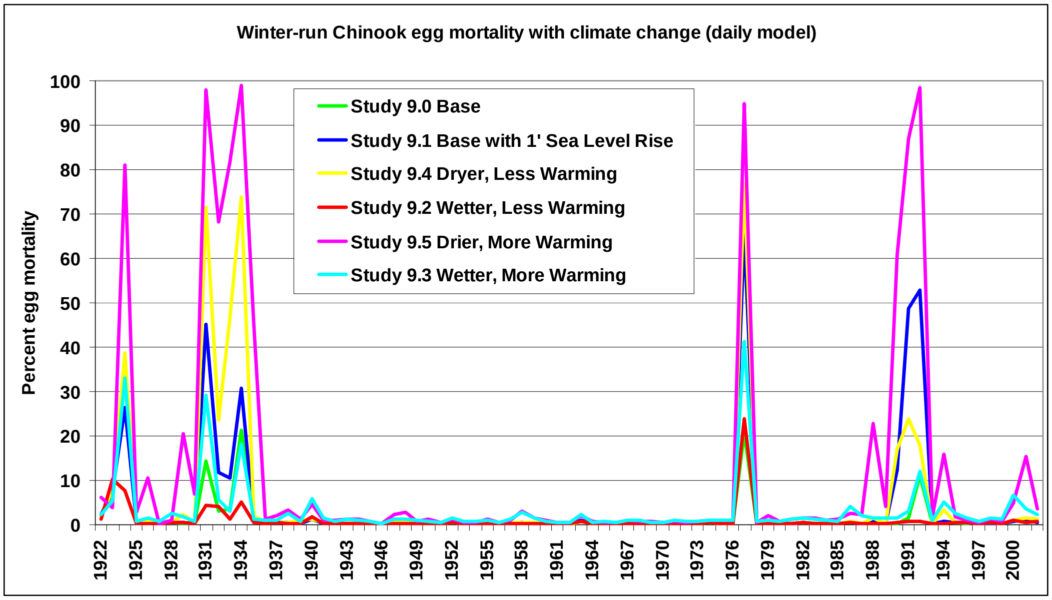

Figure 11-79. Sacramento River Winter-run Chinook egg mortality with climate change scenarios from Reclamation egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

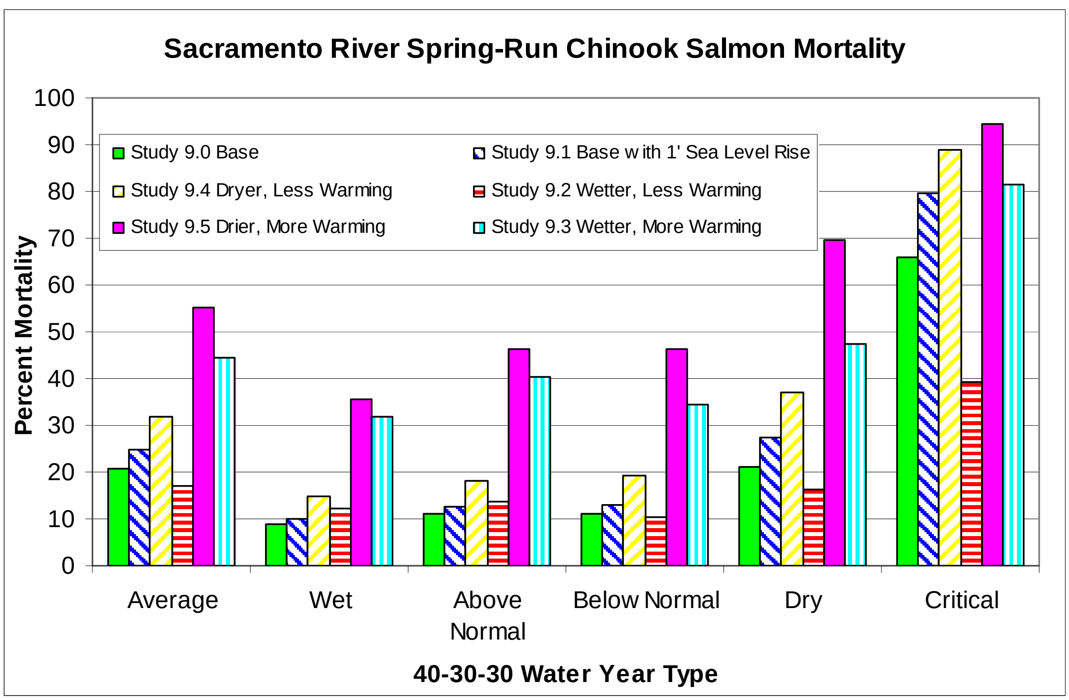

Figure 11-80. Sacramento River spring-run Chinook egg mortality with climate change scenarios from Reclamation salmon egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

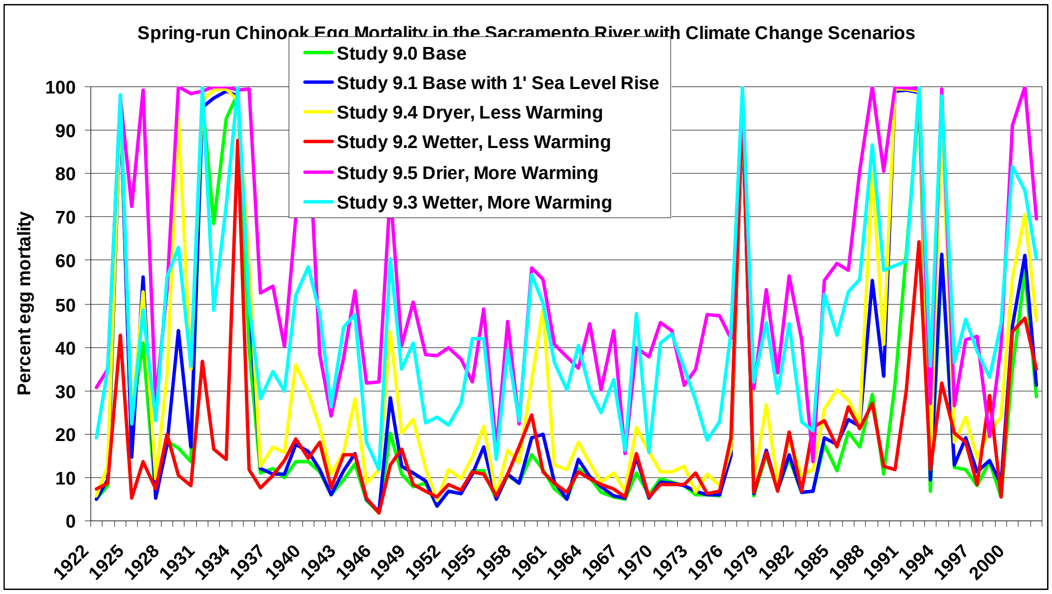

Figure 11-81. Sacramento River spring-run Chinook egg mortality with climate change scenarios record from Reclamation egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

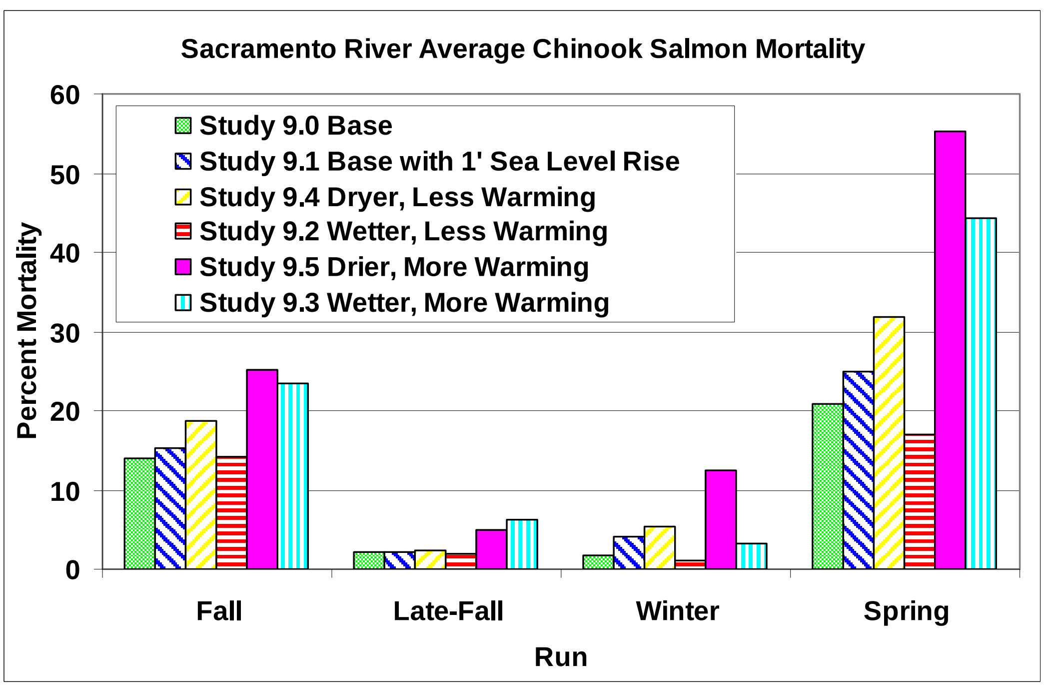

Figure 11-82. Sacramento River average Chinook salmon mortality by run and climate change scenario from Reclamation salmon egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

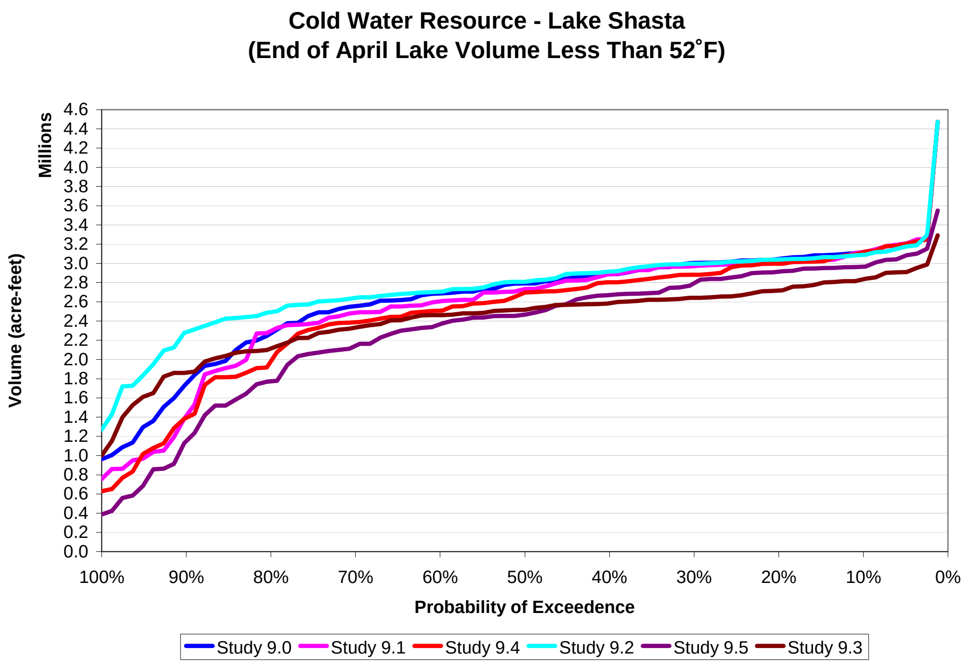

Figure 11-83.Shasta Lake coldwater pool volume at end of April with climate change scenarios. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

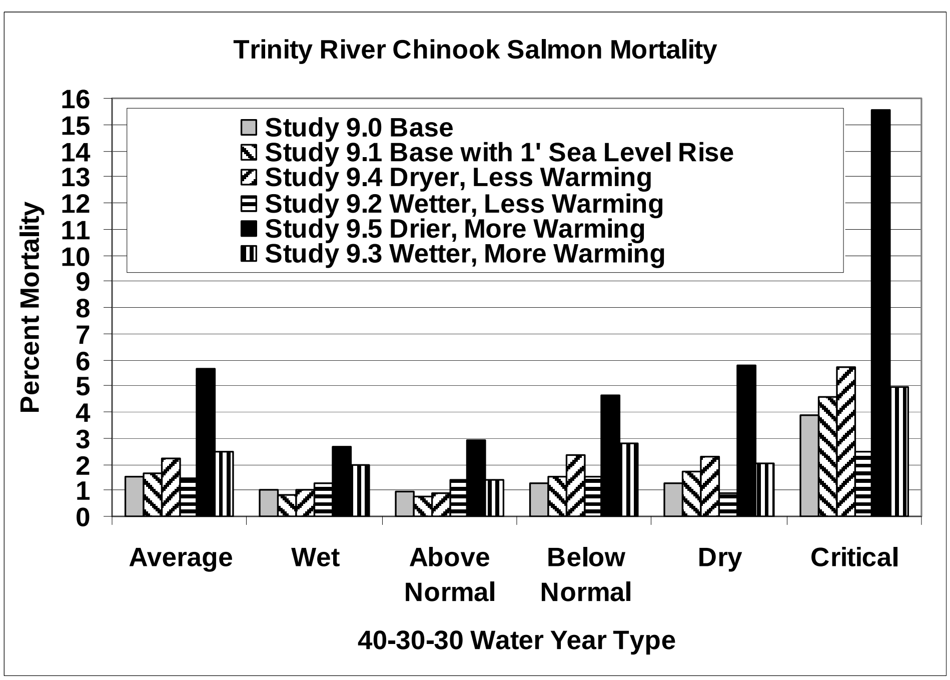

Figure 11-84. Trinity River fall-run Chinook egg mortality with climate change scenarios from Reclamation salmon egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

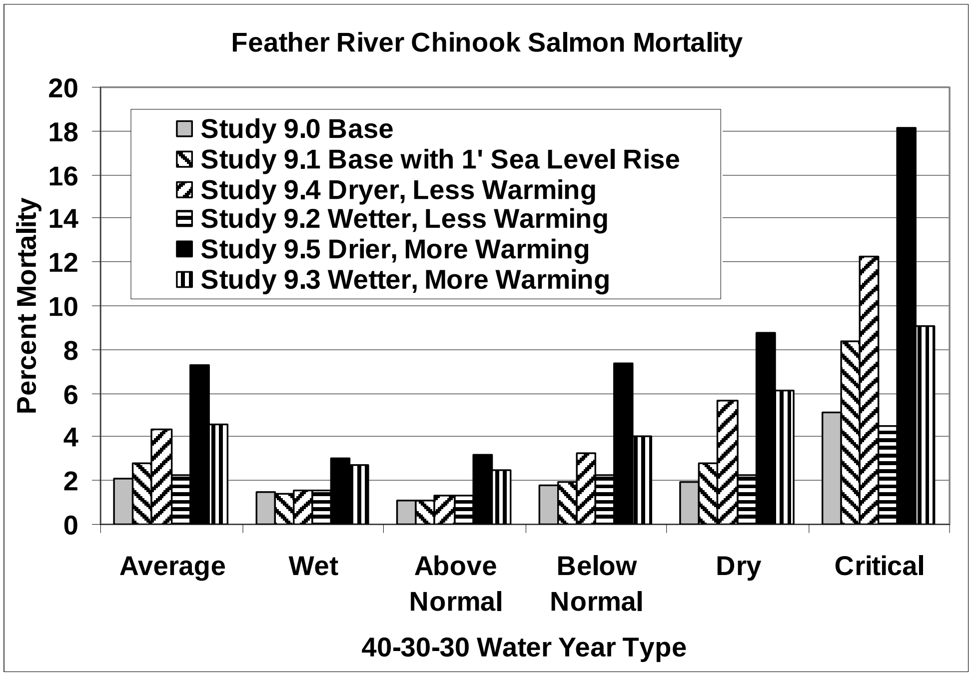

Figure 11-85. Feather River fall-run Chinook egg mortality with climate change scenarios from Reclamation egg mortality model. All studies except 9.0 include 1’ sea level rise. Study 9.0 is future conditions with D-1641.

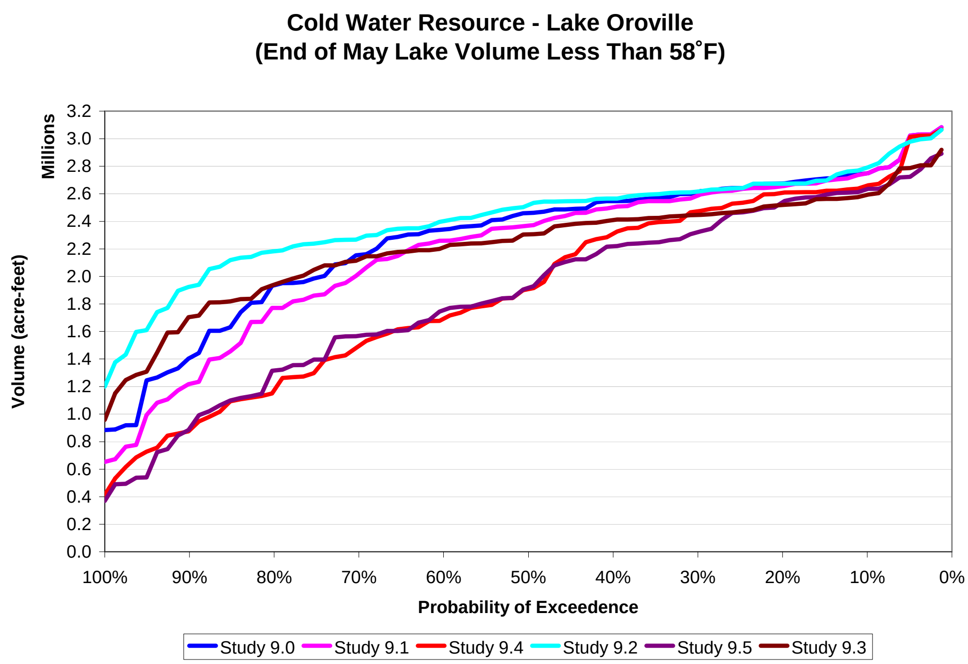

Figure 11-86. Oroville Lake coldwater pool volume at end of April with climate change scenarios. All studies except 9.0 include 1’ sea level rise. Study 9.0 is future conditions with D-1641.

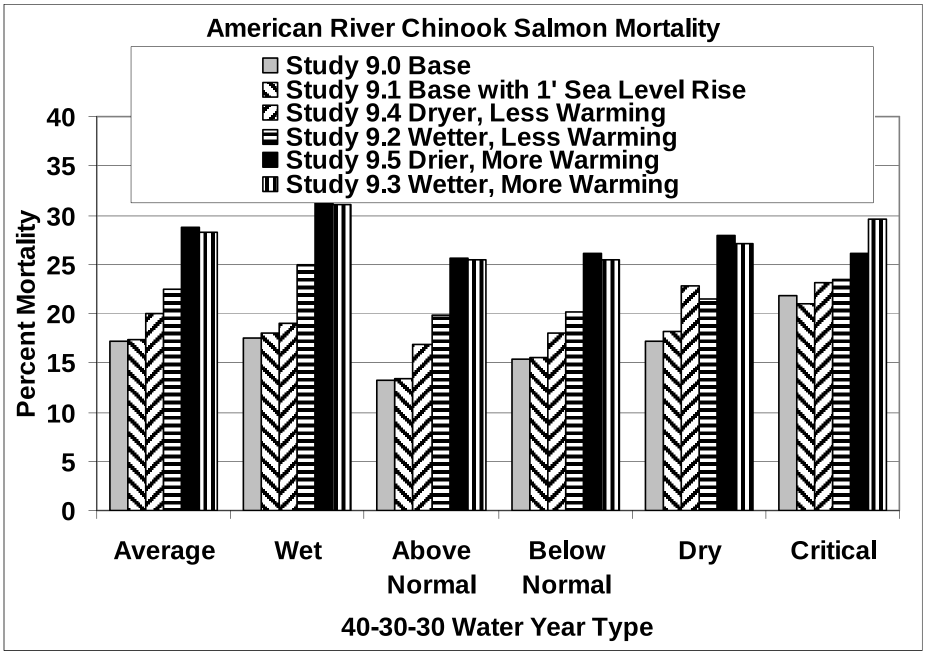

Figure 11-87. American River fall-run Chinook egg mortality with climate change scenarios from Reclamation salmon egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

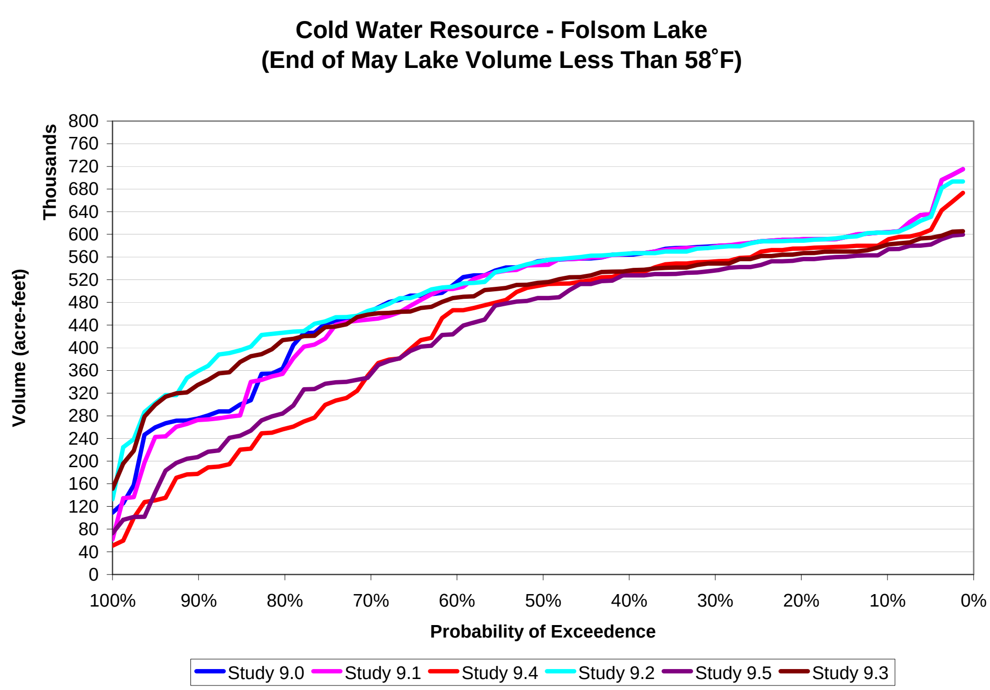

Figure 11-88. Folsom Lake end of May coldwater pool with climate change scenarios. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

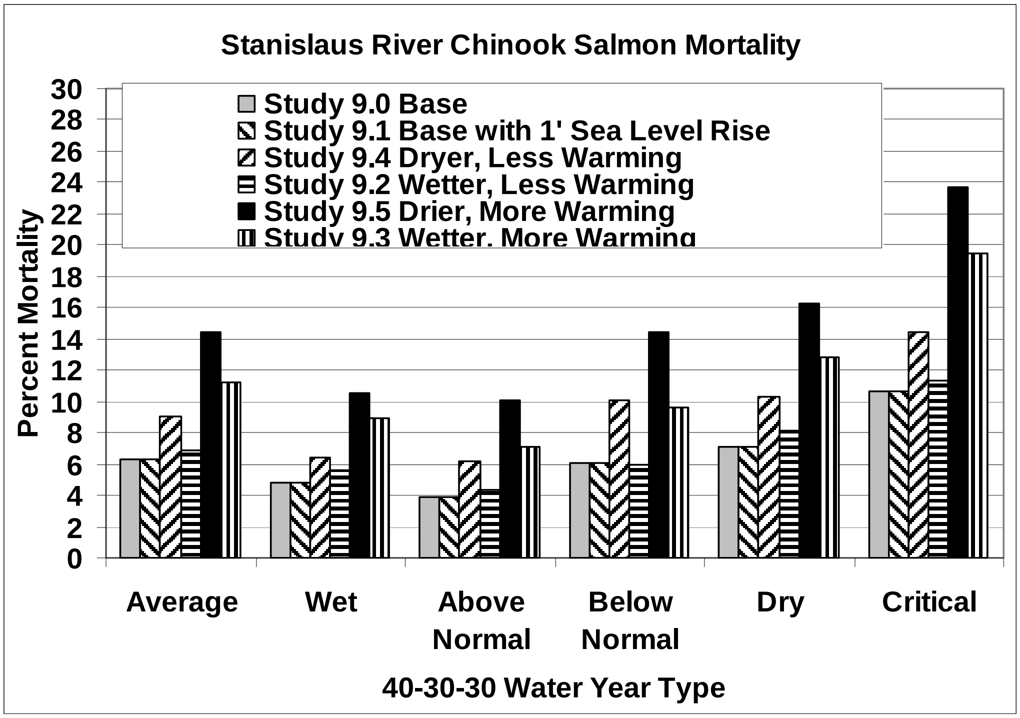

Figure 11-89. Stanislaus River fall-run Chinook egg mortality with climate change scenarios from Reclamation salmon egg mortality model. All studies except 9.0 include 1' sea level rise. Study 9.0 is future conditions with D-1641.

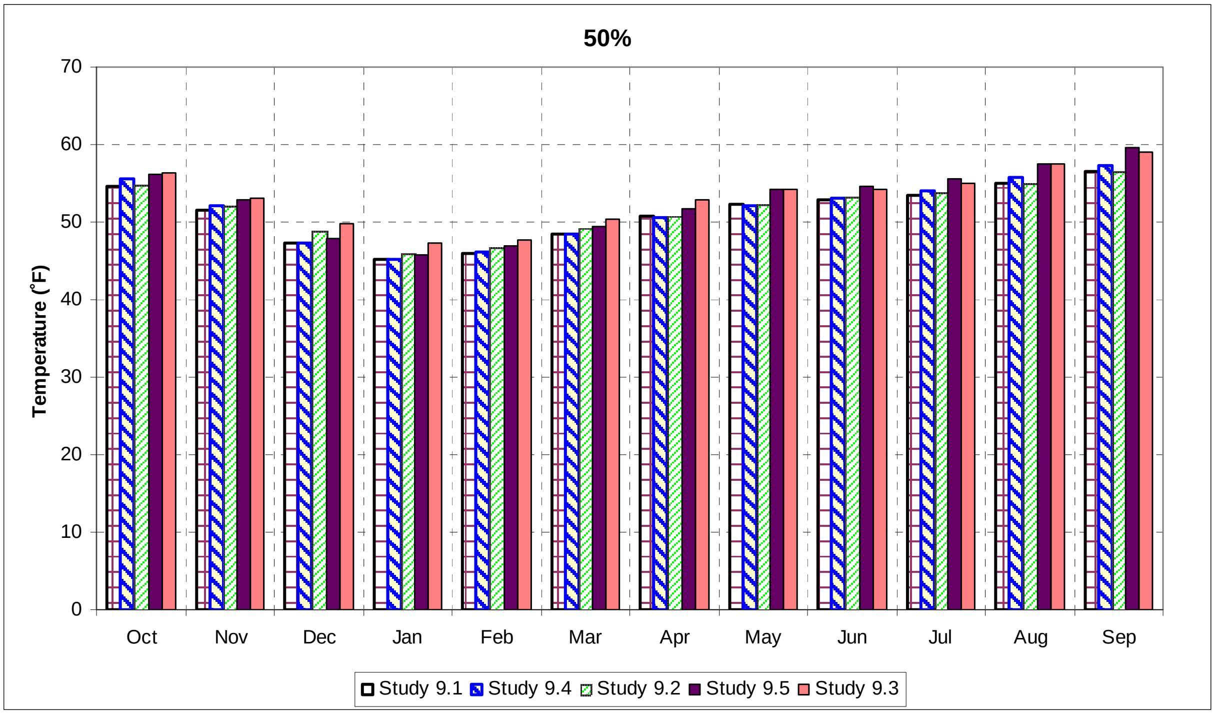

Figure 11-90. Water temperature in the Sacramento River at Balls Ferry under climate change scenarios at the 50% exceedence level.

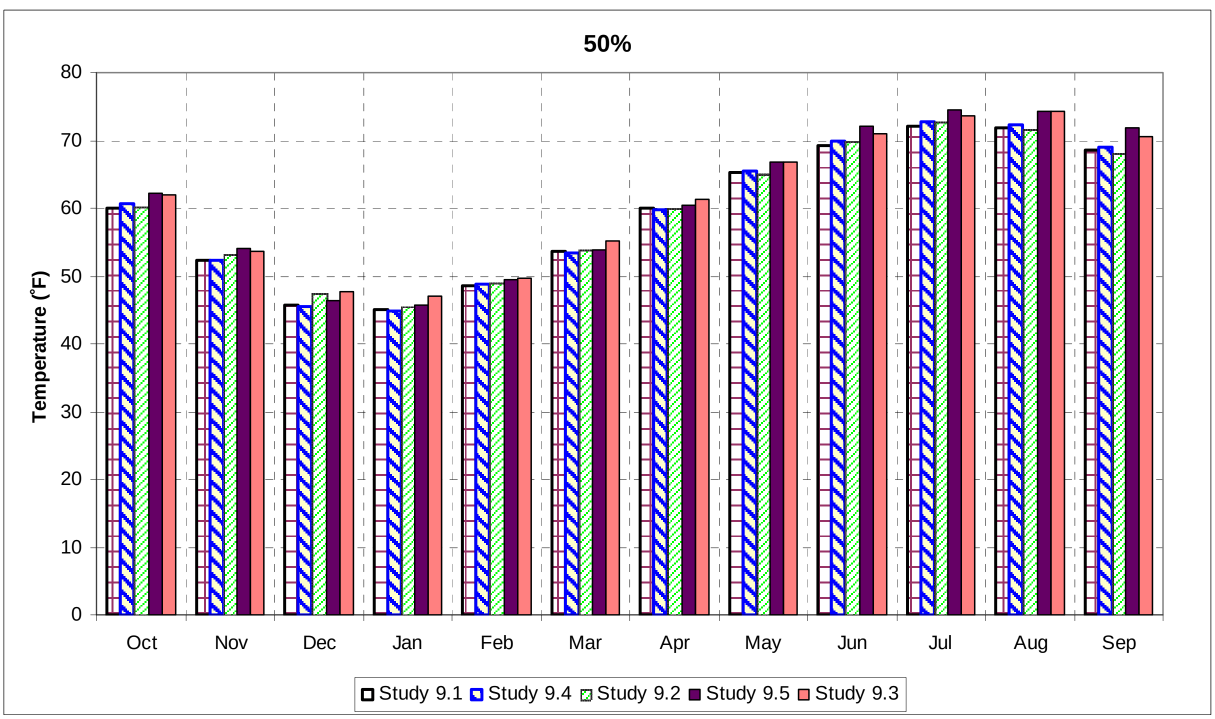

Figure 11-91. Water temperature in the Sacramento River at Freeport under climate change scenarios at the 50% exceedence level.

A mechanism exists whereby global greenhouse warning could, by intensifying the alongshore wind stress on the ocean surface (due to increased temperature gradient between land and water), lead to acceleration of coastal upwelling. Evidence from several different regions suggests that the major coastal upwelling systems of the world have been growing in upwelling intensity as greenhouse gases have accumulated in the earth's atmosphere. Effects of enhanced upwelling on the marine ecosystem are uncertain but potentially dramatic (Bakun 1990). Focusing on the California Current, Diffenbaugh et al (2003) show that biophysical land-cover–atmosphere feedbacks induced by CO_2 radiative forcing enhance the radiative effects of CO_2 on land–sea thermal contrast, resulting in changes in eastern boundary current total seasonal upwelling and upwelling seasonality. Specifically, relative to CO_2 radiative forcing, land-cover–atmosphere feedbacks lead to a stronger increase in peak- and late-season near-shore upwelling in the northern limb of the California Current and a stronger decrease in peak- and late-season near-shore upwelling in the southern limb. Barth et al (2007) show how a 1-month delay in the 2005 spring transition to upwelling-favorable wind stress in the northern California Current Large Marine Ecosystem resulted in numerous anomalies: warm water, low nutrient levels, low primary productivity, and an unprecedented low recruitment of rocky intertidal organisms. Early in the upwelling season (May–July) off Oregon, the cumulative upwelling-favorable wind stress was the lowest in 20 years, nearshore surface waters averaged 2°C warmer than normal, surf-zone chlorophyll-*a* and nutrients were 50% and 30% less than normal, respectively. Delayed early-season upwelling and stronger late-season upwelling are consistent with predictions of the influence of global warming on coastal upwelling regions.

Implications for salmonids are that if coastal upwelling does indeed increase but occur later under warming scenarios then, although uncertain, food supplies for salmonids in the ocean could increase and provide favorable foraging conditions and high ocean survival.

Consideration of Variable Ocean Conditions

Salmon and steelhead spend the majority of their lives in the ocean. Therefore, conditions in the ocean exert a major influence on the growth and survival of these fish from the time they leave freshwater until they return as adults to reproduce. Mantua et al (1997) described a recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude North Pacific basin. Over the past century, the amplitude of this climate pattern has varied irregularly at interannual-to-interdecadal time scales. This pattern is referred to as the Pacific Decadal Oscillation (PDO). Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States, while cold PDO eras have seen the opposite north-south pattern of marine ecosystem productivity.

Another pattern, called the *El Niño/Southern Oscillation (ENSO)*, occurs on a shorter time scale of six to eighteen months compared to 20 to 30 years for the PDO. The same general pattern is evident with warm periods showing inhibited productivity along the Pacific coast of the southern US and enhanced ocean biological productivity in Alaska.

Sierra snowpack and streamflow are also correlated with ENSO and PDO. During the warm phases lower snowpack and streamflows occur and during cool phases above average snowpack and streamflows occur (Mantua et al, 1997).

During the cooler phases of ENSO and PDO, California salmon populations generally experience increased marine survival. In addition, higher streamflows tend to occur during the cooler phases, enhancing freshwater production and providing the opportunity for more diverse life history types of juvenile salmonids. The inverse effects on California salmonid populations tend to occur during warm cycles. These alternating patterns of productivity, which are independent of CVP and SWP water operations, can mask most changes in populations that occur due to water operations. The effects of habitat conditions resulting from water operations interact with the effects of oceanic productivity on salmon survival/production. Ocean conditions can exert a dominant effect on year-to-year productivity. Therefore, any effects need to be considered in light of variable and difficult to quantify ocean conditions and climate variability.

Returns of several West Coast Chinook and coho salmon stocks were lower than expected in 2007. In addition, low jack returns in 2007 for some stocks suggest that 2008 returns will be at least as low. Central Valley fall run Chinook escapement was estimated to have been less than 25 percent of predicted returns and below the escapement goal of 122,000 – 180,000 adults for the first time since the early 1990's and continuing a declining trend since the recent peak abundance in 2002. For the spring and summer of 2005 (the ocean-entry year for 2004 brood fall-run Chinook and 2003 brood coho), two approaches to estimating ocean suitability for juvenile salmon both indicated very poor conditions for salmon entering the ocean, indicating poor returns for coho in 2006 and age 3 fall Chinook in 2007. Coast-wide observations showed that 2005 was an unusual year for the northern California Current, with delayed onset of upwelling, high surface temperatures, and very low zooplankton biomass. These poor ocean conditions provide a plausible explanation for the low returns of Central Valley fall Chinook in 2007 and coho in 2006 and 2007. Coho returns to Trinity River Hatchery were not reduced in 2006 but 2007 returning coho were severely reduced and would have been affected by the 2005 ocean conditions. Consistent with Central Valley fall Chinook record low jack return in 2007, the ocean indicators would predict very low fall Chinook adult returns in 2008 (Varanasi and Bartoo, 2008). As a result of predicted low returns the California commercial and recreational fishing season have been closed by the PFMC and NMFS in 2008.

According to Robert Webb (pers comm.) the timing and intensity of springtime upwelling along the west coast of the US has dramatic impacts on the productivity and structure of the California Current ecosystem with studies documenting the effects on marine mammals, coast sea birds, and marine and anadromous fish populations. Schwing et al (2006) documented the delayed onset of upwelling in the northern California Current in 2005, noting that while not unprecedented, this delay impacted dramatically organisms with life histories closely tied to the evolution of the annual cycle and dependent on the high productivity associated with the upwelling. One thing to note was the unusually warm (nutrient depleted) water that penetrated north as far as Oregon.

The wind-driven California Current System (CCS) plays a critical role as it advects cold water southward along the western coast, thus contributing to a significant land-sea temperature and pressure difference in spring-summer when the land warms. This pressure difference results in northerly coastal winds that drive coastal upwelling, bringing nutrient rich water to the surface. The California Current is also linked to the large-scale wind forcing and ocean circulation. For example, the second EOF of SST and sea surface height over the North Pacific is characterized by a dipole-like structure with a nodal line along 40°N, close to the axis of the eastward flowing

North Pacific Current. Variations of this mode primarily correspond to a strengthening and weakening of the north Pacific gyre circulation. North of Cape Mendocino (~40°N) upwelling starts in spring and lasts until fall, while south of Cape Mendocino upwelling occurs year-round. The seasonality of upwelling in the northern region appears to be crucial for ecosystem dynamics, especially for species whose life history is closely tied to the seasonal cycle.

Anomalous near-shore oceanographic conditions associated with delayed upwelling and anomalous water temperatures during the Springs of 2005 and 2006 are thought to have played the critical role in low juvenile fish survivorship. Schwing et al (2006) identified anomalous anomalous April–June sea level pressure over the North Pacific. Their analysis concluded that while El Niños can be linked to weaked/delayed upwelling along the west coast of the US, El Niños are not the only cause. Offshore transport, water column stability, and freshwater input were identified as other important influences on critical nutrient availability. A subsequent NWS analysis of the potential predictiblility of the suppressed spring upwelling in 2005 and 2006 along the west coast of the US (pers. comm. Dave Reynolds) suggests that the persistence of a cutoff low just off the coast is sufficient to disrupt "northwest flow and stratus by destroying the marine inversion and coast jet".

Habitat restoration can mitigate some of the negative impacts of climate change on salmonid habitat. However, climate change will make salmon restoration more difficult.

During times of decreased ocean productivity the production of fish from freshwater can be critical to maintaining salmon runs. The abundance of hatchery fish released into the bay tends to remain constant and could result in higher mortality of the wild fish due to competition for lower than normal krill populations or other factors.

Consideration of the Risks Associated with Hatchery Raised Mitigation Salmon and Steelhead

Reclamation funds the operation of Coleman Hatchery, Livingston Stone Hatchery, Nimbus Hatchery, and Trinity River Hatchery. DWR funds the operation of the Feather River Hatchery (FRH). The USFWS operates Coleman and Livingston Stone Hatcheries and DFG operates Feather River, Nimbus, and Trinity Hatcheries. These hatcheries are all operated to mitigate for the anadromous salmonids that would have been produced by the habitat if not for the dams on each respective river. Reclamation and DWR have discretion over how the hatcheries are operated but generally leave operational decisions on how to meet mitigation goals up to the operating agency.

Most hatchery production releases from the American and Feather Rivers are released in San Pablo Bay. The bay releases have been suspected of causing increased rates of returning adults straying into tributaries other than their tributary of origin. Examination of CWT data from the American River from 2001 and 2002 shows that straying was not as high as was suspected. Out of a contribution from Nimbus Hatchery to the Central Valley escapement of nearly 80,000 Chinook in run years 2002-2004 only about 2.8 percent (2,193 fish) returned to rivers other than the American (Table 11-17). This is well within a straying rate that could be considered normal for wild fish. The highest percentage of strays from the American (0.7 percent) occurred in the Feather/Yuba River system.

Table 11-17. Contribution of Nimbus Hatchery Chinook salmon from brood years 2000 and 2001 to Central Valley rivers based on coded wire tag returns.

Contribution of Nimbus Hatchery Fish from BY 2000 and BY 2001 to Central Valley Rivers

Sum of Contribution	runyr					
sampsite	2002	2003	2004	Grand Total	Percent of total	
ABRB			142	142	0.2%	Sacramento River (abov
AMN	2,406	49,887	12,604	64,897	82.3%	American River, in-river
BUT		25	21	46	0.1%	Butte Creek
FEA	214			214	0.3%	Feather River
FRH		14	3	17	0.0%	Feather River Hatchery
GUAD		7		7	0.0%	?
LFC			90	90	0.1%	Feather Low Flow Chan
MER		76	52	128	0.2%	Merced
MOK	166	564	55	784	1.0%	Mokelumne
MRFI			65	65	0.1%	Mokelumne River hatch
MRH	116	50	22	188	0.2%	Merced Hatchery?
NFH	1,797	6,769	2,777	11,343	14.4%	Nimbus Hatchery
SAA	397			397	0.5%	Carquinez to American
STA		110	56	166	0.2%	Stanislaus
TUO	7	81	11	99	0.1%	Tuolumne
YUB	27	220		247	0.3%	Yuba
Grand Total	5,130	57,802	15,897	78,829	100.0%	

Total straying of Nimbus hatchery fish 2002-2004
(sum of contribution recovered in rivers other than American)
2,193
2.8% recovered in other rivers compared to American

Consultations for Hatchery Genetic Management Plans are underway for Nimbus, Feather River, Coleman, and Trinity River Hatcheries. These will address the effects of hatchery operations on the listed species.

Williams (2006) summarized existing knowledge on effects of hatchery production on wild populations in the Central Valley and outlined radical recommendations for protecting or rehabilitating diverse, naturally adapted populations of salmon in the Central Valley. These recommendations include abandoning production hatcheries altogether and rely on natural production, moving fall-run hatcheries to the coast to support the fall-run Chinook fishery and eliminate competition between natural and hatchery fish in the rivers, concentrating fall-run hatchery production in one river to concentrate the effects on only one river, or substantially reduce hatchery production in all hatcheries or experimentally halt production in selected hatcheries. His formal recommendations are less radical and include: thoroughly reconsider hatchery operations, mark all hatchery fish, release fish only at hatcheries or nearby, avoid overproduction, review and document hatchery practices, and look for evidence of domestication.

Feather River Spring-Run Chinook Straying and Genetic Introgression

Prior to the construction of numerous dams (including the Oroville Dam) on the Feather River, spawning spring- and fall-run Chinook salmon were temporally and spatially separated—i.e., spring-run Chinook salmon spawned earlier and in higher reaches of the watershed compared to fall-run Chinook salmon. Although data are limited, there is a general consensus that there were once genetically distinct Chinook salmon runs in the Feather River system (Lindley et al. 2004; Yoshiyama et al. 2001).

Today, the Fish Barrier Dam located on the Feather River blocks the early-returning (arriving in April through June) run of sexually immature adult Chinook salmon in the Feather River from moving upstream to historical spawning habitat (the dam blocks access). As there is overlap in the timing of spawning, this spring-run Chinook salmon now spawns in the same location as the more numerous later-returning fall-run Chinook salmon. Findings of recent genetic studies using microsatellite markers suggest that: (1) FRH produced spring-run Chinook salmon are genetically similar to fall-run Chinook salmon and (2) phenotypic in-river spring-run Chinook salmon are genetically more similar to fall-run Chinook salmon than to spring-run Chinook salmon populations in Mill, Deer, and Butte creeks (Banks et al. 2000; Hedgecock et al. 2001; DWR 2004a).

A review of available literature suggests three opportunities for genetic introgression in the Feather River:

- Introgression between spring- and fall-run Chinook salmon in the Feather River;
- Introgression between hatchery-produced and wild spring-run Chinook salmon in the Feather River; and
- Straying and introgression between Feather River spring-run Chinook salmon and spring-run Chinook salmon in other systems.

Introgression Between Spring- and Fall-Run Chinook Salmon.

Conditions will continue to promote the commingling of spring-run and early maturing fall-run Chinook salmon on common spawning grounds, leading to increased opportunities for genetic introgression (hybridization) between spring- and fall-run Chinook salmon in the Feather River. In fact, data collected over the past 5 years by DWR on spawning populations of Chinook salmon in the Feather River do not show a bimodal peak that would be expected if there were temporally distinct spawning populations (DWR 2004a). In addition, continued hatchery practices—specifically, the inability to distinguish between spring- and fall-run Chinook salmon when artificially spawning—will continue to be an additional contributor to the observed genetic introgression. Data on the returns of tagged fish suggest that there may have been considerable cross-fertilization between nominal spring- and fall-run Chinook salmon at the FRH (DWR 2004a) over the past several years, and probably since the hatchery began operation in 1967. Under the new FERC license steps would be taken to try and segregate the spring-run and fall-run Chinook salmon in the Feather River to decrease introgression

Introgression between Hatchery-Produced and Wild Spring-Run Chinook Salmon.

One of the key questions about Feather River Chinook salmon involves the genetic and phenotypic existence of a spring run, and the potential effects of the FRH on this run. The Feather River’s nominal spring run is part of the spring-run ESU and is thus listed as threatened. Conversely, the hatchery population is not included in the ESU. The nominal spring- and fall-run Chinook salmon in the Feather River are genetically similar and are most closely related to CV fall-run Chinook salmon. There is a significant phenotypic spring run that arrives in the Feather River in May and June and enters the FRH when the ladder to the hatchery was opened. Observations of these early arriving Chinook salmon cast doubt on the presence of a Feather River spring-run, as opposed to a hatchery spring-run. DWR is currently preparing Hatchery Genetics Management Plans for the steelhead and Chinook salmon runs produced at the Feather River Fish Hatchery. It is anticipated that they will be completed in late 2008.

Due to the lack of pre-Oroville Facilities genetic data, the genetic identity of the historic Feather River spring-run Chinook salmon cannot be definitively ascertained. However, it appears that the early arriving, immature Chinook salmon run in the Feather River does not resemble current day spring-run populations in Mill, Deer, and Butte creeks. There are no data on the potential effects (e.g., reduced fitness) of inbreeding or outbreeding of FRH-produced Chinook salmon. In addition, there are no data indicating that spring-run timing on the Feather River is an inheritable trait and the loss of this phenotype would adversely affect the recovery of the CV spring-run Chinook salmon ESU (DWR 2004a). Nonetheless, under the No-Action Alternative, continued operation of the Oroville Facilities is anticipated to continue to contribute to the ongoing genetic introgression currently observed under existing conditions.

Straying and Introgression with Spring-Run Chinook Salmon in Other Systems.

As part of existing operations, FRH-produced Chinook salmon are transported and released into San Pablo Bay. This hatchery practice was intended to reduce/avoid the mortality associated with migrating through the Sacramento-San Joaquin Delta. However, data suggest that the practice of releasing to San Pablo Bay increased the incidence of straying of FRH-produced Chinook salmon (DWR 2004a). Straying can lead to increased competition for spawning habitat and exchange of genetic material between hatchery and naturally spawning Chinook salmon (Busack and Currens 1995).

To analyze the role that hatcheries play in influencing straying rates, DFG used mark-and-recapture data (coded wire recoveries) in the ocean fisheries to reconstruct the 1998 fall-run Chinook salmon cohort from the FRH (Palmer-Zwahlen et al. 2004). This analysis was used to determine the rate at which fish released in the estuary return to the Feather River and to other streams (the stray rate). DFG estimated that of the approximately 44,100 FRH-produced fish that returned to the Central Valley, 85 percent returned to the Feather River (including the FRH), 7 percent were caught in the lower Sacramento River sport fishery, and 8 percent strayed to streams outside the Feather River basin. If salmonids returned to the Feather River in the same proportion as observed in other river systems, the straying rate would be estimated to be approximately 10 percent (DWR 2004a). Although tags from FRH-produced fish were collected in most Central Valley streams sampled, about 96 percent of the 12,438 tags recovered during the 1997 to 2002 period were collected in the Feather River or at the FRH.

A lower percentage of in-basin releases than bay releases survived to reenter the estuary as adults (0.3 percent versus 0.9 percent); however, these fish returned to the Feather River with greater fidelity (approximately 95 percent as compared to around 90 percent for bay releases). Although the straying rate from bay releases is less than might be expected based on earlier studies, it is still higher than natural straying rates and higher than the 5 percent straying rate recommended as a maximum by NMFS. Before rendering definitive conclusions, it should be noted that there are several limitations in the existing data:

- Cohort analysis was only for one broodyear;
- Tag recovery efforts on most Central Valley streams do not provide statistically reliable estimates of the number of tagged fish in the spawning populations; and

- There is a significant inland sport fishery and, in recent years, sampling of this fishery and collecting tags has been spotty because of budget cuts.

It should be noted that based on tag return and genetic data, minimal interbreeding appears to have occurred between FRH spring-run Chinook salmon and spring-run Chinook salmon in Butte, Mill, and Deer creeks. Only a few FRH-produced Chinook salmon have been collected in the lower portions of Deer, Mill, and Butte creeks, in sections supporting fall-run spawning activity. In addition, the genetic structure of spring-run Chinook salmon in the Feather River is distinct from spring-run Chinook salmon from Deer, Mill, and Butte creeks.

Under the No-Action Alternative, operations of the FRH are anticipated to result in continued straying of FRH-produced Chinook salmon at rtes currently observed under existing conditions.

Feather River Spring-Run Chinook Susceptibility to Disease

Susceptibility to disease is related to a variety of factors, including fish species, fish densities, the presence and amounts of pathogens in the environment, and water quality conditions such as temperature, DO, and pH. Oroville Facilities operations have the potential to affect all of these factors at the FRH and in the Feather River downstream of the Oroville Facilities.

Several endemic salmonid pathogens occur in the Feather River basin, including Ceratomyxa shasta (salmonid ceratomyxosis), Flavobacterium columnare (columnaris), the infectious hematopoietic necrosis (IHN) virus, Renibacterium salmoninarum (bacterial kidney disease [BKD]), and Flavobacterium psychrophilum (cold water disease) (DWR 2003a). Of the fish pathogens occurring in the Feather River basin, those that are main contributors to fish mortality at the FRH (IHN and ceratomyxosis) are of highest concern for fisheries management in the region. Although all of these pathogens occur naturally, the Oroville Facilities have the opportunity to produce environmental conditions that are more favorable to these pathogens than under historic conditions:

- Impediments to fish migrations may have altered the timing, frequency, and duration of exposure of anadromous salmonids to certain pathogens;
- Out-of-basin transplants may have inadvertently introduced foreign diseases; and
- Water transfers, pumpback operations, and flow manipulation can result in water temperature changes, which potentially increase the risk of disease.

The transmission of disease from hatchery fish to wild fish populations is often cited as a concern in fish stocking programs. There is, however, little evidence of disease transmission between hatchery fish and wild fish (Perry 1995). Further, the FRH has implemented disease control procedures (e.g., disinfecting procedures) that are intended to minimize both the outbreak of disease in the hatchery and the possibility of disease transmission to wild fish populations.

Field surveys indicated that IHN was not present in juvenile salmonids or other fish in the Feather River watershed (DWR 2004a). Eighteen percent of the adults returning to the Feather River watershed were infected with IHN, but there were no clinical signs of disease in these fish. The hypothesis advanced by DFG pathologists for the cause of the recent IHN epizootics at the FRH is that planting Chinook salmon in Lake Oroville (in the hatchery water supply) resulted in the virus entering the hatchery. Hatchery conditions can then lead to stress and the infections can rapidly escalate to clinical disease, as evidenced by high mortality. No additional epizootics have been observed since the plantings of Chinook salmon in the reservoir were brought to an end. Whether the cessation of stocking Chinook salmon will prevent future IHN outbreaks at the FRH is uncertain, as the cause of specific disease outbreaks in Oroville Facilities waters is poorly understood (DWR 2004a).

Under the No-Action Alternative, continued operations of the Oroville Facilities are anticipated to result in potential exposures to pathogens similar to that currently observed under existing conditions.

Steelhead Straying and Genetic Introgression

The lack of distinction between San Joaquin and Sacramento steelhead populations suggests either a common origin or genetic exchange between the basins. Findings of a recent genetic study on CV steelhead populations (Nielson et al. 2003) indicate that:

- Feather River steelhead populations (natural and FRH-produced populations) are more similar to populations from streams in the same general geographic location—i.e., Clear Creek, Battle Creek, upper Sacramento River, Coleman National Fish Hatchery, and Cottonwood, Mill, Deer, and Antelope creeks.
- Feather River steelhead populations are not closely linked to Nimbus Hatchery and American River populations.
- Feather River steelhead population's closest relative is the FRH-produced steelhead and both are distinct from other Central Valley steelhead populations.
- There are no data on the potential effects (e.g., reduced fitness) of inbreeding or outbreeding of FRH-produced steelhead.

These data suggest that there appears to be considerable genetic diversity within the CV steelhead populations and that, although fish from the San Joaquin and Sacramento River basins cannot be distinguished genetically, there is still significant local genetic structure to CV steelhead populations (Figure 3-2). For example, Feather River and FRH-produced steelhead are closely related, as are American River and Nimbus Hatchery fish.

Estimates of straying rates only exist for Chinook salmon produced at the FRH. However, based on available genetic data, the effects of hatcheries that rear steelhead appear to be restricted to the population on hatchery streams (DWR 2004a). These findings suggest that, although ongoing operations may impact the genetic composition of the naturally spawning steelhead population in these rivers, hatchery effects appear to be localized. It should be noted that genetic data for steelhead are limited (DWR 2004a).

There appears to be little mixing of hatchery and wild gene pools in the FRH. This conclusion is based on study findings that show that only adipose clipped steelhead (hatchery-produced, presumably mostly from the FRH) ever reach the FRH. Spawned steelhead are released back to the river—there are no data to determine how many of these fish survive to spawn again.

Nevertheless, the commingling of spawning adults due to the blockage of fish to historical spawning and rearing habitat in headwater streams presumably provides an opportunity of mixing between FRH-produced and wild steelhead. Homogenization of the wild Feather River steelhead genetic structure cannot be ascertained as there are no data to show if the river spawners are of direct hatchery origin or the progeny of previous natural spawners. Moreover, as there are no pre-Oroville Facilities genetic data, it is not possible to characterize the distinctness of historical steelhead in the Feather River. However, the existing data suggest that some of the original genetic attributes remain in the current steelhead populations in the Feather River.

Given available genetic data, under the No-Action Alternative, straying of FRH-produced steelhead is anticipated to have a negligible effect on the genetic integrity of CV steelhead populations as observed under existing conditions and continued operation of the Oroville Facilities is anticipated to continue to provide potential opportunities for the genetic introgression currently observed under existing conditions in the Feather River.

Critical Habitat

The primary constituent elements (PCEs) of critical habitat include sites essential to support one or more life stages of the ESU (sites for spawning, rearing, migration, and foraging). The specific PCEs include:

1. Freshwater spawning sites
2. Freshwater rearing sites
3. Freshwater migration corridors
4. Estuarine areas
5. Nearshore marine areas
6. Offshore marine areas

Water operations can affect habitat conditions in the first four of the PCEs. These four PCEs are present in the action area. The critical habitat areas are delineated and some critical habitat effects are detailed in Chapters 3 and 5.

Spawning Sites

Sufficient spawning habitat would be maintained for all the listed salmonids in the affected rivers by maintaining coolwater releases from the reservoirs. A slight reduction in available coldwater for spawning habitat could occur in critically dry water years in the future as detailed above. This could result in fish spawning further upstream closer to the terminal dams. Spawning habitat has not been identified as a limiting factor to the listed species in any of the rivers at the current densities of spawners. When populations are higher with improved ocean conditions numbers of returning spawners could fully utilize the spawning habitat within the area of suitable water temperature. Spawning gravel additions would continue to occur to replace the deficits created by the loss of recruitment from upstream. These additions should maintain spawning habitat in the areas of the rivers near the dams with the coolest temperatures for egg incubation. High flows during flood control operations would provide needed gravel movement to keep spawning areas clean with freshly redeposited gravel.

Freshwater Rearing Sites

The project operations would not change rearing habitat availability. Habitat features such as meso and micro habitat sites, woody debris, aquatic vegetation and varied substrates would continue to be present in a similar configuration. These habitats would continue to produce food needed by the salmonids. Salmonid habitat improvement projects will continue to be funded by Central Valley Project Improvement Act funds received from water deliveries. Temperatures could be degraded somewhat through future climate change scenarios and decreased coldwater pool volume as detailed above. These scenarios would affect steelhead rearing habitat the most in rivers such as the American and Stanislaus.

Freshwater Migration Corridors

Freshwater migration corridors would not change through the project. Red Bluff Diversion Dam operations would remain the same in the near future but would allow for improved passage conditions when a pumping plant is constructed. Delta Cross Channel gates would be operated the same. Flows would be suitable for passage in all river reaches. Changes in flows and their effects on the critical habitat in the rivers and the delta are detailed above and in Chapters 10 and 12.

Estuarine Areas

Conditions in the estuary would remain about the same for salmonids through future operations. Salmonids would continue to use nearshore areas in the estuary as rearing habitat as they migrate and grow on their way to the ocean. Delta pumping operations and take of listed species will continue to be monitored so that adjustments can be made when take levels increase.

Evaluation of Viable Salmonid Population (VSP) Parameters

According to McElhany et al. (2000) the key parameters used to determine whether a population is likely to experience long-term viability are 1) abundance, 2) population growth rate, 3) population spatial structure, and 4) diversity. The following is a discussion of the effects of the project on VSP parameters.

Winter-run Chinook Salmon

Population Size

Winter-run Chinook have experienced recent population size increases followed by the most recent year drop in numbers experienced throughout southern Chinook and coho salmon populations. The population size increases encompassed two generations with three year average population sizes of around 7,000 to 12,000 individuals making up the escapement. The current three year running average population size appears to have sufficient numbers of individuals to have a high probability of surviving environmental variation of hydrological and ocean conditions experienced through the historical record. Depensatory processes are not likely to be important at current population levels since the population is limited to a specific area of the Sacramento River, ie. the fish are all present in the same area of the river at the same time. Genetic diversity should be maintained at these population levels. The winter-run population overlaps habitat use with other runs and all together they provide needed ecological functions such as cycling of spawning gravels and providing nutrients from carcasses. Current monitoring programs provide a high level of confidence in the winter-run population numbers and spatial distribution.

Population Growth Rate

The winter-run Chinook population has been consistently growing through all cohorts since the low levels of the early 1990's. The recent decline in 2007 and expected in 2008 is an exception. Even with the recent decline the population exhibited the ability to increase under current operational scenarios with suitable ocean conditions. The IOS model, with the assumptions used, indicates that under future operational scenarios the growth rate may decrease in comparison with the current condition due to the effects that could occur in critically dry water years. The current poor ocean conditions produced a population about one third of the three year prior escapement. This decrease in productivity was less than what has occurred for fall-run Chinook. The fall-run Chinook adult returns are dominated by returns from large numbers of hatchery Chinook released into San Pablo Bay. These hatchery fish do not experience the in-river conditions during their juvenile lifestage and the number released is relatively constant from year to year. The fact that winter-run Chinook returns did not decrease as much as occurred for fall-run Chinook indicates that juvenile winter-run production surviving to the ocean was probably high for the cohort and was supported by good in-river conditions. This means that for the current population, during years that are not critically dry, the freshwater productivity can compensate somewhat for poor ocean conditions and the population should remain viable. During successive dry water years winter-run would not fare as well.

Spatial Structure

Winter-run Chinook are restricted to the Sacramento River. This limits the spatial structure of the population compared to most salmonid runs which utilize multiple tributaries. Habitat patches are being maintained through water temperature management, reduction in impediments to migration (RBDD, ACID, and DCC gate), and habitat improvements (spawning gravel replacement). Battle Creek is being improved to potentially support winter-run Chinook in the future and increase spatial structure. No natural source subpopulations are currently available, although Livingston Stone Hatchery could be considered a subpopulation.

Diversity

Chinook salmon in the Central Valley exhibit a high diversity in run timing such that depending on the specific tributary there are Chinook salmon returning and spawning during virtually all months of the year. This allows the species to take advantage of the environmental conditions unique to individual tributaries. Blockage of many upstream habitats has reduced diversity and spatial structure somewhat however. Winter-run Chinook exhibit a diversity of age at return from fish that return from two to five years of age. The predominant trait is three year fish but the diversity in ages allows for overlap in case a year class experiences a large drop in abundance. Natural disturbance regimes such as high flows that redistribute the bed occur and provide some diversity in habitat. Gene flow between winter-run and other runs is likely negligible because their spawning timing is well separated from runs in the Sacramento and all other rivers. The project should maintain the existing diversity and run size will continue to fluctuate with year to year changes in precipitation and ocean conditions.

Spring-run Chinook Salmon

Population Size

The core spring-run population reproduces primarily in non-project streams. Spring-run experienced recent increases in population, similar to winter-run and currently are experiencing a positive growth rate. The component of the population in the Sacramento River is at a low level, however. The Clear Creek component has been steadily increasing and the Feather River component has been relatively stable. Depensatory processes could occur in the Sacramento River but this river is not considered a core spring-run habitat area for spring-run spawning. Spring-run, when combined with the other runs, provide needed ecological functions such as cycling of spawning gravels, and providing nutrients from carcasses. Spring-run population size is monitored relatively well and trends can be detected. The project is not expected to significantly affect the spring-run population size. For some reason spring run in the Sacramento River have not rebounded from population lows as they have in the Sacramento River tributary streams. Red Bluff Diversion Dam affects spring-run adult migrations in the Sacramento River more than any of the other runs. The ten month gates out operations in the future may allow upstream populations to increase, but it remains unknown whether the blockage of a portion of the run is what is currently limiting upstream population increases. For example spring run escapement in Clear Creek has increased under the current gate operations. Conditions downstream of RBDD are generally suitable for spring-run to hold for long periods during the summer. There are risks to the spring-run population from climate change scenarios, but these are not caused specifically by the project.

Population Growth Rate

The spring-run Chinook population has recently maintained cohort replacement rates of 1.0 or greater in most years. The recent year decline in returning fall-run and winter-run escapement will likely be seen in spring-run as well. The Feather River segment of the population includes a hatchery component making the natural productivity difficult to determine. The Sacramento River segment of the population is at low numbers. The necessity of managing coldwater for winter-run Chinook stresses spring-run spawners during the fall in the mainstem, especially in critically dry water years. Differences in spring-run production between current and future operational scenarios were not as apparent as for winter-run.

Spatial Structure

Spring-run Chinook are present in multiple Sacramento River tributaries. This provides a better buffer against catastrophic effects than exists for winter-run Chinook. The trait of the spring-run population holding over through the summer originally was an asset to the population because it allowed migrations to occur during high water when water temperatures were cool. It is currently a risk factor because the amount of over summer holding habitat with suitable water temperatures and habitat conditions is limited. Clear Creek may provide a good refuge for the population in dry water years with the presence of the coldwater pool in Trinity Reservoir and relatively small instream flow needs to maintain fish in Clear Creek. Battle Creek is also being made more accessible for spring-run and has shown promising numbers over two generations. The existing spatial structure should not be affected by the project. Improvements to passage at Red Bluff Diversion Dam could help upstream populations, thereby enhancing spatial structure.

Diversity

Chinook salmon in the Central Valley exhibit a high diversity in run timing such that depending on the specific tributary there are Chinook salmon returning and spawning during virtually all months of the year. This allows the species to take advantage of the environmental conditions unique to individual tributaries. Blockage of many upstream habitats has reduced diversity and spatial structure somewhat however. Spring-run Chinook exhibit a diversity of age at return from fish that return from two to five years of age. The predominant trait is three year fish but the diversity in ages allows for overlap in the event a year class experiences a large drop in abundance. Natural disturbance regimes such as high flows that redistribute the bed occur and provide some diversity in habitat. Gene flow between spring-run and fall-run Chinook can be substantial where the two runs co-exist. The two runs formerly spawned in different river reaches but the reduction in habitat is such that their spawning habitat and run timing overlap. This allows more opportunity for gene flow between the runs. Spring-run and fall-run in the Feather River probably have the greatest overlap leading to gene flow between the populations. Actions are being taken to separate the runs and reduce this effect on the Feather River.

Central Valley Steelhead

Population Size

The lack of monitoring data to effectively determine steelhead population size contributes as a risk factor for steelhead because it makes population trends difficult to detect. The best indicator of population size may be the ratio of hatchery (clipped) to unclipped steelhead in monitoring programs. This has remained relatively constant since clipping of all hatchery steelhead began in 1998. The diversity of life history types and the prevalence of resident O. mykiss in many rivers provides some insurance against low population size. It is evident that hatchery produced steelhead numbers are higher than naturally produced numbers.

Population Growth Rate

Because the population size is unknown in most tributaries the population growth rate is unknown. Based on existing monitoring programs there do not appear to be population increases occurring. No real change in population size is apparent. The streams with hatchery populations (American River, Feather River, Battle Creek) appear to have the majority of their runs made up of hatchery fish and the fish spawning in the rivers include a large hatchery produced component. Gene flow between the hatchery and naturally spawned component is substantial. The resident O.mykiss component present in rivers such as the Sacramento, Clear Creek, and Stanislaus provides a source of fish during down cycles in abundance. Water temperature can limit potential for natural populations to increase in some streams.

Spatial Structure

The spatial structure of the steelhead population provides some resiliency to the population. Steelhead and the resident form are the most widely distributed of the salmonids in the Central Valley. The spatial structure has been reduced, however, by the presence of dams on many streams eliminating access to upstream habitat. The resident form of the species still thrives in many of these upstream areas but gene flow from downstream to upstream has been eliminated. Upstream populations can provide a source of fish to anadromous reaches downstream where stocking has not replaced the natural stocks upstream. The habitat is patchily distributed during the warmwater periods of the year because the warmwater in the lower reaches of streams creates a barrier to migrations between tributaries. Project operations maintain coldwater downstream of reservoirs, maintaining resident O.mykiss.

Diversity

Steelhead (O.mykiss) exhibit a high diversity in life history forms. Numerous resident populations exist that are probably somewhat connected. Anadromous fish have been shown to produce both resident and anadromous offspring. Resident fish have also been shown to produce both resident and anadromous offspring. Steelhead provide some resiliency to the population in the case that some catastrophic event should wipe out a resident population in some stream. The resident form provides the same type of insurance in the case that the anadromous form suffers increased declines.

SONCC Coho Salmon

Population Size

The estimated coho salmon run size in the Trinity River has been above the 20-year average for seven of the last eight years. The ESU includes rivers other than the Trinity. The Trinity River Restoration Program is working to increase coho habitat and population size in the system. The Trinity River coho run has a large hatchery component with substantial gene flow with in-river spawners. Depensatory processes are unlikely to be important because the spawning population is concentrated in a small area of the river near the dam. The project should not adversely affect the coho population size and there should be benefits with the restoration program.

Population Growth Rate

The in-river spawning population is at a low level. The growth rate is difficult to determine with the substantial hatchery presence producing a steady number of fish each year. The growth rate does not appear to be large, however. The state of the population in the absence of hatchery production is unknown. Coho in the mainstem Trinity tend to congregate within a few miles downstream of the dam and hatchery. The operational scenarios should allow for population growth to occur.

Spatial Structure

Coho salmon are widespread throughout the ESU. This project should not affect spatial structure of the population as the Trinity River component will be maintained. The restoration program is working to improve habitat for coho salmon and maintain or increase habitat patches within the mainstem Trinity River.

Diversity

Coho salmon in this ESU primarily return in their third year, but a small number of males breed in their second year. There may be a few four year old fish. Natural processes are being maintained through the restoration program and its flow regime. The project should not affect diversity of the ESU.

Central California Coast Steelhead

No adverse effects of the project on Central California Coast steelhead have been identified. The portion of the project area intersecting the CCC steelhead DPS is in the north-western Delta leading to Susuin Creek. Suisun Creek was excluded from the Critical Habitat designation. Effects on this migratory corridor for CCC steelhead are expected to be minimal to water quality and of no measurable effect on VSP parameters for CCC steelhead.

Cumulative Effects

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area of this biological assessment. Future Federal actions that are unrelated to the proposed action are not included because they require separate ESA consultation.

Non-Federal actions that may affect the action area include State angling regulation changes, commercial fishery management changes, voluntary State or private habitat restoration, State hatchery practices, agricultural practices, water withdrawals/diversions, increased population growth, mining activities, and urbanization. State angling regulations are generally moving towards greater restrictions on sport fishing to protect listed fish species. The state closed recreational salmon fishing in California in all ocean and fresh waters except between Knights Landing and Red Bluff on the Sacramento River in the late fall. Commercial fishing regulations are designed to target the abundant fall–run Chinook and avoid fishing during times and in areas where listed species are more likely to be caught. However, during 2008 commercial salmon fishing was closed to protect the expected low numbers of Chinook salmon in the ocean.

Habitat restoration projects may have short term negative effects associated with construction work in waters but the outcome is generally a benefit to listed species. State hatchery practices (Merced, Mokelumne, American River Trout Hatchery) may have negative effects on naturally produced salmon and steelhead through genetic introgression, competition, and disease transmission from hatchery introductions. Farming activities within or near the action area may have negative effects on Sacramento and San Joaquin water quality due to runoff laden with agricultural chemicals. Essential features of critical habitat that are degraded on the Sacramento River include water, space, cover, and rearing along approximately 200 miles of mainstem river. The function of critical habitat may continue to be reduced through the cumulative loss of riparian areas along Central Valley river due to bank stabilization projects, removal of trees for levee stability, and growth and development (e.g., boat docks, marinas, sewage outfalls).

Cumulative effects include non-federal riprap projects. Depending on the scope of the action, some non-federal riprap projects carried out by State or local agencies do not require Federal permits.

These types of actions, and illegal placement of non-federal riprap are common throughout the action area. The effects of such actions result in fragmentation of existing habitat and conversion of complex nearshore aquatic habitat to simplified habitats that are less suitable for salmonids.

Cumulative effects include future non-federal water withdrawals which affect salmonids by entraining individuals into improperly screened diversions and may result in lower river flows that are needed for migration, spawning, rearing, flushing of sediment, gravel recruitment and transport of woody debris. Future temperatures in the American River are largely the result of upstream diversions impacting the coldwater pool in Folsom Reservoir. The largest diversions are screened or in planning phases with a Federal cost share. The smaller non-project diversions are largely privately owned and may have significant cumulative effects.

Cumulative effects may result from discharge of point and non-point source chemical contaminants, which include selenium and pesticides and herbicides associated with agricultural and urban activities. The proliferation of invasive species may occur from increasing water temperatures due to future level of development or climate change. Invasive species can prey on or displace native species that provide food for young fish. Contaminants may injure or kill salmonids by affecting food availability, growth rate, susceptibility to disease, or other processes necessary for survival.

Future urban growth and mining operations may adversely affect water quality, riparian function, and stream productivity. Intermittent streams used by steelhead are being impacted by urban sprawl before monitoring can detect presence/absence of the species.

Other potential cumulative effects could include: wave action in the water channel caused by boats that may degrade riparian and wetland habitat and erode banks; dumping of domestic and industrial garbage; urban land uses that result in increased discharges of pesticides, herbicides, oil, and other contaminants into the water; and non-federal dredging practices. These things also may injure or kill salmonids by affect food availability, growth rate, susceptibility to disease, or other physiological processes necessary for survival.

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Chapter 12 CVP and SWP Delta Operations

This chapter focuses on the effects of the CVP and SWP project operations in the Delta. The results in this chapter are from monthly CalSim-II output and are a coarse example of the hydrologic and hydraulic effects that project operations will have in the Delta. The effects analyzed in this chapter are due to the changes in operations and demands between the four OCAP Studies 6.0, 7.0, 7.1 and 8.0 as detailed in Chapter 10. Modeling results analyzed in this chapter will be Delta inflow, Delta outflow, Delta exports (Banks, Jones, Contra Costa Water District, and North Bay Aqueduct), SWP demand assumption changes, and EI ratio. The SWP demand assumptions (including both Table A and Article 21) will be compared against the 2004 OCAP SWP demand assumptions. The chapter's final section will focus on potential transfers amounts that were post-processed from the CalSim-II results for Study 8.0. Refer to Chapter 9 for a list of model limitations on which this analysis was based.

Inflow

Total Delta inflow in the model is treated as the sum of Yolo Bypass, Sacramento River, Mokelumne River, Calaveras River, Cosumnes River, and the San Joaquin River. Table 12-1 lists the difference in average annual inflow into the Delta on a long-term average and 1929 to 1934 average bases. The total annual inflow decreases in all comparisons on average between studies.

Table 12-1 Differences in annual Delta Inflow for Long-term average and the 1929-1934 Drought

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Longterm Annual Average Total Delta Inflow	-69	-201	-270	-70
29 - 34 Annual Average Total Delta Inflow	136	-272	-403	-130

Figure 12-1 shows the chronology of total inflow for all three of the studies. The highest inflows occur January through April due to flood flows, and July when pumping is increased through the late summer with the 50th percentiles being greater than 20,000 cfs (Figure 12-2). In the other months the inflow tends to be less than 20,000 cfs. Considering the monthly averages by 40-30-30 water year classification (Figure 12-3 to Figure 12-8), the results show little difference on average. In water years classified as critical years, Figure 12-1, the summer pumping in those years is higher for Studies 6.0 and 7.0 versus the other two studies. The increase in Studies 6.0 and 7.0 inflows for critical years during the summer are from EWA transfers being wheeled at a higher rate than in Studies 7.1 and 8.0 which are limited EWA studies.

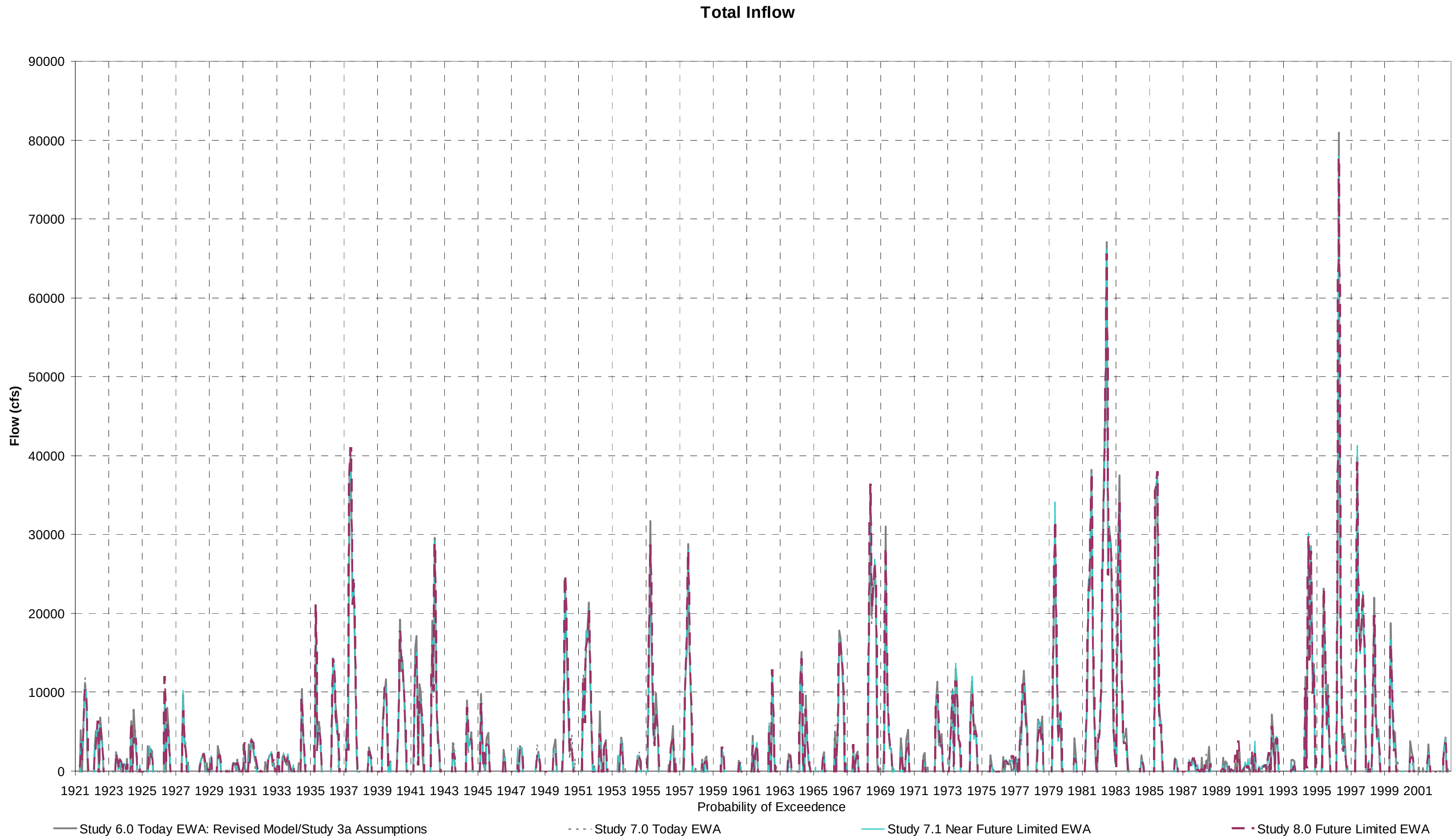


Figure 12-1 Chronology of Total Delta Inflow

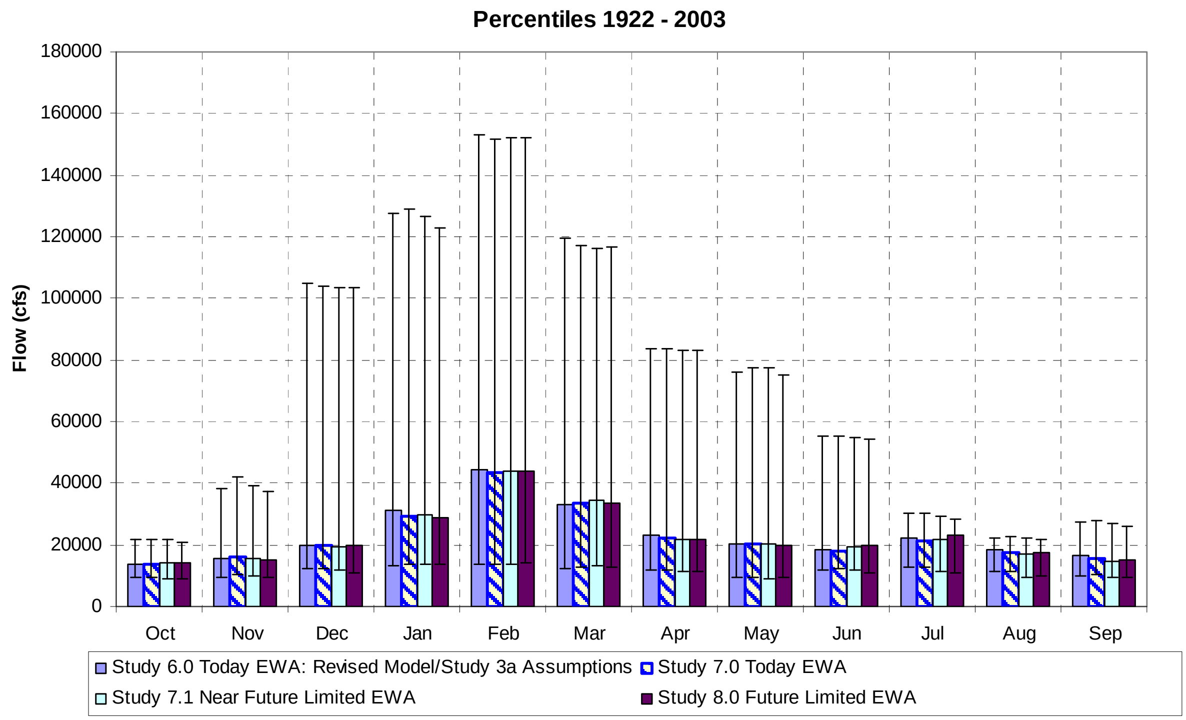


Figure 12-2 Total Delta Inflow 50th Percentile Monthly Flow with the 5th and 95th as the bars

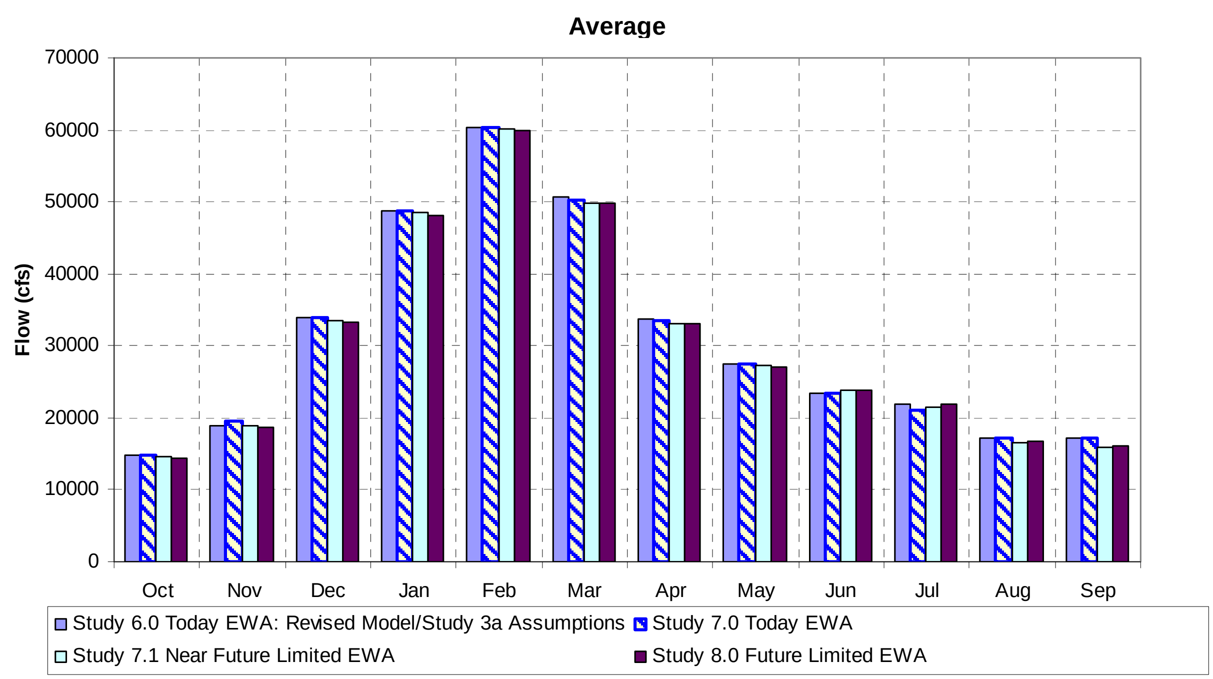


Figure 12-3 Average Monthly Total Delta Inflow

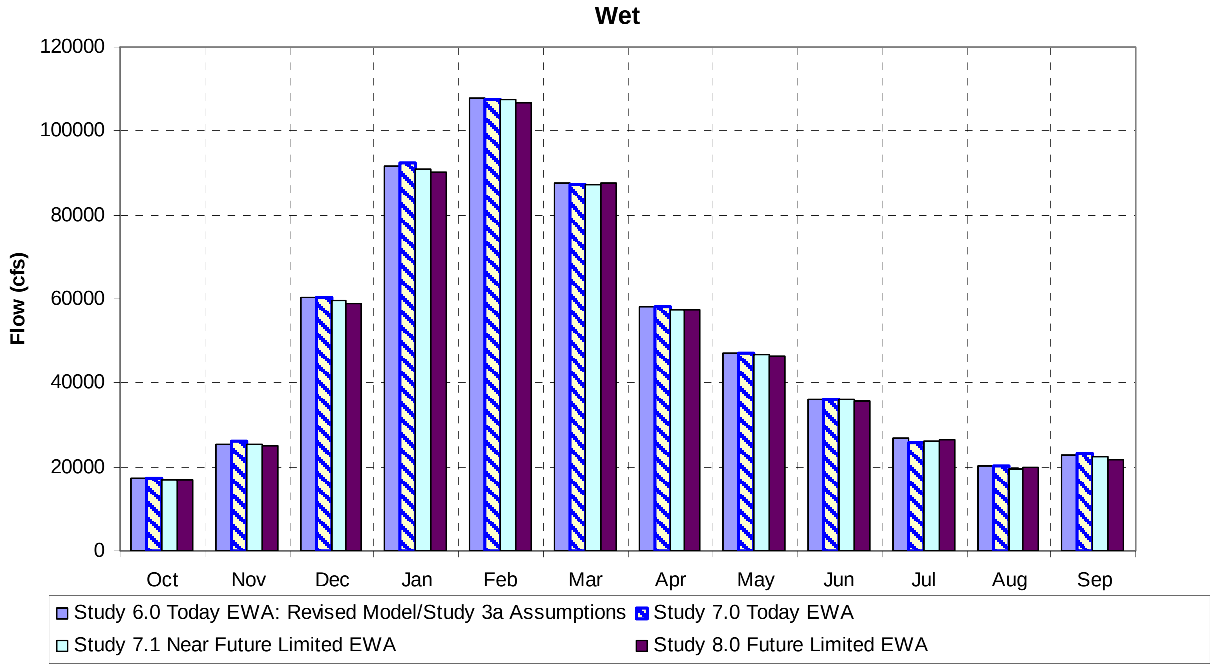


Figure 12-4 Average wet year (40-30-30 Classification) monthly Total Delta Inflow

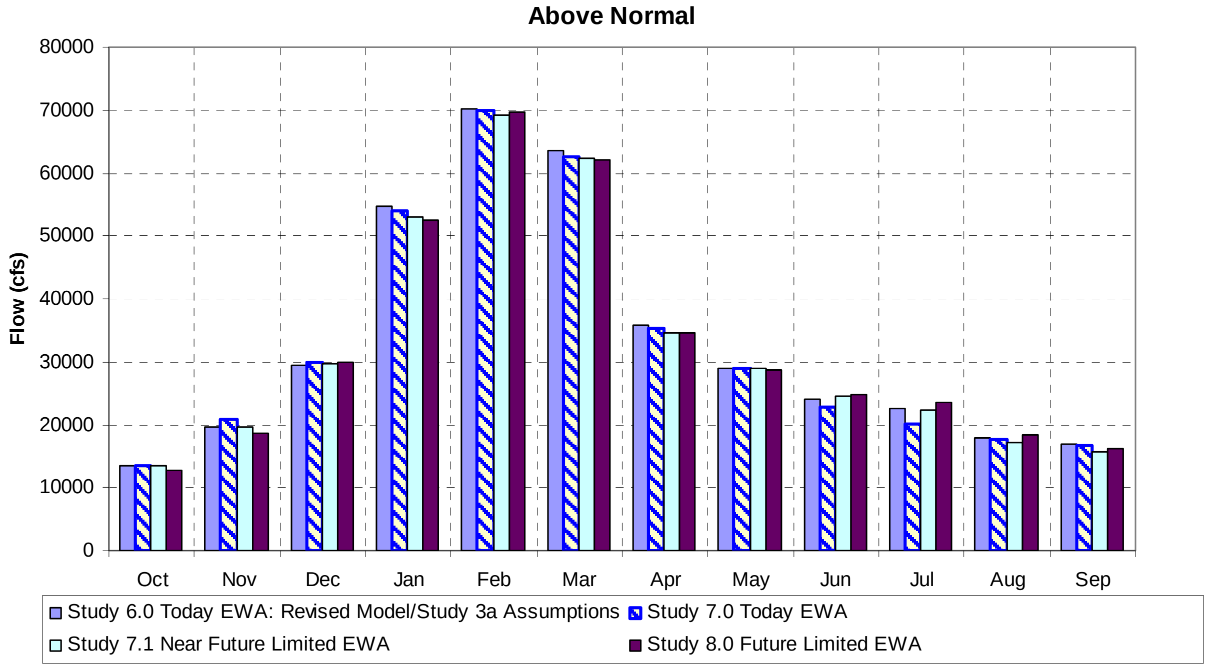


Figure 12-5 Average above normal year (40-30-30 Classification) monthly Total Delta Inflow

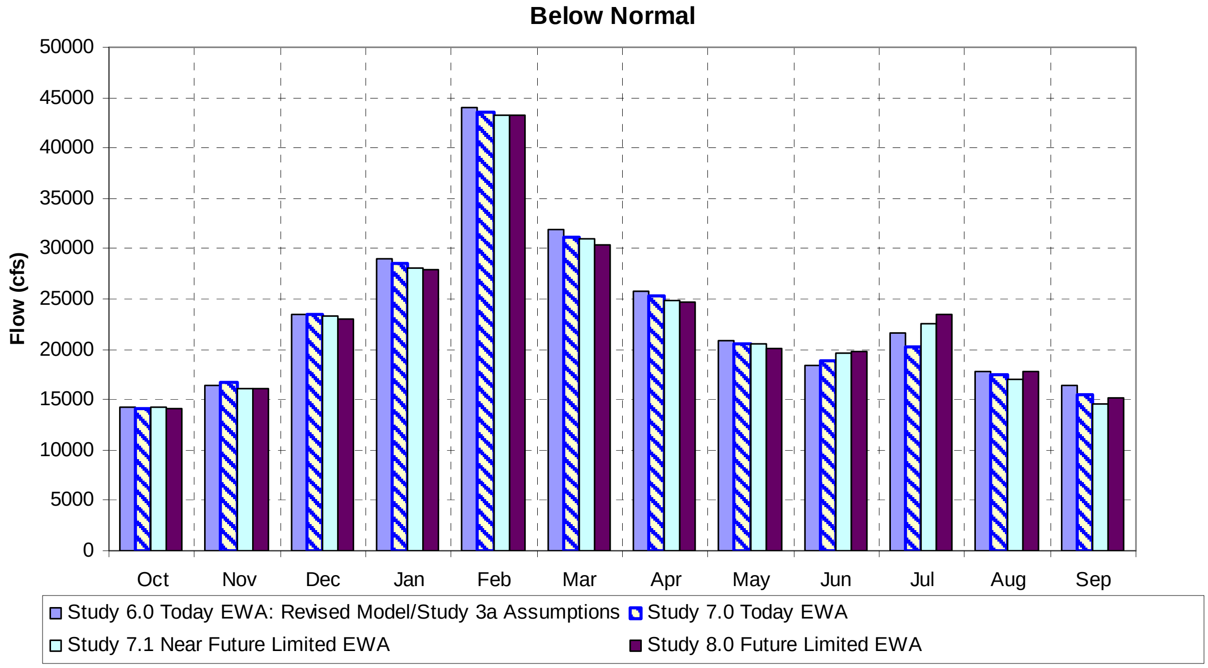


Figure 12-6 Average below normal year (40-30-30 Classification) Total Outflow Delta Inflow

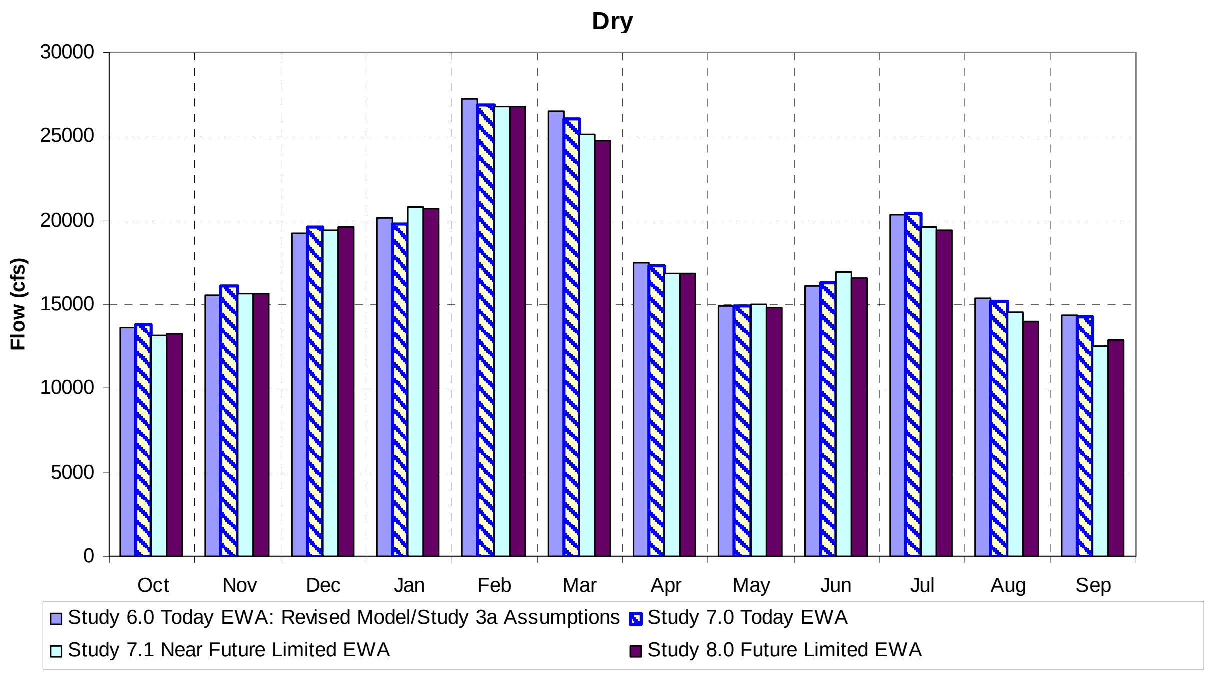


Figure 12-7 Average dry year (40-30-30 Classification) monthly Total Delta Inflow

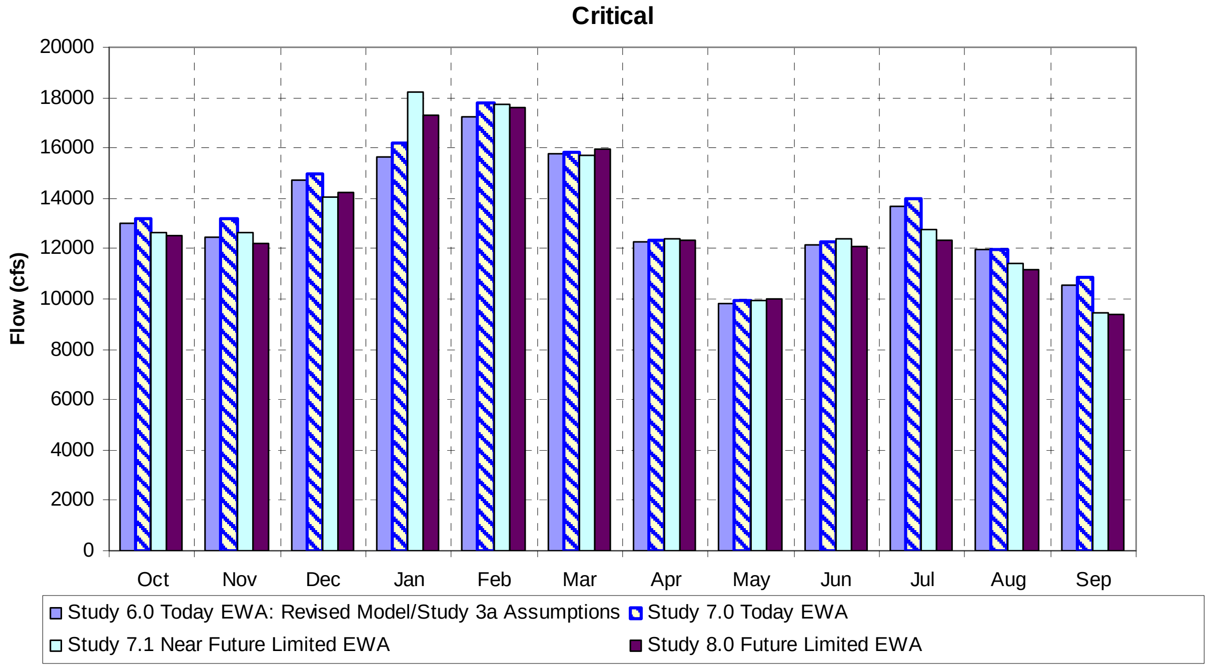


Figure 12-8 Average critical year (40-30-30 Classification) monthly Total Delta Inflow

Outflow

The chronology of Delta outflow is shown in Figure 12-9. Table 12-2 shows the difference in total outflow for the four studies. When comparing the differences from Studies 7.1 and 8.0 to Study 7.0 in Table 12-2 the average annual outflow decreases by 300 to 400 TAF for the long-term average. Study 8.0 shows a decrease in average Delta outflow of 100 TAF when compared to Study 7.1.

Both the percentile, average monthly, and average monthly by water year type for total Delta outflow can be seen in Figure 12-9 to Figure 12-16. The figures show some differences in the winter and spring months with the biggest differences in below normal, dry and critical years. The differences are generally in the late winter months where outflow increases are seen in Studies 6.0 and 7.0 versus the other two, due to Studies 6.0 and 7.0 being "full" EWA runs and the winter reductions in exports are occurring and pushing more of the flow out of the Delta.

Table 12-2 Differences in annual Delta Outflow and Excess Outflow for Long-term average and the 1929-1934 Drought

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Longterm Annual Average Total Delta Outflow	-149	-296	-400	-104
29 - 34 Annual Average Total Delta Outflow	-93	-195	-164	32

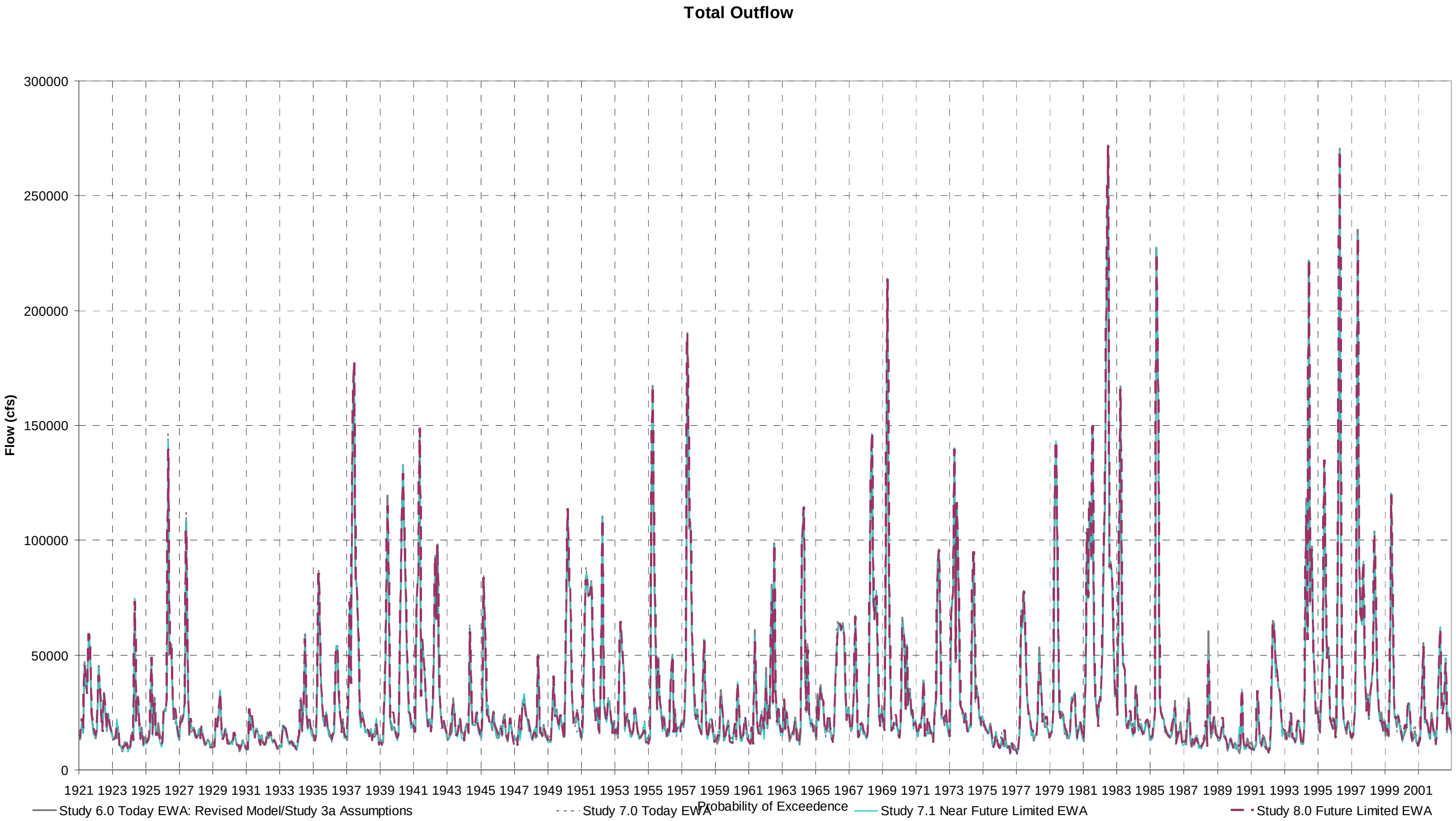


Figure 12-9 Chronology of Total Delta Outflow

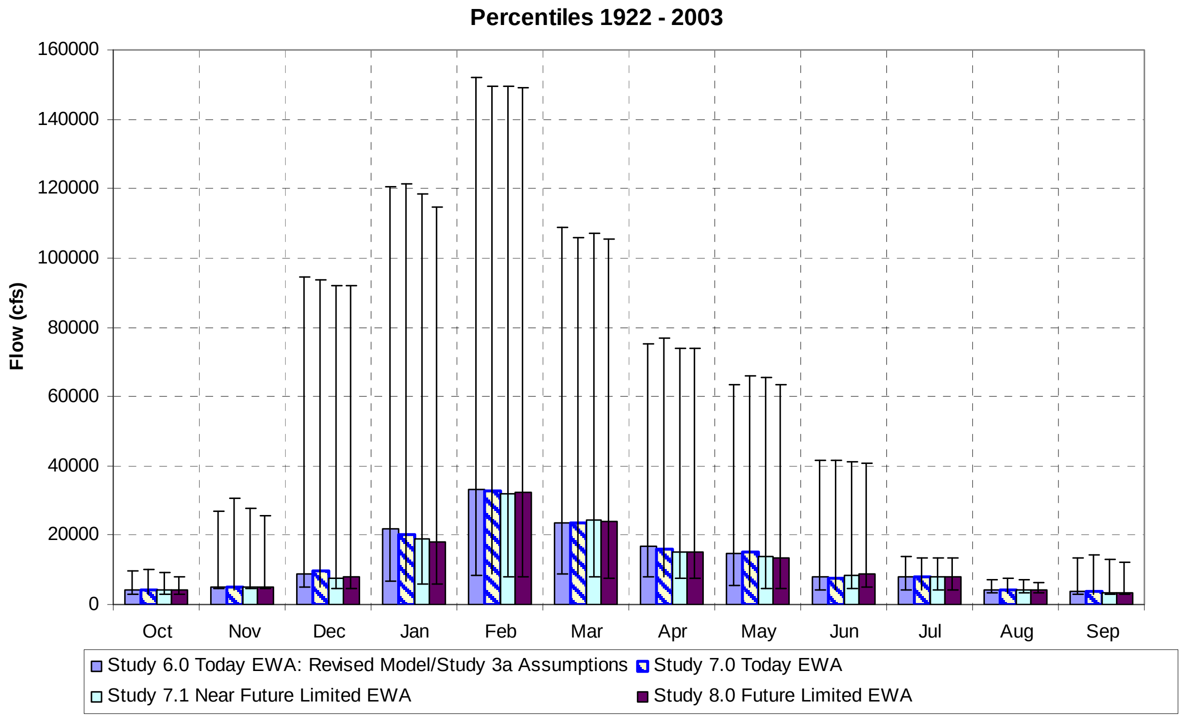


Figure 12-10 Total Delta Outflow 50th Percentile Monthly Flow with the 5th and 95th as the bars

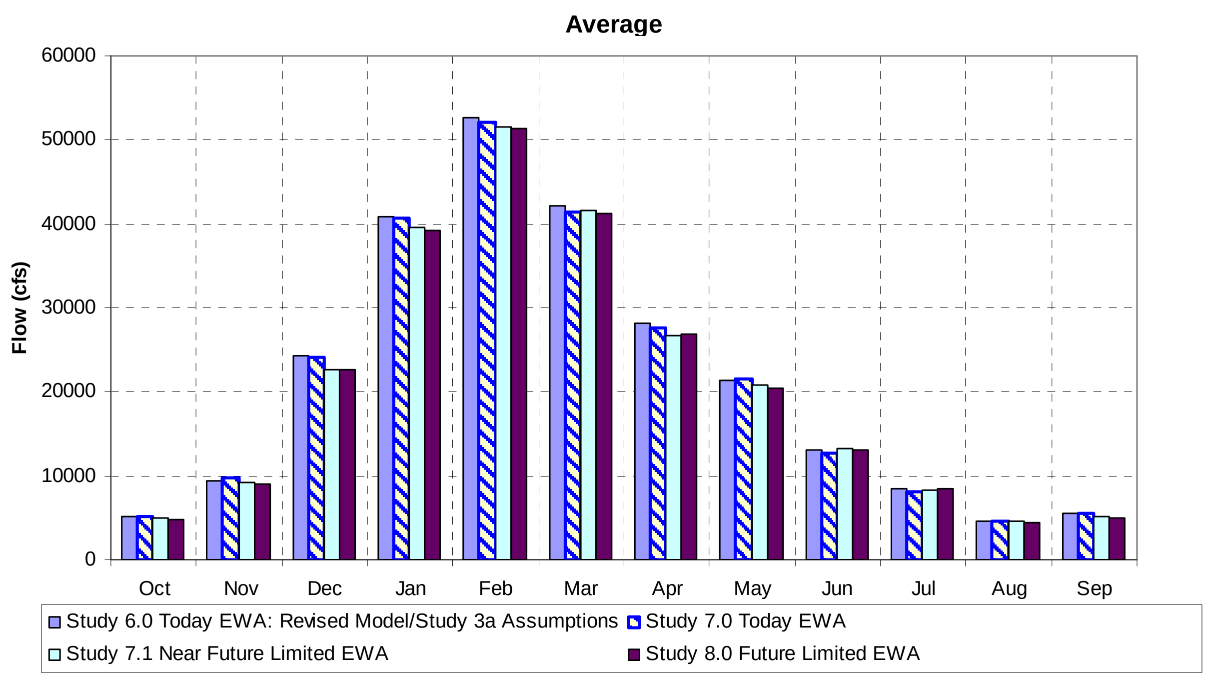


Figure 12-11 Average Monthly Total Delta Outflow

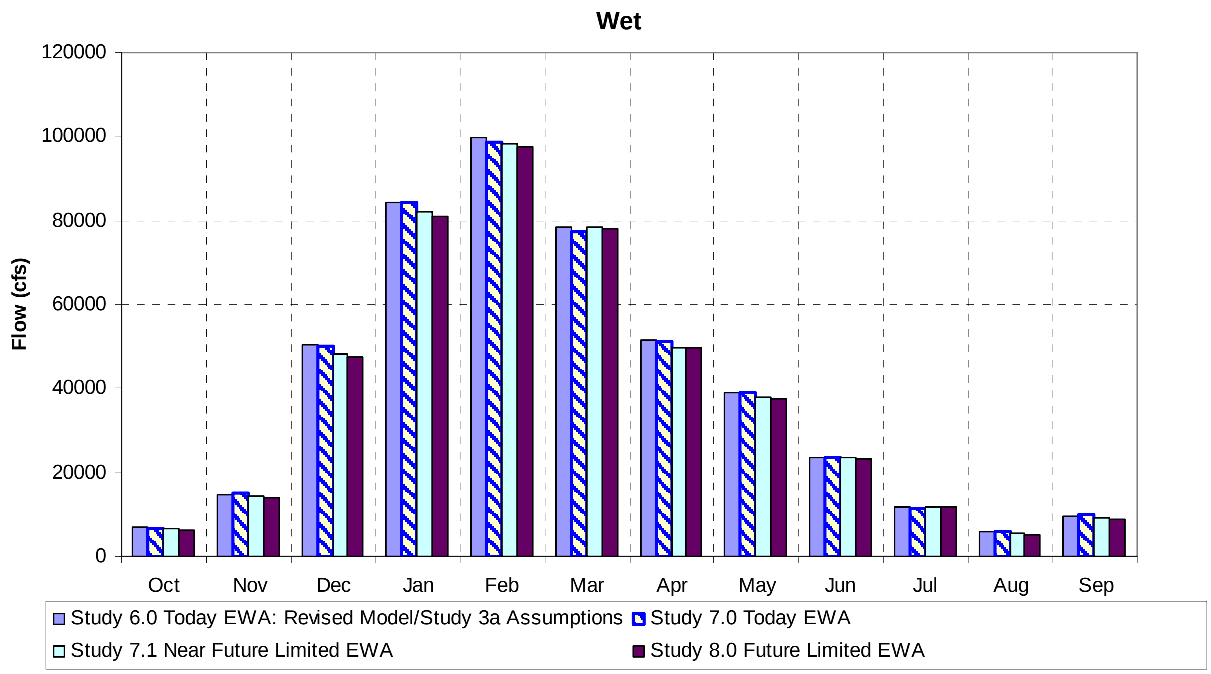


Figure 12-12 Average wet year (40-30-30 Classification) monthly Delta Outflow

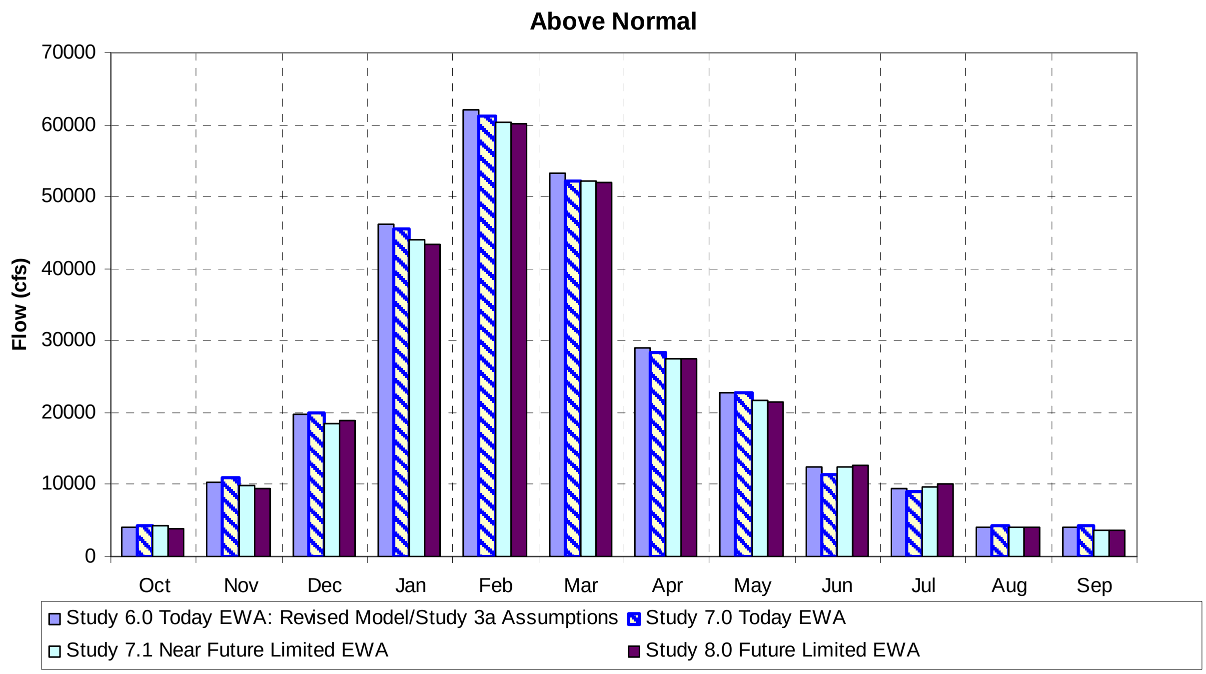


Figure 12-13 Average above normal year (40-30-30 Classification) monthly Delta Outflow

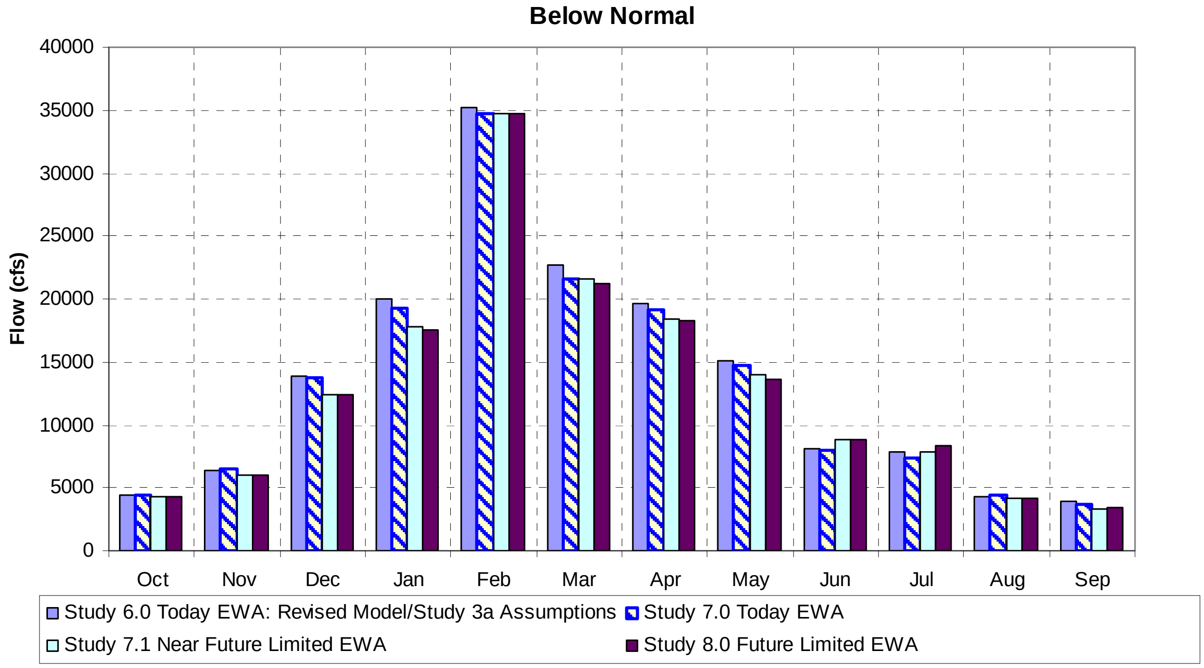


Figure 12-14 Average below normal year (40-30-30 Classification) monthly Delta Outflow

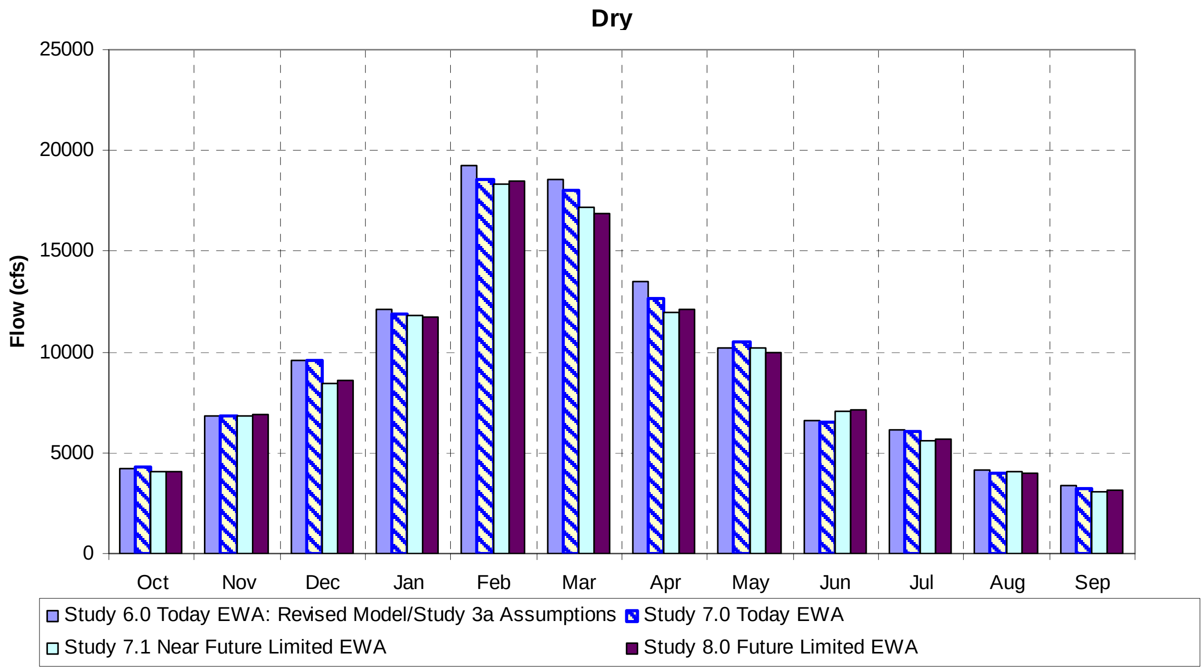


Figure 12-15 Average dry year (40-30-30 Classification) monthly Delta Outflow

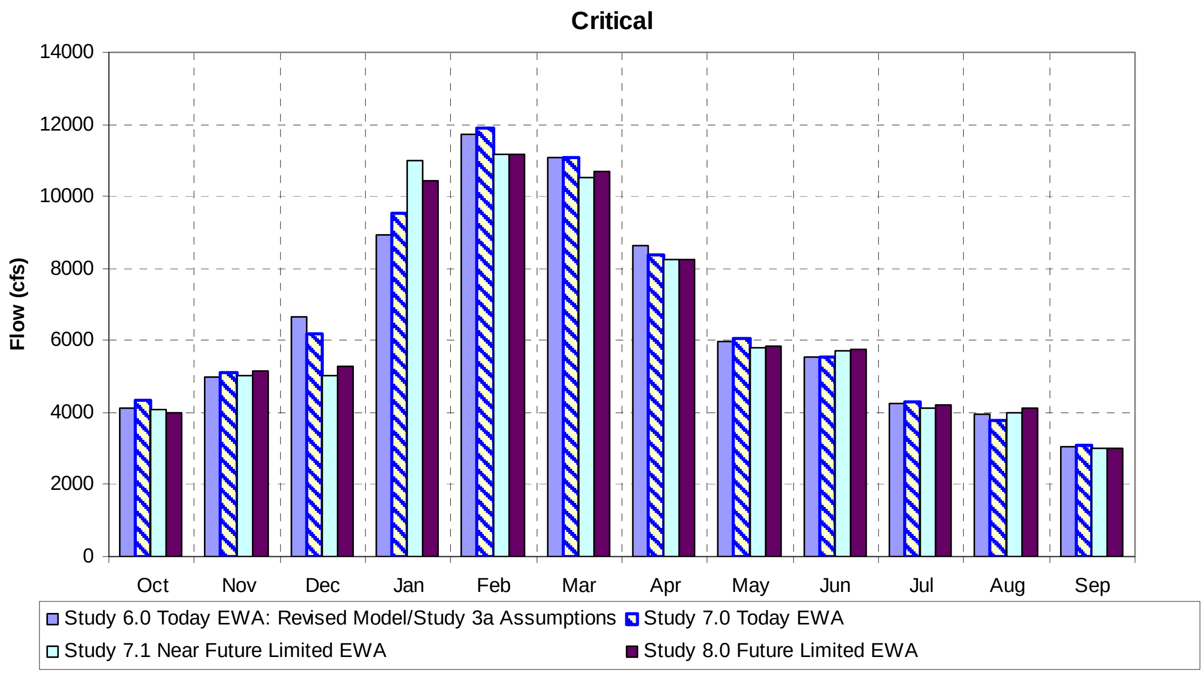


Figure 12-16 Average critical year (40-30-30 Classification) monthly Delta Outflow

Exports

The exports discussed in this section are Jones pumping, Banks pumping, Federal Banks pumping, and diversions for Contra Costa Water District (CCWD) and the North Bay Aqueduct (NBA). Figure 12-17 shows the total annual pumping of Jones and Banks facilities. Looking at Figure 12-17, Study 8.0 tends to be the more aggressive for pumping of the Studies on an annual basis because of the higher future demands south of the Delta. Study 8.0 also has lesser reductions in exports due to EWA actions relative to Studies 6.0 and 7.0. Study 7.1 also shows more aggressive annual pumping regimes due to a lesser amount of EWA actions relative to Studies 6.0 and 7.0 as well.

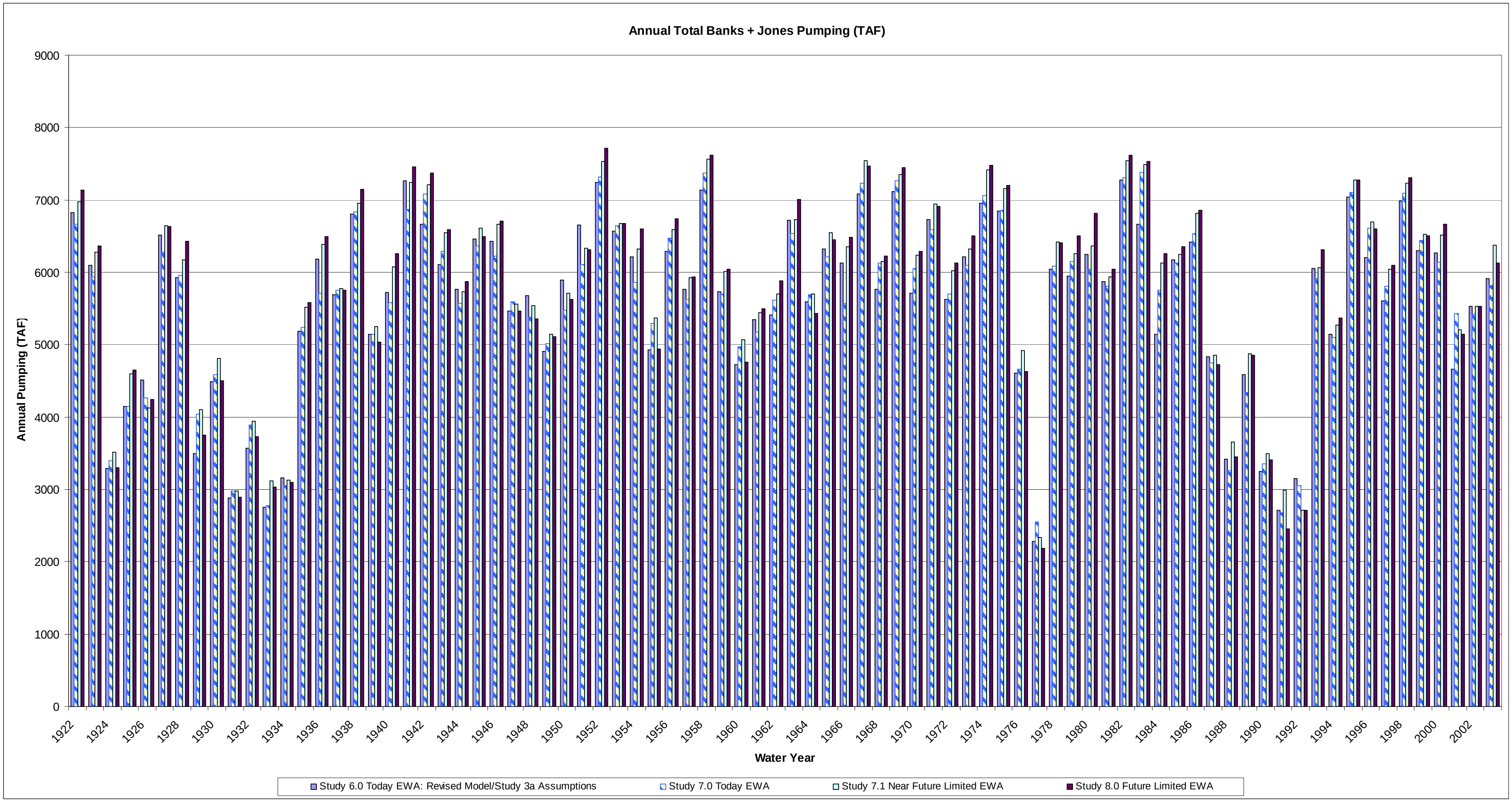


Figure 12-17 Total Annual Jones + Banks Pumping

Jones Pumping

The Jones pumping in Studies 6.0 and 7.0 is limited to 4,200 cfs plus the diversions upstream of the constriction in the Delta Mendota Canal (DMC). In Studies 7.1 and 8.0 the DMC/California Aqueduct Intertie allows pumping to increase to the facility design capacity of 4,600 cfs. Figure 12-18 shows the percentile values for monthly pumping at Jones. November through January are the months when Jones most frequently pumps at 4600 cfs with the 50th percentile at that level for most of the months in Studies 7.1 and 8.0. Wet years tend to be when Jones can utilize the 4,600 cfs pumping in Study 7.1 and Study 8.0 (see Figure 12-20).

From Figure 12-18 December through February the pumping is decreased during this time frame in Studies 6.0 and 7.0 due to the 25 taf/month pumping restriction from the EWA program. April, May, and June see reductions from the other months because of the Vernalis Adaptive Management Program (VAMP) restrictions and May has further reductions in the EWA studies due to EWA spending some assets to supplement the May Shoulder pumping reduction. July through September see pumping increasing between the three studies generally for irrigation deliveries. July and August have the 5th percentiles down to the 800 cfs minimum pumping (assumption of pumping rate with one pump on) and to 600 cfs when Shasta gets below 1,500 taf [taf or TAF] in storage.

Figure 12-19 to Figure 12-24 show similar trends in monthly average exports by year type, with pumping being greatest December through February and July through September.

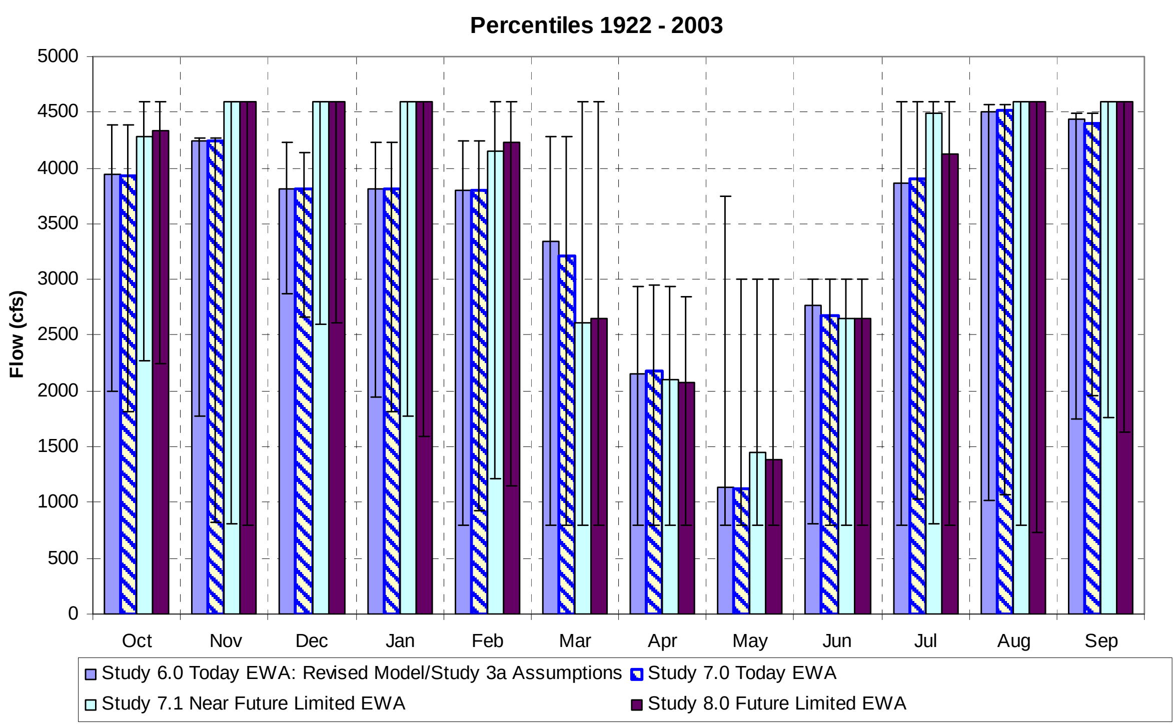


Figure 12-18 Jones Pumping 50th Percentile Monthly Export Rate with the 5th and 95th as the bars

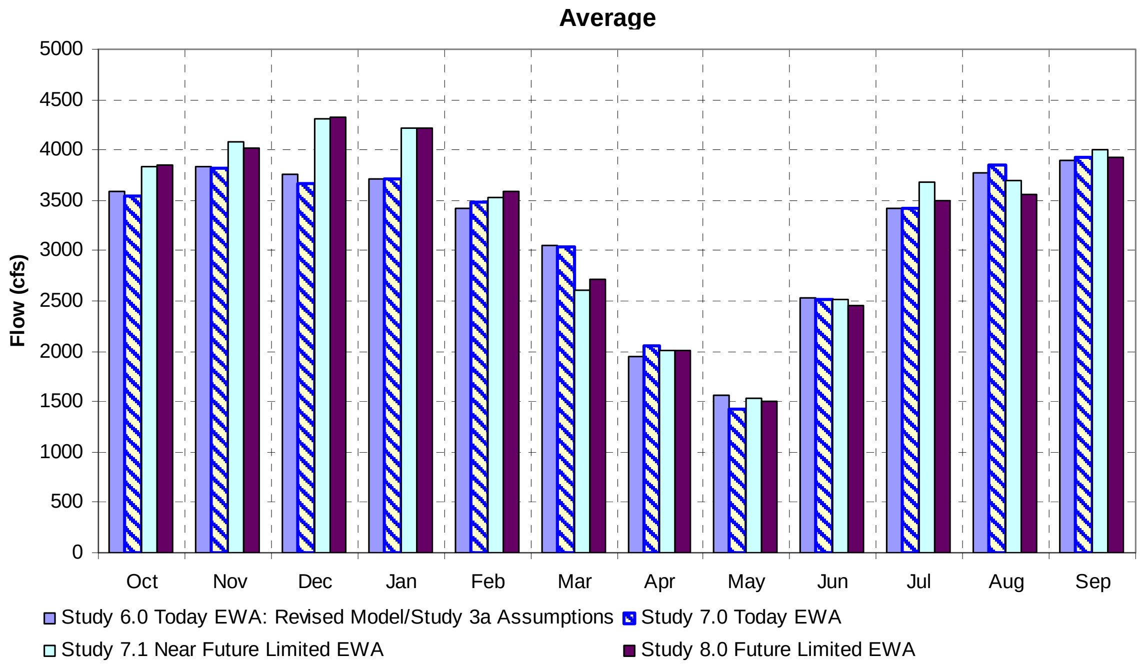


Figure 12-19 Average Monthly Jones Pumping

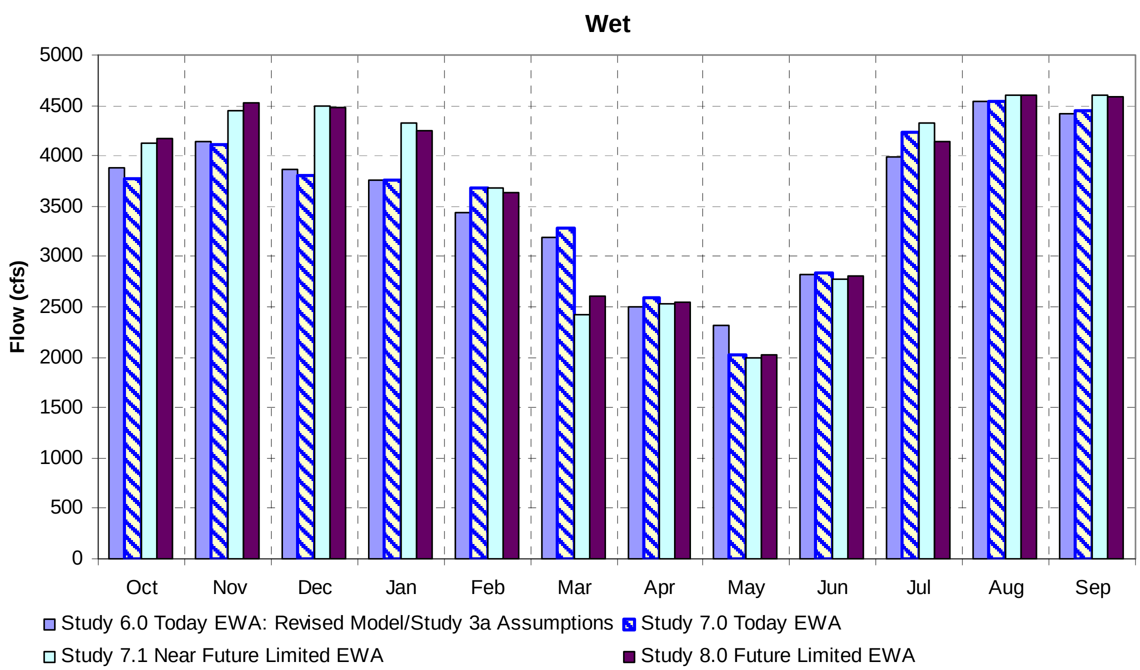


Figure 12-20 Average wet year (40-30-30 Classification) monthly Jones Pumping

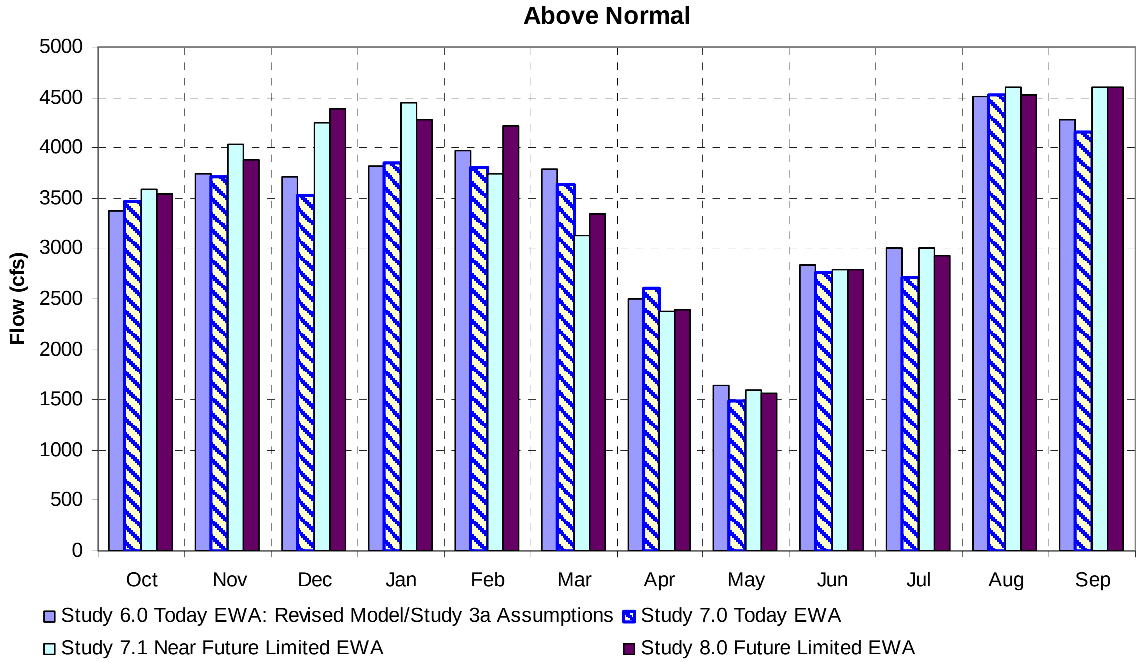


Figure 12-21 Average above normal year (40-30-30 Classification) monthly Jones Pumping

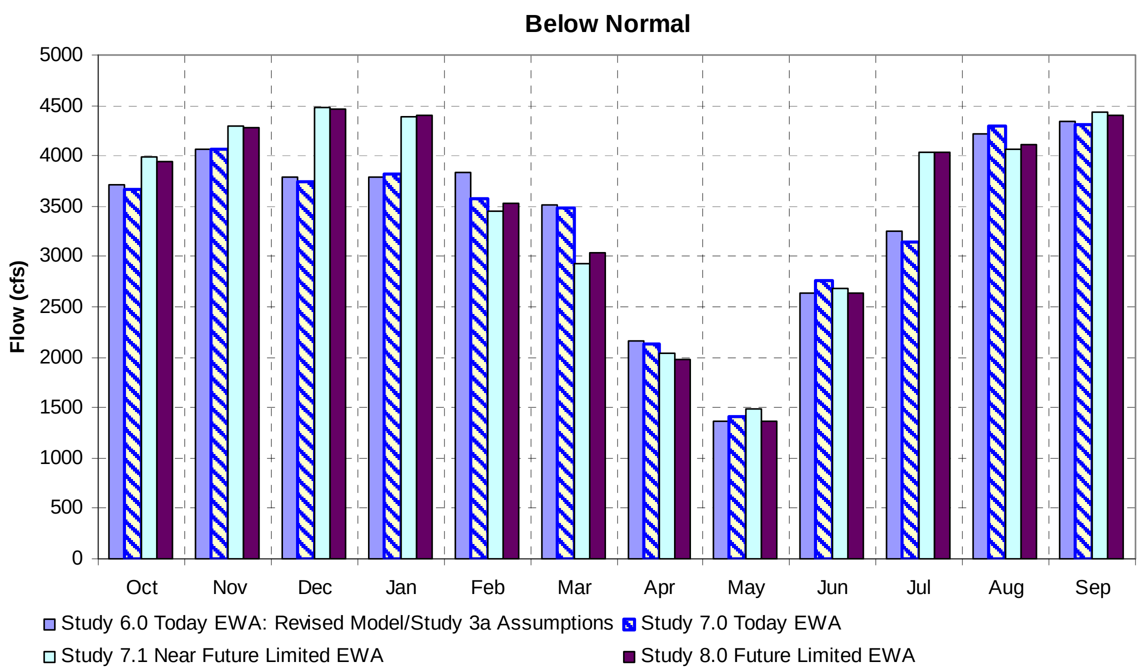


Figure 12-22 Average below normal year (40-30-30 Classification) monthly Jones Pumping

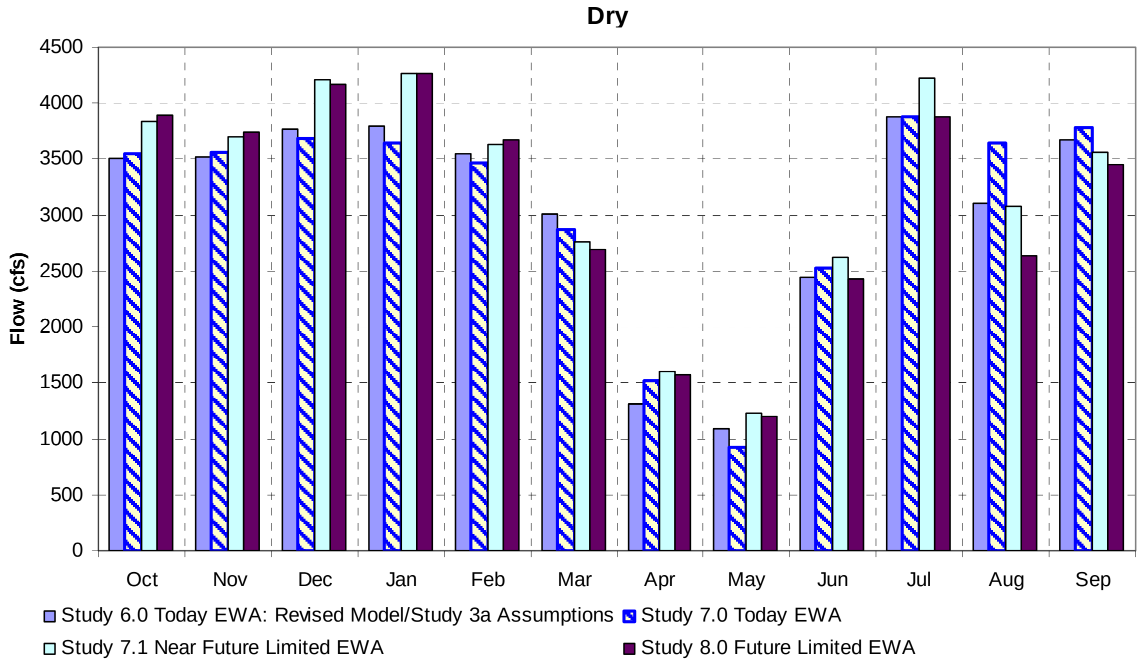


Figure 12-23 Average dry year (40-30-30 Classification) monthly Jones Pumping

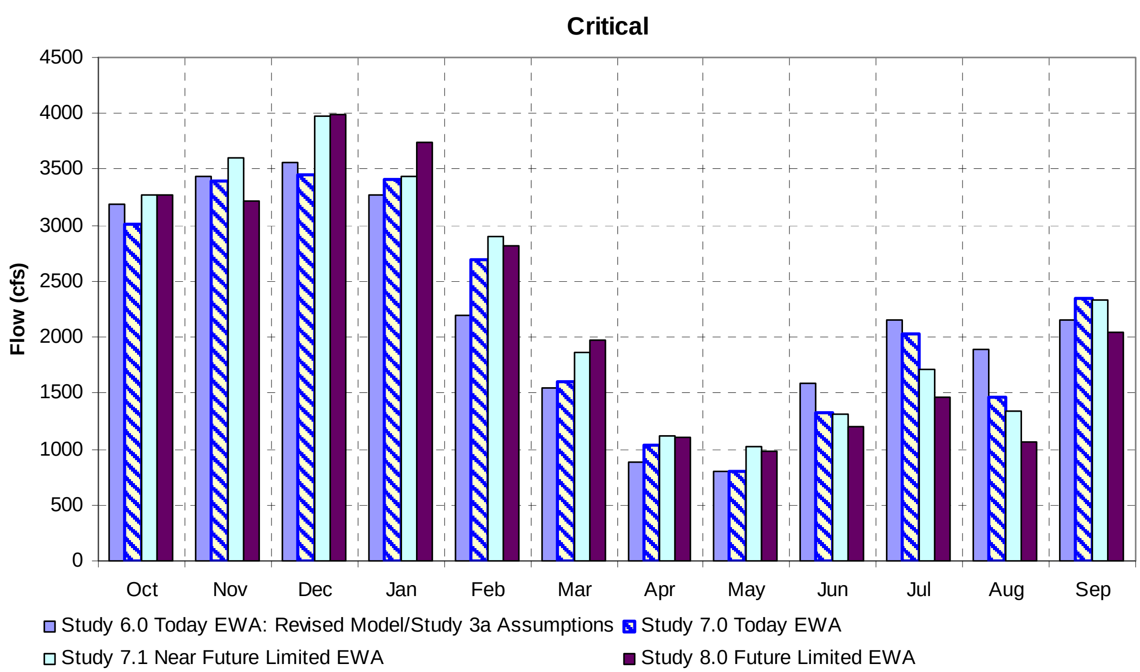


Figure 12-24 Average critical year (40-30-30 Classification) monthly Jones Pumping

Banks Pumping

Figure 12-25 through Figure 12-31 show total Banks exports for the four studies. Figure 12-25 shows a reduction in Banks pumping December, January, and February for Studies 6.0 and 7.0 due to the availability of a full EWA as compared to the limited EWA in Studies 7.1 and 8.0. In the limited EWA studies pumping reductions do not occur at Banks in the months of December to February. The figure also shows larger reductions in pumping during the April, May and June period for Studies 6.0 and 7.0 which is due to a greater amount of assets available in the full EWA. In Study 7.1 and 8.0 pumping reductions occur during VAMP up to the amount of assets in-hand and anticipated through Yuba Accord. During the summer period, July to September, Banks pumping utilizes the additional 500 cfs in order to wheel EWA assets in all of the studies.

Studies 6.0 and 7.0 show lower pumping in the winter and spring months when EWA reductions occur and higher pumping in the summer and fall month when wheeling EWA assets through Banks at a higher rate versus Studies 7.1 and 8.0 (see Figure 12-26 to Figure 12-31.).

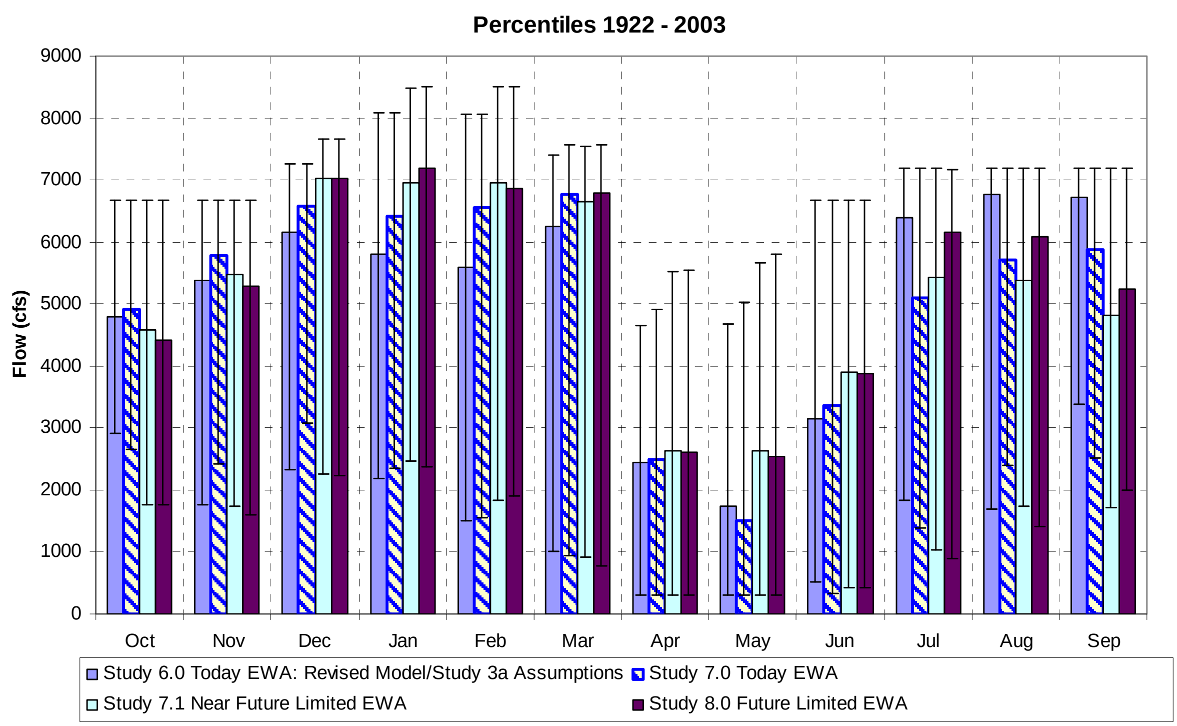


Figure 12-25 Banks Pumping 50th Percentile Monthly Export Rate with the 5th and 95th as the bars

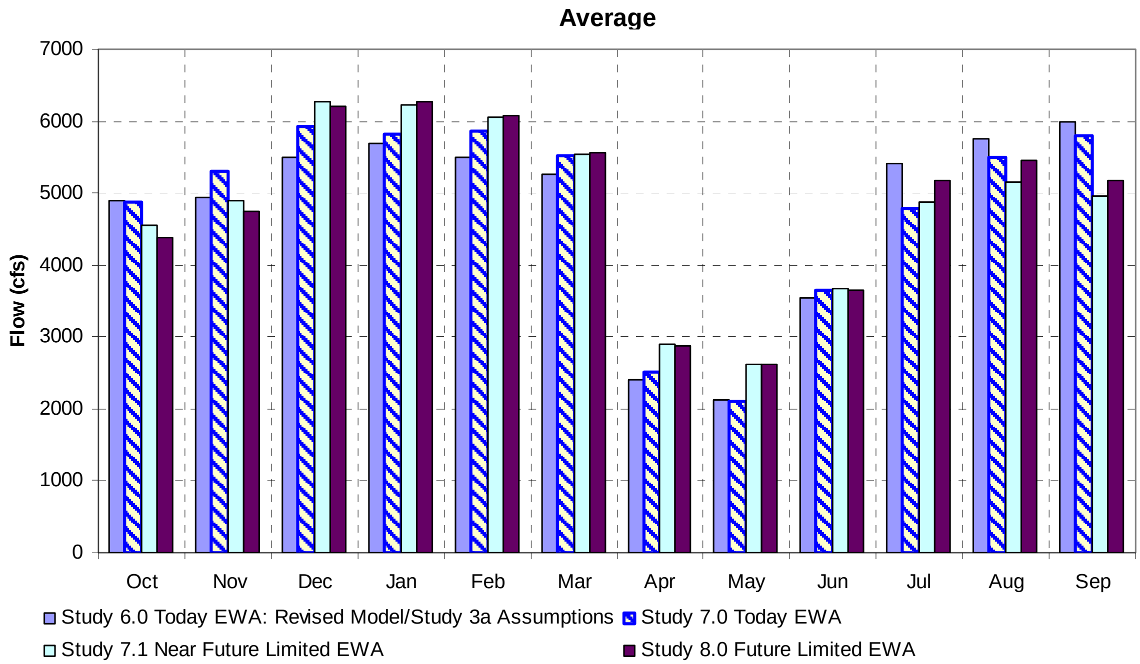


Figure 12-26 Average Monthly Banks Pumping

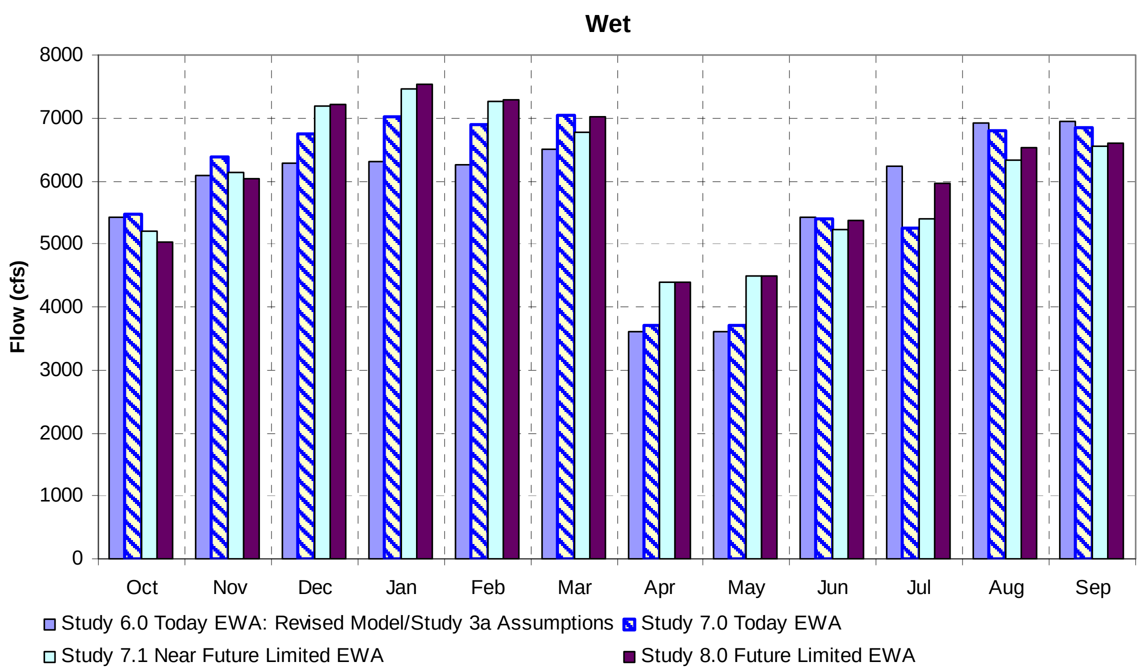


Figure 12-27 Average wet year (40-30-30 Classification) monthly Banks Pumping

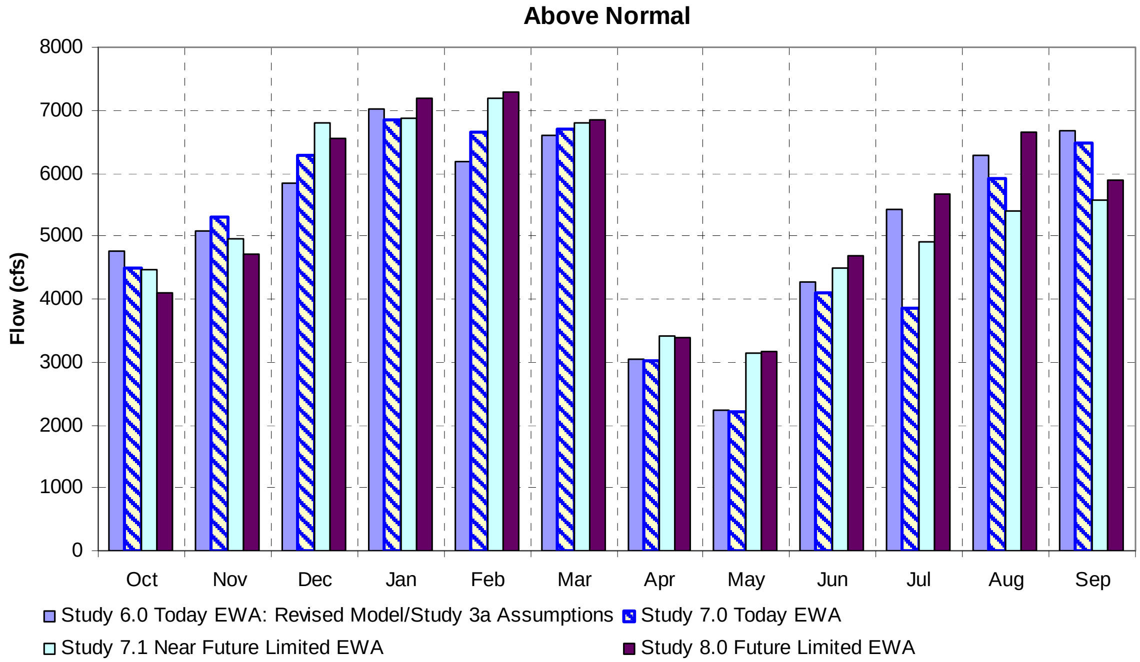


Figure 12-28 Average above normal year (40-30-30 Classification) monthly Banks Pumping

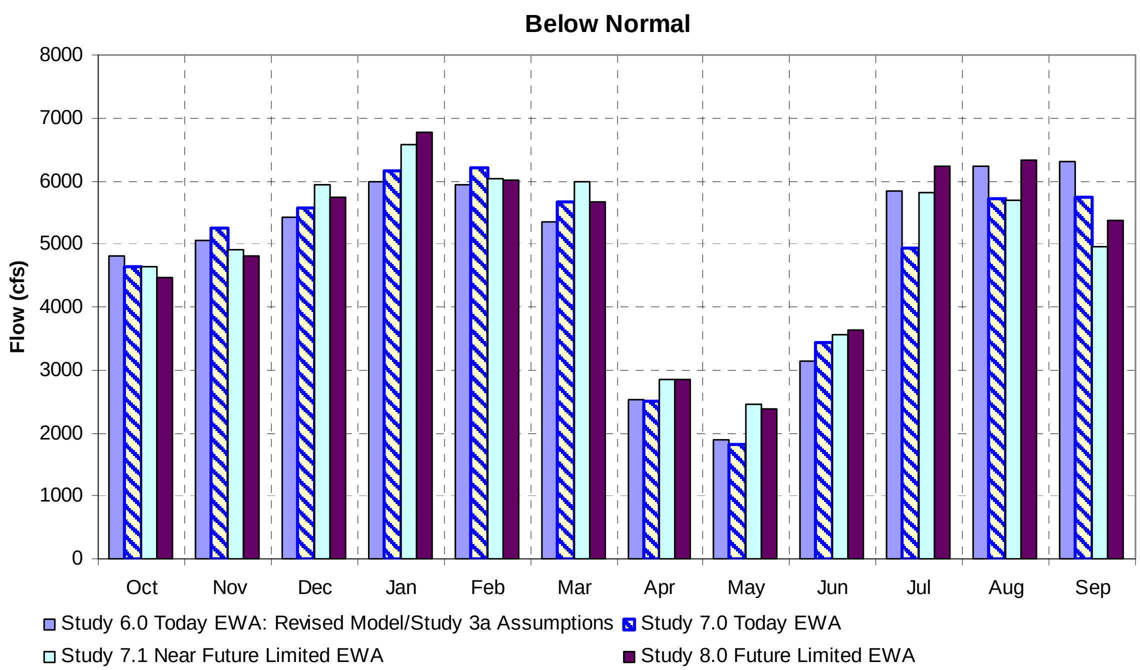


Figure 12-29 Average below normal year (40-30-30 Classification) monthly Banks Pumping

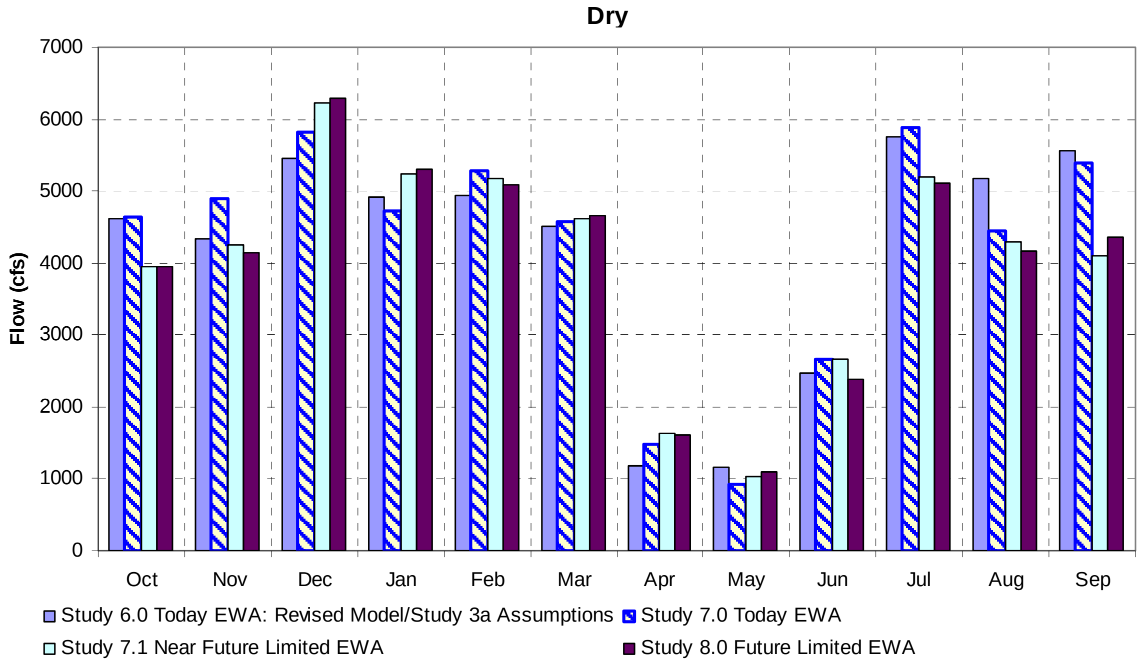


Figure 12-30 Average dry year (40-30-30 Classification) monthly Banks Pumping

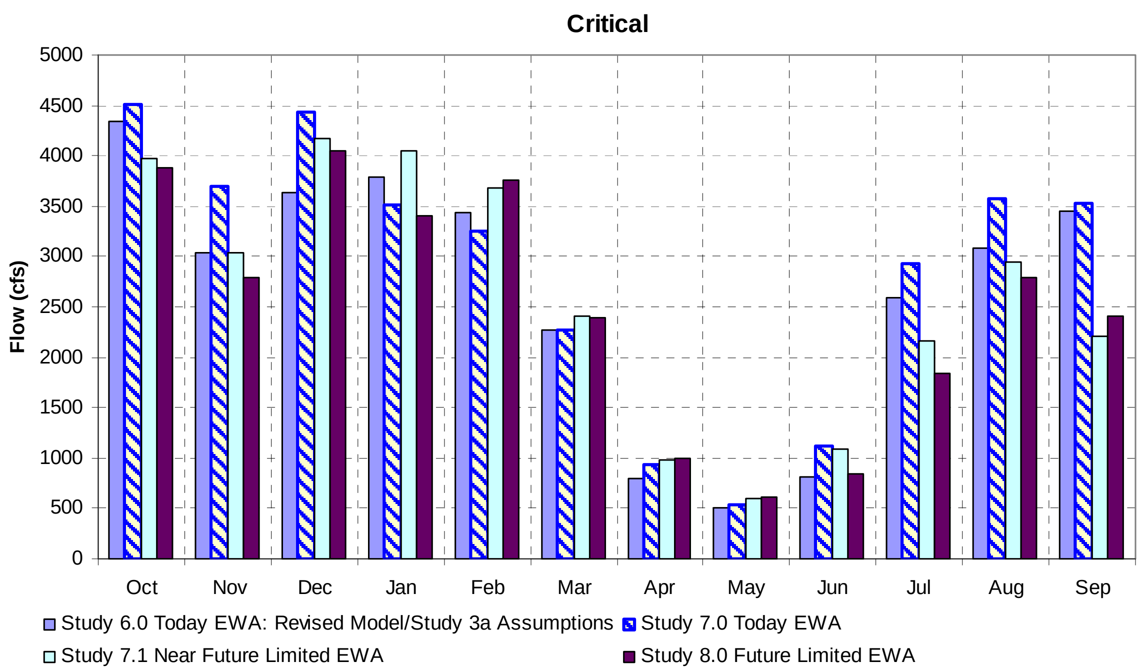
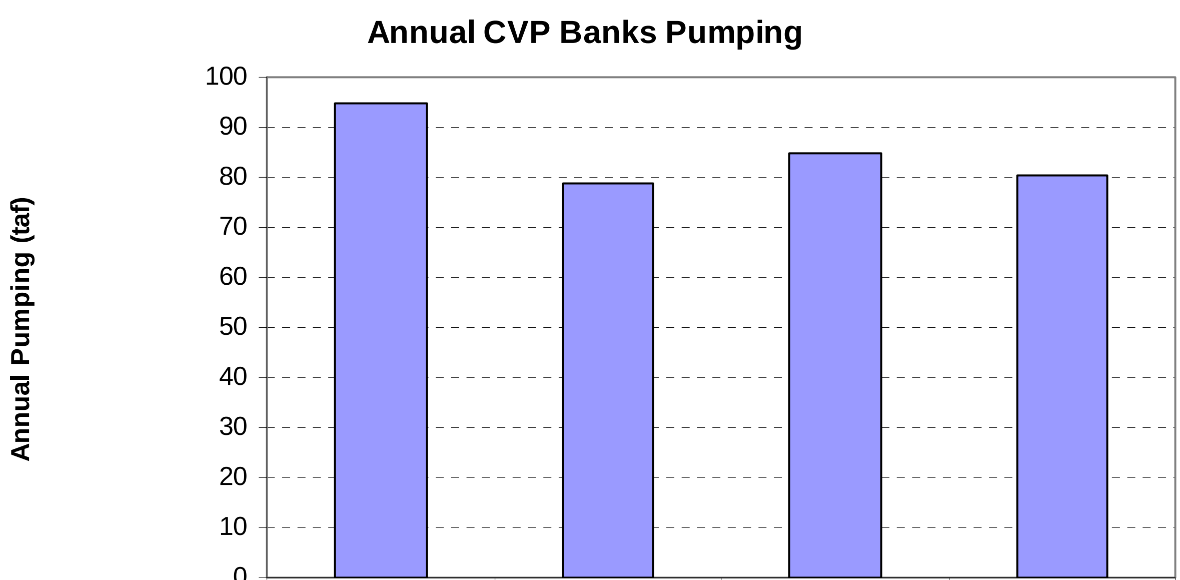


Figure 12-31 Average critical year (40-30-30 Classification) monthly Banks Pumping

Federal Banks Pumping

The use of Banks Pumping Plant for pumping CVP water is based on many factors including available capacity at Banks, available water upstream or in the Delta, and CVP South of Delta demand. Figure 12-32 shows the annual average use of Banks pumping for the CVP by study. Federal pumping at Banks generally occurs in the late summer months into October (Figure 12-33 through Figure 12-39). Some Federal pumping occurs during November through March for Cross Valley Contractors. For the most part, Federal Banks pumping is similar between the studies. However, Federal Banks pumping is a little higher in Study 7.1 due to the lack of EWA wheeling relative to Study 7.0. The available Banks capacity is reduced in Study 8.0 due to a higher SWP South of Delta demand which reduces the ability of Federal use of Banks pumping. Study 6.0 shows higher use of Federal Banks pumping primarily due to changes in the model logic. As described in Chapter 9, the intention of Study 6.0 was to mimic the assumptions in the OCAP BA 2004 model which included demand patterns. With the new demand patterns (Studies 7.0, 7.1, and 8.0) Article 56 is modeled explicitly, as discussed in the SWP Demand Assumptions section of this chapter starting on page 12-36. With modeling Article 56 is a requirement on San Luis storage to match the amount of Article 56 requested. This additional requirement reduces the amount of Federal Banks pumping during the late fall and early winter periods as shown in Figure 12-34 and Figure 12-35. Wet years show the most pumping at Banks, with pumping averages decreasing as the years get drier.



	Study 6.0 Today EWA: Revised Model/Study 3a	Study 7.0 Today EWA	Study 7.1 Near Future Limited EWA	Study 8.0 Future Limited EWA
Annual Average	95	79	85	80

Figure 12-32 Average use of Banks pumping for the CVP

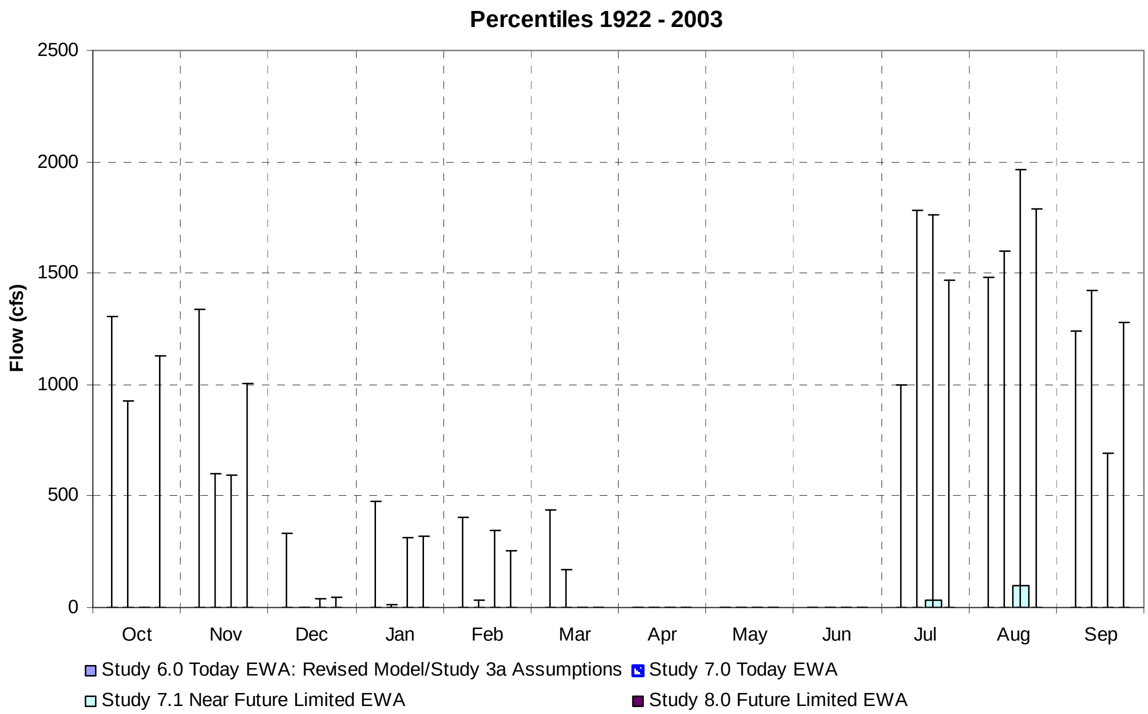


Figure 12-33 Federal Banks Pumping 50th Percentile Monthly Export Rate with the 5th and 95th as the bars

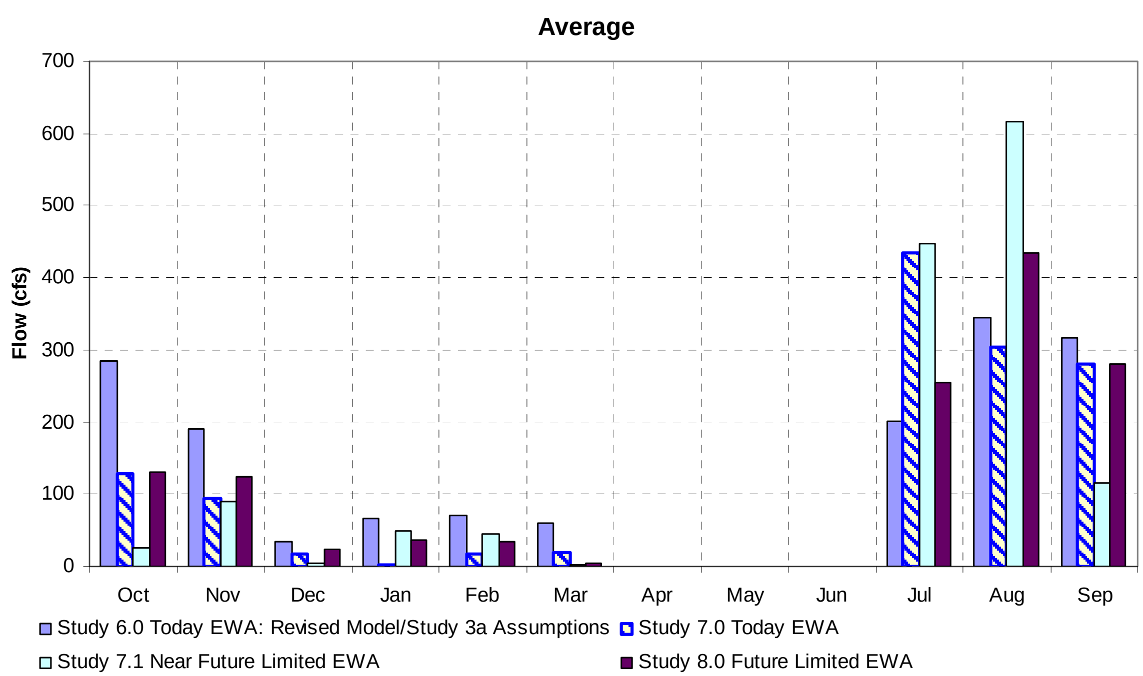


Figure 12-34 Average Monthly Federal Banks Pumping

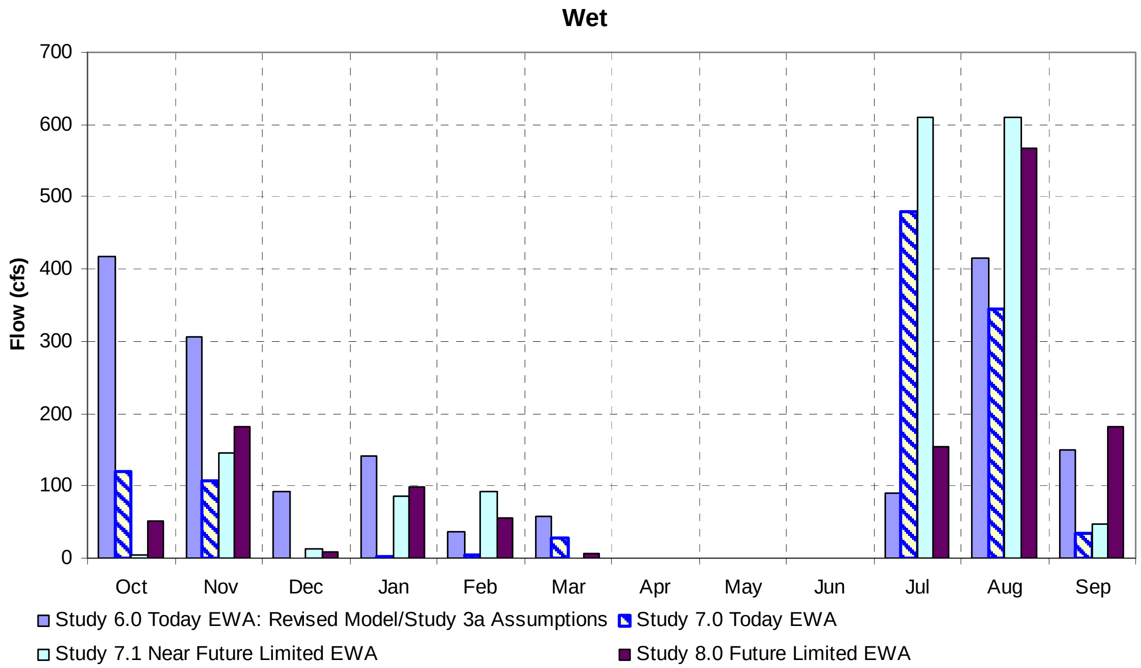


Figure 12-35 Average wet year (40-30-30 Classification) monthly Federal Banks Pumping

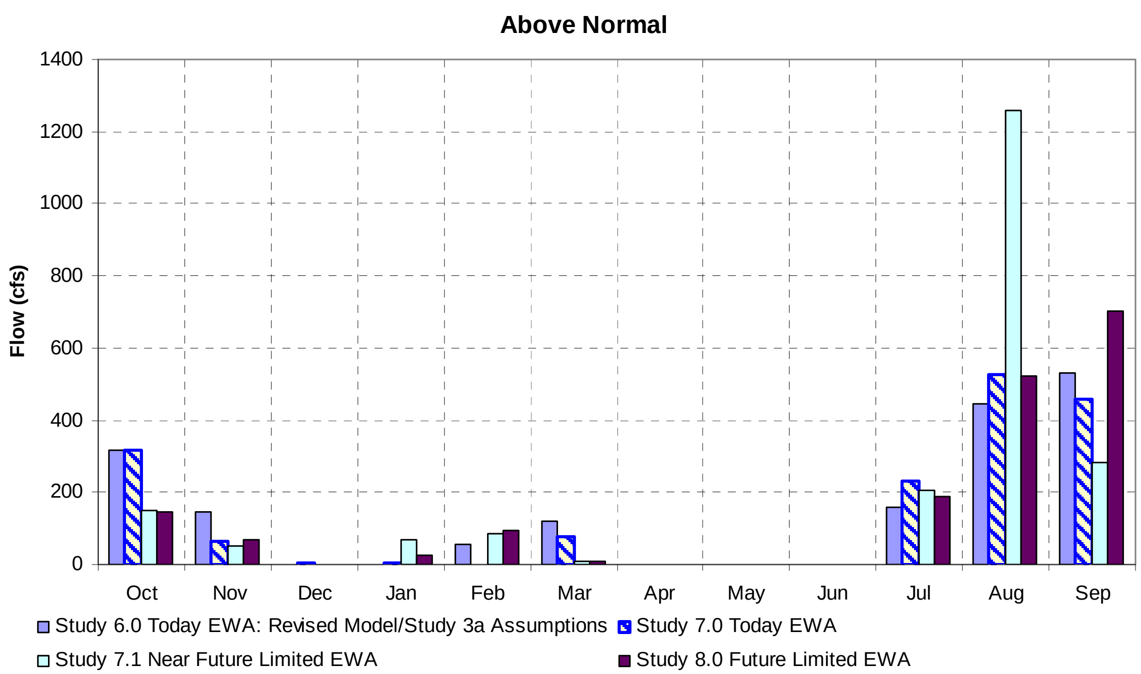


Figure 12-36 Average above normal year (40-30-30 Classification) monthly Federal Banks Pumping

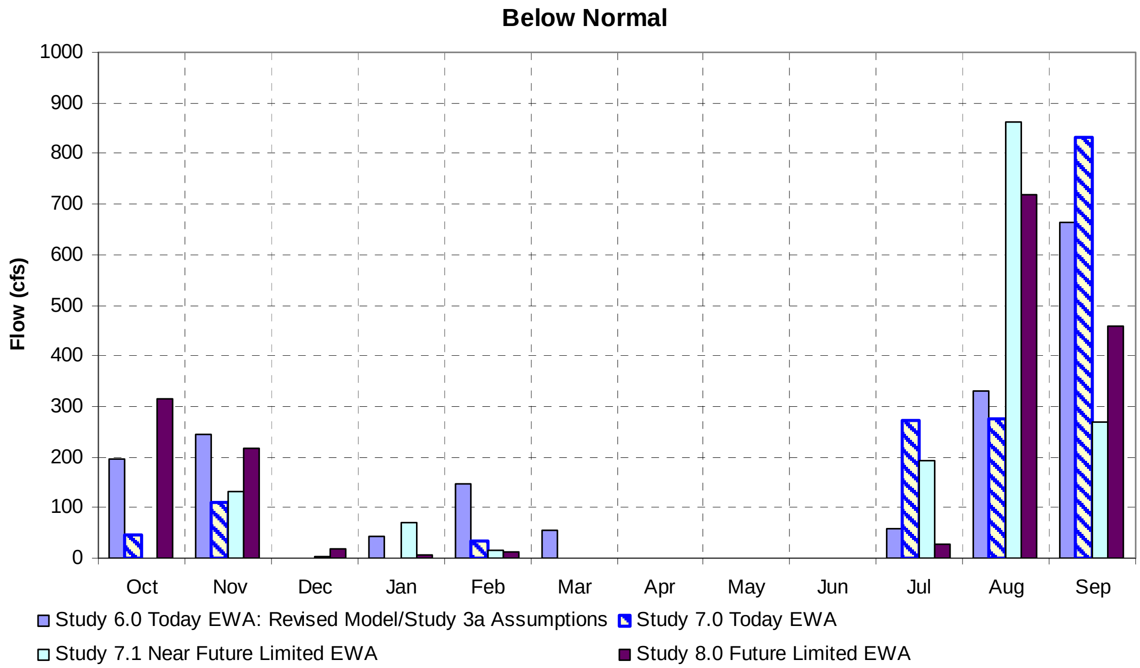


Figure 12-37 Average below normal year (40-30-30 Classification) monthly Federal Banks Pumping

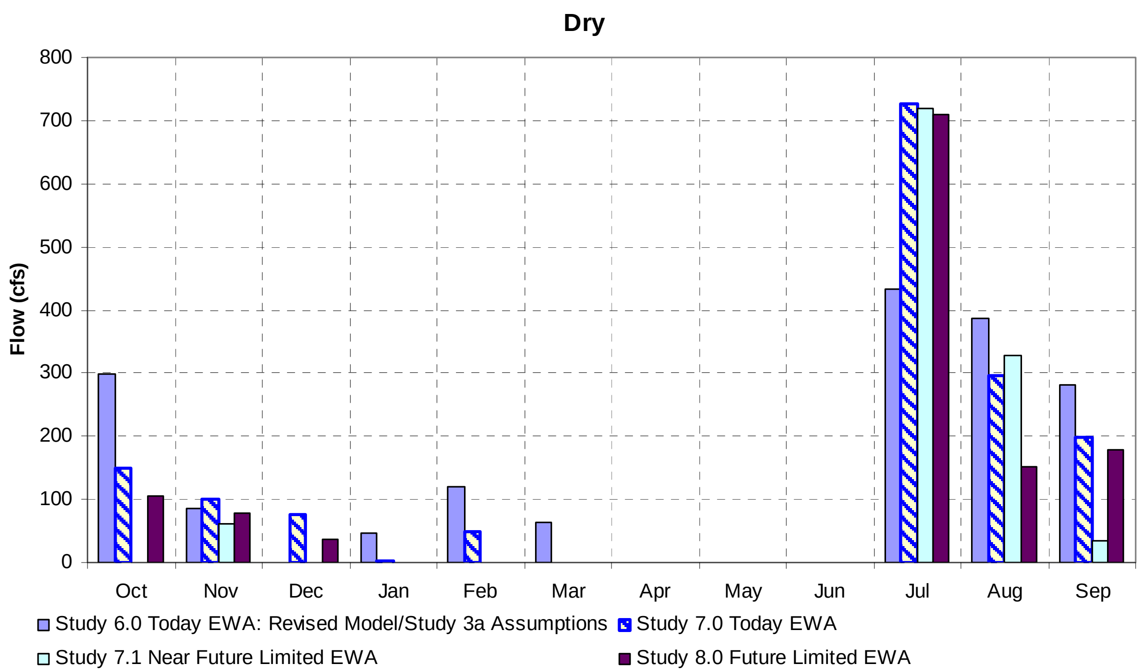


Figure 12-38 Average dry year (40-30-30 Classification) monthly Federal Banks Pumping

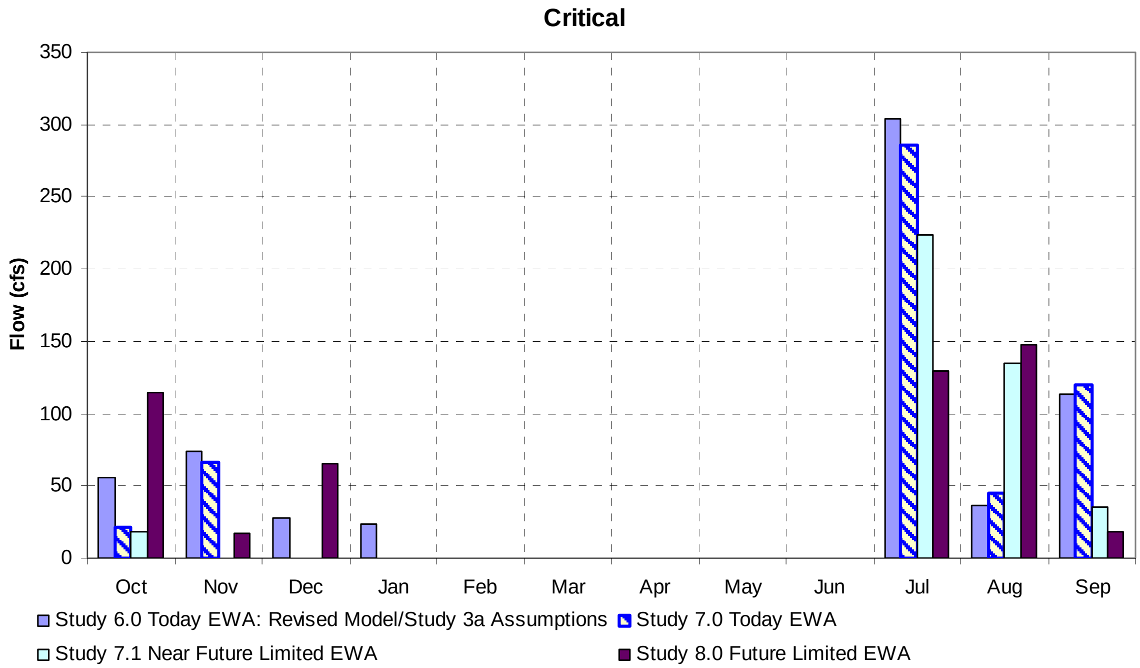


Figure 12-39 Average critical year (40-30-30 Classification) monthly Federal Banks Pumping

North Bay Aqueduct Diversions

Diversions from the NBA had no significant differences between the Existing to the Future Studies (see Table 12-3). Most of the diversions occur during the late summer months and extend into October for the NBA (Figure 12-40).

Table 12-3 Average Annual and Long-term Drought Differences in North Bay Aqueduct

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Longterm Annual Average North Bay Aqueduct	43	-3	7	10
29 - 34 Annual Average North Bay Aqueduct	32	0	1	1

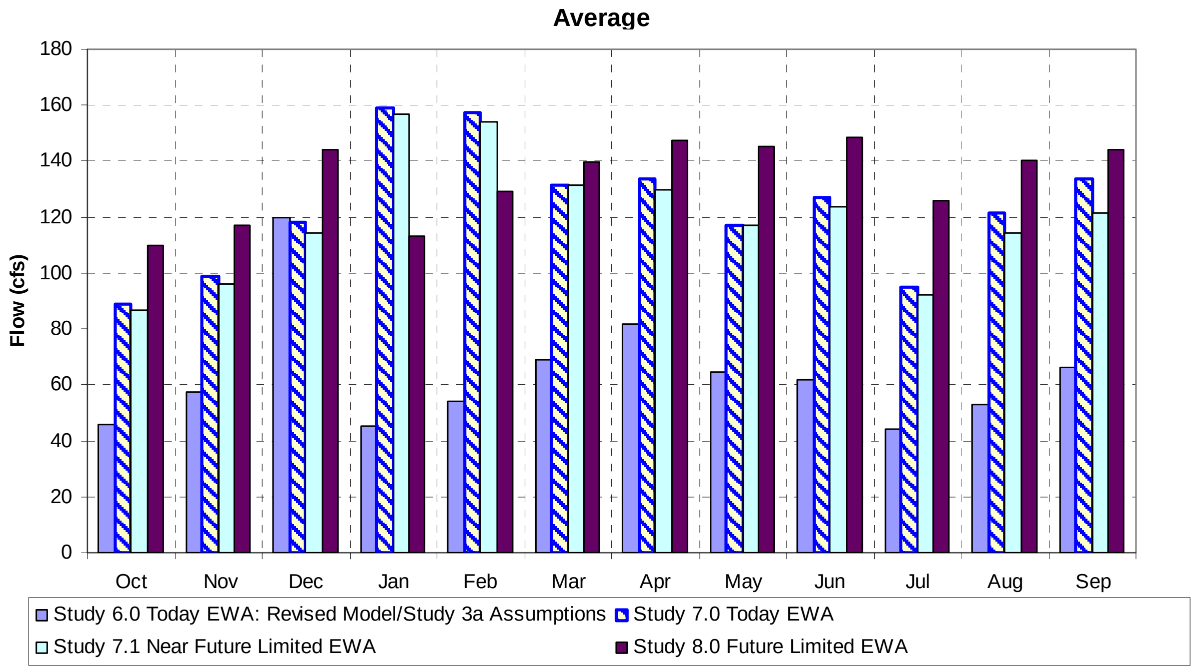


Figure 12-40 Average Monthly North Bay Aqueduct Diversions from the Delta

Export-to-Inflow Ratio

Figure 12-41 to Figure 12-46 show the E/I ratio on a monthly long-term average basis and averaged monthly by 40-30-30 index. From Figure 12-41 to Figure 12-46 during months where EWA actions are taken, the E/I ratio decreases (December, January, February, April, May and June) in Studies 6.0 and 7.0 compared to 7.1 and 8.0. The later summer months show increases in E/I due to increased pumping with the exception of some dry and critical years in the limited EWA runs due to either reduced storage or worsening salinity requirements. While Studies 6.0 and 7.0 shows increased EI Ratios in the summer months relative to the springtime due to wheeling of EWA assets.

Figure 12-47 to Figure 12-58 show the monthly E/I ratios sorted from wettest to driest by 40-30-30 Index. The graphs show generally the same trend as Figure 12-41 to Figure 12-46. Where Studies 6.0 and 7.0 show lower E/I ratios in the months when the full EWA is taking more actions in the winter and springtime relative to the limited EWA runs 7.1 and 8.0 that do not take any winter actions and limit EWA actions in the spring.

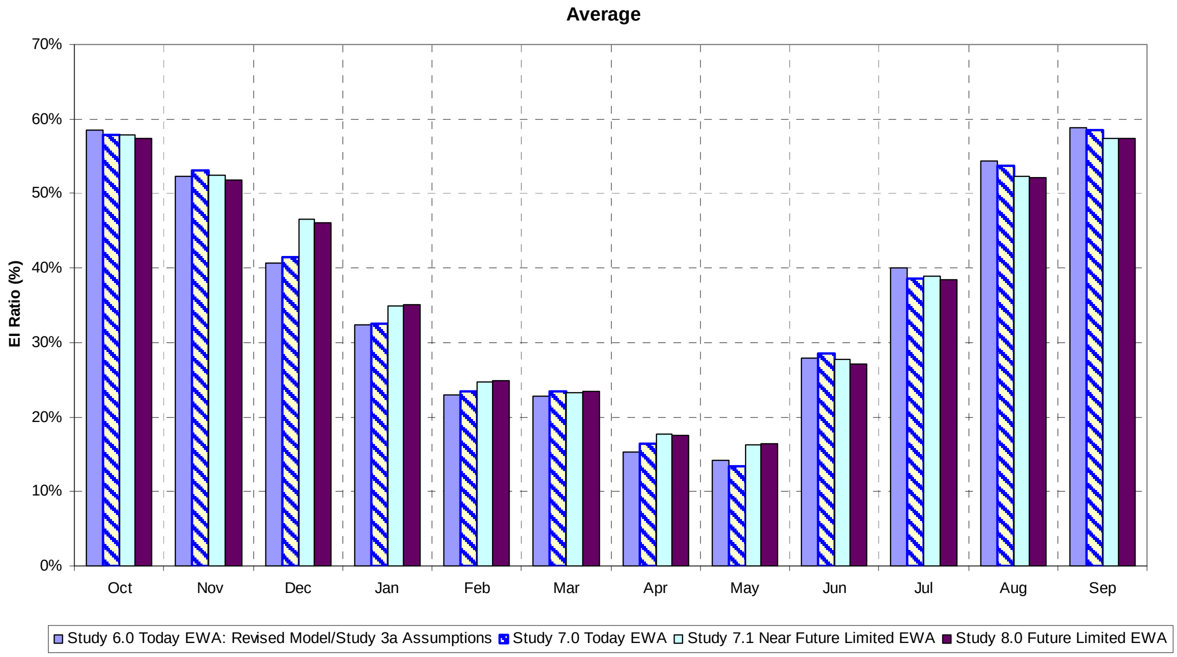


Figure 12-41 Average Monthly export-to-inflow ratio

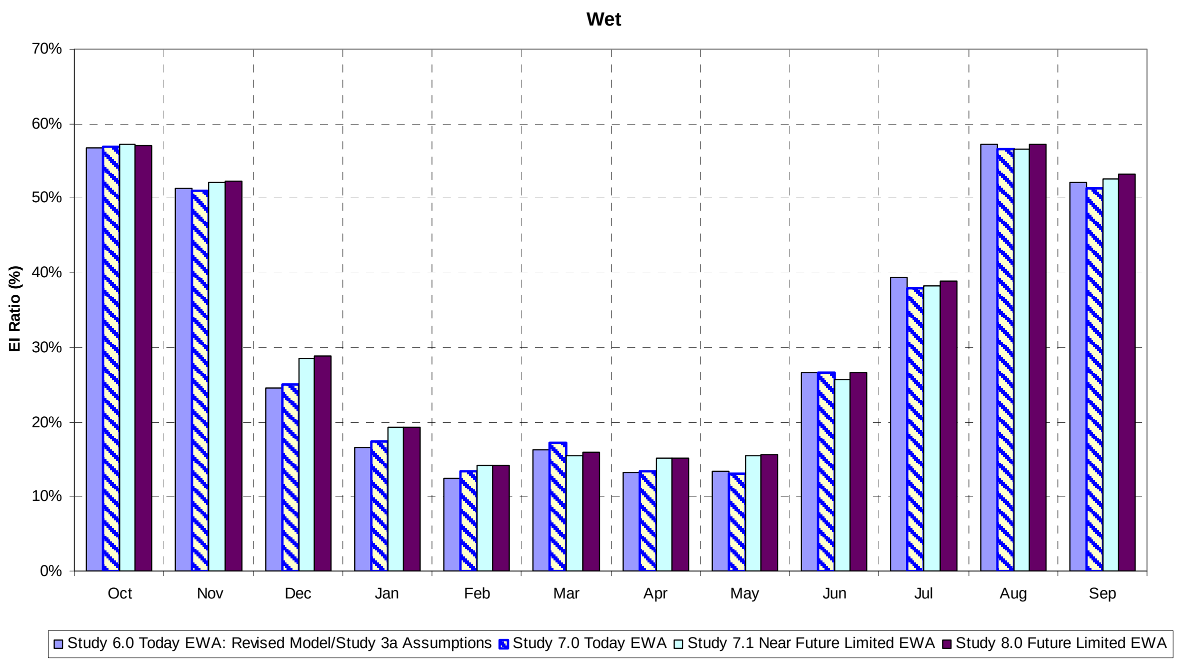


Figure 12-42 Average wet year (40-30-30 Classification) monthly export-to-inflow ratio

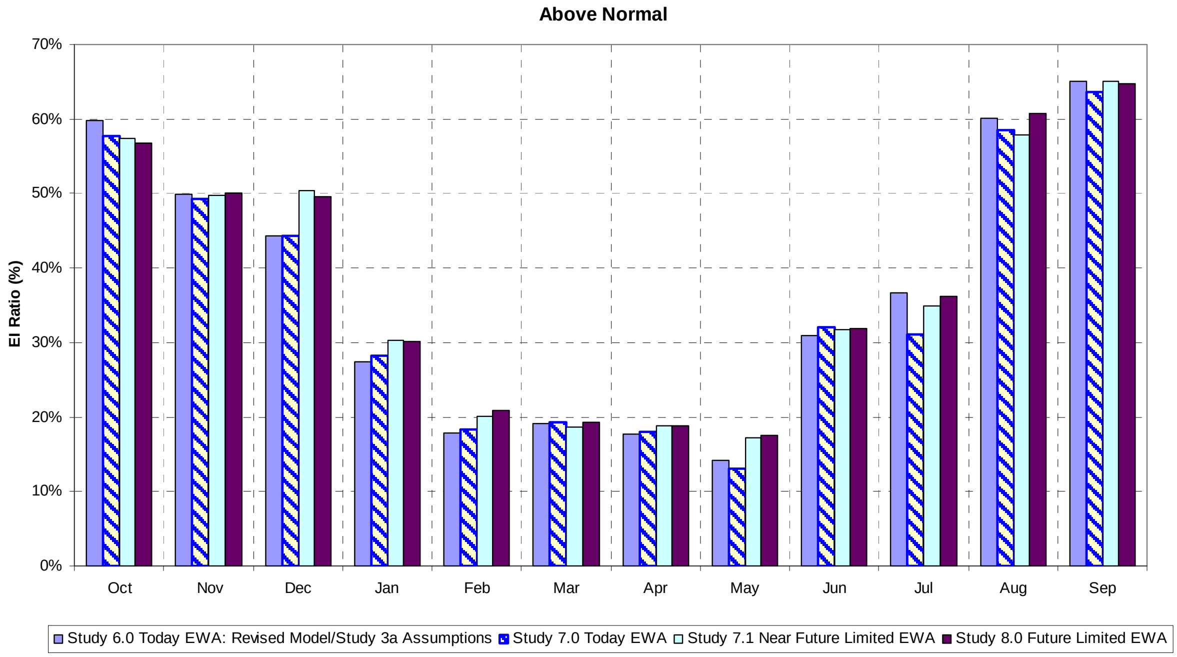


Figure 12-43 Average above normal year (40-30-30 Classification) monthly export-to-inflow ratio

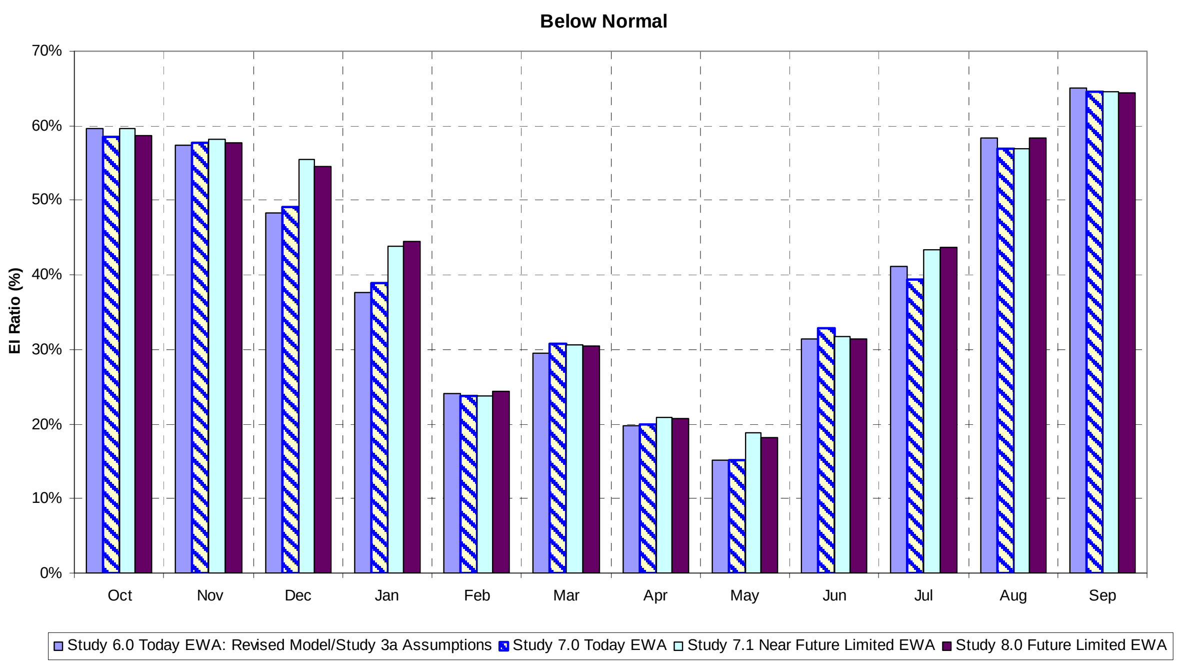


Figure 12-44 Average below normal year (40-30-30 Classification) monthly export-to-inflow ratio

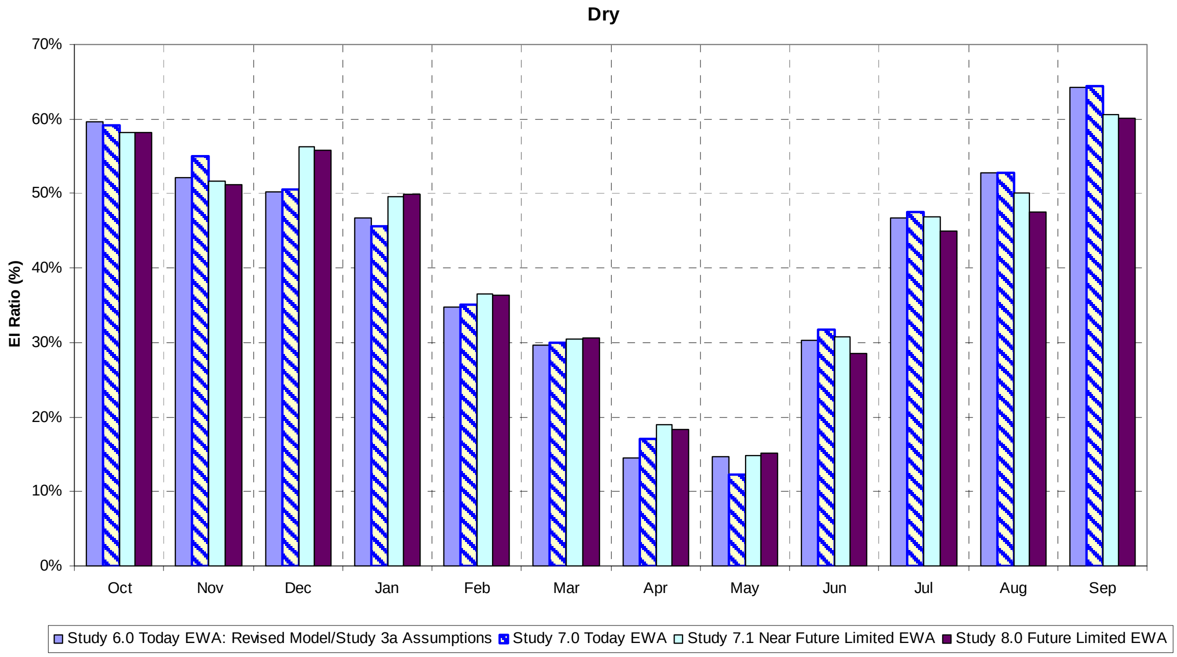


Figure 12-45 Average dry year (40-30-30 Classification) monthly export-to-inflow ratio

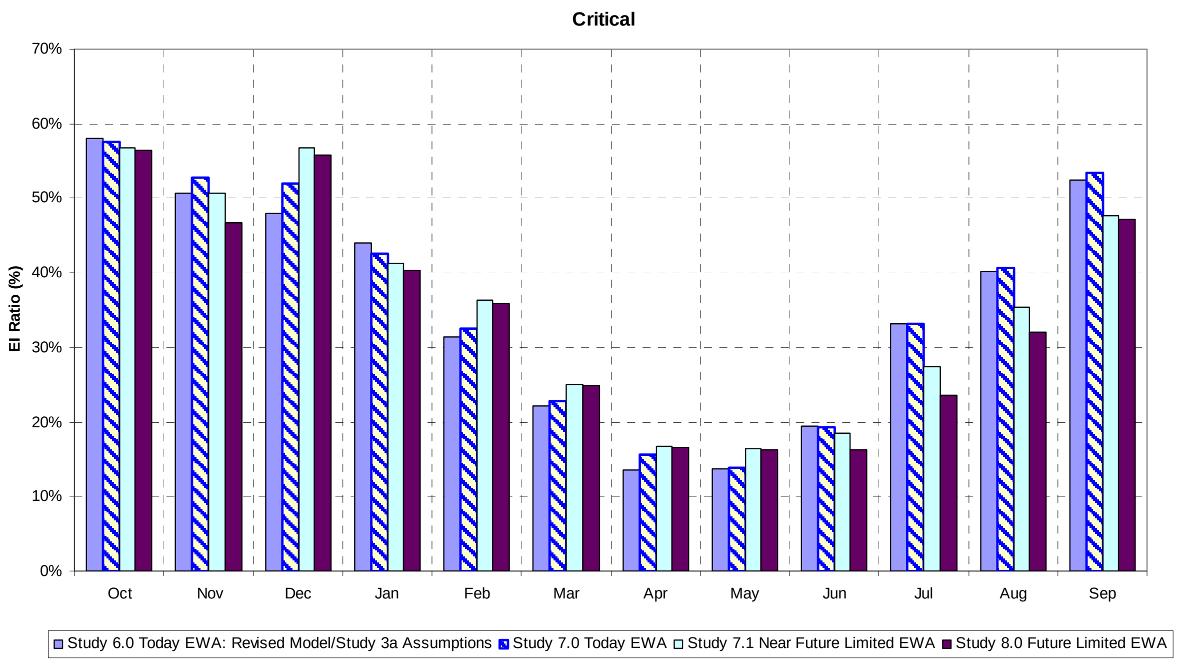


Figure 12-46 Average critical year (40-30-30 Classification) monthly export-to-inflow ratio

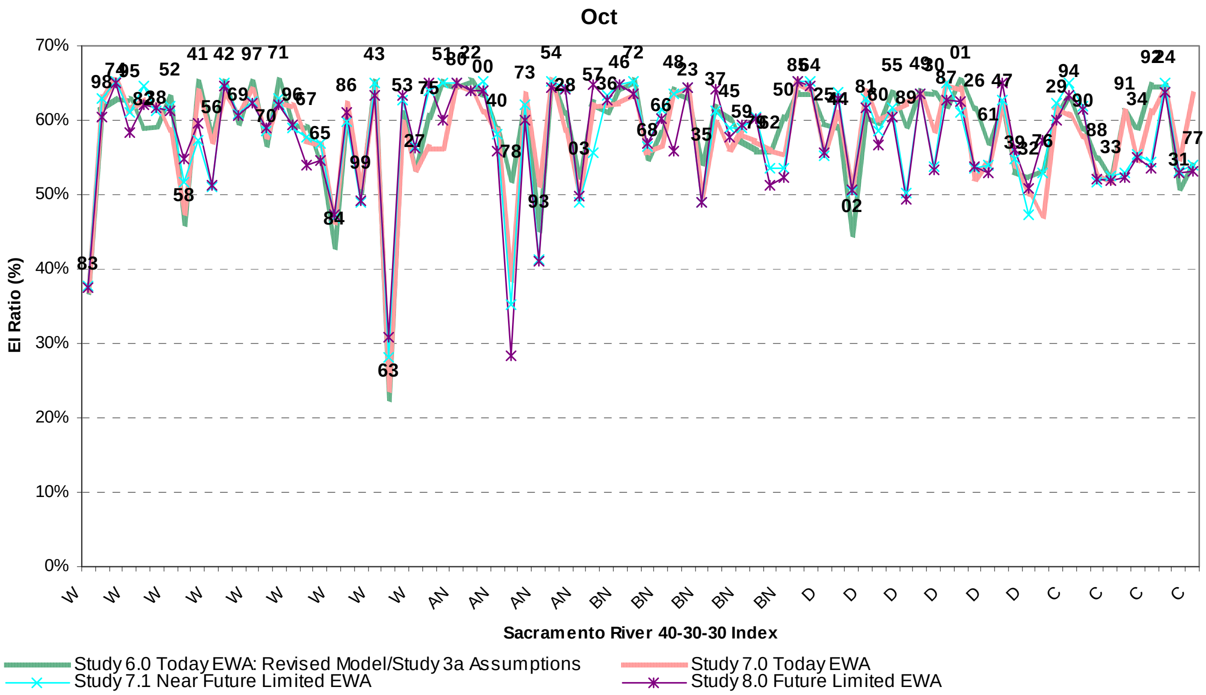


Figure 12-47 October export-to-inflow ratio sorted by 40-30-30 Index

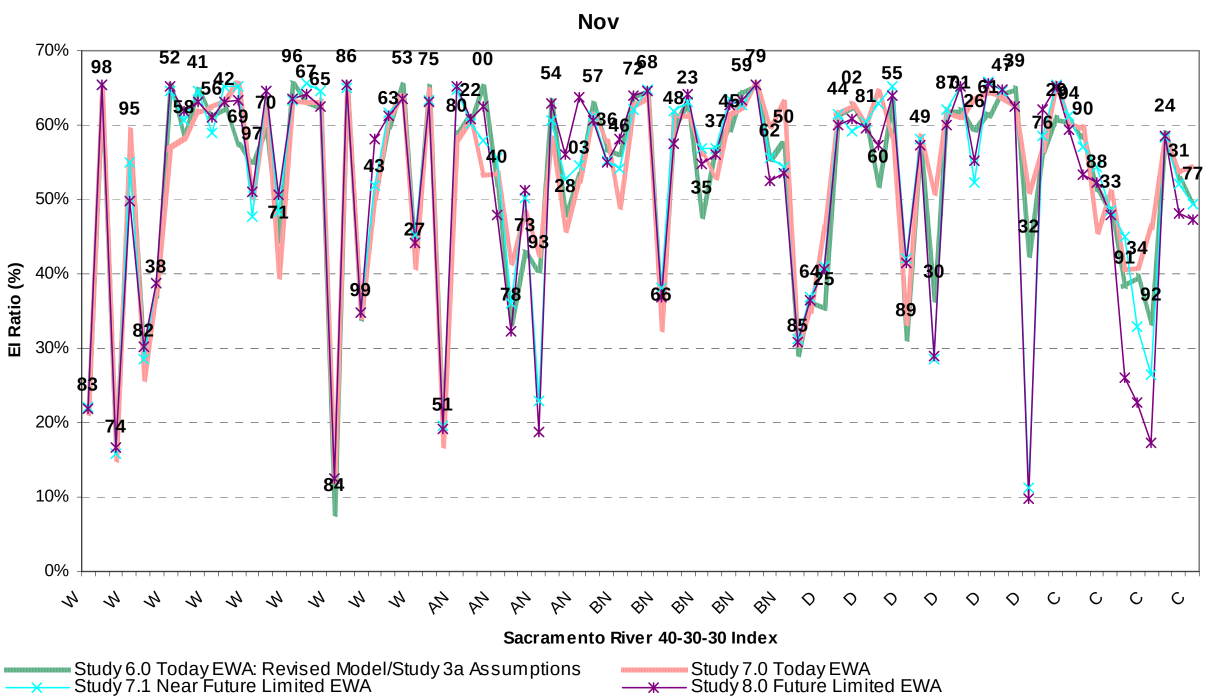


Figure 12-48 November export-to-inflow ratio sorted by 40-30-30 Index

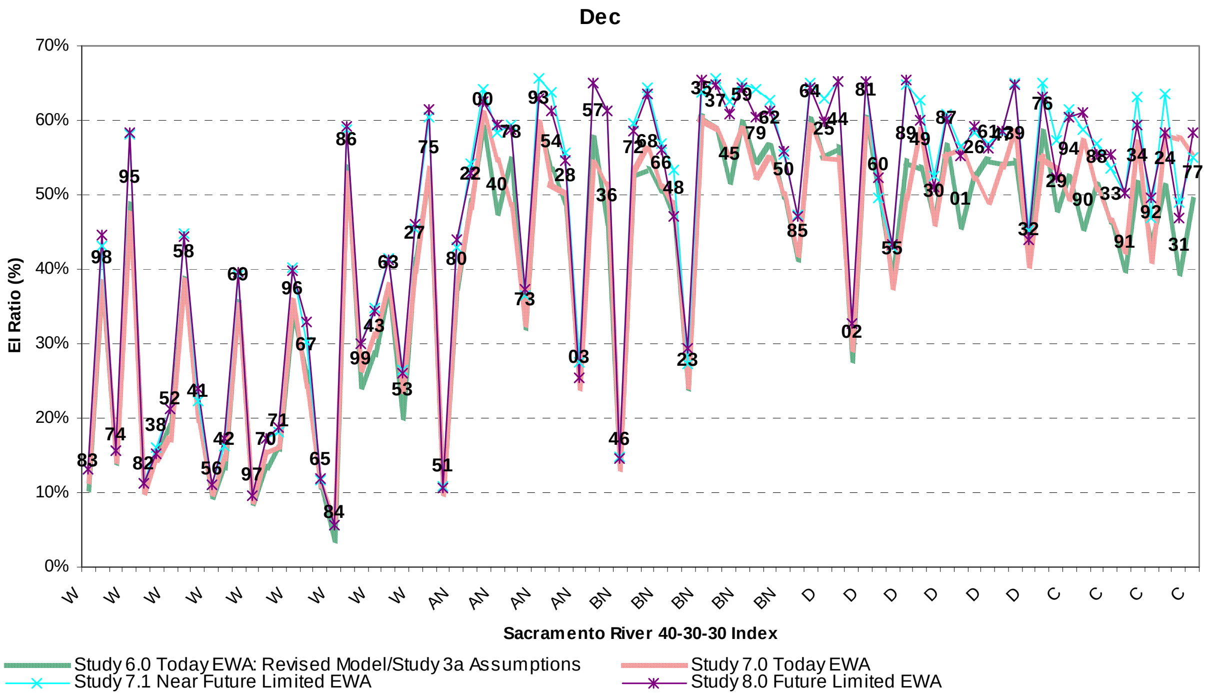


Figure 12-49 December export-to-inflow ratio sorted by 40-30-30 Index

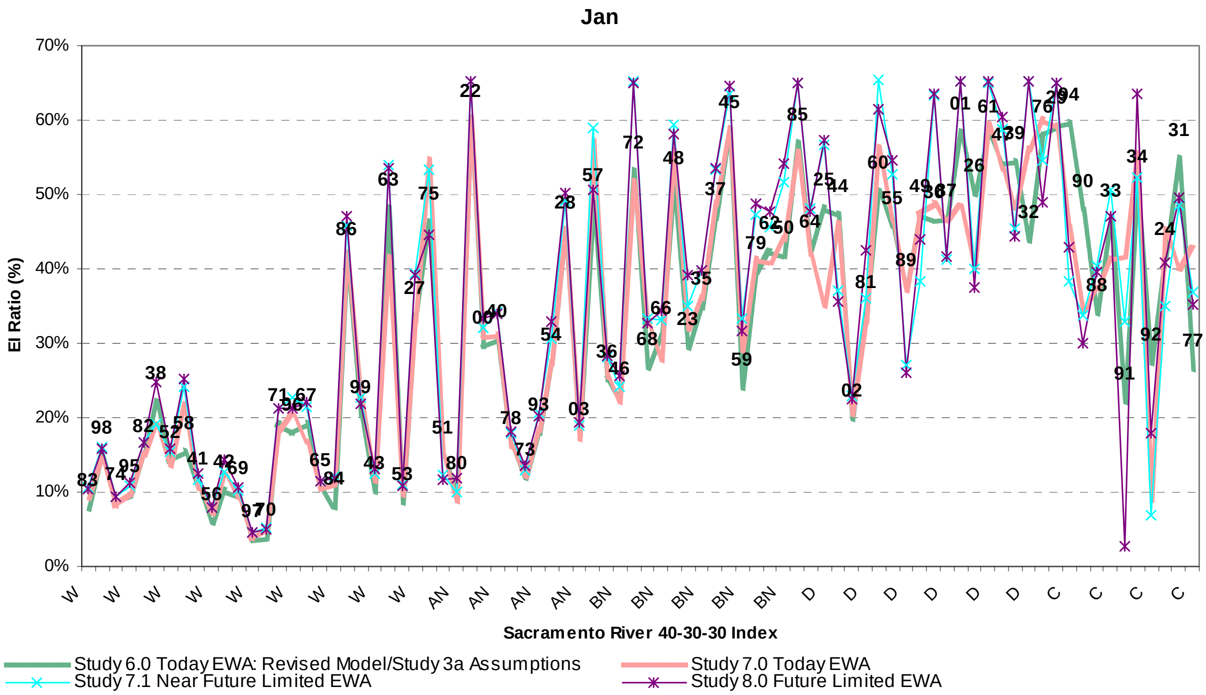


Figure 12-50 January export-to-inflow ratio sorted by 40-30-30 Index

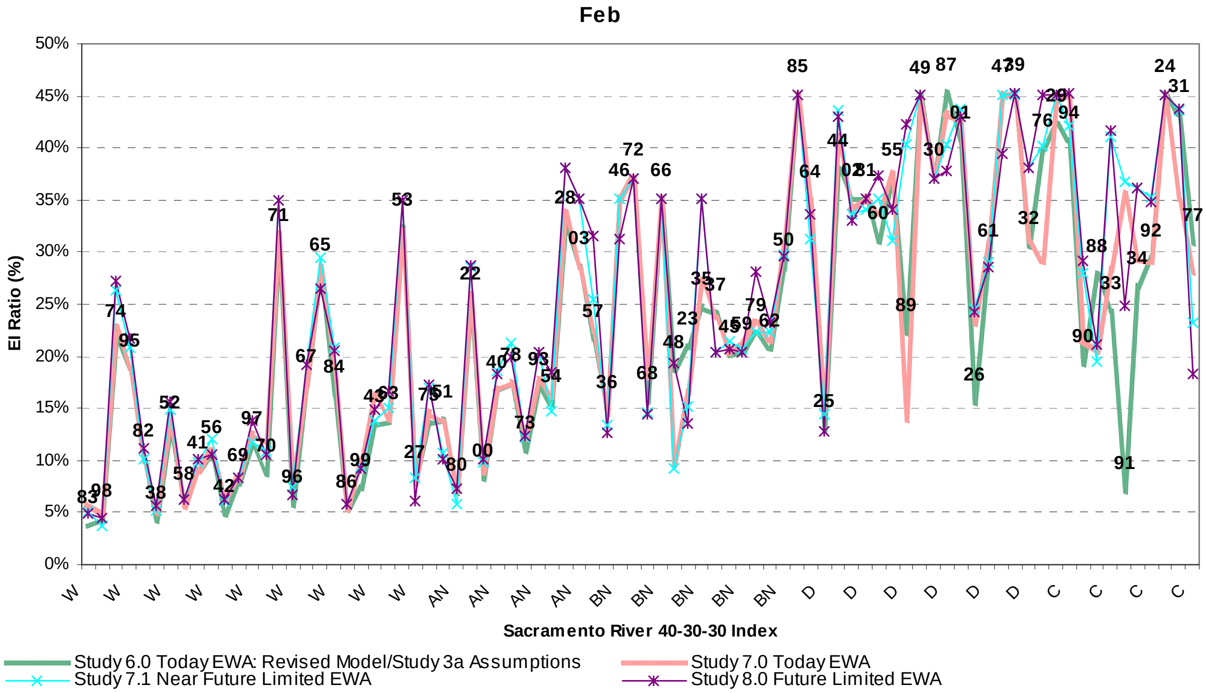


Figure 12-51 February export-to-inflow ratio sorted by 40-30-30 Index

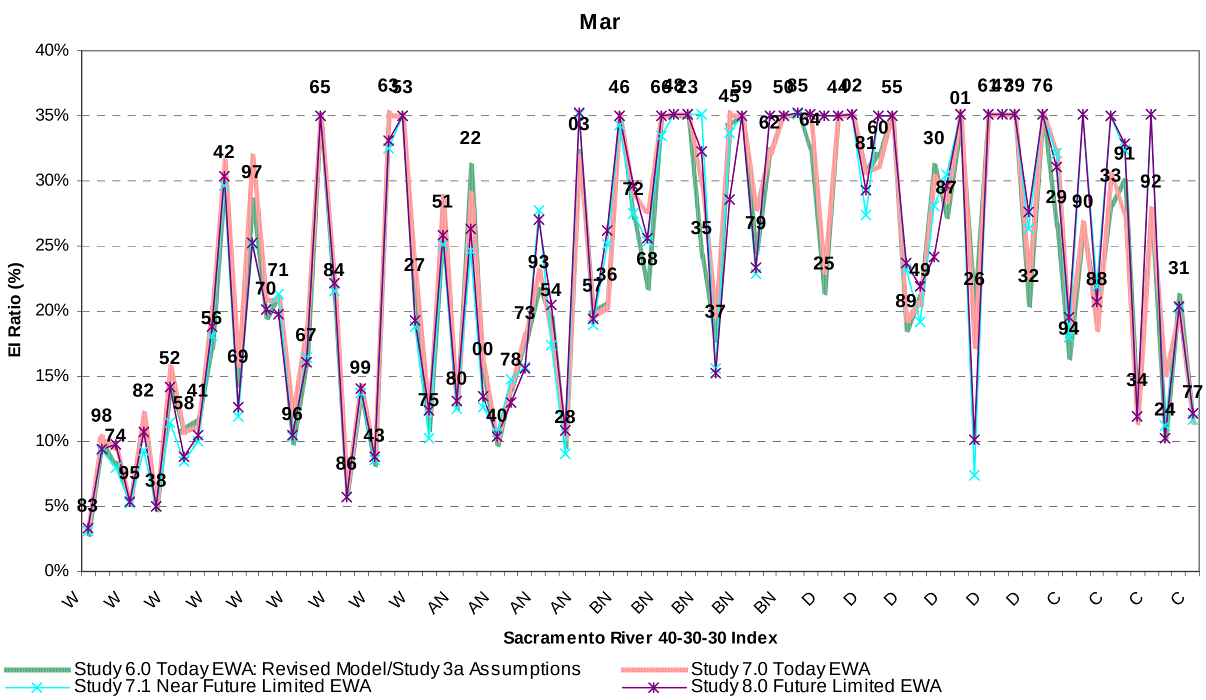


Figure 12-52 March export-to-inflow ratio sorted by 40-30-30 Index

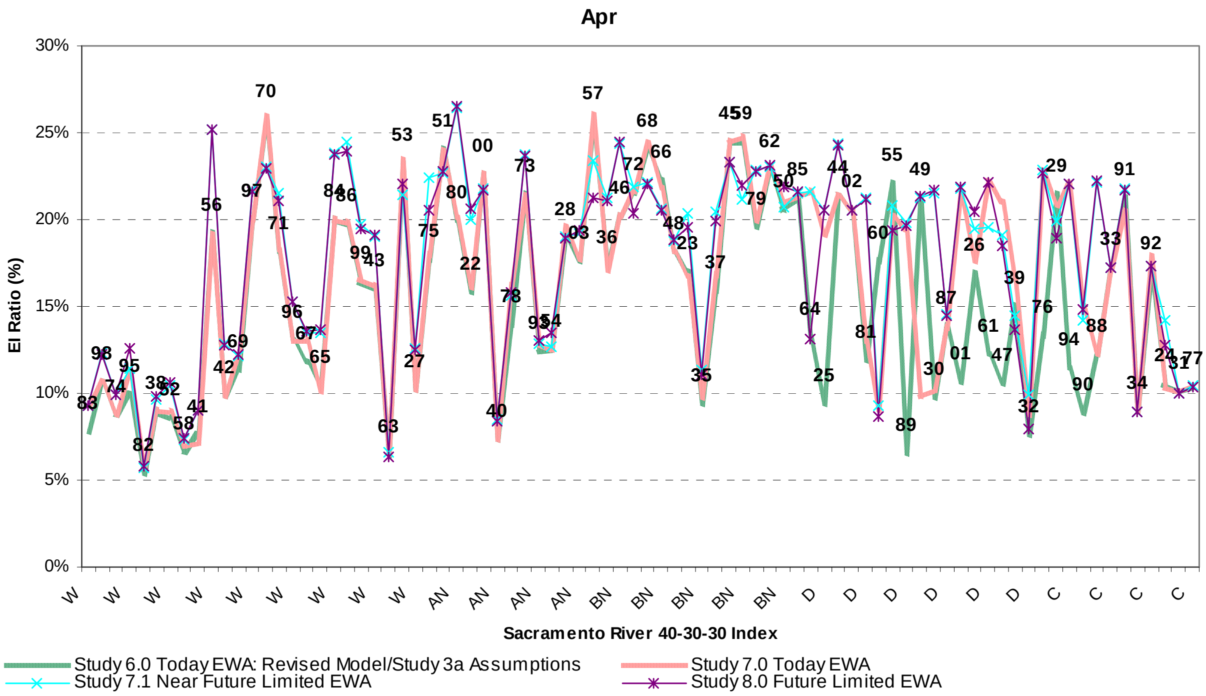


Figure 12-53 April export-to-inflow ratio sorted by 40-30-30 Index

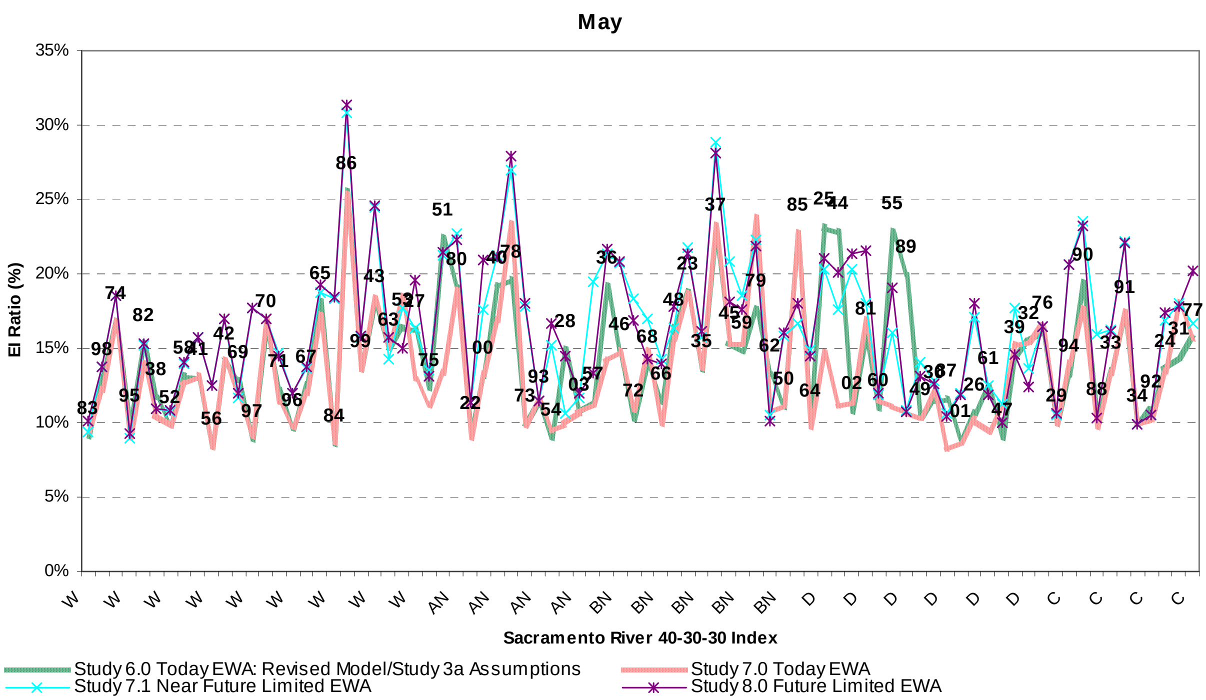


Figure 12-54 May export-to-inflow ratio sorted by 40-30-30 Index

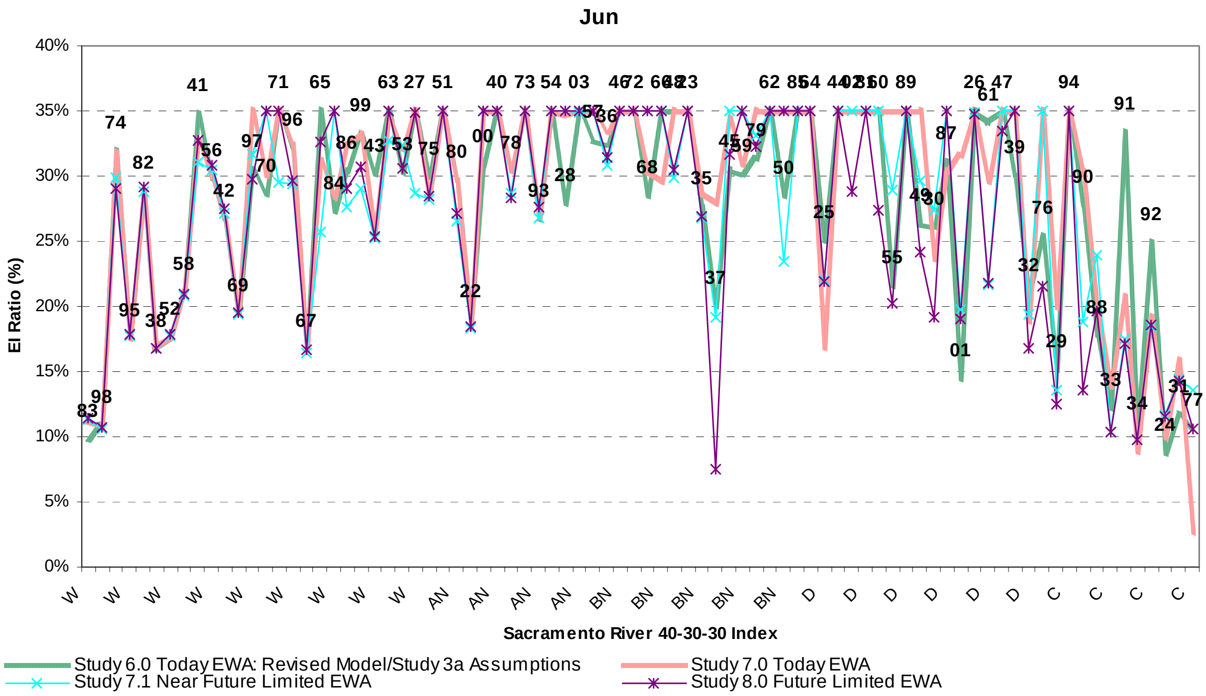


Figure 12-55 June export-to-inflow ratio sorted by 40-30-30 Index

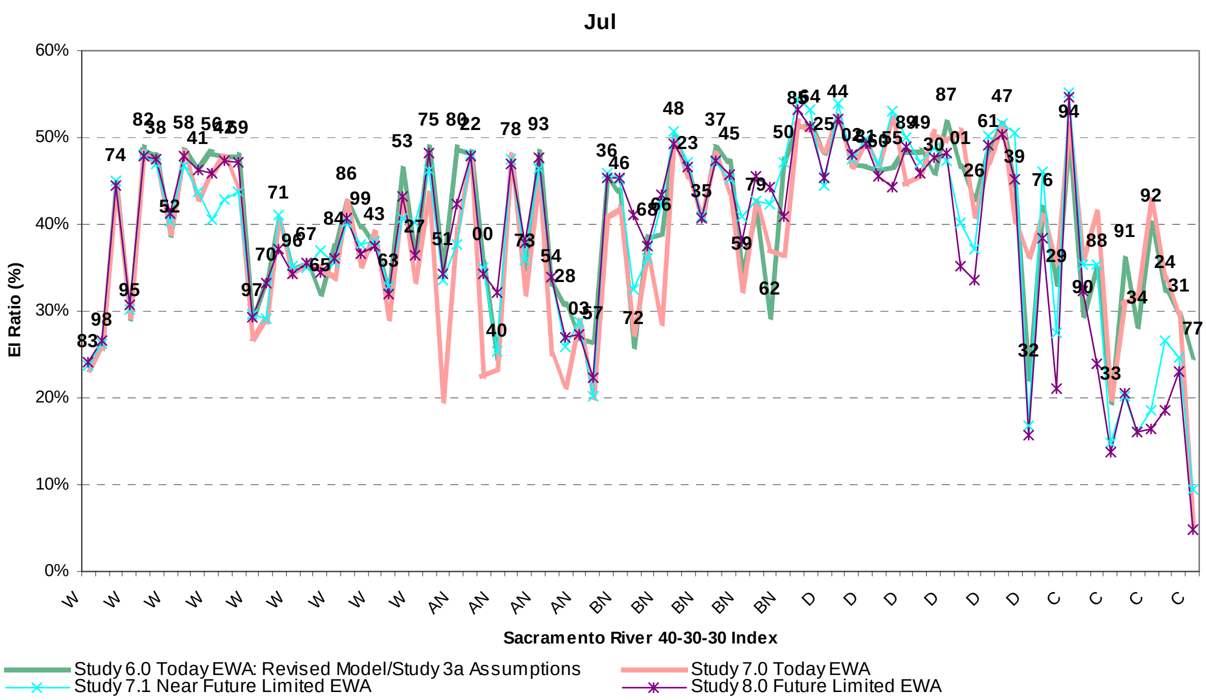


Figure 12-56 July export-to-inflow ratio sorted by 40-30-30 Index

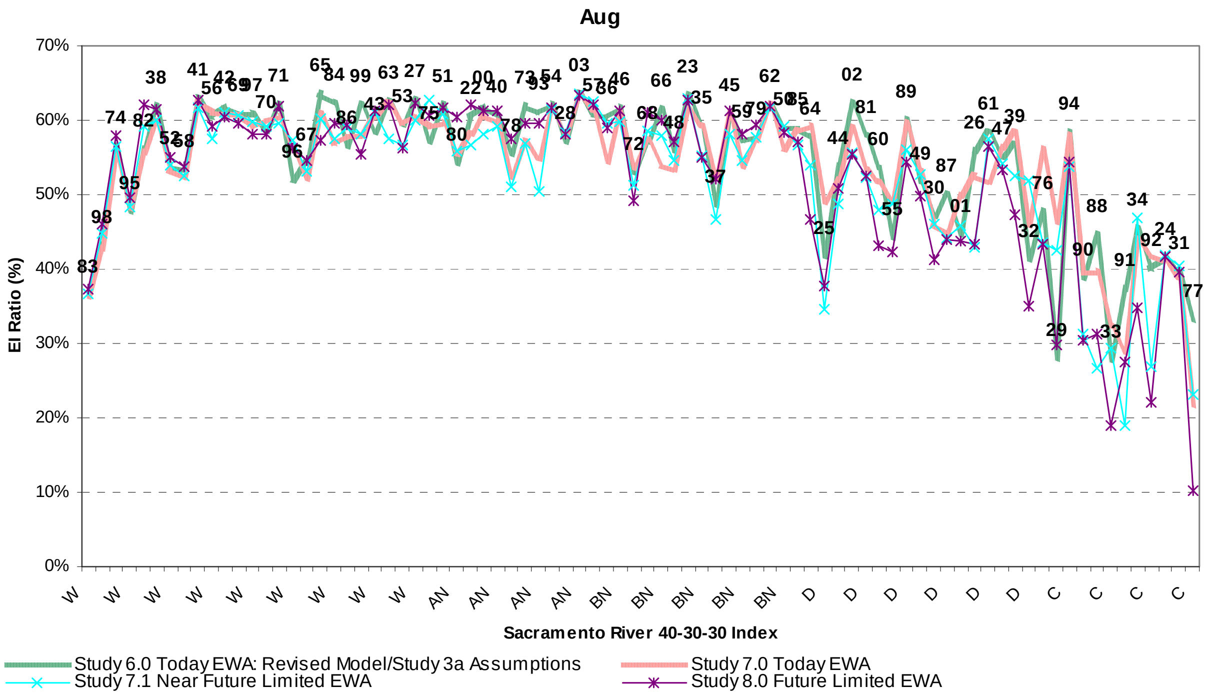


Figure 12-57 August export-to-inflow ratio sorted by 40-30-30 Index

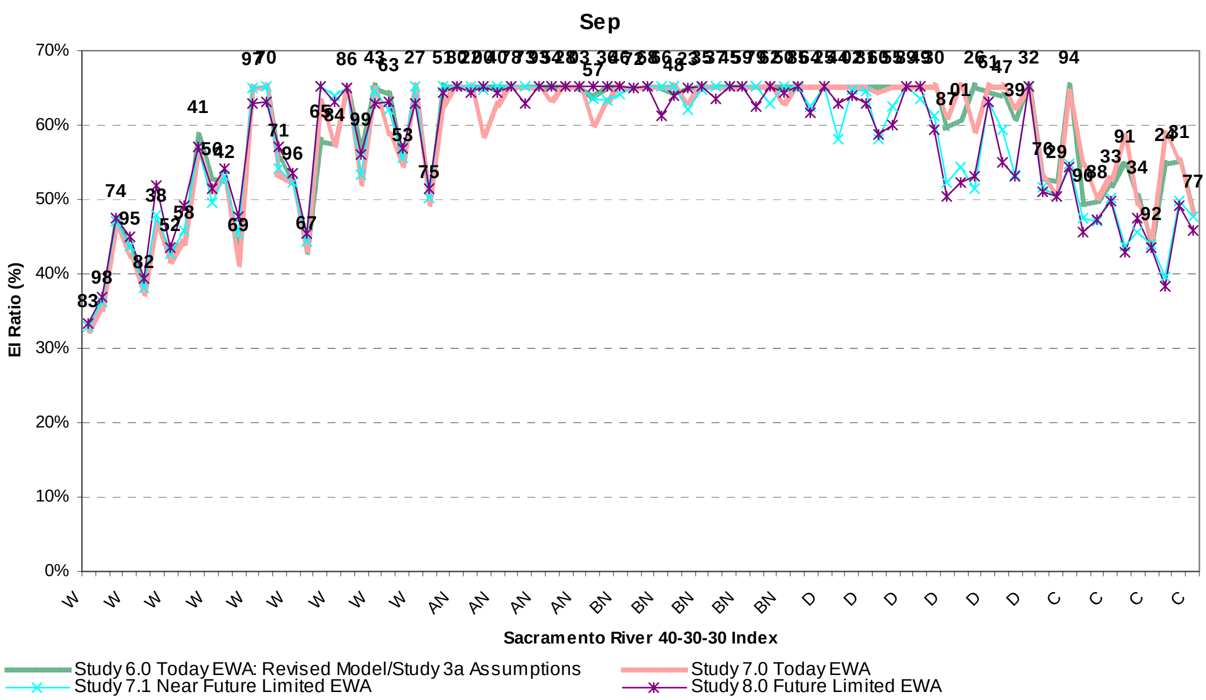


Figure 12-58 September export-to-inflow ratio sorted by 40-30-30 Index

Permanent Operable Gates

In addition to the analyses conducted for this BA, analyses were conducted for Stage 1 of the SDIP and the results presented in the SDIP EIR/EIS, Section 5.2. The tidal levels and flows at specific locations in the Delta are summarized on pages 5.2-46 through 5.2-50. Stage 1 for Alternatives 2A, 2B, and 2C is the proposed 4-gate configuration and operation included in this BA. The variable between these alternatives is the proposed method of increasing the SWP export limit to 8,500 cfs. Increasing the export limit is deferred to Stage 2 of the implementation of the proposed SDIP project and is not included in this BA.

Appendix Z describes the hydrodynamic effects of the Temporary Barriers Project and the South Delta Improvements Program Stage 1.

SWP Demand Assumptions

Since its conception, the SWP's water supply has been highly dependent on unregulated flow into the Delta. The delivery of water within the SWP in any given year is a function of operational requirements, Project storage conditions, demands (and the pattern of those demands), and the availability of unregulated flow into the Delta. To the extent that unregulated water has been available in the Delta beyond that necessary to meet scheduled Project purposes and obligations, said water has been made available to any contractor who can make use of it. The original water supply contracts for SWP contractors included various labels for this Project water depending on the intended use—including the prominently used label of "interruptible."

In 1994, the contracts were amended in what is commonly referred to as the Monterey Amendment. The basic objective of the amendment was to improve the management of SWP supplies—it did not affect the Project operations in the Delta or on the Feather River. Article 21 of the amendment stipulates that any SWP contractor is entitled to water available to the SWP when excess water to the Delta exceeds the Project's need to fulfill scheduled deliveries, meet operational requirements, or meet storage goals for the current or following years. This includes the water that was before known as "interruptible," as well as some other lesser-known labels of water diverted under the same conditions. Article 21 water is and has always been an important source of water for various contractors during the wet winter months and is used to fill groundwater storage and off-stream reservoirs in the SWP service areas. It is also used to pre-irrigate croplands, thereby preserving groundwater and local surface water supplies for later use during dry periods.

The assumptions in CalSim-II for SWP demands has been significantly refined since the 2004 OCAP to better reflect current delivery classification practices. The three significant changes in the delivery modeling are: 1) the incorporation of a three-pattern demand, 2) explicit modeling of the previous year's Table A supplies that are delivered in the current year ("Carryover" or Article 56 deliveries), and 3) increased assumption for monthly Article 21 demands from a maximum of 134 taf per month in the 2004 OCAP BA to a maximum of up to 314 per month in the current analysis.

The three-pattern demand allows for demand adjustments associated with various levels of Table A allocation. Based on the amount of Table A allocation one of the three demand patterns is selected to more accurately model the monthly delivery pattern.

In model used for the 2004 assessment a single demand pattern was used with the current year's Article 56 water inappropriately delivered at the beginning of the current year rather than being carried over for delivery in the following year. This artificially increased the Table A demand at the beginning of each year, and potentially reduced Article 21 deliveries during the early part of the year. The new delivery methodology allows for the storage, delivery, and "spilling" of the previous year's Article 56 carryover at the beginning of the current year. Delivery of the previous year's Article 56 is typically within the first three months of the current year. As the State share of San Luis Reservoir fills, there is a chance that Article 56 will "spill" which is another way of saying that it is converted to the current year's Table A supply.

The new model also incorporates an Article 21 demand increase that more accurately represents actual Article 21 demand. However, with the incorporation of the three-pattern Table A demand, Article 56, and increased Article 21 demand the total delivery remains largely the same. The previous version of the model tended to overestimate the delivery of Table A and underestimate the delivery of Article 21 by a like amount.

Figure 12-59 shows the annual exceedence chart for the OCAP runs 6.0, 7.1 and 8.0. The 50^{th} percentile of Article 21 deliveries for the Studies 7.0 and 7.1 have a 50^{th} percentile of 350 TAF.

Study 6.0 which reflects the 2004 OCAP assumption for maximum monthly Article 21 demands shows much less delivery of Article 21. In addition, Study 8.0 has a suprisingly lower delivery of Article 21 versus Studies 7.0 and 7.1. This is due to higher delivery amounts of Table A and other higher priority deliveries through Banks.

So to truly understand the interaction between all SWP delivery types one must compare model output for all SWP deliveries. Figure 12-60 and Figure 12-61 show the exceedence charts for Table A and total SWP deliveries, respectively.

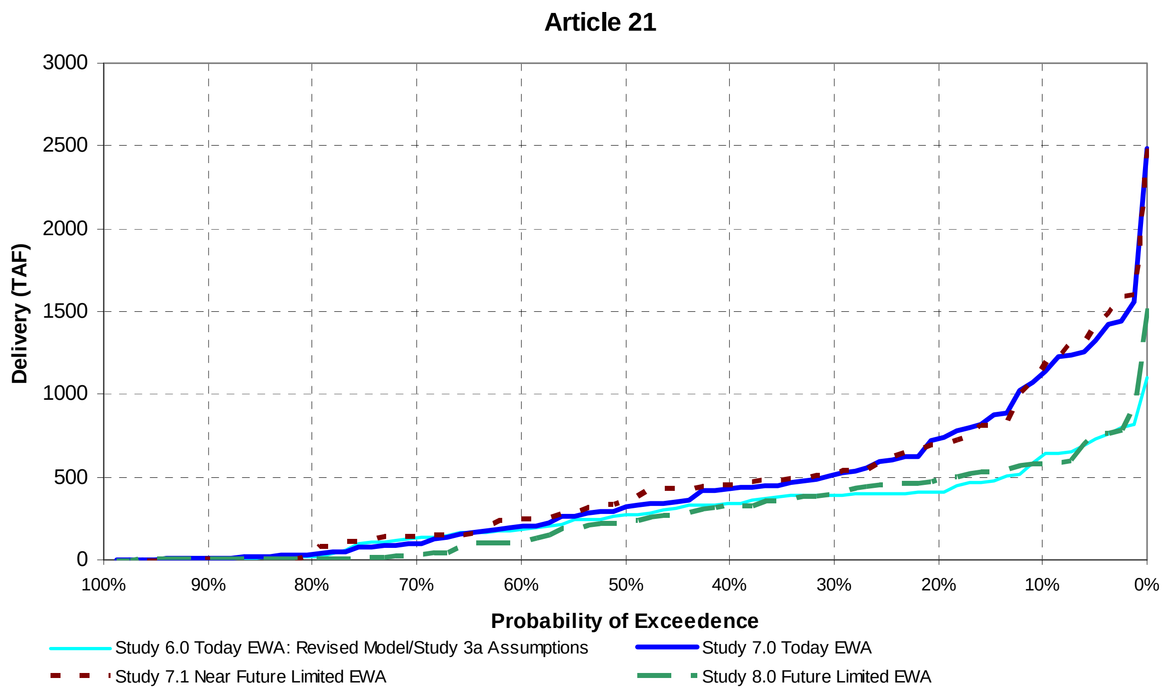


Figure 12-59 Exceedance Probability of Annual SWP Article 21 Delivery

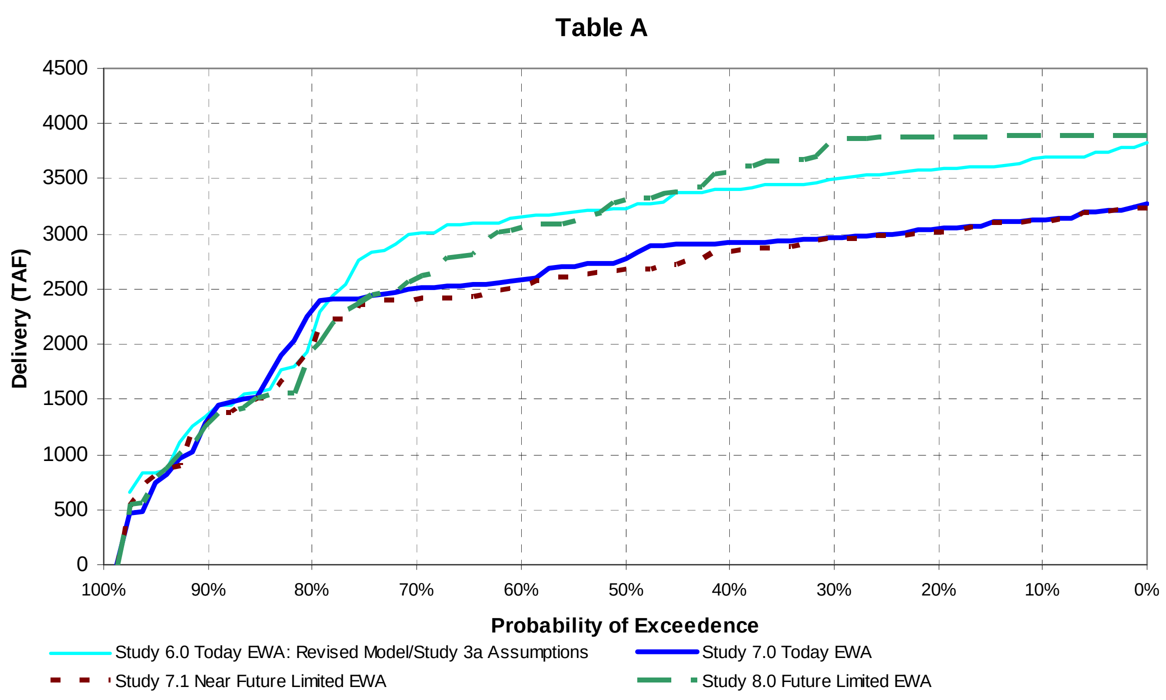


Figure 12-60 Exceedance Probability of Annual SWP Table A Delivery

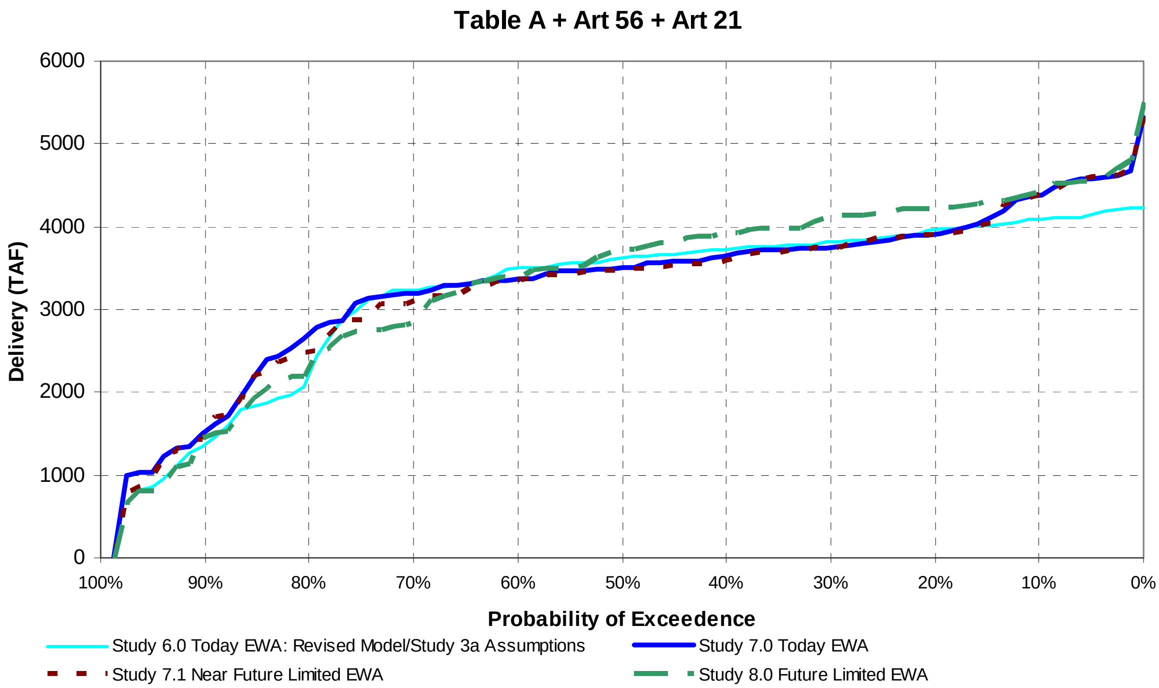


Figure 12-61 Exceedance Probability of Annual SWP Total Delivery

Water Transfers

Water transfers would increase Delta exports from about 0 to 500,000 acre-feet (af) in the wettest 80 percent of years and potentially more in the driest 20 percent years, and up to 1,000,000 af in the most adverse Critical year water supply conditions. Most transfers will occur at Banks (SWP) because reliable capacity is not likely to be available at Jones (CVP) except in the driest 20 percent of years. Most of the transfers would occur during July through September. Juvenile salmonids are rarely present in the Delta in these months, so no increase in salvage due to water transfers during these months is anticipated. Water transfers could be beneficial if they shift the time of year that water is pumped from the Delta from the winter and spring period to the summer, avoiding periods of higher salmonid abundance in the vicinity of the pumps. Some adult salmon and steelhead are immigrating upstream through the Delta during July through September. Increased pumping is not likely to affect immigrating adults because they are moving in a general upstream direction against the current. For transfers that occur outside of the July through September period, all current water quality and pumping restrictions would still be in place to limit effects that could occur.

Post-processing of Model Data for Transfers

This section shows results from post-processed available pumping capacity at Banks and Tracy for the Study 8.0 (Future Conditions - 2030). These results are used for illustration purposes. Results from the Existing Conditions CVP-OCAP study alternatives do not differ greatly from those of Study 8.0, and produce similar characteristics and tendencies regarding the opportunities for transfers over the range of study years. The assumptions for the calculations are:

- Capacities are for the Late-Summer period July through September total.
- The pumping capacity calculated is up to the allowable E/I ratio and is limited by either the total physical or permitted capacity, and does not include restrictions due to ANN salinity requirements with consideration of carriage water costs.
- The quantities displayed on the graph do not include the additional 500 cfs of pumping capacity at Banks (up to 7,180 cfs) that is permitted to offset reductions previously taken for fish protection. This may provide up to about 90 taf of additional capacity for the July-September period, although 60 taf is a better estimate of the practical maximum available from that 500 cfs of capacity, allowing for some operations contingencies. Under some water supply conditions, DWR has proposed to use the additional 500 cfs to divert SWP water, if permit conditions are met. Under those conditions, no capacity would be available for transfers.
- Figure 12-62 and Figure 12-63 show the available export capacity from Study 8.0 (Future Conditions-2030) at Banks and Jones, respectively, with the 40-30-30 water year type on the x-axis and the water year labeled on the bars. The SWP allocation or the CVP south of Delta Agriculture allocation is the allocation from CalSim-II output from the water year.

From Figure 12-62, the most capacity at Banks will be available in Critical and some Dry years (driest 20 percent of study years) which generally have the lowest water supply allocations, and reflect years when transfers may be higher to augment water supply to export contractors. For the other 80 percent of study years (generally the wettest 80 percent) the available capacity at Banks for transfer ranges from about 0 up to 500 taf (if the additional 60 taf accruing from the proposed permitted increase of 500 cfs at Banks is included). Transfers at Jones (Figure 12-63) are probably most likely to occur in the driest 20 percent of years (Critical years and some Dry years) when there is available capacity and low allocations.

Limitations

The analysis of transfer capacity available derived from the CalSim-II study results shows the capacity at the export pumps and does not reflect the amount of water available from willing sellers or the ability to move through the Delta. The available capacity for transfer at Banks and Jones is a calculated quantity that should be viewed as an indicator, rather than a precise estimate. It is calculated by subtracting the respective project pumping each month from that project’s maximum pumping capacity. That quantity may be further reduced to ensure compliance with the Export/Inflow ratio required. In actual operations, other contingencies may further reduce or limit available capacity for transfers: for example, maintenance outages, changing Delta outflow requirements, limitations on upstream operations, water level protection criteria in the south Delta, and fishery protection criteria. For this reason, the available capacity should be treated as an indicator of the maximum available for use in transfers under the assumed study conditions.

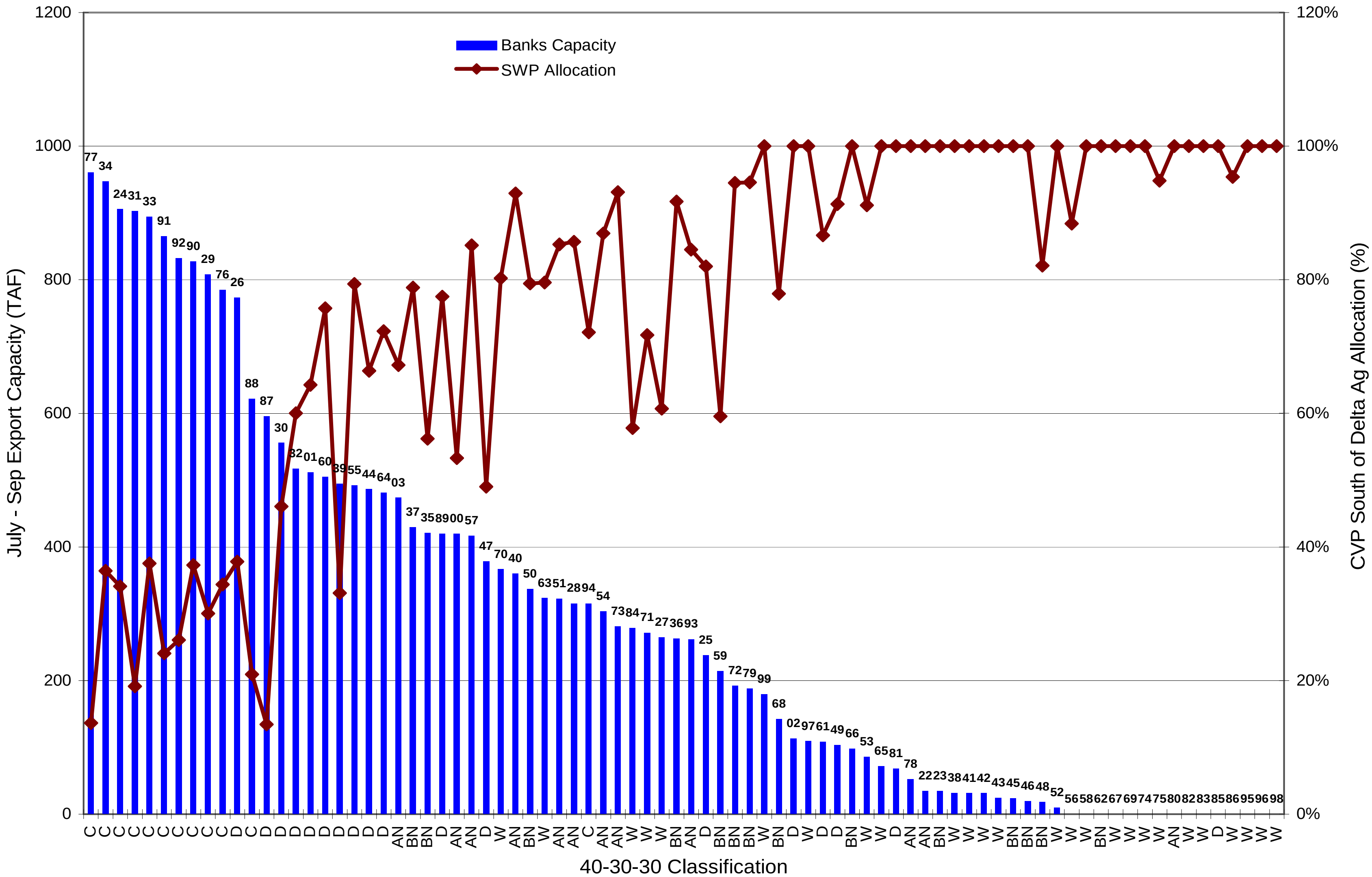


Figure 12-62 July to September Banks Export Capacity from Study 8.0

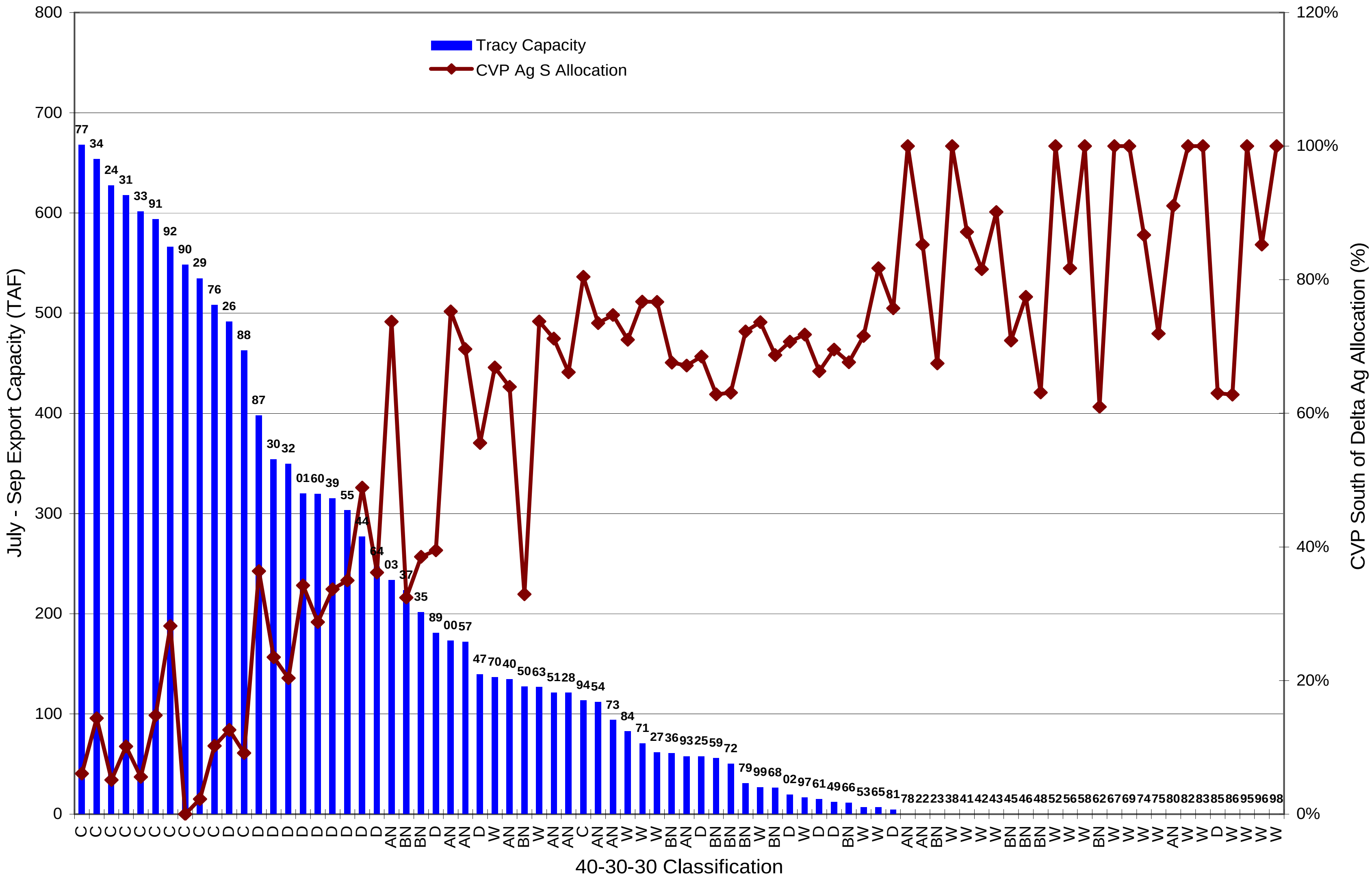


Figure 12-63 July to September Jones Export Capacity from Study 8.0

Chapter 13 CVP and SWP Delta Effects on Species

Introduction

This chapter deals with the effects the Central Valley Project (CVP) and State Water Project (SWP) may have on delta smelt, and on steelhead, Chinook salmon, and green sturgeon while the latter three species are present in the Delta. The Delta effects on these species are presented in detail in this Chapter in two separate sections for the purpose of clarity and because the effects are significantly different for the resident pelagic species versus migratory species. The first section describes the Delta effects on delta smelt and the second section addresses the effects on steelhead, Chinook salmon and the green sturgeon.

It is important to note that this chapter focuses specifically on the effects of the projects on these species. However, these effects are evaluated in context with the broader factors that influence abundance and distribution as described in Chapter 4 (steelhead) Chapter 6 (Chinook salmon) Chapter 7 (delta smelt) and Chapter 8 (green sturgeon).

In the section discussing delta smelt and referred material in Chapter 7 some of the likely contributing causes of the POD such as toxic effects from agro-chemicals are discussed that may be unrelated to water project operations; however others such as entrainment are in fact directly related. The discussion in this chapter outlines both the direct and indirect potential effects in addition to modeling results related to Delta pumping, in-Delta flows (represented by Old and Middle River flows) and X2 for both current and future conditions.

In the second section, which discusses the Delta effects on steelhead, Chinook salmon, and green sturgeon, the impacts seem to be primarily associated with direct entrainment at various project pumping facilities and fish passage issues at the Suisun Marsh Salinity Control Gates. In addition, this section provides a description of the CVP and SWP monitoring data and modeling results estimating the salvage and loss of fish by species and life stage.

The general approach taken here considers both direct entrainments at the Jones and Banks facilities and indirect effects that may occur elsewhere in the Delta. The objective is to evaluate effects that current and future water project operations may have on each species. Evaluation of the effect of future operations is in each case accomplished by quantitative comparison of relevant variables in models representing future cases with the corresponding variables in the present-operations case. Evaluation of the effects of present operations varies by species. There is substantial uncertainty about the importance of some effects. These uncertainties are usually limited to the magnitude of the effect. Whether an effect is likely harmful or beneficial is usually more certain. It should also be noted that potential effects might be amplified or muted by variation in distribution of fishes in the Delta (which changes from year to year and among months within years), unanticipated secondary biological effects, or by unanticipated effects emerging from climate change. A summary of conclusions drawn from these analyses is presented in Chapter 15.

CVP and SWP Delta Effects on Delta Smelt

Statistical analyses of the long-term delta smelt abundance trends (Manly and Chotkowski 2006) confirm that there has been a long-term decline of delta smelt, with substantial interannual variation. A period of increase in the late 1990s was followed by a rapid and sustained decline beginning about 2000. Current delta smelt numbers are at or near their all-time low since monitoring began (Baxter et al. 2008, DFG unpublished 2008 monitoring results). The 2007 POD Synthesis report posits that delta smelt abundance has been strongly influenced since the start of that decline by adult abundance, habitat conditions, and entrainment (Baxter et al. 2008 and see Chapter 7). Feyrer et al. (2007) found that there has been a significant stock-recruit relationship (i.e., adults affect juvenile production) since 1987; this relationship was improved by including fall habitat conditions (as defined by salinity and turbidity), indicating that habitat also affects abundance. Long-term temperature increases in the Delta (Jassby 2008) may further constrain habitat, particularly in summer (Nobriga et al. 2008). Food availability may also have been historically important to this planktivorous fish as Kimmerer (in review) noted a statistically significant relationship between juvenile smelt survival and zooplankton biomass over the long term. The decline in the mean size of adult delta smelt following the introduction of the overbite clam *Corbula* (Sweetnam 1999; Bennett 2005), which caused declines in key zooplankton prey, is also consistent with food web effects. Feyrer et al. (2007) also found that stock and habitat effects were important when food supply was low following the invasion of *Corbula*. It may also be that the delta smelt population is now at such low levels that large increases in a single year are unlikely, but will require multiple years of successful reproduction and recruitment.

While some of the likely causes of the POD, such as the gradual accumulation of ecologically disruptive exotic species in the Delta, may have developed independently or partially independently of water project operations, other likely contributing causes are clearly related to water project operations. The degree of project effects on delta smelt varies considerably among years and may also vary substantially from month to month, depending on changing distribution of fish, Delta hydrology, and other factors. The POD analysis proposes that changes in water project operational regimes have contributed to the recent decline both directly (via entrainment) and indirectly (via habitat alteration). During some of the recent POD years, increased water project exports during winter resulted in higher losses of adult smelt (Chapter 7), particularly early spawning fish (and their offspring) that may be proportionally more important to the population. By contrast, reduced exports during spring may have increased survival of later-spawned larvae in recent years. Reduced spring exports from the Delta have been partially the result of the Vernalis Adaptive Management Plan (VAMP), a program designed to improve survival of outmigrating juvenile Chinook salmon. VAMP has been operating since 2000.

With respect to an indirect effect, habitat alteration, a long-term upstream shift of X2 during fall has negatively affected delta smelt habitat and has been linked to changes in delta smelt abundance (Feyrer et al. 2007). The steady-state location of the low-salinity zone is a function of total Delta outflow, which under most non-flood conditions is determined primarily by the operations of the CVP and SWP. However, non-CVP and SWP factors such as increased diversions from, and accretions to Delta tributaries may have contributed to the upstream shift of X2 in the fall months. The relative contributions of all factors contributing to the fall shift has not been determined, and probably vary from year to year.

Seasonal Breakdown of Potential Effects

Evidence of a role for each of the factors developed in the POD investigation in the long-term and recent abundance patterns of delta smelt is described in detail below for each season (Baxter et al. 2008). Note that this is a general summary of the broad suite of factors that may affect delta smelt during different seasons; however, the subsequent effects analysis is focused on a subset of these factors known to be related to water project operations.

It is also important to recognize that the present understanding of the factors affecting smelt has many limitations. As described in Baxter et al. (2008), many studies used for the recent POD synthesis are works-in-progress that have not reported final results. Preliminary results from these studies have been provided whenever possible, but peer-reviewed products from these studies may not be available for some time to come. As a consequence, while this review uses such results because they represent the best available science, Baxter et al. (2008) encouraged users of their POD synthesis report to be cautious when evaluating the relative importance of the different factors. Specifically, statements not based on well-developed and peer-reviewed literature should be viewed with more skepticism.

Summer

Summer is the season that usually has the highest primary and secondary productivity in a temperate zone estuary. Given their annual life cycle, summer represents the primary growing season for delta smelt. However, the availability of prey species is strongly affected by food web changes stemming from changes in grazing pressure from the benthos (particularly *Corbula amurensis*). Moreover, in the decade including the early POD years, there has been a further decline in the abundance of calanoid copepods in Suisun Bay and the west Delta (Kimmerer et al., in prep, Mueller-Solger et al., in prep.), part of the core summer habitat of delta smelt (Nobriga et al. 2008). At the same time, these calanoid copepods are being replaced by the small cyclopoid copepod *L. tetraspina* which is presumed to be a less suitable prey species (Bouley and Kimmerer 2006).

The long-term reduction in preferred prey availability has likely resulted in slower growth rates of delta smelt, detectable as a reduction in the mean size of delta smelt in autumn since the early 1990s (Sweetnam 1999; Bennett 2005). The latest POD report (Baxter et al. 2008) proposes that over the long term, reduced summer growth rates have reduced the survival of juvenile delta smelt, perhaps from predation, as smaller fish remain more vulnerable for longer periods (Bennett et al. 1995; Houde 1987). As evidence that changes in prey availability have had survival consequences for this fish species, Kimmerer (in press) found a statistically significant relationship between summer-to-fall delta smelt survival and zooplankton biomass in the low salinity zone from 1972 to 2005. Recent preliminary analyses suggest that total zooplankton biomass may not have changed substantially within the core summer habitat of delta smelt, at least when all species including *L. tetraspina* are included (Mueller-Solger, unpublished data). In 2006, zooplankton biomass, including the biomass of the important food organism *P. forbesi*, even increased substantially in the delta smelt summer habitat, but this was not followed by a recovery of delta smelt. Moreover, summer-to-fall survival since 2000 does not appear to be substantially different from survival for all other years since 1972. Survival since 2000 has actually been somewhat higher than in 1972—1980 when delta smelt abundance indices were much higher than they are now (Mueller-Solger, unpublished data). Finally, summer and fall delta smelt abundance indices have been closely correlated to each other during the POD years. However, while the fall abundance indices since 2000 have spanned almost the full range of delta smelt abundance indices during the previous three decades, the summer abundance indices have remained in the lower portion of the pre-POD summer abundance range.

These results suggest that impaired recruitment, growth, and survival before the summer period may also have been important during the POD years. It is possible that summer food limitation was a more important stressor when population densities were higher and that the decline in summer food availability has contributed more to the long-term decline in delta smelt abundance than to its dramatic deterioration in the POD years (Mueller-Solger, unpublished data).

Summer habitat may be more restricted than in the past. Nobriga et al. (2008) noted a complete absence of delta smelt in the southern Delta that coincided with increased water clarity. However, although these changes in turbidity appear to play a role in the longer-term declines in delta smelt, they are unlikely to be an important new cause of the post-2000 declines because delta smelt have not successfully utilized the southern and central Delta in large numbers since the late 1970s. Nobriga et al. also noted that delta smelt distribution is affected by temperature. Moreover, Jassby (2008) found regional increases in water temperature, including areas within the range of delta smelt. Hence, delta smelt may be affected by long-term increases in water temperature in the Estuary.

Direct entrainment effects at the CVP and SWP export facilities in the south Delta are not thought to have been important during most summers because the delta smelt population is north and west of the zone affected strongly by water exports and delta smelt salvage is generally very near zero from July-November (IEP unpublished data). When the toxic blue-green alga *M. aeruginosa* blooms during summer, it occurs primarily upstream of delta smelt, so it is unlikely to have been a major factor in the delta smelt's historical decline. This may have changed in 2007, when *M. aeruginosa* blooms extended into eastern Suisun Bay, well into the historical rearing habitat of delta smelt. Other water quality variables such as contaminants could be important, but are yet to be identified as seasonal stressors for this species.

In summary, there is evidence of bottom-up and habitat suitability effects on delta smelt during the summer over the long-term, but the evidence suggests that since 2000, delta smelt population dynamics have been largely driven by factors occurring in seasons other than summer. Near zero salvage suggests SWP/CVP entrainment effects are minimal during this period under historical flow conditions. Nonetheless, better habitat and food conditions during the summer might improve long-standing effects and increase survival as well as individual fitness of maturing delta smelt.

Fall

Fall represents the time period when the delta smelt year class matures to adulthood. The evidence to date indicates that habitat is a significant issue for delta smelt in fall (Feyrer et al. 2007). Delta smelt presence is strongly associated with low salinity and water clarity, which can be used to index the "environmental quality" of habitat for the species. Feyrer et al. (2007) report that fall environmental quality has declined over the long-term in the core range of delta smelt, including Suisun Bay and the Delta. This decline was largely due to changes in salinity in Suisun Bay and the western Delta, and changes in water clarity within the Delta. There is statistical evidence that these changes have had adverse population-level effects (Feyrer et al. 2007). A multiple linear regression of fall environmental quality in combination with adult abundance provided statistically significant predictions of juvenile production the following year. Hence, both habitat and stock-recruit factors are important issues during fall.

Reduction of habitat area as defined by environmental quality likely interacts with bottom-up and top-down effects. Restricting fish to a smaller geographical area with inadequate food supply would likely maintain or even magnify the bottom up and top down effects already occurring during the summer, although these factors are poorly-understood during fall. Greater mortality due to predation, small adult size by the end of the fall, and the low fecundity of smaller fish likely all contribute to the adult abundance effect observed by Feyrer et al. (2007).

Direct entrainment has not historically been a major stressor during the fall. Delta smelt are usually not salvaged in substantial numbers at the CVP and SWP until late December. However, distribution of suitable habitat (as indexed by salinity and water clarity) affects the location of delta smelt in fall, which may contribute to their subsequent vulnerability to entrainment in winter by advancing them into the geographical area influenced by the pumps. In summary, both bottom-up effects and habitat restriction appear to be important during the fall. Slow growth because of food limitation combined with habitat restriction may also have resulted in higher mortality due to predation. Poor growth in the summer and fall likely contribute to reduced size and fecundity of maturing fish.

Winter

Winter represents the main period of adult delta smelt migration and spawning. Entrainment of adults and larvae (top-down effects) are particularly important to the delta smelt population during this critical season. The increase in salvage of adult delta smelt during winter since 2000 suggests that entrainment levels have been higher as a proportion of the population during the POD years (Baxter et al. 2008; Grimaldo et al. in review). Although in long-term analyses monthly or semi-monthly export volumes explain only 1-3 percent of the variability in same-water year delta smelt abundance (Manly and Chotkowski 2006), these losses may still be important to the population as a component of the total array of pressures on the species. First, this was a long-term analysis. There is a clear coincidence between higher entrainment and population decline in the short period from 2000 (and especially 2002) onward, a period for which there are even now few data with which to fit elaborate statistical models. Moreover, it has been proposed that entrainment losses may manifest effects in the following water year. For example, Bennett (unpublished) has hypothesized that losses of larger females may have a disproportionate effect on the delta smelt population. Specifically, losses of more fecund, early spawning large females and their offspring could eliminate a portion of the cohort most likely to survive to reproductive age, and possibly most likely to be fecund. Winter exports may also have an effect on the number of adults which survive a second year, a possible important factor affecting delta smelt population resilience (Bennett 2005). Manly and Chotkowski (unpublished workshop presentation) note that export effects may not be large during many years, especially very wet years, because exports by the water projects are relatively small compared to Delta inflow and outflow. However, they may be larger in a minority of years when various (at present mostly undescribed) factors affecting the spawning distribution of delta smelt converge to place larger numbers of smelt in areas vulnerable to entrainment.

There is presently no evidence of habitat constriction or food limitation during winter (Baxter et al. 2008); however, no studies have addressed these questions. Contaminant effects are possible during flow pulses, but there is no major evidence yet that these events have caused toxicity to delta smelt. One toxics issue that may have winter-spring effects and is under investigation is the potential role toxic concentrations of free ammonium ion contained in partially treated wastewater discharged into the Sacramento River in the north Delta may have on adult, larvae, and juvenile delta smelt in that region (Werner et al. unpublished data).

Spring

Bennett (unpublished analysis) proposes that reduced spring exports resulting from VAMP has selectively enhanced the survival of delta smelt larvae that emerge during VAMP by reducing direct entrainment. Initial otolith studies by Bennett's lab suggest that these spring-spawned fish dominate subsequent recruitment to adult life stages; by contrast, delta smelt spawned prior to the VAMP have been poorly-represented in the adult stock in recent years. He further proposes that the differential fate of winter and spring cohorts may affect sizes of delta smelt in fall because the spring cohorts have a shorter growing season. These results suggest that direct entrainment of larvae and juvenile delta smelt during the spring may be a significant issue in some years. However, Bennett has not published some of his results, and it remains unclear whether his central hypothesis is true. We have therefore not attempted to directly evaluate whether water project operations modeled under the various scenarios differentially affect early-spawning delta smelt.

Because of natural variability and the CVP's and SWP's operations to meet X2 water quality standards, there is no long-term trend in spring salinity (Jassby et al. 1995; Kimmerer 2002a). This suggests there was unlikely to have been a recent change in spring habitat availability or suitability. However, other habitat effects including contaminants or disease could play a role during spring.

Summary of Potential Project Effects

The previous section provided a generalized discussion of the the suite of factors thought to seasonally affect delta smelt. The following summarizes project-specific issues considered relevant for the effects analysis. Note that the following evaluation does not take into account the fact that the climate and geography could be markedly different in the future. A global rise in temperatures, rising sea levels, and changes in streamflow could substantially affect the status of delta smelt including their distribution, population viability, and vulnerability to project effects. There is substantial effort underway to try to model climate conditions 500-100 years away, although the "state of the art" in these simulations is changing almost monthly. Moreover, as the climate-change review in this Biological Assessment indicates, there is no clear prediction whether overall precipitation rates in these watersheds will rise or fall as a result of climate change (see Appendix R). Given these uncertainties, our evaluation focuses on what is known about the current biology and distribution of delta smelt and water project operations.

Direct entrainment of geographically vulnerable delta smelt is likely to occur during a period extending from mid-December through mid-July. Adults are likely to be entrained during their spawning migration from mid-December to April, while juveniles are likely to be entrained from

April until environmental conditions, particularly water temperatures, drive surviving juveniles into the west Delta in June or July. The onset of winter entrainment often coincides with the “first flush” of turbid water through the Delta following early rainstorms in December.

Direct entrainment risk varies with rate of export pumping, and is also affected by other factors, including atmospheric conditions, the tides, and the Delta’s tributary inflows. The rate of export pumping and these other factors jointly determine the geographical boundary of the “zone of entrainment”, described as the zone within which passive, neutrally buoyant particles are moved toward, and eventually entrained into, either Clifton Court Forebay and the Banks Pumping Plant in Byron or the Jones Pumping Plant in Tracy (see development of this concept in Kimmerer and Nobriga 2007). Because other factors modulate the effect of export pumping, the actual boundary of this zone is in constant motion. However, with other factors being held constant, the average northward reach of the pumps increases with pumping rate.

In this analysis, we assume that the net change in direct entrainment risk varies linearly with both total export pumping rate and Old and Middle River (OMR) flow. We also assume that actual historical entrainment varied in proportion to empirically measured salvage at the Jones and Banks facilities. In the following discussion, evidence of a linear or quasi-linear relationship between salvage at the Jones and Banks facilities and export pumping or OMR flow is interpreted as evidence of qualitatively similar relationships between actual entrainment and those hydrodynamic variables. It is important to note that salvage imperfectly indexes actual entrainment. The reasons for skepticism include (1) unknown and possibly substantial size-filtering of the incoming fish by the physical screen system, which does not divert fishes of all sizes with equal likelihood; (2) unknown effects of incoming water velocity on the efficiency of the screening system; (3) unknown (for delta smelt) prescreen mortality in Clifton Court Forebay, which presumably depends on the residence time of fish in the forebay before salvage. The assumption of linearity has general support both regressions of salvage against OMR flow (Grimaldo et al. in review; P. E. Smith, unpublished but influential analysis cited in Baxter et al. 2008). We expect the relationship between entrainment and OMR flow to be somewhat cleaner than that between salvage and total export pumping rate because of the variable time delay and other complications created by Clifton Court Forebay. However, that the known salvage-OMR relationship for adult smelt appears to increase faster than linearly at high negative OMR flow suggests that our assumption of linearity will not overstate the increase in risk at higher pumping, and might understate it.

We have not attempted to separately evaluate the effects of Jones and Banks pumping here, because the hydrodynamic effects of pumping, with which we associate fish transport and entrainment, result from the combined effect of pumping at both facilities. Furthermore, incidental take restriction on the export facilities is administered as a combined limit. Finally, the present analysis does not take into account finer scale factors that may have a substantial effect on entrainment risk. As described in Grimaldo et al. (in review), peaks in adult entrainment at the water projects coincide closely with turbidity pulses into the Delta. At present, we do not have the capability to model how different operational scenarios would change the pattern of winter turbidity pulses into the Delta. Future models and monitoring may allow better prediction of these events.

Change in the availability of habitat of the proper low salinity and turbidity and in habitat quality can be caused by water project operations through alteration of Delta outflow and in the sources of water permitted to reach the western Delta. As described above, the disposition of the low salinity zone may be important to delta smelt during the summer, and is likely to be important during the fall. Unlike the fall, the there is no simple linkage between summer Delta salinity and delta smelt abundance (Nobriga et al. 2008). During the winter, turbidity associated with flow pulses may be an important migratory cue for delta smelt (Grimaldo et al. in review). In this analysis, we use the location of the 2 ppt isohaline (hereafter called “X2”) to index the location of the low salinity zone, which in part identifies suitable habitat for post-larval delta smelt. The definition and measurement of X2 is technically complicated, because isohaline location varies with depth and is in constant tidal motion. Regulation of X2 at specific locations between February and June is among the criteria controlling water project operations under Water Rights Decision D-1641 and other authorities. However, it is allowed to vary at other times, including the fall, during which the position of the low salinity zone is useful as an index of environmental quality for delta smelt as described in Chapter 7 and above.

The environmental quality work described above and in Chapter 7 indicates that the historical movement of fall X2 upstream from Suisun Bay is associated with declines in environmental quality for delta smelt during the same period. In particular, movement of the low salinity zone upstream of Collinsville (at River Kilometer Index 81) is associated with a sharp decrease in the quality of delta smelt habitat. In this analysis, we present the projected X2 in each month of the year under the scenarios described in CalSim-II studies 6.1, 7.0, 7.1, and 8.0. In each case, we examine the base X2 in Study 6.1 and departures from that location in the other studies. The data are also binned by hydrology. For October through December, we have used the water-year type of the previous water year; for January through May we used quintiles of the Eight River Index, which represents the unimpaired runoff in the Sacramento and San Joaquin watersheds; for the remaining months, we used the water-year type of the current water year. For convenience the Eight River Index quintiles are represented by the same five labels as the water-year types.

Model Results Used

Most of this analysis of effects on delta smelt is organized around monthly comparisons because the CalSim-II model results, which are presented on a monthly timestep, are the only available simulations representing all the studies considered in this Biological Assessment. In each model case comparison, we have considered (1) changes in total exports at the CVP and SWP export facilities for each month of the year with respect to Study 6.1; (2) predicted net OMR flow during each month; and (3) X2 and changes in it among the studies for each month. Study 6.1 comparisons are provided here in the BA because we believe Study 6.1 is most representative to the operating regime in the years immediately before the POD than the other model cases. Given that changes in water project operations are likely a contributing, or partial, cause of the POD, it is important to provide comparisons that give some indication of differences in water project operations immediately before and after the POD. However, Study 6.1 is not an especially satisfactory representation of pre-POD water project operations. The pre- and post-POD comparisons desirable for these analyses could be performed through additional CalSim-II simulations or using an alternative approach in which statistical models of water project operations during different periods are constructed using actual historical data. The models would then be used for direct comparison of water project characteristics during the pre- and post-POD eras. While we have not adopted an alternative statistical approach in this biological assessment, we believe it would be a useful way to further assess changes in water project operations during the POD era and we recommend that the Service consider such an analysis as further refinement to this BA. We have used OMR flow results generated via DSM2 modeling for studies 7.0, 7.1, and 8.0 because DSM2-based estimates are regarded as more credible for OMR than those derived from the CalSim-II modeling.

The climate change analysis presented here is adapted from Appendix R, which comprises a detailed analysis of the implications of four “bookend” climate change scenarios meant to represent plausible combinations of high or low future precipitation and temperature. The analyses in Appendix R are departures from CalSim-II model case 8.0, and rely on a base assumption of sea level rise. As noted previously, there is great uncertainty how local climate will evolve as global climate change proceeds. The authors of Appendix R caution against assuming that any one of the scenarios in the Appendix is especially likely relative to the others and that key analytical assumptions may have potentially significant uncertainties, and we repeat that caution here.

The CalSim-II output examined here models the base operation of the water projects in each of the Studies. It does not incorporate discretionary adjustments to water operations that might be implemented by the Water Operations Management Team to avoid adverse impacts on listed species, including delta smelt that might be caused by export pumping, Old and Middle River flow, or low salinity zone location. Such operational adjustments would be based on actual conditions at the time. For this reason, actual impacts, where adverse impacts are predicted to occur, might be smaller than the following results indicate.

Analyses and Results

Direct Entrainment at the CVP and SWP

Some delta smelt are entrained by the south Delta export facilities, with most dying in the process. Because the species is migratory, entrainment is seasonal. Adult delta smelt may be present in the south Delta and vulnerable to entrainment from December through April; larvae and juveniles are likely to be present and vulnerable during late March through early July.

Export Pumping

To evaluate the effects of direct entrainment we reviewed the total CVP + SWP pumping (as “Jones” plus “Total Banks”) in the CalSim-II output. Hydrologic data from the years 1921 to 2003 were used to fit the model. For each comparison presented in Table 13-1 through Table 13-12, differences among model cases are presented as average percent change from the average total pumping in Study 6.1. We have not calculated a numerical estimate of the change in salvage of delta smelt, because that is not a necessary step in evaluating the differences in risk among studies. The export pumping numbers represent the average pumping (in cfs) reported in the CalSim-II simulations for a given month and water year type.

It is important to note that the base operating regime simulated in Study 6.1 represents high levels of winter and spring pumping that have been implicated as a likely contributing cause of the Pelagic Organism Decline (see Chapter 7 and introductory discussion of winter pumping above). Hence study comparisons principally serve to indicate where this existing risk might be redistributed, enhanced, or diminished by the assumptions made in studies 7.0, 7.1, and 8.0.

Percentage changes in pumping in studies 7.0, 7.1, and 8.0 represent the average differences between corresponding cases, and we interpret them to represent predicted *average differences in entrainment* during the water-year types and months represented in each table.

The risk of entrainment depends not only on export pumping rates, but also on the discharge of delta tributaries and the distribution of fish. The distribution of delta smelt may vary substantially from year to year and between months. For example, in years which do not have a significant "first flush" event in December or early January, adult smelt might not be in the central Delta, and might therefore be at lower risk of entrainment during that period. The pumping values and differences reported below should be used to infer an average level or average difference in entrainment.

Results: During October through December, total pumping in studies 7.0, 7.1, and 8.0 is generally 2-10 percent lower than in Study 6.1 (Table 13-1 through Table 13-3). These reductions would be expected to reduce losses of delta smelt; however, salvage is typically low prior to the "first flush" that often occurs late in this period, so the reductions are likely to make little difference in terms of direct losses of delta smelt. Exceptions include Below Normal, Dry, and Critically Dry years in studies 7.1 and 8.0, which featured 2.8-9.4 percent increases in pumping over Study 6.1 in December.

Table 13-1 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for October.

OCTOBER	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	9360	9054	-3.3%	8915	-4.8%	9083	-3.0%
Above Normal	8141	7982	-1.9%	7362	-9.6%	7722	-5.2%
Below Normal	8623	8100	-6.1%	7717	-10.5%	7729	-10.4%
Dry	7603	8111	6.7%	7325	-3.7%	7567	-0.5%
Critically Dry	6868	6799	-1.0%	6460	-5.9%	6468	-5.8%

Table 13-2 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for November.

NOVEMBER	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	10247	10503	2.5%	10743	4.8%	10699	4.4%
Above Normal	8198	8414	2.6%	8581	4.7%	8422	2.7%
Below Normal	9077	8851	-2.5%	8829	-2.7%	8922	-1.7%
Dry	7628	7416	-2.8%	7717	1.2%	7748	1.6%
Critically Dry	6424	6278	-2.3%	6391	-0.5%	5801	-9.7%

Table 13-3 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for December.

DECEMBER	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	11000	10438	-5.1%	11515	4.7%	11585	5.3%
Above Normal	10085	8870	-12.1%	10012	-0.7%	9662	-4.2%
Below Normal	9260	8770	-5.3%	9829	6.1%	9876	6.7%
Dry	9548	8924	-6.5%	9816	2.8%	9817	2.8%
Critically Dry	7183	7107	-1.1%	7855	9.4%	7522	4.7%

During January and February, most of the differences in pumping are reductions in 7.0, 7.1, and 8.0 with respect to 6.1 (Table 13-4 through Table 13-6). These reductions make 7.0, 7.1, and 8.0 more protective of delta smelt than 6.1 in January and February. In March, though, there are consistently substantial (3.1 percent to 15.7 percent) increases in 7.0, 7.1, and 8.0 over 6.1 in Wet and Above Normal water years. These increases would be expected to increase losses of delta smelt. Salvage is often low during these wetter years, although the hydrograph can have a substantial effect on the magnitude and timing of losses. Hence, it is difficult to assess the relative importance of the higher March export levels. It is important to note that the base pumping in Study 6.1 during these months may have contributed to excessive winter and spring delta smelt entrainment during the POD years.

Table 13-4 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for January.

JANUARY	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	11007	10668	-3.1%	11537	4.8%	11425	3.8%
Above Normal	11679	10074	-13.7%	11433	-2.1%	11539	-1.2%
Below Normal	10996	9908	-9.9%	10815	-1.6%	10960	-0.3%
Dry	10041	8410	-16.2%	9584	-4.5%	9682	-3.6%
Critically Dry	7899	7224	-8.5%	7646	-3.2%	7986	1.1%

Table 13-5 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for February.

FEBRUARY	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	10361	10295	-0.6%	10507	1.4%	10617	2.5%
Above Normal	10951	10143	-7.4%	10728	-2.0%	11062	1.0%
Below Normal	9802	9759	-0.4%	9625	-1.8%	9171	-6.4%
Dry	8533	8322	-2.5%	7982	-6.5%	8137	-4.6%
Critically Dry	5620	5154	-8.3%	6061	7.9%	5853	4.2%

Table 13-6 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for March.

MARCH	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	8729	10099	15.7%	9138	4.7%	9524	9.1%
Above Normal	9374	10386	10.8%	9660	3.1%	10138	8.2%
Below Normal	8328	8692	4.4%	8387	0.7%	8472	1.7%
Dry	7235	7367	1.8%	7270	0.5%	7188	-0.6%
Critically Dry	4449	3798	-14.6%	4316	-3.0%	4241	-4.7%

During April through May most of the differences between 6.1 and the other studies represent lower pumping in the other studies, including substantially proportionately lower pumping in some cases, particularly in Study 7.0 (Table 13-7 through Table 13-9). However, in June there are large increases (up to 134 percent, representing an increase of about 2000 cfs in average export pumping) in Dry and Critically Dry years in 7.0, 7.1, and 8.0. The net result of these changes is that losses of larvae and early juveniles should be lower in early spring, but with increased losses of juveniles in the late spring of drier years.

Table 13-7 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for April.

APRIL	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	7155	6226	-13.0%	6944	-2.9%	6987	-2.3%
Above Normal	6262	5488	-12.4%	6173	-1.4%	6226	-0.6%
Below Normal	5460	4472	-18.1%	4737	-13.2%	4708	-13.8%
Dry	3532	2716	-23.1%	3329	-5.7%	3339	-5.5%
Critically Dry	1891	1780	-5.9%	2035	7.6%	1893	0.1%

Table 13-8 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for May.

MAY	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	7160	6114	-14.6%	6950	-2.9%	6924	-3.3%
Above Normal	5544	4174	-24.7%	5193	-6.3%	5011	-9.6%
Below Normal	4746	3069	-35.3%	4149	-12.6%	4051	-14.7%
Dry	3769	2222	-41.0%	3259	-13.5%	3073	-18.5%
Critically Dry	1783	1595	-10.5%	1751	-1.8%	1644	-7.8%

Table 13-9 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for June.

JUNE	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	7930	8414	6.1%	8635	8.9%	8616	8.7%
Above Normal	6937	7344	5.9%	7961	14.8%	7802	12.5%
Below Normal	6296	6480	2.9%	6988	11.0%	6890	9.4%
Dry	4429	5621	26.9%	6212	40.3%	6118	38.1%
Critically Dry	1513	3540	133.9%	2754	82.0%	2416	59.7%

The trend of higher pumping in June is continued in July, with substantial (14 percent to 179 percent) increases in pumping in all water year types. These increases would cause correspondingly higher juvenile smelt entrainment in some years. In August there is higher (9.4 percent to 95.9 percent) pumping in all water year types Study 7.0, with corresponding increases in Wet, Above Normal, and Below Normal years in studies 7.1 and 8.0. In September most changes were small, with only Critically Dry years standing out (+24 percent) in Study 7.0 and Dry years in 7.1 and 8.0 (-17 percent and -19 percent, respectively) being substantial different from Study 6.1. Since delta smelt entrainment tends to be very low in August and September, these changes in late summer are not expected to have significant population effects.

Table 13-10 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for July.

JULY	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	8898	10154	14.1%	10773	21.1%	10875	22.2%
Above Normal	6936	8899	28.3%	10037	44.7%	9736	40.4%
Below Normal	7907	10476	32.5%	11111	40.5%	10641	34.6%
Dry	6747	10593	57.0%	10539	56.2%	10123	50.0%
Critically Dry	1887	5270	179.3%	3675	94.8%	3359	78.0%

Table 13-11 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for August.

AUGUST	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	10010	11549	15.4%	11491	14.8%	11627	16.2%
Above Normal	8969	11474	27.9%	11082	23.6%	11168	24.5%
Below Normal	8676	10514	21.2%	9814	13.1%	9717	12.0%
Dry	6958	7611	9.4%	5720	-17.8%	5277	-24.2%
Critically Dry	2156	4224	95.9%	2020	-6.3%	1880	-12.8%

Table 13-12 Comparison of total export pumping in studies 7.0, 7.1, and 8.0 with Study 6.1 for September.

SEPTEMBER	Study 6.1	Study 7.0		Study 7.1		Study 8.0	
WY Type	CFS	CFS	Change	CFS	Change	CFS	Change
Wet	10804	11469	6.2%	11249	4.1%	11315	4.7%
Above Normal	10320	10498	1.7%	10325	0.1%	10710	3.8%
Below Normal	9998	10128	1.3%	9755	-2.4%	9924	-0.7%
Dry	8475	8571	1.1%	7024	-17.1%	6838	-19.3%
Critically Dry	4706	5828	23.8%	4922	4.6%	4777	1.5%

Old and Middle River Flow

Old and Middle River flow provides an alternative approach to estimating entrainment risk. It provides a direct measure of the strength of the transport process responsible for the movement of delta smelt to the export facilities (Grimaldo et al. in review), and is thus somewhat “cleaner” than analyses relying solely on export pumping. As with X2 and the boundary of the zone of entrainment, OMR flow is in a constant state of flux because of the tides, wind, river flows, operation of the South Delta Temporary Barriers, and export pumping. The relevant quantity for analyzing the transport of fish is the tidally averaged net OMR flow. It is not possible to accurately predict OMR flow from CalSim-II output. Here we use DSM2-based OMR flow predictions provided by CDWR instead of CalSim-II. Only cases representing studies 7.0, 7.1, and 8.0 were provided.

The net velocity of water in Old and Middle River scales a transport process that can affect delta smelt survival, reproduction, and dispersal in two ways. First, upstream flow may directly deliver delta smelt larvae, juveniles, and adults to the threshold of the water project export facilities, where they become entrained. Second, upstream flow may indirectly affect adult delta smelt by creating confusing or adverse migratory conditions at locations remote from the export facilities. A discussion of evidence for both direct and indirect effects is presented in Chapter 7.

Both the direct and indirect effects associated with upstream, or negative OMR flow increase in severity or likelihood with the magnitude of the upstream flow, as discussed in Chapter 7. As with export pumping, we assume (following P.E. Smith, unpublished analysis; Grimaldo et al. in review) that *entrainment escalates at least in proportion to the magnitude of average net upstream OMR flow, and at high OMR flow escalates faster*. As Smith's analysis showed, downstream OMR flow is usually associated with almost nonexistent entrainment risk to delta smelt that are north of Old and Middle Rivers. The assumption of a linear relationship between entrainment and OMR flow only works for upstream OMR flow less than about 4000 cfs. Plots that include historical data for periods of strong upstream flow reveal that the entrainment/OMR flow relationship is in reality exponential, and entrainment increases much faster than negative OMR flow. However, at low upstream OMR flow rates a line fits the relationship reasonably well. Whether the rapid increase in entrainment at higher flow rates is due to changes in the size or disposition of the zone of entrainment or to other characteristics of the transport process itself, or both, is uncertain.

In this analysis, we summarized the median OMR flow for each month, binned by water year type. Data from the years 1975 to 1991 were used to fit the model. The figures represent medians computed over full months. Because there are only 16 years of data, water year types are consolidated into Wet + Above Normal, Below Normal + Dry, and Critically Dry. According to DWR (Aaron Miller, pers. Comm..), there are strong antecedent effects from the boundary conditions used to frame each monthly time period that may skew the results to some extent.

The Smelt Work Group (SWG, formerly the Delta Smelt Work Group) used DSM2-based particle tracking methods to analyze the effects of OMR on the limits of the zone of entrainment during the winter and spring of 2008 (See also Kimmerer and Nobriga 2008 for a more general exposition). The SWG concluded that under hydrodynamic conditions prevailing during March and April 2008 a daily net upstream OMR flow no greater than 2000±500 cfs effectively prevented entrainment of simulated particles injected into the San Joaquin River as far southeast as the mouth of Potato Slough (a fish monitoring location known as "Station 815"). In this analysis, we consider upstream flow of 2000 cfs to be a rough indicator of the limit beyond which increasingly negative OMR flow causes the zone of entrainment to expand beyond the south Delta into the San Joaquin River at Station 815 and farther downstream under operational circumstances similar to those existing in spring 2008. Furthermore, we regard upstream flow of 4000 cfs to be a rough benchmark value separating the linear domain from the exponential domain of the entrainment/flow relationship, and upstream flows exceeding 4000 cfs are likely to be associated with substantially larger entrainment, all other things being equal.

In the following tables, two blocks of months are presented: December through March, representing the period of adult delta smelt vulnerability to entrainment, and April through July, representing juvenile vulnerability.

In Wet + Above Normal years, the results suggest median OMR flows are usually downstream during the winter months (Table 13-13). However, they become negative in June (-3506 to -3869 cfs) and strongly so in July (-6652 to -7996 cfs) (Table 13-14). This suggests that losses of adult delta smelt and early juveniles would result in very low levels of losses. Negative flows during later months would result in more substantial losses of juvenile delta smelt from the central Delta and north of it, including higher losses in years when fish are still within reach of the pumps in July.

Table 13-13 Projected monthly net OMR flow for Wet + Above Normal years during months of adult delta smelt entrainment vulnerability

WYTS: W/AN Study	December	January	February	March	Average
OCAP 7.0	1437	206	2759	5819	2555
OCAP 7.1	-127	-713	5719	8029	3227
OCAP 8.0	-152	-506	5860	7713	3229

Table 13-14 Projected monthly net OMR flow for Wet + Above Normal years during months of juvenile delta smelt entrainment vulnerability

WYTS:W/AN Study	April	May	June	July	Average
OCAP 7.0	3666	931	-3869	-6652	-1481
OCAP 7.1	3469	75	-3666	-7647	-1942
OCAP 8.0	3444	42	-3506	-7996	-2004

In Below Normal + Dry years, the results indicate strong negative OMR flows (-4645 cfs to -6793 cfs) for the months of December through March (Table 13-15). Moderately negative flows in April and May (-897 cfs to -2845 cfs) are followed by strong negative flows in June (-5551 cfs to -6644 cfs) and even stronger negative flows in July (-9028 cfs to -11014 cfs) (Table 13-16). Analyses of particle tracking (see above) and salvage data (Grimaldo et al., in review) indicate that winter losses of adults would likely occur in these drier years, but losses of early larvae and juveniles would likely be relatively low in spring. Strong negative flows in June and July would be expected to result in substantial losses of juveniles from the central Delta and probably the lower Sacramento River in these drier years.

Table 13-15 Projected monthly net OMR flow for Below Normal + Dry years during months of adult delta smelt entrainment vulnerability

WYTS: BN/D Study	December	January	February	March	Average
OCAP 7.0	-5203	-4645	-6763	-6146	-5689
OCAP 7.1	-6212	-6104	-5660	-4692	-5667
OCAP 8.0	-6793	-5759	-6207	-4756	-5879

Table 13-16 Projected monthly net OMR flow for Below Normal + Dry years during months of juvenile delta smelt entrainment vulnerability

WYTS: BN/D Study	April	May	June	July	Average
OCAP 7.0	-897	-1258	-5551	-9028	-4183
OCAP 7.1	-2199	-2845	-6644	-11014	-5676
OCAP 8.0	-2181	-2676	-6654	-10908	-5605

In Critically Dry years, strong negative OMR flows in December (-4637 cfs to -6419 cfs) are followed by moderately to weakly negative flows (-837 cfs to -1594 cfs) in January through March (Table 13-17). April and May (-1335 cfs to -1698 cfs) feature moderately negative OMR flows, while June and July (-3195 cfs to -5490 cfs) feature moderate to strong flows (Table 13-18). Analyses of particle tracking (see above) and salvage data (Grimaldo et al., in review) indicate that losses of adults would occur December of Critically Dry years, with much lower losses in the later winter months. Losses of early larvae and juveniles would be expected to be relatively low in spring. Strong negative flows in June and July would be expected to result in substantial losses of juveniles in these very dry years.

Table 13-17 Projected monthly net OMR flow for Critically Dry years during months of adult delta smelt entrainment vulnerability

WYTS: C Study	December	January	February	March	Average
OCAP 7.0	-5829	-1000	-1040	-825	-2173
OCAP 7.1	-6419	-1031	-2022	-976	-2612
OCAP 8.0	-4637	-1525	-1594	-1087	-2211

Table 13-18 Projected monthly net OMR flow for Critically Dry years during months of juvenile delta smelt entrainment vulnerability

WYTS: C Study	April	May	June	July	Average
OCAP 7.0	-1335	-1574	-4493	-5490	-3223
OCAP 7.1	-1642	-1698	-3195	-3573	-2527
OCAP 8.0	-1655	-1509	-2354	-3350	-2217

X2

We used projected monthly X2 from the CalSim-II simulations to estimate X2 in each model case for each of the 12 months. These are presented as Figure 13-1 through Figure 13-36. Each figure consists of five panels representing hydrologic classification as described above. Months using an Eight Rivers Index classification use the same bin names for consistency. In all panels the "x" axis represents X2 in kilometers in Study 6.1, while the "y" axis represents the departure from that X2 in another study. The dashed lines in each figure are smooth. A full set of monthly figures for studies 7.0, 7.1, and 8.0 is presented, but the months of greatest potential significance for delta smelt are, as discussed above, those falling in the summer and fall seasons.

The general disposition of X2 in Study 6.1 varies by month and hydrology. Early and late in the water year, X2 tends to be compressed into a narrow range between approximately 83 and 90 km in drier years, while in wet years values range from the low 70s to the high 80s. In the middle of the water year, X2 varies considerably in all hydrologic categories, depending on the weather. This means that in drier years, especially during the summer and fall months, X2 in Study 6.1 is usually above Collinsville (RKI 81), often by as much as 5 km. Analyses of historical data indicates that habitat conditions are relatively poor and contribute to delta smelt producing fewer offspring in years when X2 is located above Collinsville during autumn (Feyrer et al. 2007). The effects in summer are less clear, with no simple correlation between Delta salinity (a surrogate for X2) and delta smelt abundance during summer (Nobriga et al. 2008).

Summer X2 Deviation in Studies 7.0, 7.1, and 8.0

In Wet and Above Normal years, July X2 is usually similar to Study 6.1, though there is some scatter both below and above parity (Figures 13-10, 22, 34). Below Normal, Dry, and Critically Dry years show progressively greater upstream deviation from Study 6.1, though it is usually of less than 5 km. This pattern is repeated in August, with a small positive offset in all hydrologic categories (Figures 13-11, 23, 35). The upstream X2 deviation in a Dry or Critically Dry August is usually 3-5 km. These results suggest little consistent pattern in the amount of habitat (based on salinity) available to delta smelt during summer for the different studies, except in very dry years. Note that this result is congruent with the finding that there is no long-term trend in summer X2 (Kimmerer 2002). Moreover, there is no simple linkage between summer Delta salinity and delta smelt abundance (Nobriga et al. 2008).

Fall X2 Deviation in Studies 7.0, 7.1, and 8.0

Although Most of September properly belongs to the summer, it is included here for consistency with Feyrer's habitat analysis. In September, studies 7.0, 7.1, and 8.0 all feature substantial upstream shifts of X2 in all five hydrologic categories, with most differences being approximately 5 km (Figures 13-12, 24, 36). In October and November, studies 7.0, 7.1, and 8.0 all feature substantial (5+ km) upstream shifts of X2 in the the four driest year categories (Figures 13-1, 2, 13, 14, 25 & 26). In December, there is a general tendency for X2 in studies 7.0, 7.1, and 8.0 to deviate farther upstream than Study 6.1 in years where Study 6.1 X2 was 70 km or greater (Figures 13-3, 15 & 27). Below that, deviations were generally negative except for very low Study 6.1 X2 (less than approx. 55 km). Hence, the effects changes in X2 on delta smelt habitat and juvenile production would be mixed, depending on Delta outflow.

Based on analyses for the entire autumn (Feyrer et al. 2007), the consistent upstream shift in X2 during September through November (and December in years with high X2) relative to Study 6.1 and high absolute X2 would be expected to reduce the amount of habitat for delta smelt and subsequent production of juveniles. The movement of X2 upstream by several km during drier years might also shift the distribution of delta smelt far enough east that adult entrainment might begin to occur in Fall under circumstances of high export pumping, or at least to occur earlier than it would otherwise. Similarly, it may also position delta smelt geographically closer to the export pumps at the time of "first flush" and make them more vulnerable to entrainment.

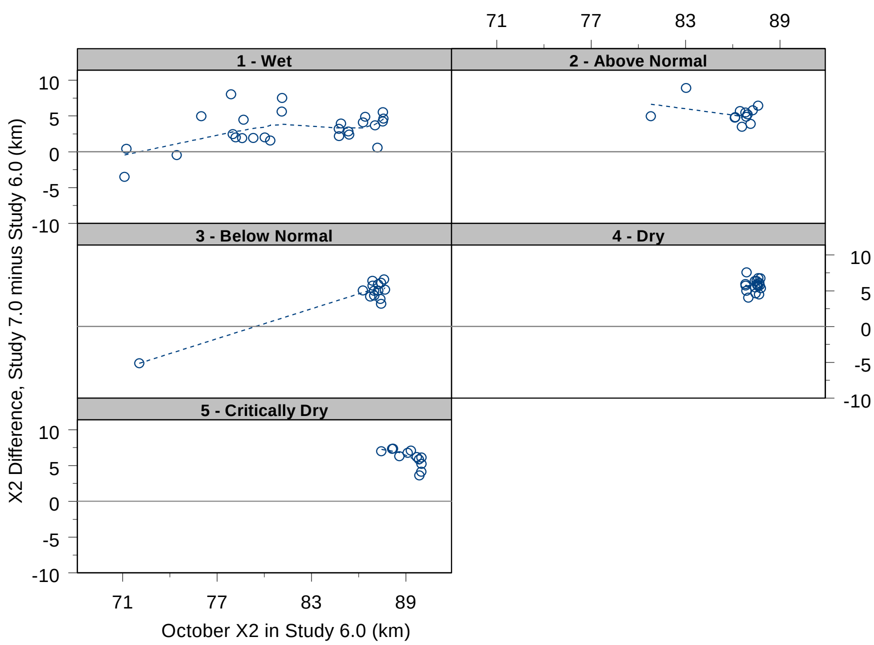


Figure 13-1 Variation in X2 in Study 7.0 with respect to Study 6.1 in October

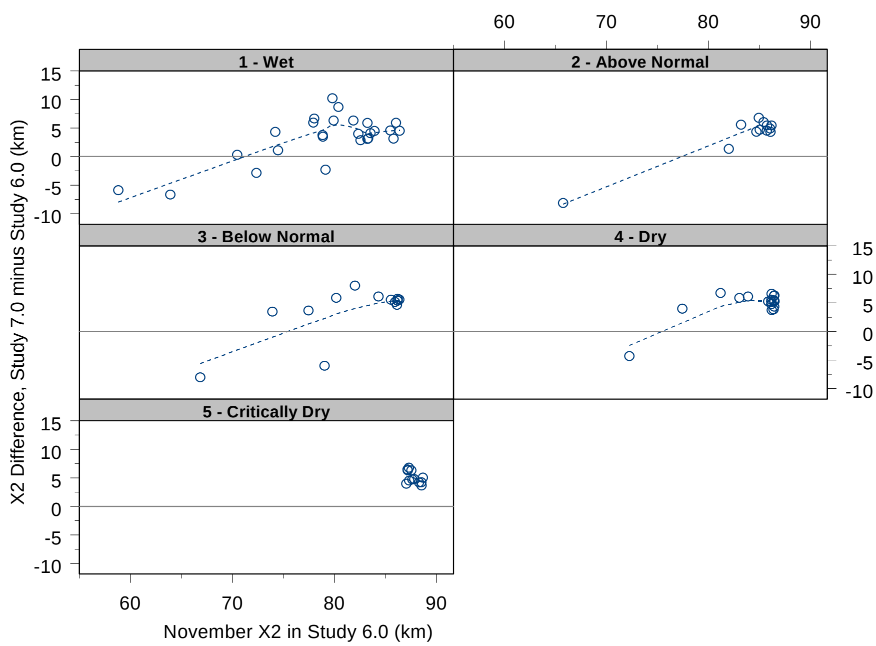


Figure 13-2 Variation in X2 in Study 7.0 with respect to Study 6.1 in November

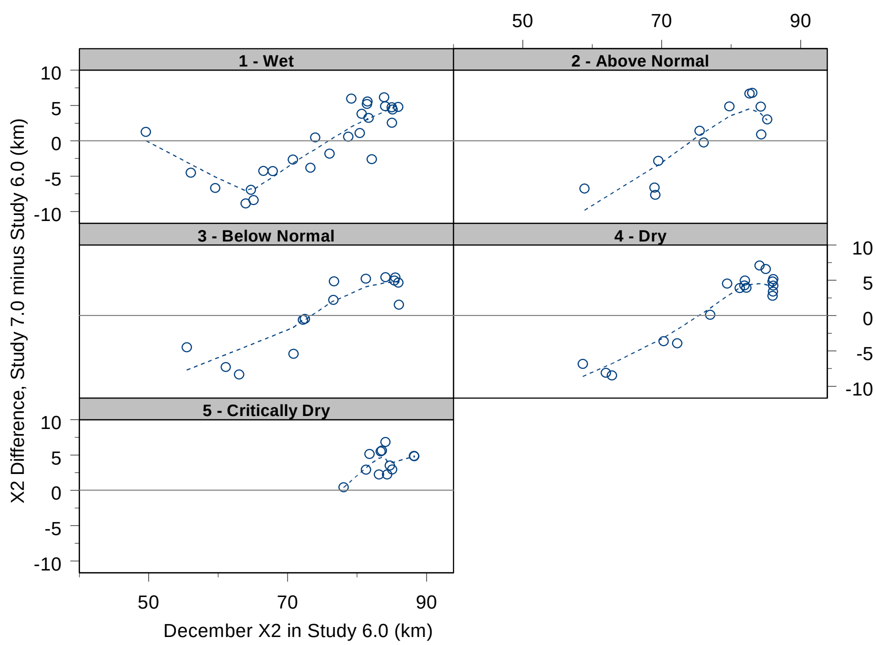


Figure 13-3 Variation in X2 in Study 7.0 with respect to Study 6.1 in December

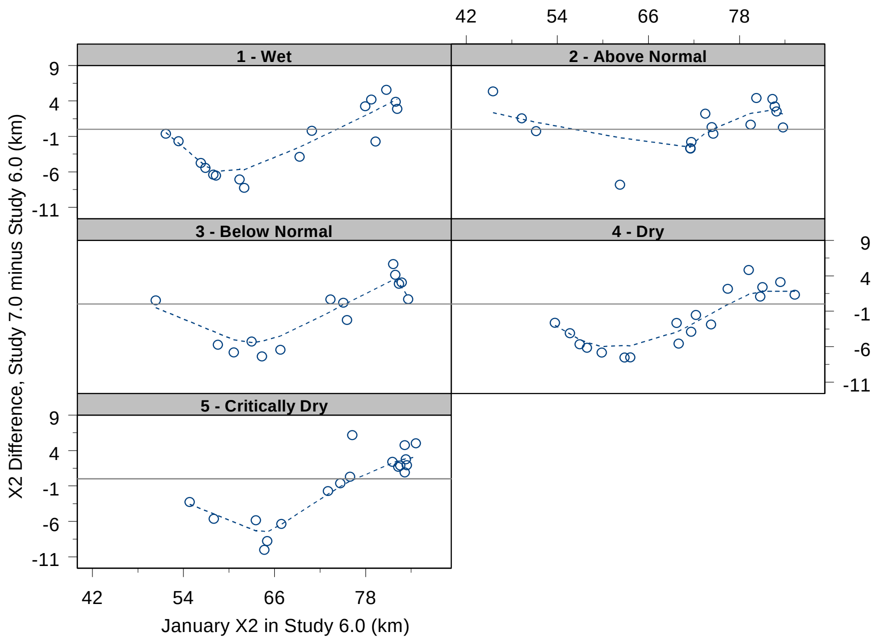


Figure 13-4 Variation in X2 in Study 7.0 with respect to Study 6.1 in January

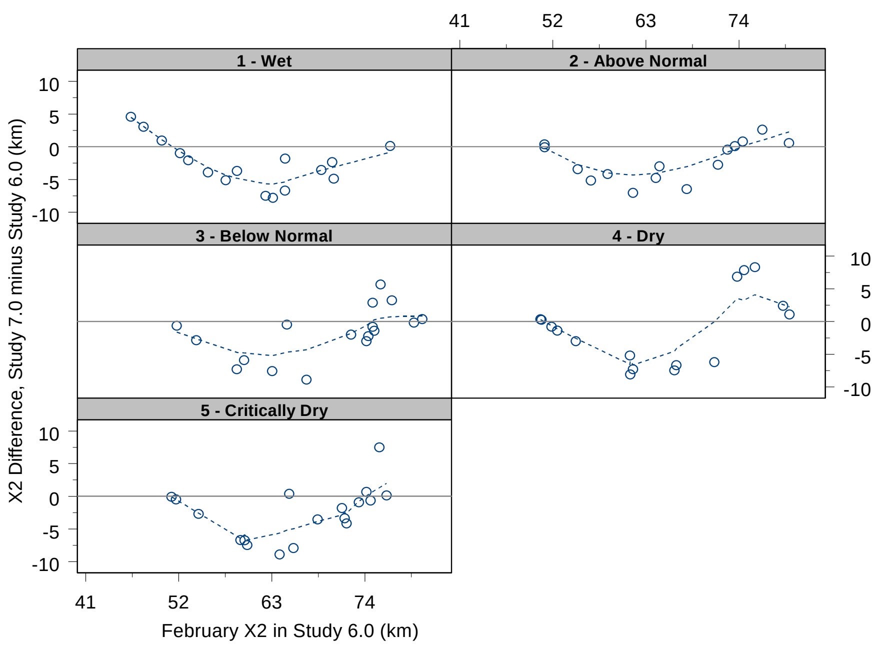


Figure 13-5 Variation in X2 in Study 7.0 with respect to Study 6.1 in February

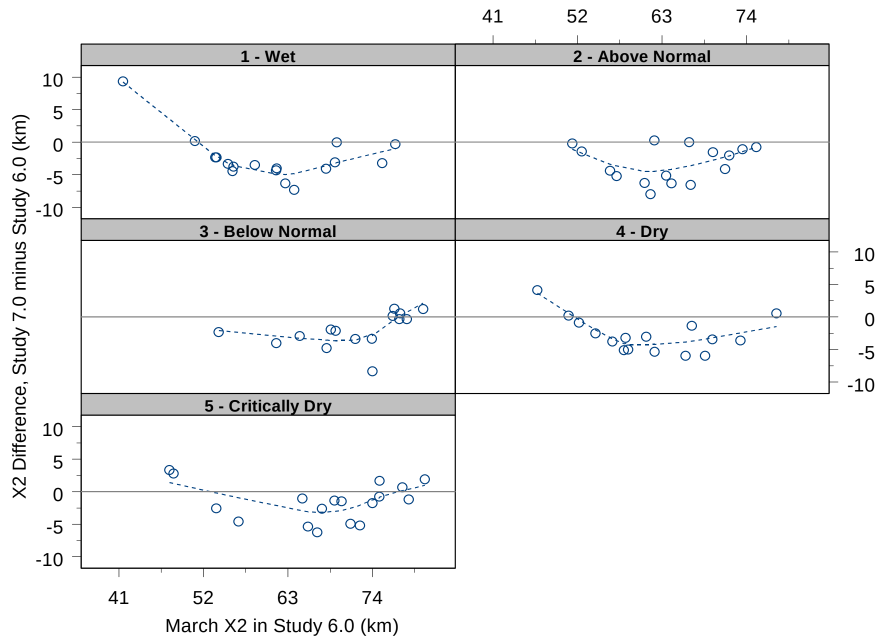


Figure 13-6 Variation in X2 in Study 7.0 with respect to Study 6.1 in March

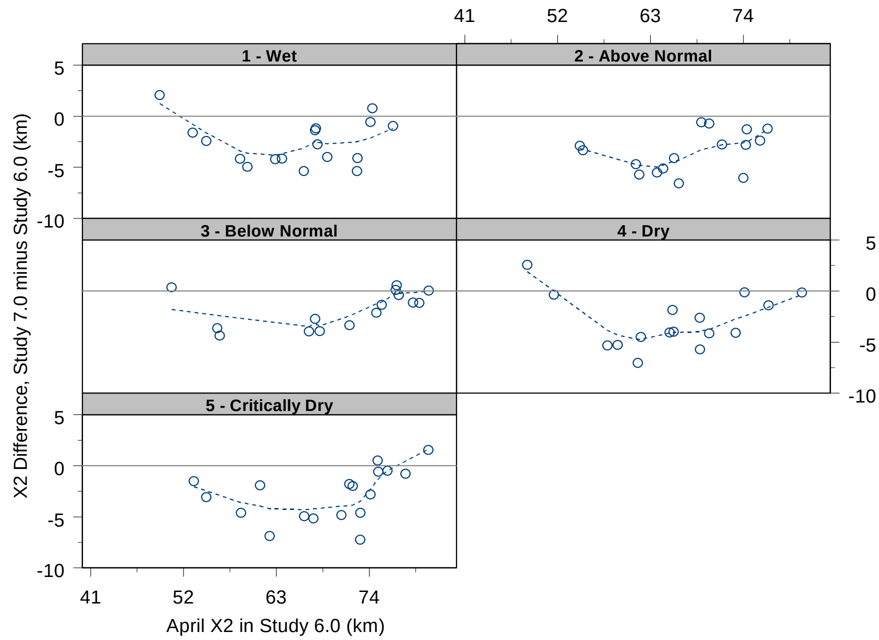


Figure 13-7 Variation in X2 in Study 7.0 with respect to Study 6.1 in April

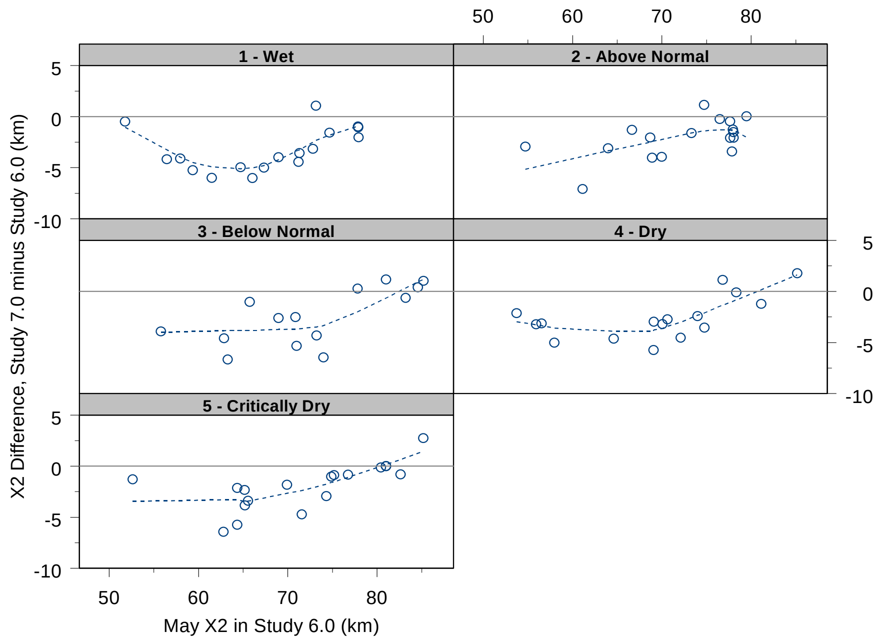


Figure 13-8 Variation in X2 in Study 7.0 with respect to Study 6.1 in May

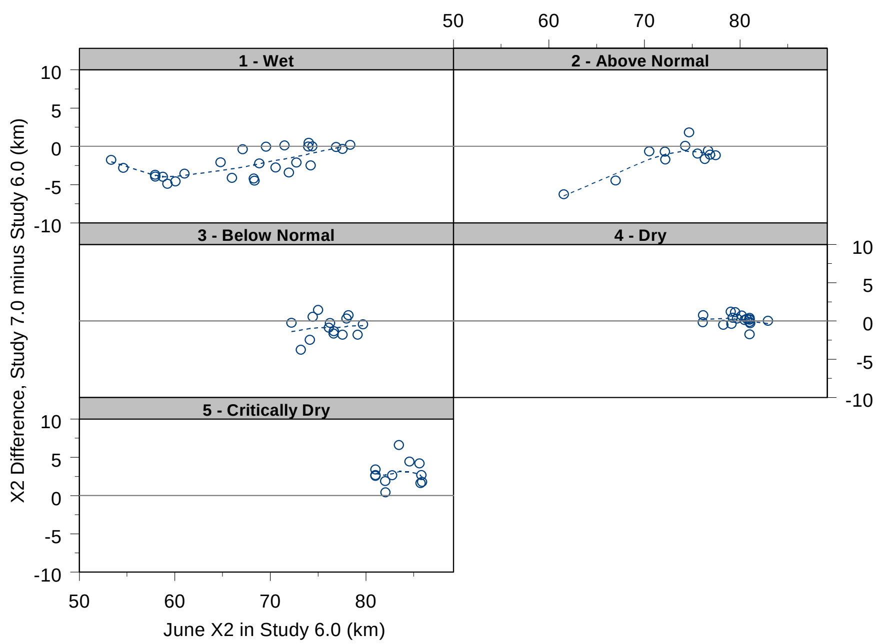


Figure 13-9 Variation in X2 in Study 7.0 with respect to Study 6.1 in June

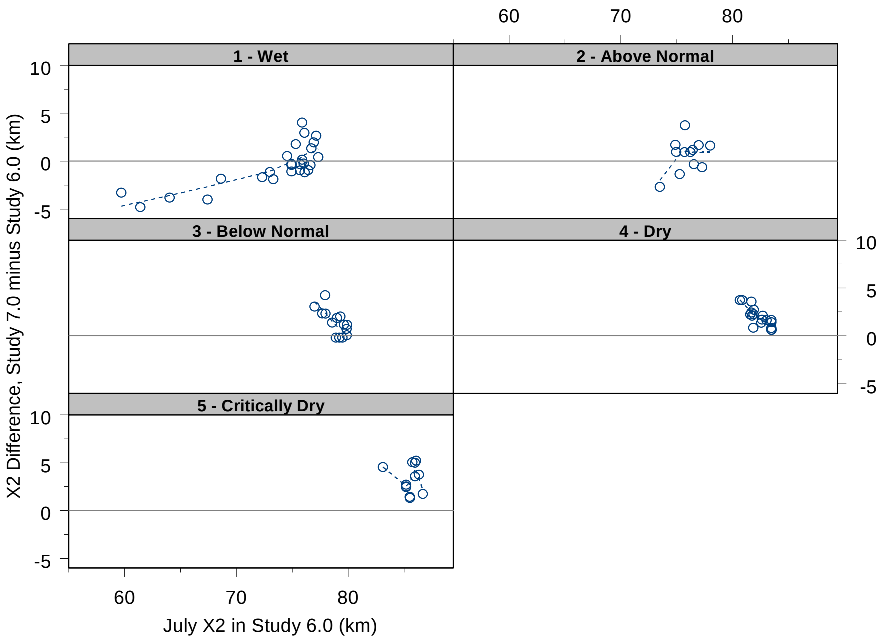


Figure 13-10 Variation in X2 in Study 7.0 with respect to Study 6.1 in July

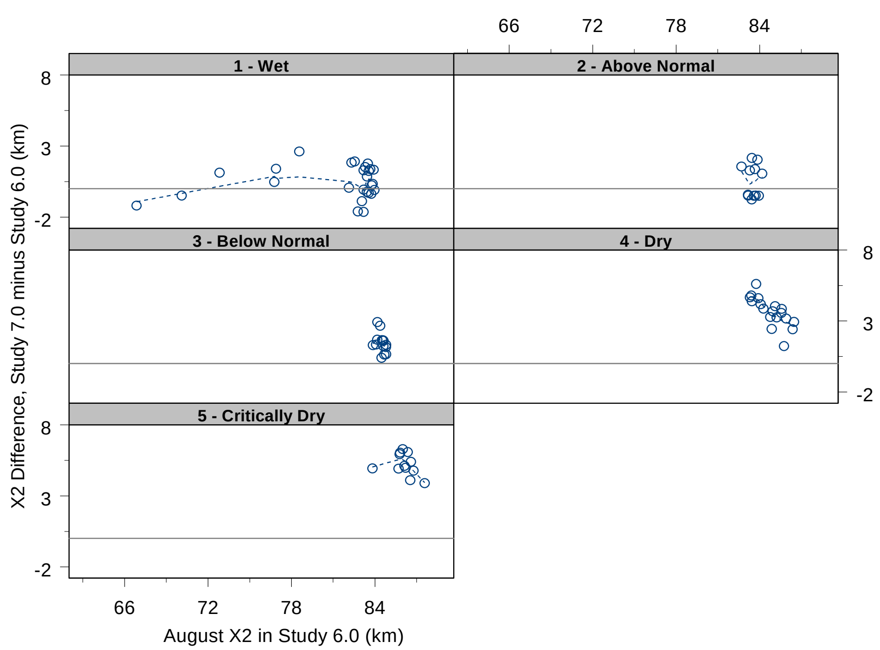


Figure 13-11 Variation in X2 in Study 7.0 with respect to Study 6.1 in August

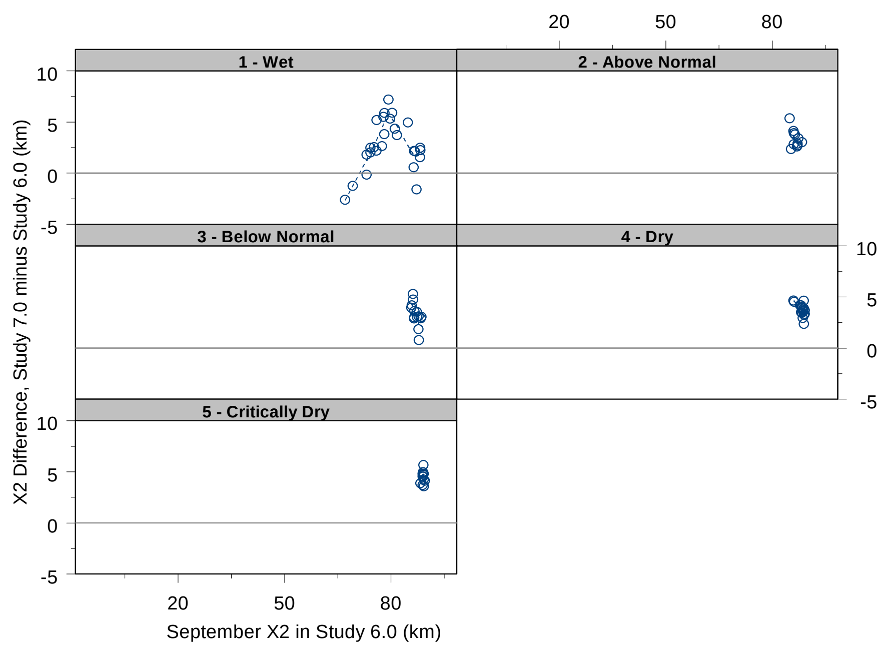


Figure 13-12 Variation in X2 in Study 7.0 with respect to Study 6.1 in September

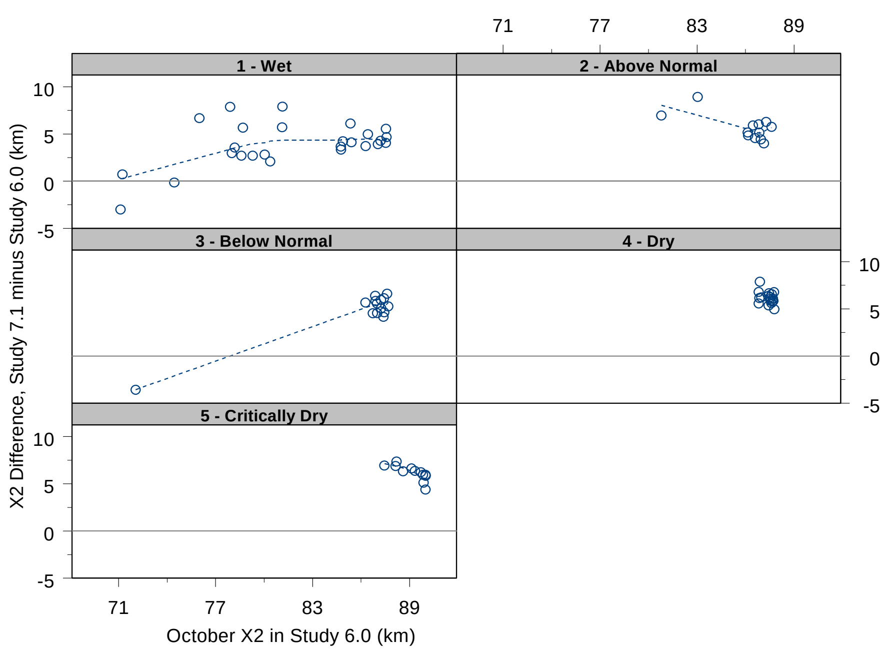


Figure 13-13 Variation in X2 in Study 7.1 with respect to Study 6.1 in October

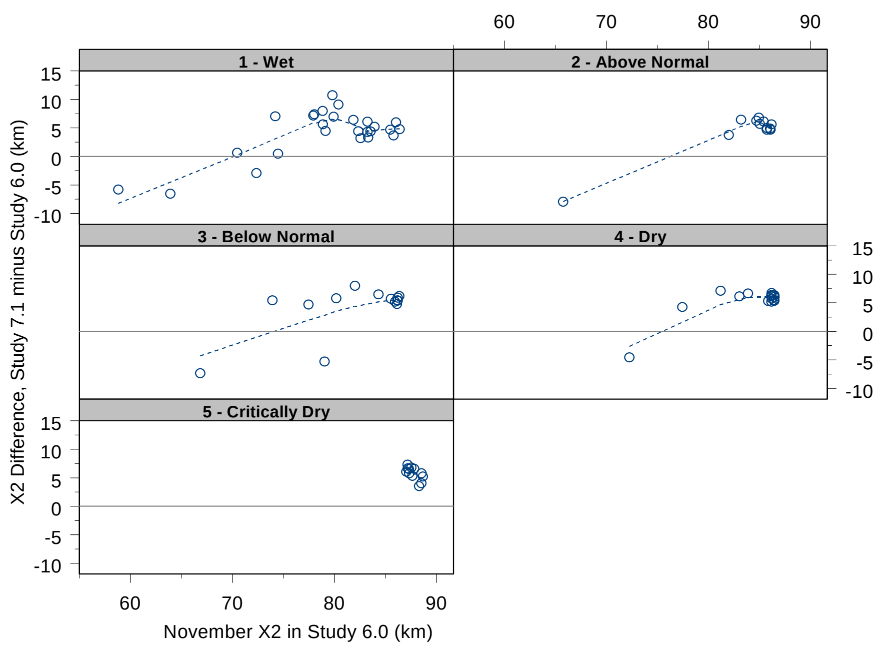


Figure 13-14 Variation in X2 in Study 7.1 with respect to Study 6.1 in November

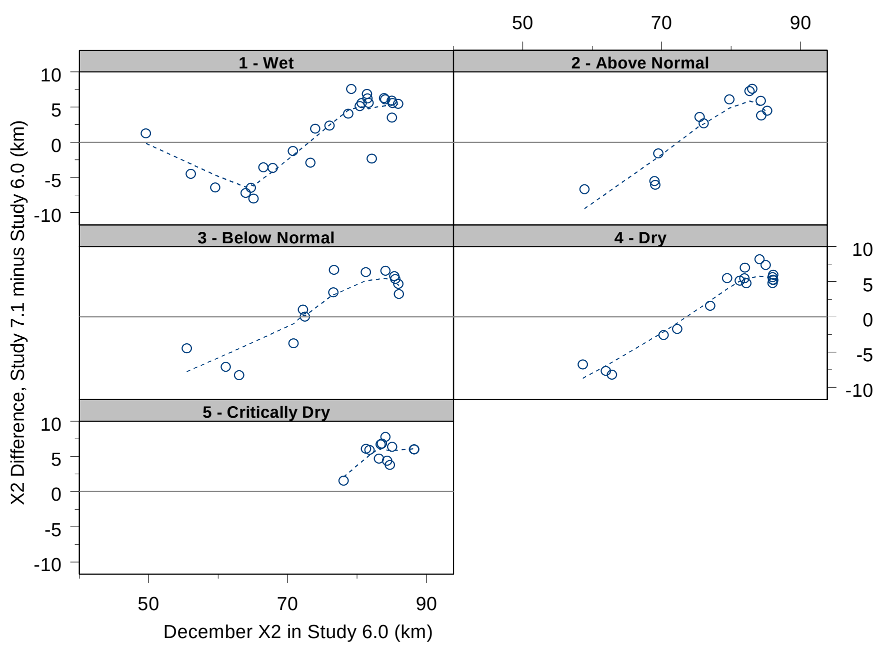


Figure 13-15 Variation in X2 in Study 7.1 with respect to Study 6.1 in December

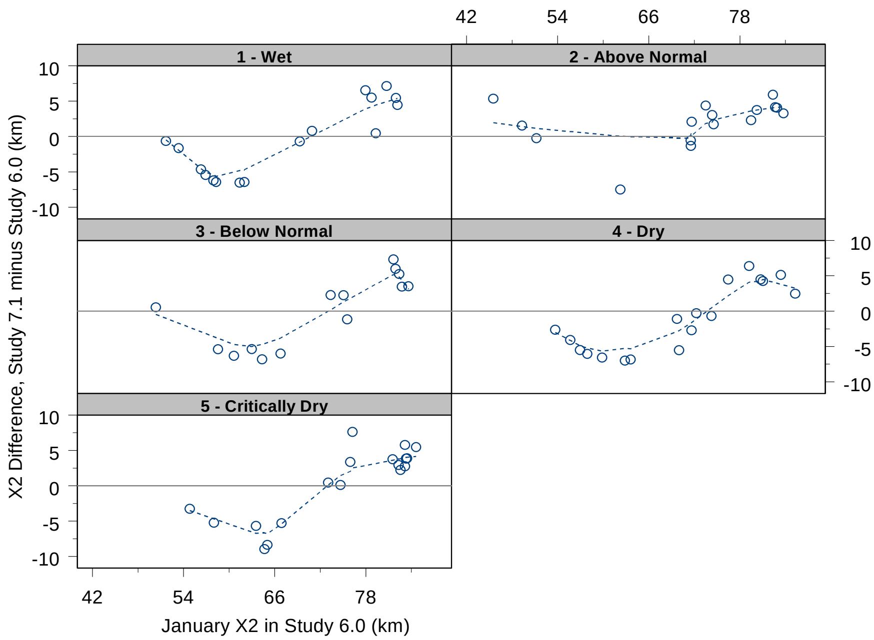


Figure 13-16 Variation in X2 in Study 7.1 with respect to Study 6.1 in January

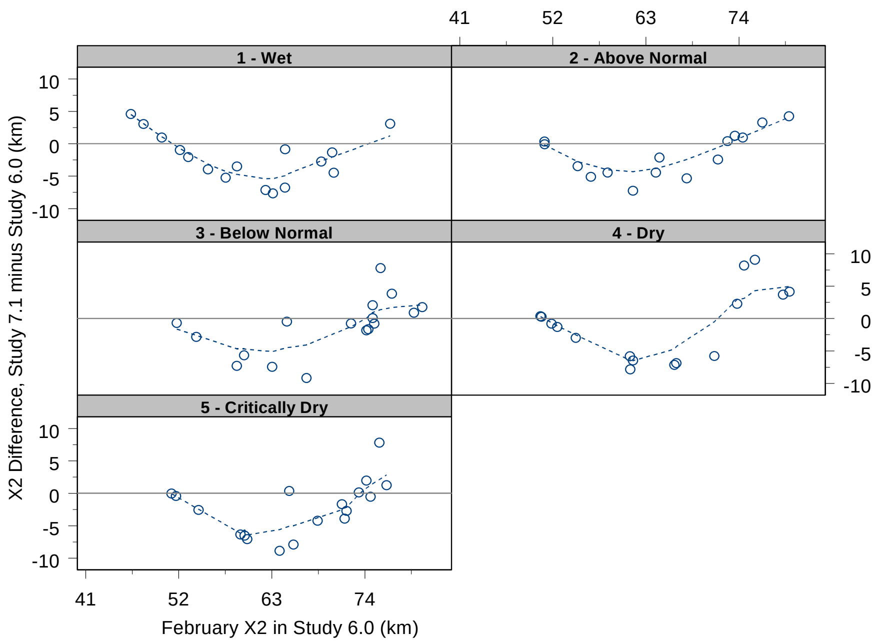


Figure 13-17 Variation in X2 in Study 7.1 with respect to Study 6.1 in February

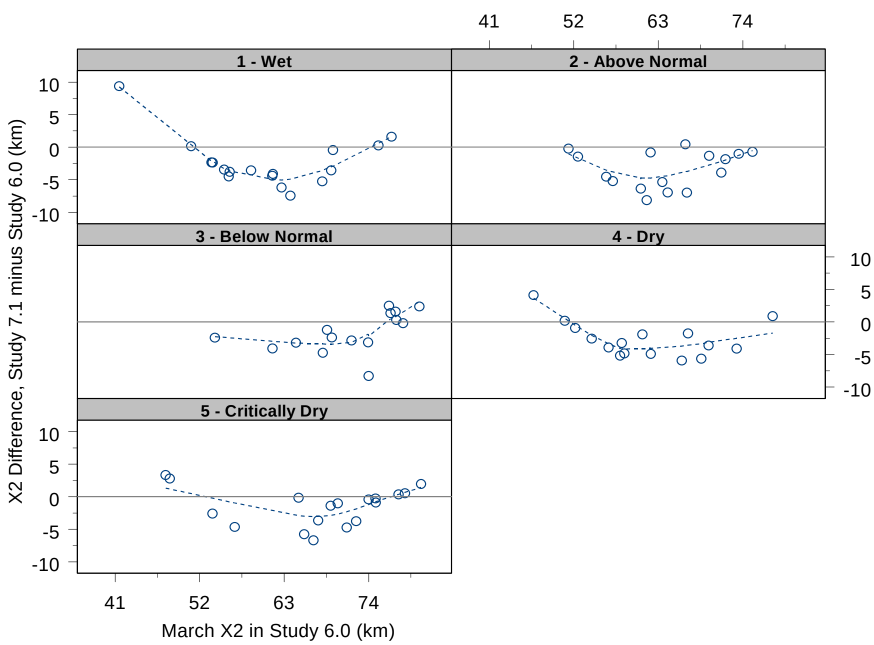


Figure 13-18 Variation in X2 in Study 7.1 with respect to Study 6.1 in March

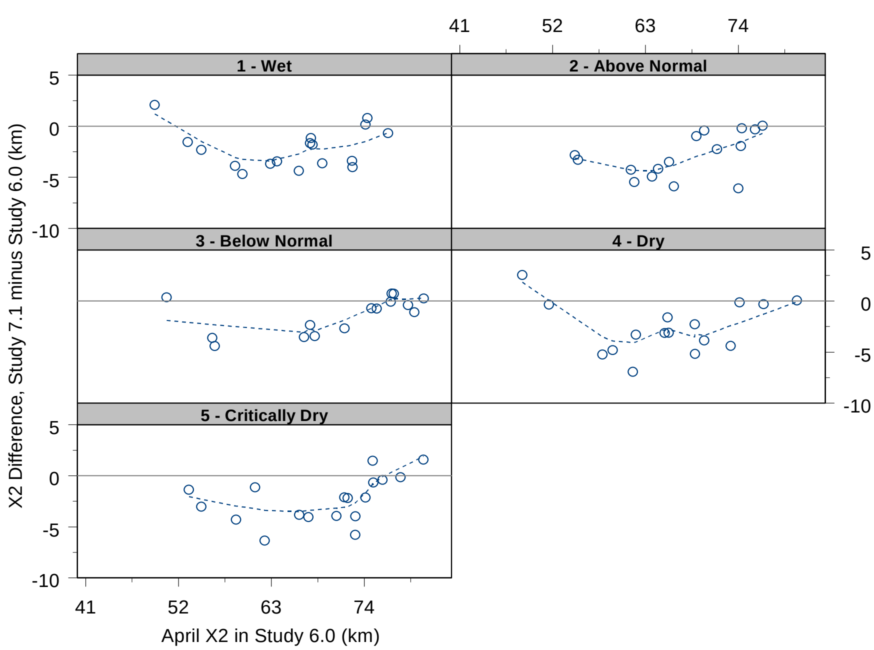


Figure 13-19 Variation in X2 in Study 7.1 with respect to Study 6.1 in April

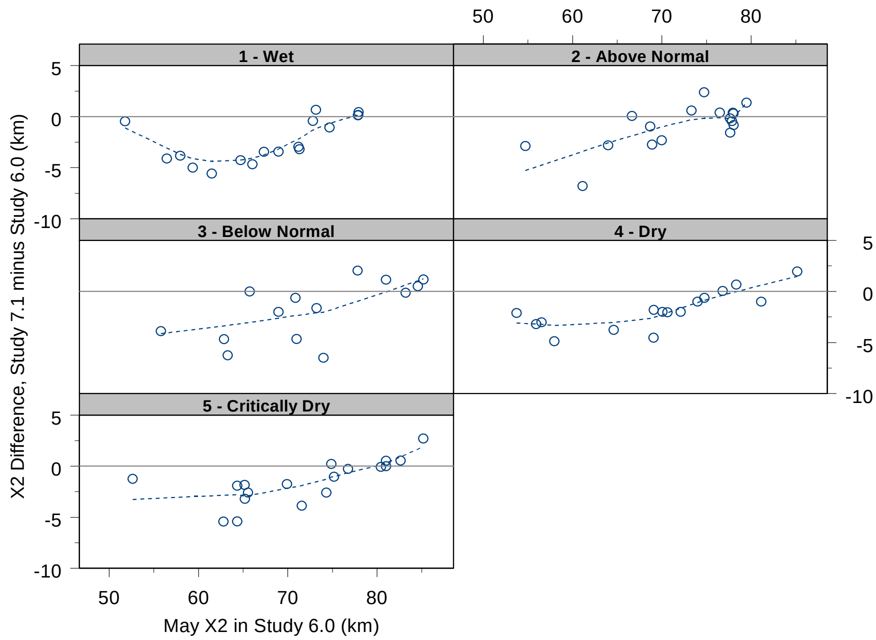


Figure 13-20 Variation in X2 in Study 7.1 with respect to Study 6.1 in May

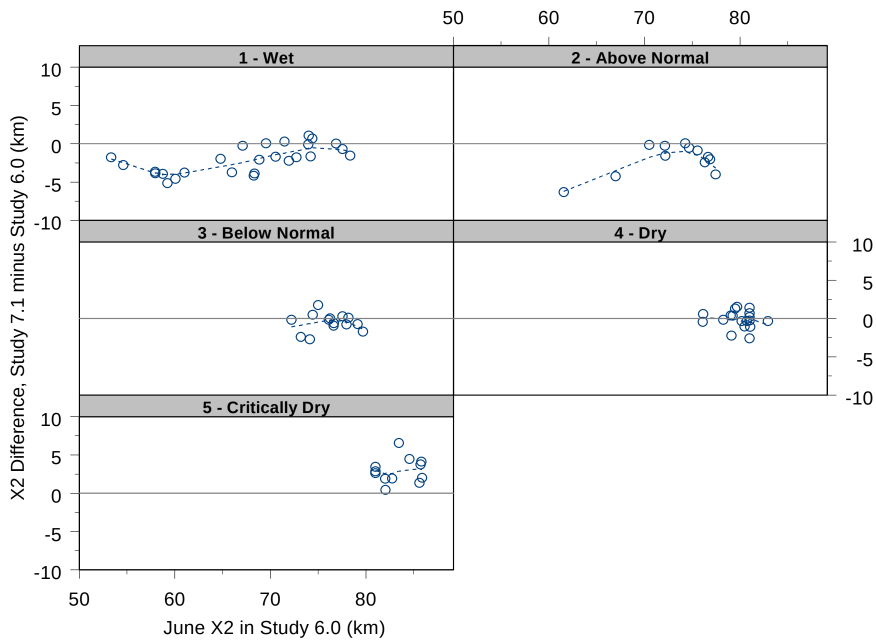


Figure 13-21 Variation in X2 in Study 7.1 with respect to Study 6.1 in June

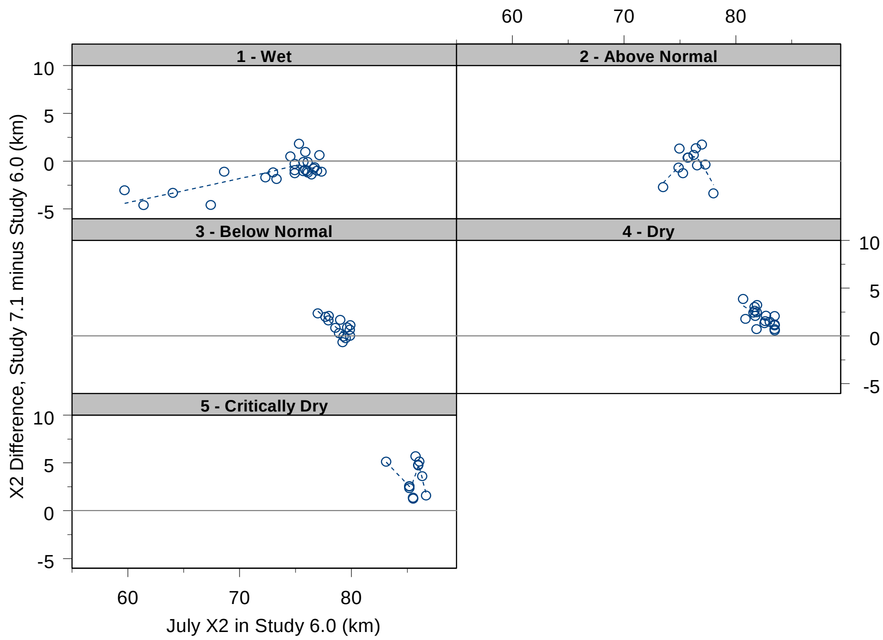


Figure 13-22 Variation in X2 in Study 7.1 with respect to Study 6.1 in July

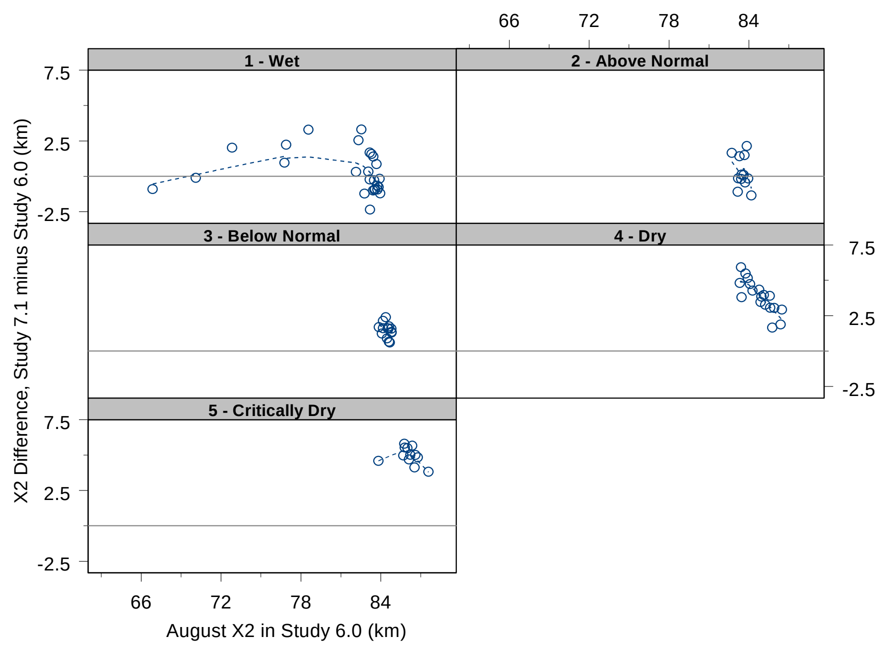


Figure 13-23 Variation in X2 in Study 7.1 with respect to Study 6.1 in August

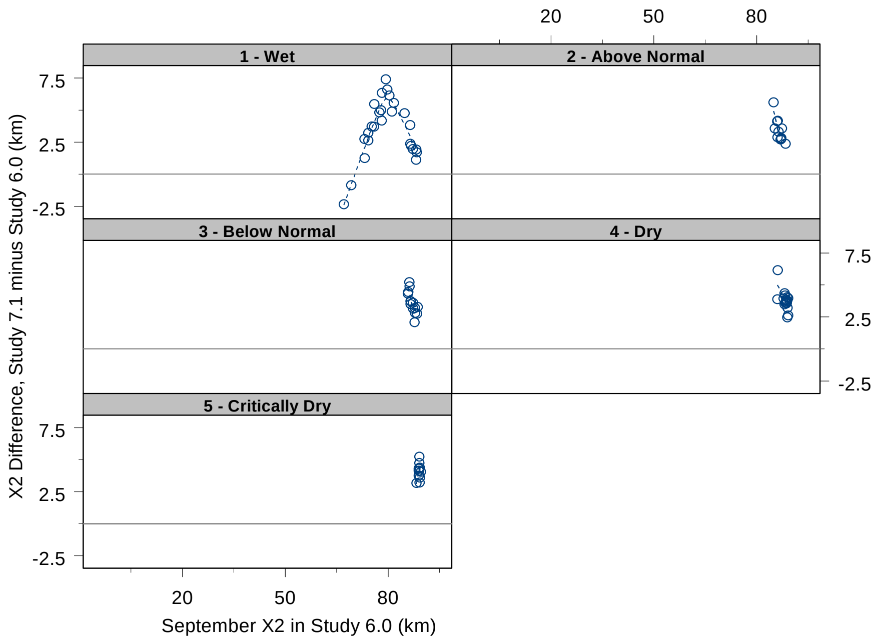


Figure 13-24 Variation in X2 in Study 7.1 with respect to Study 6.1 in September

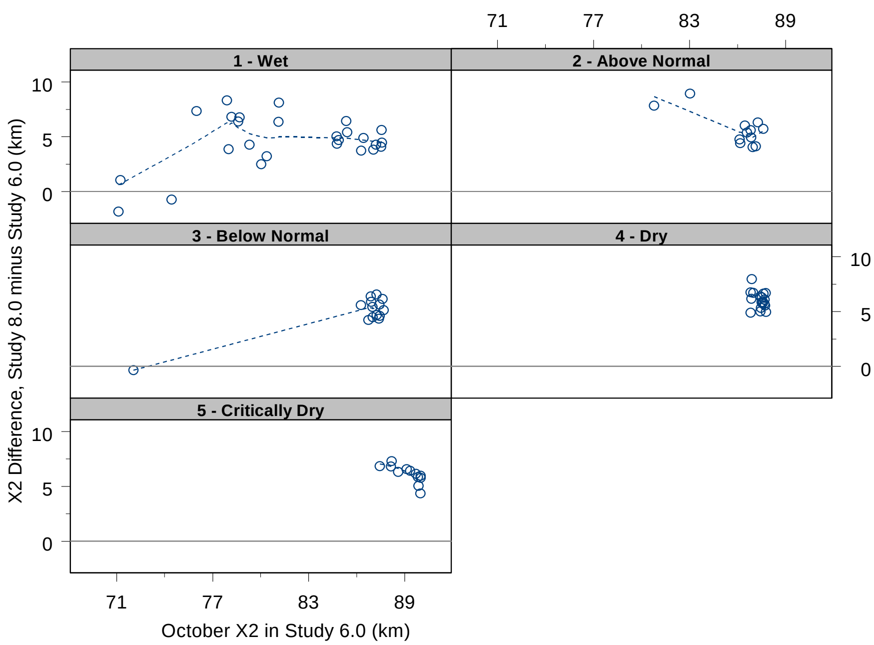


Figure 13-25 Variation in X2 in Study 8.0 with respect to Study 6.1 in October

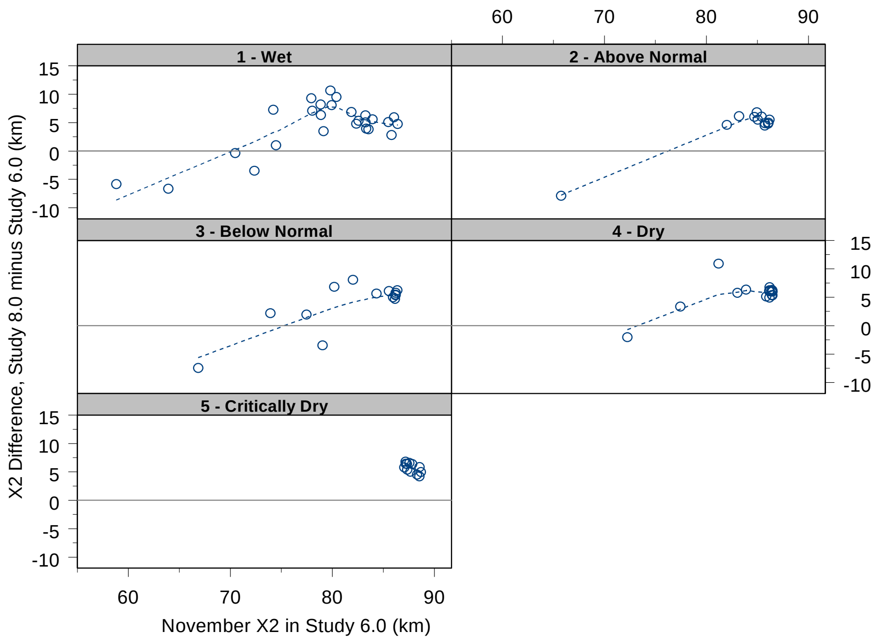


Figure 13-26 Variation in X2 in Study 8.0 with respect to Study 6.1 in November

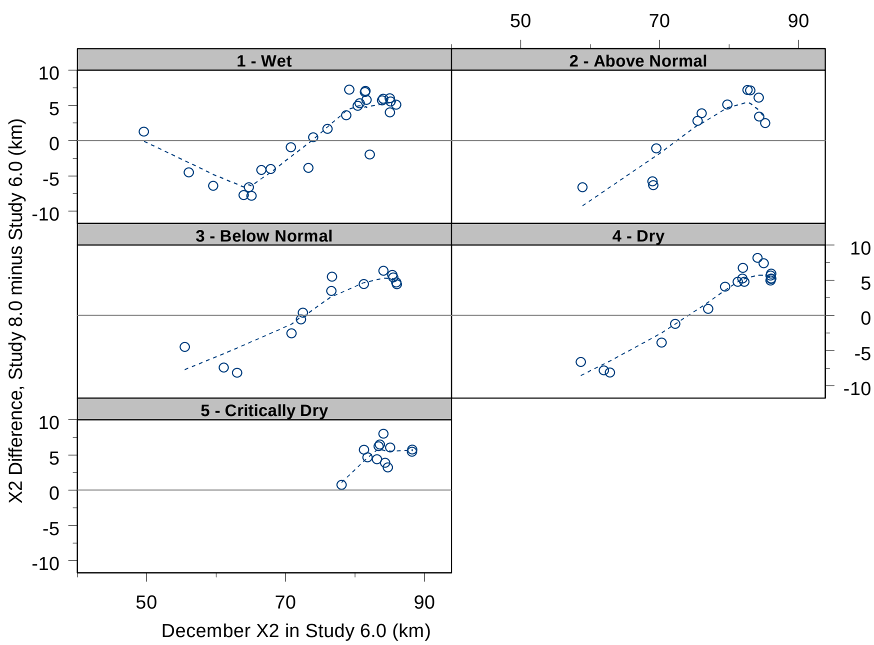


Figure 13-27 Variation in X2 in Study 8.0 with respect to Study 6.1 in December

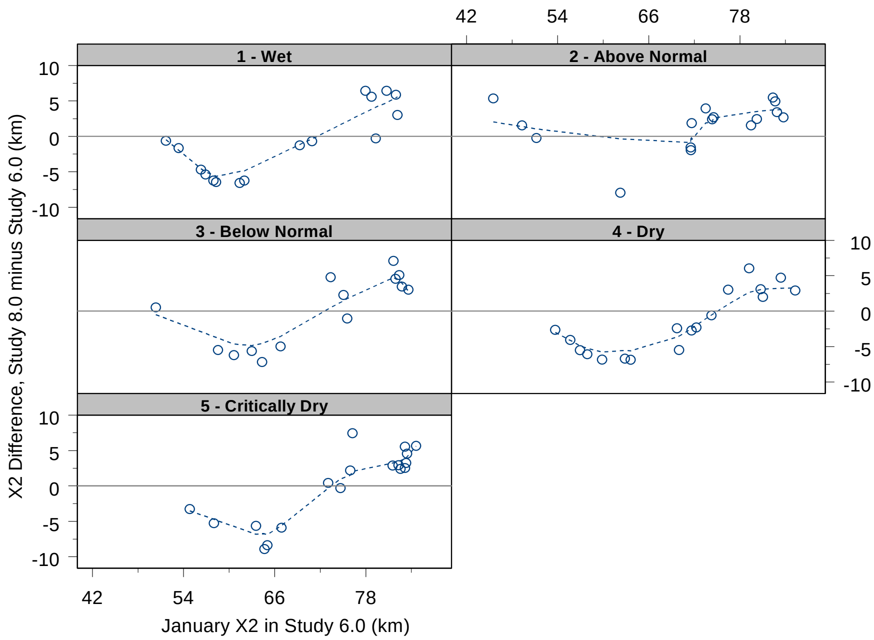


Figure 13-28 Variation in X2 in Study 8.0 with respect to Study 6.1 in January

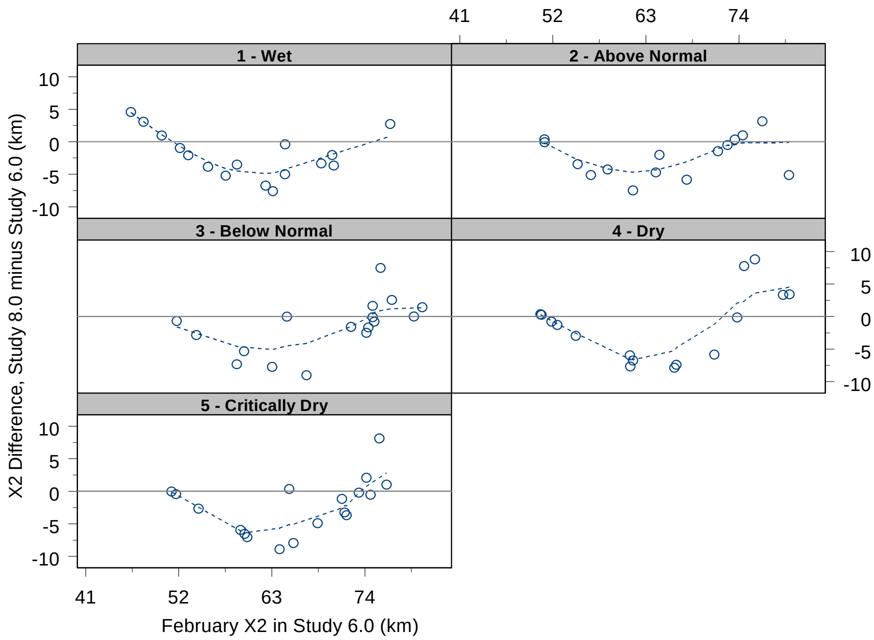


Figure 13-29 Variation in X2 in Study 8.0 with respect to Study 6.1 in February

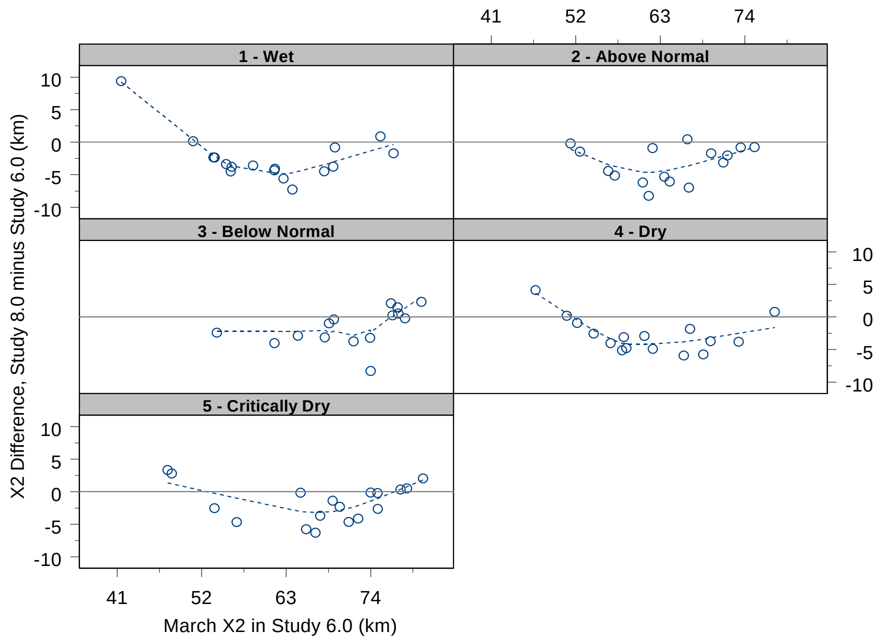


Figure 13-30 Variation in X2 in Study 8.0 with respect to Study 6.1 in March

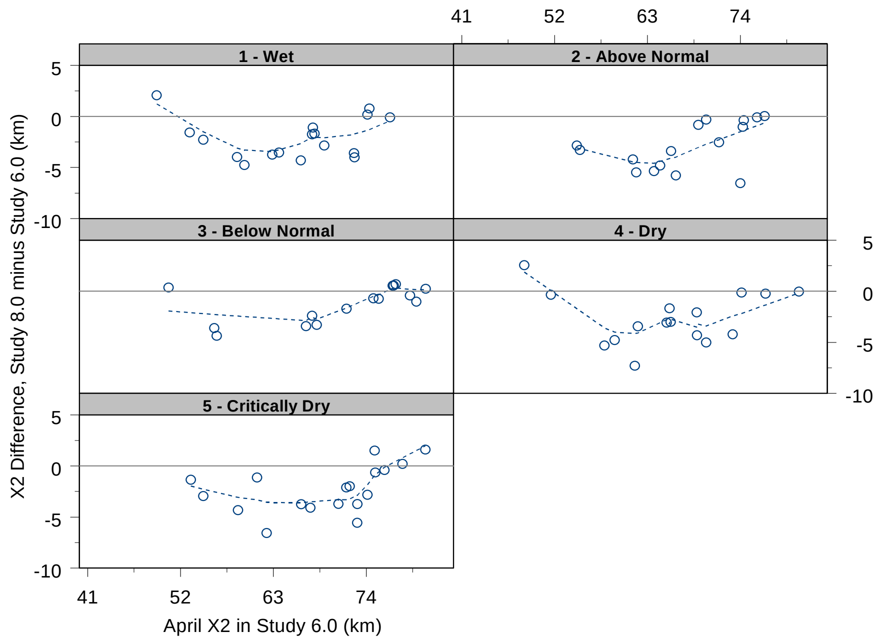


Figure 13-31 Variation in X2 in Study 8.0 with respect to Study 6.1 in April

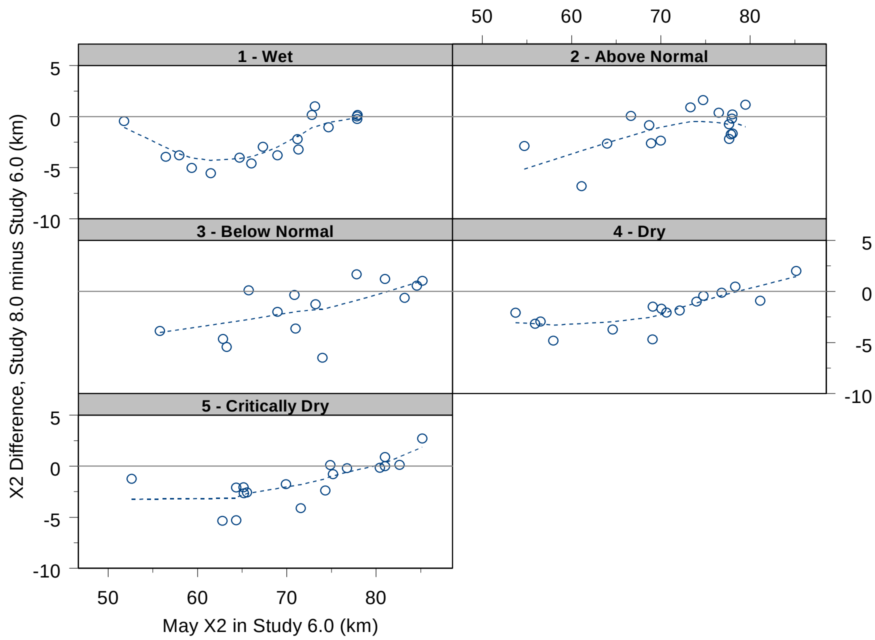


Figure 13-32 Variation in X2 in Study 8.0 with respect to Study 6.1 in May

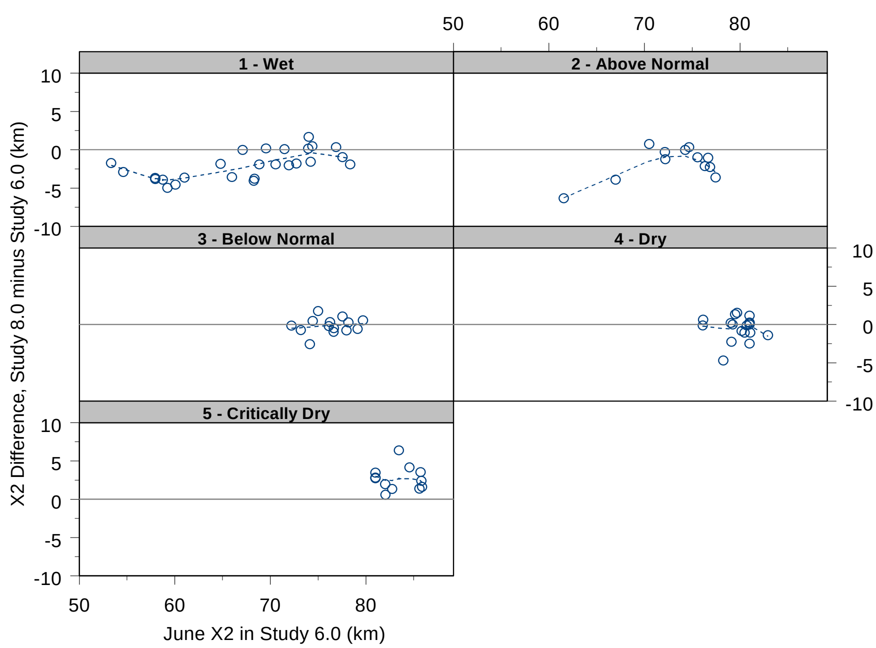


Figure 13-33 Variation in X2 in Study 8.0 with respect to Study 6.1 in June

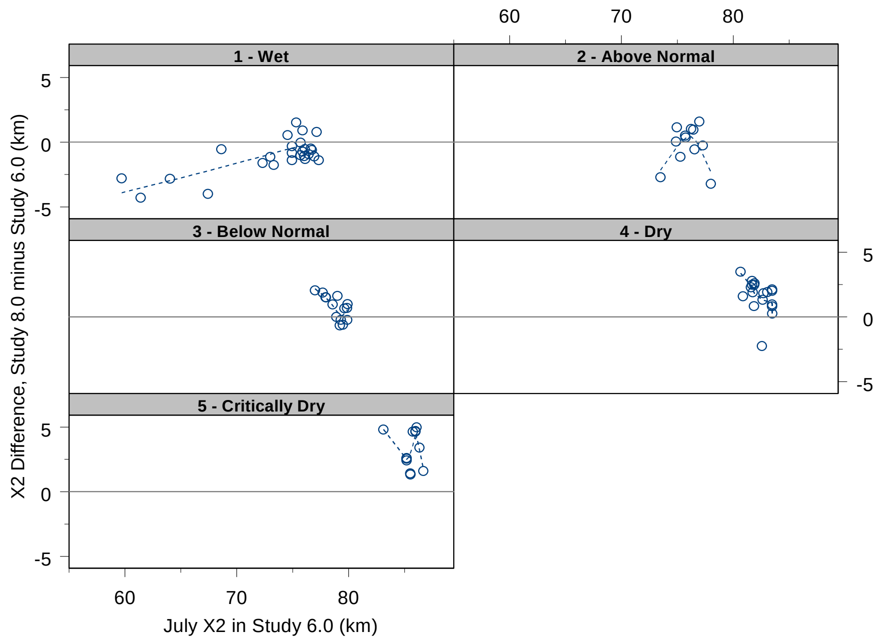


Figure 13-34 Variation in X2 in Study 8.0 with respect to Study 6.1 in July

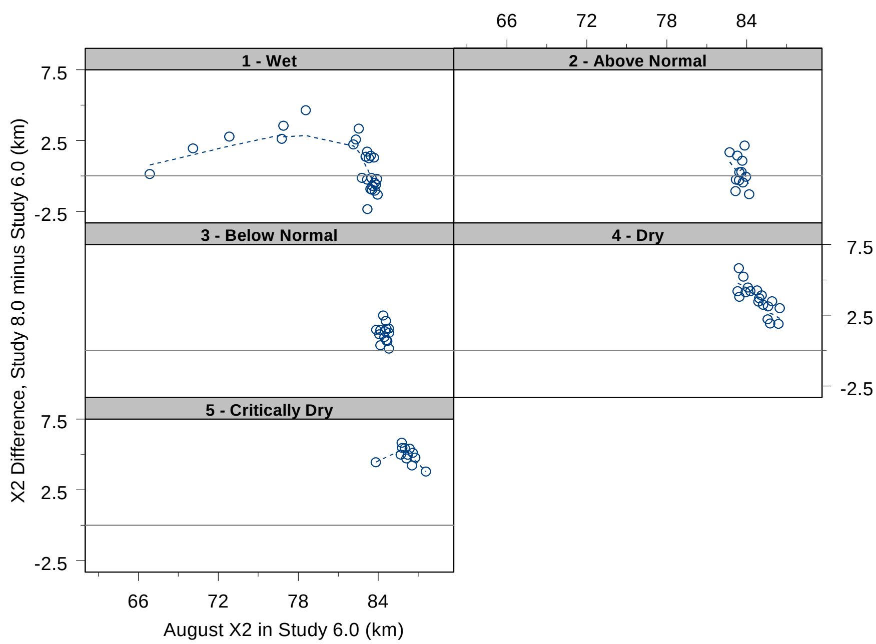


Figure 13-35 Variation in X2 in Study 8.0 with respect to Study 6.1 in August

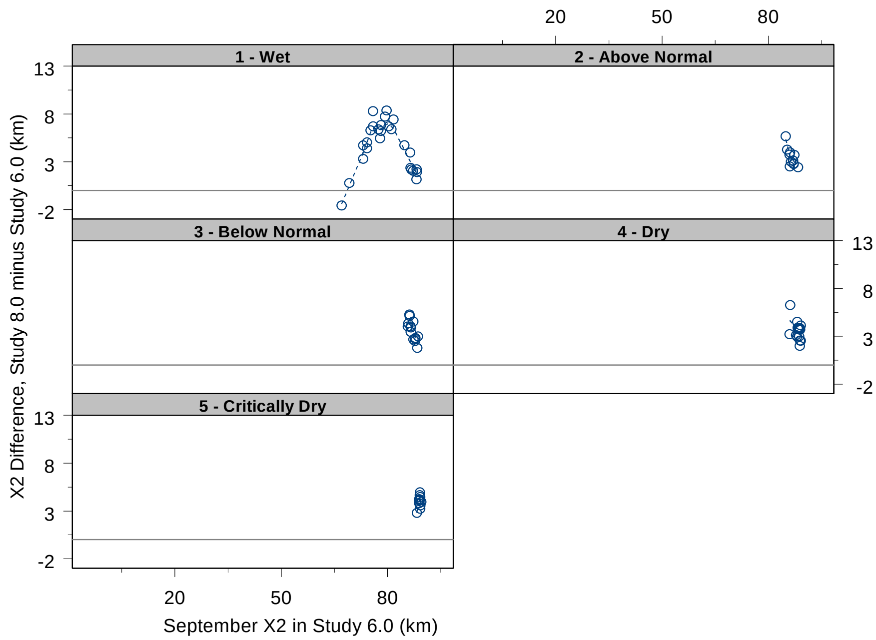


Figure 13-36 Variation in X2 in Study 8.0 with respect to Study 6.1 in September

Climate Change

The evaluation of climate change effects presented here is adapted from Appendix R sections 4.2.2 through 4.3.2. Appendix R reports an analysis of the potential implications of climate change for the CVP and SWP that is intended to examine the sensitivity of of CVP/SWP operations and system conditions to a range of future climate conditions that may evolve over the consultation horizon (2030) of the BA. It develops four climate change scenarios intended to bookend the range of possibilities arising from available climate projection information. The bookends span the range of outcomes developed under the assumptions of CalSim-II Study 8 with respect to two variables: precipitation and temperature. All four scenarios are based on the assumptions, derived from published sources, that sea level will rise approximately 30 cm by 2030, and that the tidal range will increase by 10 percent.

We have considered the possible consequences to delta smelt that arise out of the four scenarios. For delta smelt, the impacts likely to be associated with climate change would be caused by (a) changes in the availability and distribution of habitat, as indexed by X2, and (b) changes in entrainment at the CVP and SWP export facilities in the south delta. To address the possibility that changes in habitat and entrainment rates might affect delta smelt under the four climate change scenarios, this evaluation consists of the following elements:

(1) Consideration of the effects of a 1 ft (30 cm) sea level rise in a comparison with the base case (no change in temperature or precipitation)

(2) Consideration of X2 for each of the four climate change scenarios

(3) Consideration of the DSM2 OMR flows results for each of the four climate change scenarios [with adapted tables 17,18,19]

(4) Consideration of uncertainties associated with the climate change analyses

Effects of Sea Level Rise Alone

This review is limited to the months of February through June, which are the months addressed in Appendix R. However, because sea level is likely to proportionately rise in all seasons, we expect results for the summer and fall to be similar to the modeled months in which the least precipitation occurs (May and June). The assumed 1 ft rise in sea level is likely to move X2 upstream by 1 km to 3 km in the base study, Study 9.1 (Figure 13-37 blue and red-hashed white columns). For the months of February through approximately April, X2 and its variability are similar (Figure 13-37). However, for the months of May and June, the median X2 moves upstream in the presence of sea level rise relative to the base case (loc cit). Moreover, the 95th percentile X2 in those months is much farther upstream (approx. 15 km in May and 20 km in June) than in the base case, indicating circumstances that would be expected to very substantially alter delta smelt habitat availability and location.

These results suggest that sea level rise alone is likely to result in upstream movement of delta smelt habitat during months not modeled and also not subject to X2 control, particularly the fall months. We would expect a 1-3 km upstream movement of X2 during the fall on top of movement expected under Study 8.0 to reduce the availability of high quality habitat available to maturing delta smelt (see X2 section below). Furthermore, increased late spring/summer entrainment risk arising from movement of smelt habitat closer to the export pumps is a possibility that should be considered, at least in the more extreme cases predicted by the model.

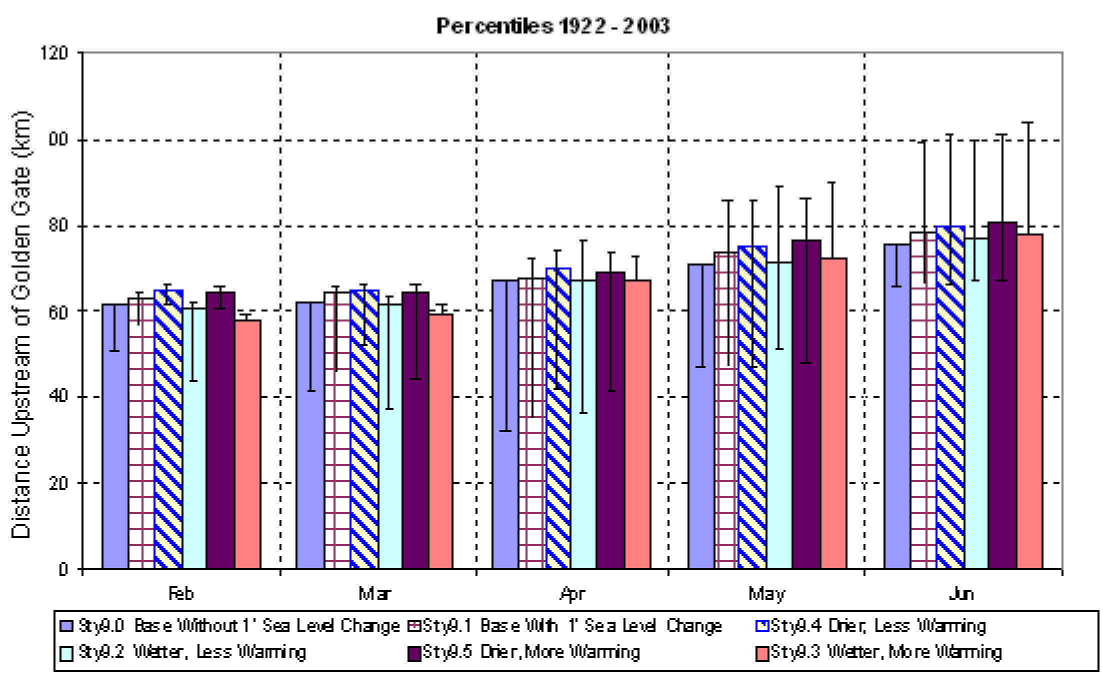


Figure 13-37 X2 in climate change studies. The bars represent 50th percentile with 5th and 95th as the whisker.

Changes in X2 in Climate Change Scenarios

This review is limited to the months of February through June, which are addressed in Appendix R. However, because sea level is likely to proportionately rise in all seasons, we expect expect results for the summer and fall to be similar to the modeled months in which the least precipitation occurs (May and June). The wetter scenarios (wetter/less warming and wetter/more warming) produced similar outcomes (Figure 13-37). In the wetter scenarios, X2 is similar to or lower than the base case for February through May, but both high precipitation scenarios result in a 1-2 km upstream movement of X2 in June. Both wetter scenarios also predict a higher incidence of X2 movement upstream of the median than the base case.

The drier scenarios (drier/less warming and drier/more warming) were also similar to one another (loc cit). Both drier scenarios produced upstream movements of 2-3 km in all months during February through June. As with the wetter scenarios, both produced a higher frequency of substantial upstream X2 movement exceeding 20 km in June.

These results suggest that the drier scenarios would produce more substantial movement of X2 upstream than sea level rise alone, but that the wetter scenarios either conform to the sea level-based prediction or (in February and March) may result in downstream X2 movement. Upstream movement of 1-3 km in several scenarios would likely result in a loss of habitat quality for delta smelt in the fall months (see X2 section below). Extreme upstream movement occurring in a small percentage of years could also substantially increase the risk of entrainment during these months.

Changes in OMR Flow in Climate Change Scenarios

We examined OMR flow rather than export pumping predictions because of the tighter relationship between OMR flow and entrainment. The changes in OMR flow under the various scenarios were more mixed than changes in X2. Fall and winter flows were the most sensitive to climate change, with the polarity of changes depending on precipitation:

(a) Negative winter flows become more extreme during drier years in all scenarios and during wetter years for the drier climate change scenarios

(b) Negative winter flows increase during wetter years for the wetter, less warming scenario

(c) Winter flows changed from negative to positive during wetter years for the wetter, more warming scenario

OMR flow in the base case, changes in OMR flow, and percent change in OMR flow are presented in Appendix R Tables 15, 17, and 19 (pp. 99-103) for “more warming” scenarios and Tables 16, 18, and 20 (pp. 100-104) for “less warming” scenarios.. In these tables, negative values indicate an upstream shift in OMR flow. Increases in upstream OMR flow are likely to cause proportionately higher levels of delta smelt entrainment during the months of December through March (adults) and March through July (larvae and juveniles).

Overall, the pattern of results suggests that OMR flow during January through June becomes more negative during dry years in the drier/less warming and drier/more warming scenarios, but with some substantial changes that are mostly either increases in negative flow or decreases in positive flow in the other scenarios. In other words, in the drier climate change scenarios we would generally expect to see higher entrainment of delta smelt during January through June under the operational assumptions of Study 8 than in the absence of climate change.

Uncertainty about Climate Change

Appendix R cautions that there are several sources of uncertainty in this modeling, and, in fact, has been structured to reflect the absence of a “most likely” or consensus climate trajectory arising from available projections. The uncertainties enumerated in Section 5 of Appendix R include:

(a) uncertainties about climate forcing, including greenhouse gas emission pathways, the role of biogeochemical cycles, and atmospheric contributions to climate forcing

(b) climate simulation, including the physical paradigms underlying climate models and computational methodologies

(c) climate projection bias-correction

(d) climate projection downscaling to local scales

(e) watershed response to changing climatic conditions

(f) social response to changing climate

(g) discretionary operational response to changing climatic conditions and evolving pressures associated with the change

Given these qualifications, the evaluation here should be viewed as conditional upon both the assumptions made in Appendix R and those made here and in Chapter 7, with potentially significant uncertainties neither quantified nor represented.

500 CFS Increased Diversion to Provide Reduced Exports Taken to Benefit Fish Resources

Delta Smelt

Clifton Court Forebay (CCF) is typically operated at or near the rates defined in the USACE Public Notice 5820A, Amended, unless otherwise restricted. Public Notice 5820A, Amended, requires that daily summer diversions into CCF not exceed 13,870 AF and a three-day average not to exceed 13,250 AF. Banks Pumping Plant is operated to the available physical capacity, as constrained by CCF operations. Banks Pumping Plant is also adjusted to assist in maintaining velocity criteria at Skinner Fish facility as exports allow. Maximum average monthly SWP summer exports from Banks Pumping Plant are 6,680 cfs.

Under the 500 cfs increased diversion, the maximum allowable daily diversion rate into CCF during the months of July, August, and September would increase from 13,870 AF up to 14,860 AF and three-day average diversions would increase from 13,250 AF up to 14,240 AF. This increased diversion over the three-month period would result in an amount not to exceed 90,000 AF each year. Maximum average monthly SWP exports during the three-month period from Banks Pumping Plant would increase to 7,180 cfs. Variations to hydrologic conditions coupled with regulatory requirements may limit the ability of the SWP to fully utilize the proposed increased diversion rate. Also, facility capabilities may limit the ability of the SWP to fully utilize the proposed increased diversion rate

Water exported under the 500 cfs increased export limit would first be used to recover export reductions taken during the VAMP period (assumed mid-April to mid-May) or applied to the "shoulder" periods preceding or following the VAMP period. Any remaining water could be applied to other export reductions for fish protection during that calendar year or be stored in San Luis Reservoir to be applied to export reductions for the subsequent calendar year. As the SWP share of San Luis Reservoir is filled, there is a risk that this water would be "spilled" from the reservoir. "Spilling" the stored water would result in lower exports from the Delta during the time the reservoir is filling. Normally, this would occur during December – March. The fishery agencies would decide whether to implement an export reduction in the fall or winter time period equivalent to the water stored in the reservoir or assume the risk that the water would be spilled later on. Additional details regarding the implementation of the 500 cfs increased diversion are contained in Chapter 2.

Analyses Contained in the Initial Study

Much of the information in this discussion is taken from the *Initial Study for the 2005 – 2008 State Water Project Delta Facility Increased Diversion to Recover Reduced Exports Taken to Benefit Fish Resources* (DWR 2004). The operation analyzed in the Initial Study and implemented in 2005 – 2008 is slightly different than the operation contained in this project description. The difference is the ability to carry over water exported under the 500 cfs increased diversion limit into the subsequent calendar year. The operation analyzed in the Initial Study and implemented through 2008 does not allow carry over of the exported water. The operation to begin in 2009 allows carry over of the exported water as long as it does not affect the ability to fill the SWP share of San Luis Reservoir. Water exported under the 500 cfs export limit is to be used only for export reductions to benefit fish resources.

The Initial Study uses a comparative analysis to quantify the impacts of the 500 cfs increased diversion (Project) compared to a no-project (Base) condition. The range of potential impacts is defined by modeling two hydrologies: a year of low delta inflow, and a year of high delta inflow. The hydrologies are used as input for the DWRDSM2 HYDRO and QUAL studies, which evaluate changes in flow, stage, velocity, and salinity. Tidally averaged comparisons of water quality, flow, stage, and velocities for all the locations studied are in Appendix II of the Initial Study (DWR 2004). The modeling assumptions for the Project include the following:

- Two 30-day periods to reduce diversions to benefit fish resources are chosen: May 15-June 15, and November 15–December 15. The total reduction in diversions cannot exceed 90 TAF.
- The operations of the SWP and CVP must comply with existing Bay-Delta requirements of the SWRCB Decision 1641. Operations are assumed to comply with the ESA, and other regulatory and contractual requirements related to the Sacramento-San Joaquin River Delta.
- Current SWP operations allow a maximum three-day average diversion rate of 6,680 cfs during July, August, and September. Project diversions during that period must exceed the maximum three-day average diversion rate of 6,680 cfs to constitute a with-Project condition since diversions less than that amount are already permitted in the base condition.

- The increased diversions during July, August, and September of any calendar year equals the amount of reduced diversions during that calendar year.

The historic hydrologies were examined to find a representative period and a high and low inflow year. The representative period is from1987 to 1999 and the low and high inflow years are 1992 and 1997. The reasons for selecting 1992 and 1997 are discussed below.

1992, Low Delta Inflow Year

Two difficulties in selecting a year of low delta inflow occurred. Exports in years of low delta inflow during each of the two 30-day periods, (May 15-June 15, and

November 15–December 15) typically did not exceed 90 TAF. Current constraints on export/inflow ratios were instituted in 1995 under the Bay-Delta Accord. All years since 1995 have been classified as wet years (up to the year 2000). Therefore, historic operations during a year of low delta inflow with current regulatory constraints did not exist at the time of the study.

Three years of low delta inflow were considered: 1987, 1988, and 1992. In 1987 and 1988, exports during the two 30-day periods, (May 15-June 15, and November 15-December 15) could be reduced by 90 TAF. However, operations prior to 1995 were not subject to existing regulatory requirements, and thus the export/inflow ratios during 1987 and 1988 exceeded existing export/inflow requirements of the SWRCB. In 1987, daily exports exceeded present requirements by an average of 2744 cfs, and a maximum of 6146 cfs. Therefore, 1987 and 1988 were eliminated from consideration.

In 1992, exports during the two 30-day periods, May 15-June 15, and November 15-December 15, were approximately 46 TAF and 66 TAF, respectively. Therefore, exports could not be reduced by the full proposed amount of 90 TAF. Although export/inflow ratios exceeded existing requirements, the existing requirements could be met with minor adjustments to the historic inflow. In 1992, present export/inflow ratio requirements could be met by increasing Sacramento River inflow by an average of 11 cfs. For these reasons, 1992 was selected as the year to represent conditions of low Delta inflow.

1997, High Delta Inflow Year

Current constraints on export/inflow ratios were instituted in 1995 and delta inflow during the subsequent years was high. Therefore, several years of historic operations with high delta inflow and current regulatory constraints exist. Thus, 1995-1999 were considered. SWP exports during May 15-June 15 exceeded 90 TAF in 1995, 1996, and 1997. In 1998 and 1999, SWP exports during May 15-June 15 were only 78 TAF and 71 TAF, respectively, which would not allow a reduction for the full proposed amount of 90 TAF. 1995 was not chosen because SWP exports during the November 15 to December 15 period were only 6,210 AF. 1996 was not chosen because SWP exports during May 15-June 15 were 294 TAF, and this was not considered a representative year. In 1997, SWP exports during May 15-June 15 and November 15 to December 15 period were 100 TAF and 644 TAF, respectively.

Historic vs. Base Hydrologies

The historic hydrologies were modified so the base hydrologies would comply with the initial assumptions explained above and repeated below:

- The operations of the SWP and CVP must comply with existing requirements of SWRCB Decision 1641, with the ESA, and other regulatory and contractual requirements related to the Sacramento-San Joaquin River Delta.
- Current SWP operations allow a maximum three-day average diversion rate of 6,680 cfs during July, August, and September. Project diversions during that period must exceed the maximum three-day average diversion rate of 6,680 cfs because diversions less than this base condition are already permitted.

Sacramento River flows were also modified from historic conditions. When export/inflow ratios exceeded existing requirements, Sacramento River flows were increased until existing constraints were met. When exports were modified, Sacramento River flows were modified to maintain the net delta outflow. Thus, the SWP was simply changing the time when storage in Oroville was being moved to San Luis Reservoir.

The potential changes in diversion rate into CCF will affect fish salvage at the SWP. To determine the impact of such export changes, historic salvage data from 1992 and 1997 (representative low and high Delta inflow years used in the modeling) were used to estimate the impact of the Project on fish salvage. Historic salvage density was used to estimate salvage under the different export scenarios through extrapolation as shown in the table below.

Potential Impacts of Water Quality and Flow on Fish

Potential impacts to 10 species, including delta smelt, salmon, steelhead and sturgeon, were examined by two methods. First, the water quality and flow modeling results were examined to determine if they posed potential impacts to fish. Second, historic salvage data was examined to determine if the Project posed potential impacts to delta smelt, salmon, steelhead and sturgeon salvage.

The modeling results predicted minor changes in water quality, which would result in no impacts to delta smelt.

The changes in flow predicted by the modeling suggest that there will be no significant negative impacts to delta smelt distribution. The largest changes in flow occurred during the spring pumping reduction. Flows towards CCF decreased by as much as 2,250 cfs. Decreased flows towards CCF may decrease the potential vulnerability of delta smelt to SWP salvage. The modeling results predicted that flows only slightly increased towards CCF during the increased pumping period, suggesting there will be no impact on delta smelt distribution and subsequent vulnerability to SWP salvage. There are no anticipated changes in total outflow that could impact delta smelt.

Potential Impacts to Fish Salvage

Historic salvage data for ten sensitive fish species or runs, including delta smelt, were analyzed to determine the impact of the proposed project. The fish species may occur in the project area during the project period.

The potential changes in diversion rate into CCF will affect fish salvage at the SWP. To determine the impact of such export changes, historic salvage data from 1992 and 1997 (representative low and high Delta inflow years used in the modeling) were used to estimate the impact of the Project on fish salvage. Historic salvage density was used to estimate salvage under the different export scenarios through extrapolation.

The difference in fish salvage between the base and Project conditions was used as the effect of the Project on fish salvage. Base (No-Project) salvage was calculated as the product of historic salvage density (number of fish salvaged per AF diverted) and modeled base exports. Project salvage was calculated as the product of historic salvage density and modeled Project exports. The effect of the Project on fish salvage was the difference between the Project and base salvage estimates. For example:

historic salvage / historic AF diverted = historic salvage density (HSD)

HSD x base exports = estimated base salvage (BS)

HSD x Project exports = estimated Project salvage (PS)

PS – BS = estimated difference in salvage from the base caused by the Project.

The results of this analysis (Table 13-19) suggest that salvage of delta smelt is likely to substantially decrease under the spring scenarios and not substantially change under the fall scenarios; reduced exports in the months of May and June in the spring scenario are likely to reduce the salvage of delta smelt for the year. The studies can be used to draw conclusions about other potential operations. For example, if the export reduction were taken only in May 1997 (48 taf), 90 taf were exported in July-September, and the remaining 42 taf applied as reduced exports in December, the net reduction in delta smelt salvage for the May-December period would be 10,286 (with a reduction of 10,282 occurring in May).

Table 13-19 Delta smelt

Spring 1992	May	Jun	Jul	Aug	Sep	Total
Historic exports	42,376	57,220	25,689	90,836	161,905	378,026
Historic salvage	1,903	2,367	24	0	0	4,294
Historic salvage density	0.0449	0.0414	0.0009	0.0000	0.0000	-
Base exports	15,099	56,040	410,018	410,018	396,792	1,287,968
Base salvage	678	2,318	383	0	0	3379
Project exports	0	25,469	425,732	425,732	411,036	1,287,969
Project salvage	0	1,054	398	0	0	1,451
Percent change	-100%	-55%	4%	0	0	--57%

Fall 1992	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	25,689	90,836	161,905	62,303	168,276	509,009
Historic salvage	24	0	0	0	0	24
Historic salvage density	0.0009	0.0000	0.0000	0.0000	0.0000	-
Base exports	410,018	410,018	396,792	66,651	35,531	1,319,011
Base salvage	383	0	0	0	0	383
Project exports	432,852	432,852	417,390	35,917	0	1,319,011
Project salvage	404	0	0	0	0	404
Percent change	5%	0	0	0	0	5%

Spring 1997	May	Jun	Jul	Aug	Sep	Total
Historic exports	78,236	153,854	321,231	269,918	341,334	1,164,573
Historic salvage	16,760	6,140	216	0	0	23,116
Historic salvage density	0.2142	0.0399	0.0007	0.0000	0.0000	-
Base exports	47,995	153,058	410,018	410,018	396,792	1,417,882
Base salvage	10,282	6,108	276	0	0	16,666
Project exports	0	111,953	440,708	440,708	424,512	1,417,882
Project salvage	0	4,468	296	0	0	4,764
Percent change	-100%	-27%	7%	0	0	-71%

Fall 1997	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	321,231	269,918	341,334	292,036	419,732	1,644,251
Historic salvage	216	0	0	0	257	473
Historic salvage density	0.0007	0.0000	0.0000	0.0000	0.0006	-
Base exports	410,018	410,018	396,792	292,923	196,804	1,706,556
Base salvage	276	0	0	0	121	396
Project exports	440,708	440,708	424,512	245,403	155,224	1,706,556
Project salvage	296	0	0	0	95	391
Percent change	7%	0	0	0	-21%	-1%

Note: Row headers for the above table are as follows:
Historic exports = Actual SWP exports for given month (AF).
Historic salvage = Actual SWP salvage for given month.
Historic salvage density = Historic salvage ÷ historic exports (number of fish/AF).
Base exports = Modeled base exports for given month.
Base salvage = Historic salvage density x modeled base exports.
Project exports = Modeled project exports for given month.
Project salvage = Historic salvage density x modeled project exports.
Percent change = (Project salvage – Base salvage) x 100%/Base salvage

Clifton Court Forebay Aquatic Weed Control Program

Effects on Delta Smelt

The Department of Boating and Waterways (DBW) prepared an Environmental Impact Report (2001) for a two-year Komeen research trial in the Delta. They determined there were potential impacts to fish from Komeen treatment despite uncertainty as to the likelihood of occurrence. Uncertainties exist as to the direct impact that Komeen and Komeen residues may have on fish species. “The target concentration of Komeen is lower than that expected to result in mortality to most fish species, including delta smelt” (Huang and Guy 1998). However, there is evidence that, at target concentrations, Komeen could adversely impact some fish species. The possibility exists that Komeen concentrations could be lethal to some fish species, especially during the first nine hours following application. Although no tests have examined the toxicity of Komeen to Chinook salmon or steelhead, LC50 data for rainbow trout suggest that salmonids would not be affected by use of Komeen at the concentrations proposed for the research trials. No tests have been conducted to determine the effect of Komeen on splittail, green sturgeon, pacific lamprey or river lamprey.” (DBW, 2001) or delta smelt.

In 2005, no fish mortality or stressed fish were reported during or after the treatment. The contractor, Clean Lakes, Inc was looking for dead fish during the Komeen application. In addition, no fish mortality was reported in any of the previous Komeen or Nautique applications. In 2005, catfish were observed feeding in the treatment zone at about 3 pm on the day of the application (Scott Schuler, SePro). No dead fish were observed. DWR complied with the NPDES permit that requires visual monitoring assessment.

Due to the uncertainty of the impact of Komeen on fish that may be in the Forebay, we will assume that all delta smelt in the Forebay at the time of application are taken. The daily loss values vary greatly within treatments, between months and between years. Figure 13-38 illustrates the presence of delta smelt in the Forebay during treatments. There are no loss estimates for delta smelt, so the relationship between salvage and true loss of delta smelt in the Forebay in unknown.

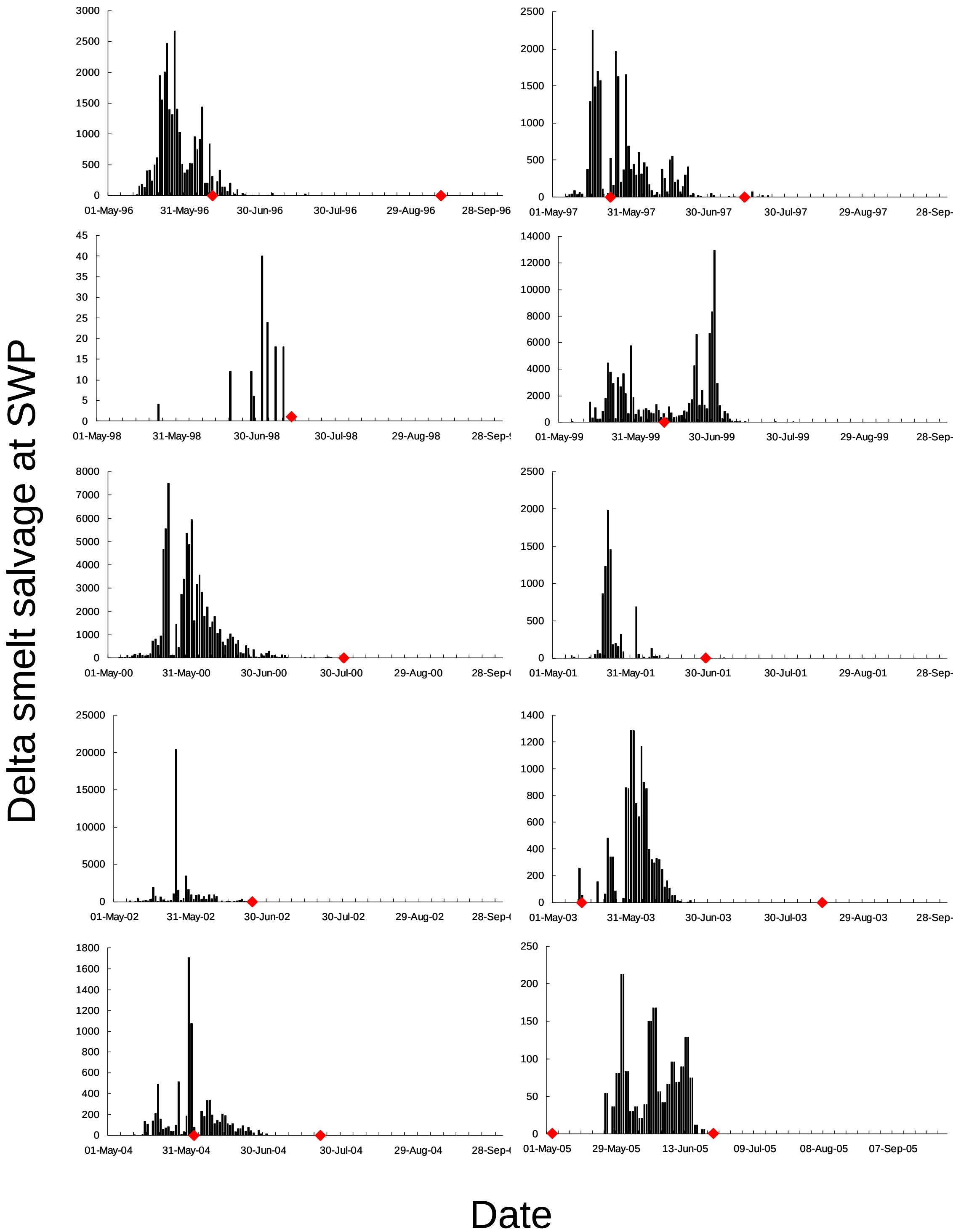


Figure 13-38 May-September delta smelt salvage at the SWP Banks Pumping Plant, 1996-2005, with the start and end dates of Komeen or Nautique aquatic weed treatment indicated by the red diamonds.

North Bay Aqueduct

Summer (Jun-Aug)

The summer pumping rates of NBA diversions were not different between studies 7.0 and 7.1 (average 42 cfs) but both were 12 percent lower than study 8.0 (average 48 cfs) (Chapter 12). Hydrodynamic modeling results from the Solano County Water Agency (SCWA) indicate that at a 42 cfs pumping rate, the major water source pumped by the NBA during normal water years origins from Cambell Lake, a small non-tidal lake north of Barker Slough. Thus under most summer-time conditions the entrainment effects are likely to be low, especially since delta smelt move downstream by July (Nobriga et al. 2008). In dry seasons, the NBA entrains water from Barker and Lindsay sloughs (SCWA), indicating a potential entrainment risk for delta smelt. Historically, delta smelt densities have been low in Barker and Lindsay sloughs but the modeling data suggest that delta smelt could exhibit some level of entrainment vulnerability during dry years. But it should be noted, that these effects are likely to be small since most delta smelt reach 20 mm SL by June (http://www.delta.dfg.ca.gov/data/NBA/) and are therefore protected by the fish screens on the NBA intakes designed to protect smelt this size.

Fall (Sept-Nov)

North Bay aqueduct diversions are lowest in the fall (Chapter 12) only averaging 18 cfs in study 7.0, 17.6 cfs in study 7.1, and 23 in study 8.0. Overall, there was no difference in fall diversions rates among the studies. As discussed previously, delta smelt reside in the Suisun Bay to Sherman Island region during the fall months and are not at sizes vulnerable to NBA entrainment at this time. Thus, there are no expected direct effects of the NBA on delta during this period. Because pumping rates are low and the hydrodynamic models indicate only a small percentage of water entrained enters from Barker Slough, it is unlikely the NBA has any measurable indirect effects during this period.

Winter (Dec-Feb)

North Bay Aqueduct diversions are highest during the winter months. There were no differences between studies 7.0 and 7.1 during the winter but diversion rates rate for study 8 in December (64 cfs) was higher than diversion rates for studies 7.0 (43 cfs) and 7.1 (41 cfs). The hydrodynamic modeling of NBA diversions indicates that the majority of water diverted origins from Cambell Lake and Calhoun Cut during the winter. As previously mentioned, delta smelt migrate up into the Delta during the winter months. However, since the screens on the intakes meet criteria for protecting 20 mm SL delta smelt, adult entrainment is not a concern.

In some years, delta smelt will begin spawning in February when temperatures reach about 12 ^{o}C (Bennett 2005). Thus in some years, delta smelt larvae may be entrained at the NBA diversions. However since the majority of water diverted origins from Cambell Lake during the winter, these effects are likely to be minimized to the areas of Barker Slough near the NBA intakes. During years when the Yolo Bypass floods, the entrainment risk of larvae into the NBA is also probably extremely localized because of a hydrodynamic “plug” that forms between Barker and Lindsay sloughs with Cache Slough. When this happens, hydrodynamic mixing between Cache Slough and Lindsay/Barker sloughs decreases, causing spikes in turbidity and organic carbon in Barker and Lindsay Sloughs (DWR, North Bay Aqueduct Water Quality Report). Entrainment vulnerability would be greatest during dry years when the NBA diversions entrain a large portion of water from Barker and Lindsay Sloughs and are often years when delta smelt will spawn in the North Delta (Sweetnam 1999).

Spring (Mar-May)

The only difference in NBA diversions during the spring were for April, where study 8.0 had an approximately 20 percent higher diversion rate than studies 7.0 and 7.1 (Chapter 12). NBA diversions ranged between 30 and 54 cfs during the spring, indicating that the majority of water diverted origins from Campbell Lake at these diversions rates. Thus a 20 percent increase in study 8 from studies 7.0 and 7.1 is negligible when you account for the source of water diverted. Overall, spring represents the period of greatest entrainment risk for delta smelt larvae at the NBA, especially in dry years when delta smelt spawn in the North Delta (http://www.delta.dfg.ca.gov/data/NBA/).

Rock Slough Intake

CCWD diverts water from Old River via Rock Slough into the Contra Costa Canal at the Rock Slough Intake. The diversion is presently unscreened. Reclamation, in collaboration with CCWD, is responsible for constructing a fish screen at the Rock Slough Headworks under the Central Valley Project Improvement Act and under the 1993 USFWS Biological Opinion for the Los Vaqueros Project. Reclamation has received an extension on fish screen construction until December 2008, and is preparing to request a further extension until at least 2013 because the requirements for screen design will change as CCWD proceeds with its project to replace the earth-lined portion of the canal with a pipeline.

Before 1998, the Rock Slough Intake was CCWD’s primary diversion point. It has been used less since 1998 when Los Vaqueros Reservoir and the Old River Pumping Plant began operating. The diversion at the headworks structure is currently sampled with a sieve net three times per week from January through June and twice per week from July through December. A plankton net is fished at the headworks structure twice per week during times larval delta smelt could be present in the area (generally March through June). A sieve net is fished at Pumping Plant #1 two times per week from the time the first Sacramento River winter-run Chinook salmon is collected at the CVP and SWP (generally January or February) through June. Numbers of listed fish species captured during monitoring are shown in Table 13-20.

The numbers of delta smelt entrained by the facility since 1998 have been extremely low, with only a single fish taken in February 2005 (Table 13-20).

The Contra Costa Canal Replacement Project will replace the 4-mile unlined section of canal from Rock Slough to Pumping Plant #1 with a pipeline. The project is fully permitted (NMFS issued its concurrence letter on June 11, 2007 and USFWS issued a BO on June 21, 2007) and the first phase of the project is scheduled to begin in the Fall of 2008. When completed, the Canal Replacement project will eliminate tidal flows into the Canal intake section and should significantly reduce entrainment impacts and improve the feasibility of screening Rock Slough.

Because most diversions at the Rock Slough intake now occur during the summer months when delta smelt and salmonids are not present in the vicinity of the diversion and because very few listed fish species (one winter–run Chinook, 14 spring-run sized Chinook, 6 unclipped steelhead, and one delta smelt) have been captured during monitoring from 1998 to 2008, the Rock Slough diversion is not believed to be a significant source of mortality for any of the listed species. No green sturgeon have been captured at the site.

It is expected that entrainment in the future will be reduced with the addition of CCWD's Alternative Intake Project because CCWD diversions in general during the migration period will be reduced, with most of that reduction taking place at the Rock Slough intake. (See the July 3, 2007 NMFS biological opinion on the Alternative Intake Project). Few listed runs have been captured in sampling since 1996 so take of listed runs is expected to be very low, probably fewer than 50 spring–run, 50 winter–run, and 20 steelhead. Estimates of future losses of spring-run Chinook salmon and winter-run Chinook salmon at the Rock Slough Intake with the Alternative Intake Project in service have been made assuming future CCWD demands of 188,000 af/year. Based on average densities of the salmon in channels (from monitoring programs over the past 10 years), losses were estimated at about 5 winter-run and 16 spring-run juveniles per year.

Table 13-20 Summary of listed fish captured at the Rock Slough Headworks and Pumping Plant 1 and amount of water diverted each year, 1998 – 2008.

Summary of Sieve Net and Plankton Net Monitoring Conducted at the Rock Slough Headworks and Pumping Plant 1 (PP1) from August 1998 through March 2008.

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Totals
Months Monitoring Occurred	**Aug-Dec**	**Mar-Dec**	**Mar-Dec**	**Jan-Aug**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Mar**	
Amount of Water Diverted at Rock Slough Acre Feet	68,683	43,037	51,421	26,749	35,904	27,302	31,283	35,686	43,273	39,366	5,848	408,552
Number of Headworks &PP1 Sieve Net Surveys	Unknown	Unknown	Unknown	Unknown	Unknown	35	102	131	133	107	54	**562**
Number of Headworks Plankton Net Surveys	Unknown	Unknown	Unknown	Unknown	10	0	34	26	15	23	10	**118**
Winter-run Chinook	Dec=1	0	0	0	0	0	0	0	0	0	0	**1**
Spring-run Chinook	0	0	0	0	0	0	Mar=1 Apr=5	May=4	May=4	0	0	**14**
Central Valley steelhead (unclipped)	0	0	0	0	0	0	0	Mar=2 Apr=1	Jan=1 Mar=1	May=1	0	**6**
Central Valley steelhead (clipped)	0	0	0	0	0	0	0	0	0	0	Feb=6 Mar=2	**8**
Central Valley steelhead (unknown)	0	0	0	0	0	0	0	Feb=1	0	0	0	**1**
Fall run/late fall run Chinook (unclipped)	0	0	May=3	0	0	0	Mar=2 Apr=3 May=1	Apr=2 May=6 Jun=1	May=1	0	0	**19**
Fall run/late fall run Chinook (clipped)	0	0	0	0	0	0	May=1	May=1	0	0	0	**2**
Green sturgeon	0	0	0	0	0	0	0	0	0	0	0	**0**
Delta smelt	0	0	0	0	0	0	0	Feb=1*	0	0	0	**1**
Longfin smelt	0	0	0	0	0	0	0	0	0	0	Mar=1**	**1**

South Delta Temporary Barriers (TBP)

The following evaluation is limited to the operational effects of these projects on delta smelt. Section 7 consultation for the construction and operation of the TBP through 2010 has been completed with NMFS. The operation effects of the TBP are being consulted upon with FWS through this OCAP BA. The construction effects requiring ESA consultation with FWS will be evaluated in a separate consultation process.

Simulation modeling completed for this OCAP BA incorporates the effects of the South Delta Temporary Barriers Project and 500 cfs increased export in Studies 6.1 and 7.0. The SDIP Stage 1, the 500 cfs increased export, and the CVP aqueduct intertie are incorporated into Studies 7.1 and 8.0. The Temporary Barriers are not included in Studies 7.1 and 8.0. A full evaluation of the combined effects of these elements on Chinook salmon, steelhead and green sturgeon are presented in Chapter 13. Because the simulation models examined the combination of these elements, it is not possible to separate and examine the effects of any single project element by itself. Therefore, the effects analysis for these individual projects is taken largely from prior Biological Assessments and other related consultations. The specific documents from which material was obtained include: *DWR 2000 Proposed Mitigated Negative Declaration and Initial Study Temporary Barriers Project 2001-2007 and 2007 Supplemental Biological Assessment South Delta Temporary Barriers Project.* Because the modeling for these documents was conducted a few years ago, it naturally differs to some degree from what was conducted for the OCAP Biological Assessment. However, the differences are not such that they would alter any interpretation of the likely general effects of these projects individually. For clarity, provided below are brief descriptions of the projects, details of the modeling approaches for the former documents, and an assessment of likely effects. Additional discussion of the flows in Old and Middle Rivers during the spring and early summer with and without the temporary barriers is included in Appendix Z.

The following information is from the 2007 Supplemental Biological Assessment. This supplement to the 2000 TBP Biological Assessment presents information and results of analyses to assess the impacts of the TBP on special status species in light of recent ESA listings by the NMFS and their subsequent request for re-initiation of consultation. This supplemental biological assessment serves to update permits prior to the installation of the temporary barriers in 2007, as required by NMFS. New permits, permit extensions, and project approval were needed to continue the TBP for a fourth operation interval that began in 2008. DWR has already obtained a DFG Streambed Alteration Agreement and Incidental Take permit extending the TBP through 2010. NMFS has issued a Biological Opinion and Incidental Take permit covering the TBP from 2008 through 2010. The FWS has issued a statement extending their previous Biological Opinion and Incidental Take permit for the TBP through 2008 and will apply the OCAP BA as their basis for extending operations of the TBP beyond 2008. However the FWS will require separate consultation on the installation and removal impacts of the TBP to cover ESA beyond 2008. The US Army Corps of Engineers have issued permits based upon the NFMS and FWS responses extending the TBP through 2010.

Hydrodynamic Effects

The TBP causes changes in the hydraulics of the Delta, which may pose impacts to fish. The TBP does not alter total Delta outflow, thus the position of X2, the linear position where bottom salinity measures two parts per million in the estuary, is not affected by the project. However, the TBP does cause hydrodynamic changes within the interior of the Delta. When the barrier at the head of Old River is in place, most water flow is effectively blocked from entering Old River. This in turn increases the flow in Turner and Columbia Cuts, two major central Delta channels that flow towards the south Delta. The underlying result of this hydrodynamic change is that there is an increase in reverse flow in these and other interior Delta channels. In most instances, net flow is directed towards the CVP and SWP pumps and local agricultural diversions. The directional flow towards the pumping facilities may increase the vulnerability of fish to entrainment by the pumps. Larval and small fishes are especially susceptible to these flows.

Unfortunately, the varying operational configurations of the TBP, natural variations in fish distribution, and a number of other physical and environmental variables prohibit statistical confidence in assessing fish salvage when the TBP is operational versus when it is not. The most effective direct method for examining the effect of the hydrodynamic consequences of the TBP on fish is by examining real-time fish salvage, however statistical results are lacking. Nobriga and others (2000) and Grimaldo (unpublished data) found that under certain conditions, salvage of delta smelt could increase dramatically when the TBP is operational. In 1996, the installation of the spring barrier at the head of Old River caused a sharp reversal of net flow in the south Delta to the upstream direction. Coincident with this change was a strong peak in delta smelt salvage. This data indicates that short-term salvage, especially that of delta smelt and other small species and juveniles can significantly increase when the TBP is installed in such a manner that causes a sharp change or reversal of positive net daily flow in the interior south and central Delta. Tidally averaged daily flow data for the south Delta was obtained from the U.S. Geological Survey to look for similar phenomena in previous years for a variety of fish species, however nothing was found to be as dramatic as that which occurred in 1996.

The Vernalis Adaptive Management Plan (VAMP), initiated in 2000 as part of the State Water Resources Control Board’s Decision 1641, is a large-scale, 12-year, interdisciplinary experimental program designed to protect juvenile Chinook salmon migrating from the San Joaquin River through the Delta. VAMP is studying how salmon survival rates change in response to alterations in San Joaquin River flows and SWP/CVP exports with the installation of the barrier at the head of Old River. VAMP employs an adaptive management strategy to use current knowledge of hydrology and environmental conditions to protect Chinook salmon smolts, while gathering information to allow more efficient protection in the future. In each year, VAMP schedules and maintains pulse San Joaquin River flows and reduced project exports for a one month period, typically from April 15 - May 15 (May 1-31 in 2006). Tagged salmon smolts released in the San Joaquin River are monitored as they move through the Delta in order to determine their fate. While VAMP studies attempt to limit project impacts to salmonids, the associated reduction in exports reduces the upstream flows that occur in the south and central Delta. This reduction limits the southward draw of water from the central Delta, and thus shortens the Projects’ zone of influence with regard to the passive entrainment of fishes.

Temporary Barriers Fish Monitoring

In 1992, DFG initiated the TBP Fish Monitoring Program in order to examine the impacts of the TBP on resident fish communities in the south Delta. Ten permanent sites within the south Delta were sampled with electrofishing and gill nets to study resident fish community composition and distribution (DWR 1998). Unfortunately, a lack of pre-project monitoring data and gear type made an analysis of overall project impacts impossible. This data could only be used to provide simple descriptive species presence/absence information. Similarly, a number of other fish monitoring and special study program data sets were used to assess potential impacts of the TBP. Because these other programs were not designed to specifically test TBP impacts, analysis from these data are also largely descriptive.

Predation Impacts to Fish

The physical presence of the TBP may attract piscivorous fishes and influence predation on special status fish species. However, past studies by the DFG TBP Fish Monitoring Program has indicated that predation on special status fish species near the Temporary Barriers is negligible (DWR 2000a). The top predatory fish in the Delta, the striped bass, primarily feed on threadfin shad and smaller striped bass, as adults. Having highly opportunistic diets, striped bass are known to consume about anything that is in high abundance (Moyle 2002). Rearing-age green sturgeon and other fish much larger than 10 cm escape predation by most adult striped bass (Nelson et. al. 2006).

Water Quality Impacts to Fish

Monitoring of water quality parameters has been conducted during the DFG TBP Fish Monitoring of the study area and also by DWR as part of the DWR annual TBP Monitoring Reports. These studies have found that water quality is not significantly impacted by the TBP (DWR 2000a). In general, electrical conductivity (EC) is slightly higher upstream of the TBP facilities than downstream. This is mostly due to the fact that Sacramento River water is drawn to the south Delta when the TBP is operational. Sacramento River water has generally lower EC than the San Joaquin River and thus improves water quality within the south Delta, downstream of the TBP facilities. Hydrodynamic and water quality modeling has shown that EC in the south Delta increases when SWP pumping decreases (DWR 2000b). The decreased pumping reduced the draw of Sacramento River water in the south Delta and thus water quality “degraded” in the form of increased EC.

Dissolved oxygen (DO) sags have occurred in the project area during years when the TBP was both operational and when it was not, over the same time period. The DO sags appear to be related to increased water temperatures in the summer and have even occurred in high outflow years such as 1998 (DWR 1999). Data from the 1997 fish monitoring water quality element suggest that the TBP does not promote low DO upstream of the facilities (DWR 1998). At the Old River at Tracy (ORT) barrier from March through August, DO levels above the barrier were lower on the flood tide than they were on the ebb tide. This can occur above the ORT barrier whenever flood tides are not strong enough to push enough water over and through the ORT barrier weir and culverts to increase circulation toward the head of the Grant Line Canal. The ORT barrier height is 2.0 feet MSL, while the other two agricultural barriers are at 1.0 feet MSL, a design meant to force circulation up Old River and down the Grant Line Canal. When flood tides are not strong enough, null zones can occur upstream of the ORT barrier due to a combination of weak tides and agricultural diversions. These null zones are areas of low circulation where EC can increase and DO levels can be lower than on the downstream side of the barrier.

Water impounded upstream of the three agricultural barriers is seasonally warmed into the 70-80+ °F range, depending on location, from May – October. There is a concern that fishes that become trapped upstream of the agricultural barriers and are therefore susceptible to high water temperatures.

Vulnerability to Local Agricultural Diversions

Fish that may become trapped upstream of the TBP agricultural barriers may suffer increased vulnerability to local agricultural diversions. There are numerous local diversions within the southern Delta that are generally most active from April through October (Cook and Buffaloe 1998), the same time period of TBP operation. However, there are many agricultural diversions on the downstream side of the barriers in the central and northern delta as well, consequently, whether there is a difference in vulnerability upstream versus downstream of the TBP agricultural barriers is unknown.

The Interagency Ecological Program (IEP) conducted a Delta Agricultural Diversion Study from 1993 through 1995 in attempt to determine the impacts of in-Delta diversions on resident and anadromous fish (Cook and Buffaloe 1998). No delta smelt were captured in the fyke net. Overall, threadfin shad, catfish and sunfish were the dominant species captured, comprising over 99 percent of the total catch.

Similar sampling of diversions in other regions of the Delta (Cook and Buffaloe 1998) has captured small numbers of delta smelt, Chinook salmon, splittail. These data suggest that fish vulnerability, especially delta smelt, to in-Delta diversions increases when fish density is high in the immediate vicinity of the diversion. The fact that presumably no species considered under this supplemental B.A. were entrained in the diversion within the TBP area is probably due to the fact that their densities were extremely low in this area during the study period. It can be expected that a few of these fishes will be entrained into local diversions however; the overall impact is expected to be minimal based upon the results of the IEP study.

Impacts to Potential Fish Prey Items

The conditions posed by the TBP may not influence the abundance and distribution of food items used by delta smelt.

The extent to which the distribution and abundance of these organisms will be influenced by the conditions posed by the TBP is difficult to determine. Because the TBP does not influence the position of X2, organisms that exhibit a strong abundance-X2 relationship (i.e. mysid shrimp) (Jassby and others 1995), will not be impacted. These data suggest that the TBP probably will not influence prey populations within the Delta.

Past Measures

Under Terms and Conditions 1 (e) of the USFWS Biological Opinion (4/26/96), DWR was required to install at least three fish screens on agricultural diversions per year in the Delta. To date, DWR has installed a total of 14 screens on agricultural diversions and has capped another diversion at Sherman Island, for a total of 15 screens (3 screens per year for the permit period). DWR also contributed to funding a study that examined the entrainment patterns of two side-by-side screened and unscreened diversions at Sherman Island. DWR will continue the operation and maintenance of all 14 fish screens that have been installed at Sherman Island. The previously mentioned DWR study on the entrainment patterns of two side-by-side screened and unscreened diversions at Sherman Island provided evidence that screens can protect fish from entrainment into agricultural diversions (Nobriga and others 2000).

Under Terms and Conditions 3 of the USFWS Biological Opinion (4/26/96), DWR was required to mitigate for the footprint of the Grant Line Canal barrier. DWR fulfilled this requirement by acquiring a 1:1 ratio of 0.064 acres of riparian scrub, 0.011 acres of shaded mudflat, 0.411 acres of shallow water, and 0.250 acres of intertidal vegetation at Kimball Island.

Under Condition 11 of the DFG 1601 Agreement (5/2/96), DWR was required to mitigate for the impact to shallow water habitat. DFG agreed to credit the Kimball Island mentioned above habitat purchase to satisfy this mitigation requirement.

Under Condition 16 of the DFG 1601 Agreement (5/2/96), DWR was required to screen two agricultural diversions in the Bay-Delta Estuary. The fish screen project at Sherman Island fulfilled this requirement.

An additional conservation measure will be to notch each of the agricultural barriers similar to the HORB fall barrier to provide passage for migrating adult salmon that have strayed into Old and Middle Rivers and Grant Line Canal.

South Delta Improvement Program Operable Gates

The following assessment identifies potential effects of operating the gates with the implementation of Stage 1 of the South Delta Improvements Program (SDIP) on delta smelt in the Delta. SDIP Stage 1 consists of the installation and operation of gates at four locations in the south Delta. There is no increase in the export diversion rate in Stage 1. Stage 2 includes the operable gates with the increase in exports up to 8,500 cfs.

ESA consultation for the operation of the SDIP gates in Stage 1 is being done within this OCAP BA. ESA consultation for the potential construction-related, predation and passage effects will be done separately. The operational effects are discussed and the other effects summarized in the subsequent text.

Simulation modeling completed for this OCAP BA incorporates the effects of the South Delta Temporary Barriers Project and 500 cfs increased export in Studies 6.1 and 7.0. The SDIP Stage 1, the 500 cfs increased export, and the CVP aqueduct intertie are incorporated into Studies 7.1 and 8.0. A full evaluation of the combined effects of these elements is presented in Chapter 13. Because the simulation models examined the combination of these elements, it is not possible to separate and examine the effects of any single project element by itself. Therefore, the effects analysis for the SDIP Stage 1 is taken largely from *South Delta Improvements Program Action Specific*

Implementation Plan (DWR and USBR 2006), and the *South Delta Improvements Program EIS/EIR* (DWR and USBR 2006), http://baydeltaoffice.water.ca.gov/sdb/sdip/documents/final_eis_eir.cfm. The effects of operation of the gates are discussed in the following text. Details on the hydrodynamics of the SDIP operable gates are in Appendix Z.

Effects of Gate Operation on Delta Smelt Spawning and Rearing Habitat, and Entrainment

Head of Old River Operations Effects

Operation (closing) of the head of Old River fish control gate is proposed to begin on April 15. Spring operation is generally expected to continue through May 15, to protect outmigrating salmon and steelhead. During this time, the head of Old River gate would be fully closed, unless the San Joaquin River is flowing above 10,000 cfs or the Gate Operations Review Team (GORT) recommends a partial opening for other purposes.

Under constant SWP and CVP pumping, Head of Old River gate closure causes additional net flow to be drawn from the San Joaquin River and south through Old River, Middle River, and Turner Cut. The increased net flow toward the south may increase entrainment of larval and juvenile delta smelt. The effects of the Head of Old River closure are similar for Alternatives 1 (No Action) and 2A (SDIP Stage 1), however the fish control gate constructed under Alternative 2A is fully closed compared to the temporary barrier at the head of Old River which has culverts that allow a portion of the San Joaquin River flow through the south Delta. Use of the permanent operable fish control gate at the Head of Old River is not limited to fully open or fully closed settings. The operable gate can be set at any height within its operable range, thus allowing a variety of flows into the south Delta via Old River.

The most notable effect seen in implementation of the permanent operable gates is in years when the San Joaquin River flow is between 5,000 cfs and 10,000 cfs. In these years, under the temporary barriers project, the Head of Old River barrier would not be constructed because the flows in the San Joaquin River are greater than 5,000 cfs. But the permanent gate is operated because it can be operated when the San Joaquin River is flowing up to 10,000 cfs. Whereas under the temporary barriers project there is little to no additional net flow being drawn from the San Joaquin River through Turner and Columbia Cuts, now, through the operation of the Head of Old River gate there is significant flows being drawn in. Delta smelt presence in the lower reaches of the San Joaquin River, especially in the central Delta, would be affected by this scenario. This hydrodynamic effect is discussed further in Appendix Z.

Operations during the months of October and November (fall operations) to improve flow and water quality conditions (i.e., low dissolved oxygen) in the San Joaquin River for adult migrating Chinook salmon is expected to provide a benefit similar to that achieved with the temporary barrier. Operations would not occur if the San Joaquin River flow at Vernalis is greater than 5,000 cfs because it is expected that this flow would maintain sufficient DO in the San Joaquin River.

Head of Old River gate operations in the fall are confined to the months of October and November. This operation is the same as the existing operation of the temporary Head of Old River barrier use. There is no additional impact associated with the fall operation because Delta smelt are not in the Delta during this period and the operations are the same as existing conditions.

Flow Control Gate Operations Effects

The flow control gates in Middle River, Grant Line Canal, and Old River near the DMC, would be operated (closed during some portion of the tidal cycle) throughout the agricultural season of April 15 through November 30. As with the head of Old River fish control gate, when the gates are not operated, they are fully lowered in the channel.

Spring Operations

During April 15 through May 15 (or until the Spring operation of the head of Old River gate is completed), in most years, water quality in the south Delta is acceptable for the beneficial uses but closure of the head of Old River fish control gate has negative impacts on water levels in the south Delta. Therefore, the flow control gates would be operated to maintain minimum water levels of 0.0 feet msl. In the less frequent year types, dry or critically dry, when water quality in the south Delta is threatened by this static use of the gates, circulation may be induced to improve water quality in the south Delta channels.

Summer and Fall Operations

When the Spring operation of the head of Old River fish control gate is completed and through November 30, the gates would be operated to control minimum water levels and increase water circulation to improve water quality in the south Delta channels. Reclamation and DWR have committed to maintaining water levels during these times at 0.0 foot msl in Old River near the CVP Tracy facility, 0.0 foot msl at the west end of Grant Line Canal, and 0.5 foot msl in Middle River at Mowry Bridge. It is anticipated that the target level in Middle River would be lowered to 0.0 foot msl following extension of some agricultural diversions.

The proposed gate operations will increase the tidal circulation in the south Delta channels. This is accomplished by tidal flushing upstream of the flow-control gates with relatively low-salinity water from Old River and Middle River downstream of the gates (i.e., high fraction of Sacramento River water). The flow-control gates would remain fully open during periods of flood tide (i.e., upstream flow) and then two of the gates would be fully closed (i.e., top elevation of gates above upstream water surface) during periods of ebb tide (i.e., downstream flow). The remaining gate (i.e., Grant Line) would be maintained at a lower elevation (i.e., 0.0 feet msl) to allow the ebb tide flow to exit from the south Delta channels so that the flood-tide flow over the gates can be maximized during each tidal cycle. This is the same operation described as Purpose 5 earlier in the description of the SDIP gates.

Flow control gates in Middle River, Grant Line Canal, and Old River at DMC could affect access to spawning and rearing habitat for delta smelt in the south Delta channels. These gates would be open at tide elevations between 0.0 feet msl and about 3 feet msl, an increase in the tidal range currently allowed by the temporary barriers. Total tidal volume would approach 80 percent of the tidal volume that would occur without gates in place. The flow control gates could have a beneficial effect on movement of delta smelt by enhancing access to Middle River, Grant Line Canal, and Old River. Measurable benefits to delta smelt, however, are likely small considering the assumed high probability that larval and juvenile delta smelt spawned in the south Delta would be entrained in agricultural diversions and operation of these gates is not started until later in the spring.

Operations of the flow control gates to preserve water stage in the south Delta has lower impacts than construction of the existing temporary agricultural flow control barriers. The temporary barriers are constructed at a higher elevation than what is required to maintain water stage. Because of the difference in height, the temporary barriers block more San Joaquin River flow from entering the south Delta, thus directing more water through Turner and Columbia Cuts. Similar in effect to the Head of Old River gate, the increased net flow from the central Delta toward the export facilities may increase entrainment of larval and juvenile delta smelt.

Operations of the flow control gates to induce circulation in south Delta channels will have similar impacts as those experienced with the existing temporary barriers. Flows from the central Delta to the south Delta are not significantly different between the two project scenarios. The fate of larval and juvenile Delta smelt will be very similar once in the south Delta channels. Particle tracking simulations in the south Delta have shown that the fate of particles released in the south Delta is either in agricultural intakes or the export facilities. Other particle tracking analysis is offered in Appendix Z.

Construction-related, Predation and Passage Effects

The potential construction-related, predation and passage effects are summarized below. All the details of the effects of the SDIP actions, including construction, predation and passage effects, are addressed in detail in the *South Delta Improvements Program Action Specific Implementation Plan* (DWR and USBR 2006), and the *South Delta Improvements Program EIS/EIR* (DWR and USBR 2006), http://baydeltaoffice.water.ca.gov/sdb/sdip/documents/final_eis_eir.cfm.

Permanent gates would be constructed at the head of Old River and in Middle River, Grant Line Canal, and Old River at the Delta Mendota Canal (DMC). Construction of the gates includes grading the channel bank, dredging the channel bottom, constructing sheet-pile cofferdams or an in–the-wet construction method, driving foundation piles and placing riprap, concrete, and other materials on the channel bank and bottom.

Dredging for all of the permanent gates would occur between August and November. Cofferdams would also be placed in the channel during the August through November timeframe. Work outside of the channel and within the cofferdams, if used, is assumed to occur during any month.

Dredging of Middle River and portions of Old River would increase the tidal conveyance capacity of the channels. Tidal flow velocity may be slightly reduced in West Canal and, depending on existing channel constrictions, circulation may be increased in Middle River, Old River, and Grant Line Canal.

The operation of the permanent flow control gates on Middle River, Grant Line Canal, and Old River would maintain water surface elevation above 0.0 feet msl during April 15 through November. Under current conditions, tides range from about 1.0 foot below mean sea level to 3.0 feet msl two times each day. The maximum change in SWP pumping (and CCF operations) could reduce the daily higher high tide from about 2.6 to 2.4 feet msl near the CCF gates. The reduction in higher high tide attributable to change in SWP pumping is less with distance from the CCF gates. When closed during tide levels below 0.0 feet msl, the flow control gates block fish passage. When opened during tide levels greater than 0.0 feet msl, fish passage is restored. The volume of water exchanged during each tidal cycle is reduced by about 20 percent for the channels upstream of the gates on Middle River, Grant Line Canal, and Old River.

During the spring, the head of Old River fish control gate would be operated to block flow and movement of juvenile fall-run Chinook salmon and other fishes from the San Joaquin River into Old River from about April 15 through May 15, or other periods as recommended by USFWS, NOAA Fisheries, and DFG. Juvenile Chinook salmon move down the San Joaquin River past Stockton, a pathway believed to enhance survival relative to movement into Old River (Brandes and McLain 2001).

During fall, the head of Old River fish control gate would be operated to increase flow in the San Joaquin River past Stockton from about September 15 through November 30. The increased flow in the San Joaquin River potentially improves water quality, including increased DO, in the San Joaquin River channel near Stockton (Giulianotti et al. 2003). Improved water quality could benefit upstream migrating adult Chinook salmon.

Construction-Related Loss of Spawning Habitat Area for Delta Smelt

Delta smelt spawn in the Delta. As indicated in the methods description, existing information does not indicate that spawning habitat is limiting population abundance and production (U.S. Fish and Wildlife Service 1996).

Shallow areas that may provide spawning habitat for delta smelt could be permanently modified by construction of the gates in the south Delta and subsequent maintenance activities. The area of shallow habitat affected by the gate footprints, riprapped levee, and dredging may total several acres. The permanent gates constructed under Alternative 2A would have minimal effect on habitat within the construction footprint at the head of Old River, Middle River, and Old River at DMC. Construction of the temporary barriers has previously modified shallow water habitat. Three of the four permanent gates would be constructed in the same location as the temporary barriers and would result in little change in habitat quality and quantity relative.

Construction of a new gate on Grant Line Canal and the proposed dredging in West Canal, Middle River, and Old River potentially would remove and modify existing shallow habitat. The loss of spawning habitat in the Delta has not been explicitly identified as a factor contributing to the decline of delta smelt, and the south Delta channels have not been identified as important spawning habitat (U.S. Fish and Wildlife Service 1996). The relative importance of spawning habitat in the south Delta in contributing to population abundance is likely low. Nonnative species currently dominate the fish community in shallow areas of the south Delta (Feyrer 2001), and many of the species prey on delta smelt and their eggs. In addition, entrainment of larvae in diversions, especially CVP and SWP pumping, would minimize the importance of spawning habitat in the south Delta.

Construction-Related Loss of Rearing Habitat Area for Delta Smelt

Delta smelt larvae, juveniles, and adults rear in the Delta and Suisun Bay. The importance of rearing habitat in the south Delta, however, appears to be relatively low. Nonnative species currently dominate the fish community in the south Delta (Feyrer 2001), and many of the species prey on delta smelt larvae and juveniles. In addition, entrainment of larvae and juveniles in diversions, especially CVP and SWP pumping, would minimize the importance of rearing habitat in the south Delta. Rearing habitat loss associated with gate construction, maintenance activities, and dredging is determined to be minimal.

Construction-Related Reduction in Food Availability for Delta Smelt

Many of the same factors affecting rearing habitat area would be expected to affect food production and availability for delta smelt. Construction of the gates in the south Delta and maintenance activities have the potential to permanently modify channel form and remove bottom substrates. Delta smelt, however, feed on zooplankton and effects on benthic invertebrate habitat may not affect food for delta smelt. This potential effect is minimal for the same reasons discussed for effects on rearing habitat.

Construction-Related Loss of Delta Smelt to Accidental Spill of Contaminants

Contaminants associated with construction activities, including gate construction, placement of riprap, dredging, and maintenance dredging, could be introduced into the south Delta channels and could adversely affect delta smelt and their habitat. Environmental commitments, including an erosion and sediment control plan, hazardous materials management plan, spoils disposal plan, and environmental training, will be developed and implemented before and during construction activities. The environmental commitments would substantially reduce the likelihood of any considerable contaminant input. Contaminants would have a minimal effect on delta smelt and their habitat in the south Delta because the potential for increased contaminant input following implementation of environmental commitments is small.

Construction-Related Loss of Delta Smelt to Direct Injury

Construction of the gates would include placement of sheetpiles and riprap and could directly injure fish present during the time of construction. Dredging could entrain and injure delta smelt. Cofferdams, if used, would be installed to isolate gate construction areas from the channel. Placement of cofferdams in the channels could trap larval, juvenile, and adult delta smelt. Fish that become trapped inside the cofferdams could be killed during desiccation of the construction area and construction activities. Direct injury associated with construction and maintenance activities, including dredging, would have a minimal effect on delta smelt because the number of fish injured is likely small given that:

- in-water construction, including the construction of a cofferdam, would occur between August and November;
- the area of construction activity is small relative to the channel area providing similar habitat quality in the south Delta; and
- most juvenile and adult delta smelt would move away from construction activities and into adjacent habitat of similar quality.

Construction-Related Loss of Delta Smelt to Predation.

Construction of gates and extension of agricultural intakes would add permanent structure and cover to the south Delta channels. The addition of structure has the potential to increase the density of predator species and predation on fish moving around and past the structure. Concentrations of disoriented fish increase prey availability and create predator habitat.

Predation associated with the addition of the operable gates and the agricultural intake extensions to the south Delta channels could cause a small and likely negligible (i.e., minimal effect) increase in mortality of the delta smelt moving past the structures. The determination is based on several factors. Design elements will minimize turbulence that could disorient fish and increase vulnerability to predation. The structures would not create conditions that could concentrate delta smelt. Flow velocity would be similar to velocities within the channel upstream and downstream of the gates and the agricultural intake extensions.

The transition zones between various elements of the gates (e.g., sheetpiles and riprap) could provide low-velocity holding areas for predatory fish. Predatory fish holding near the gates and agricultural intakes could prey on vulnerable species. The additional predator habitat created by the gates and intake extensions would have a minimal effect on delta smelt because the increase in potential predator habitat is small relative to habitat in adjacent areas, including the habitat currently created by the temporary barriers and habitat at the existing agricultural intakes. Disorientation and concentration of juvenile and adult fish would be minimal given the size and design of the gates.

Suisun Marsh Salinity Control Gates

The SMSCG is generally operated as needed September through May to meet State salinity standards in the marsh (Table 13-21). The number of days the SMSCG are operated in any given years varies. Historically, the SMSCG were operated between 60-120 days between October and December (1988-2004). With increased understanding of the effectiveness of SMSCG in lowering salinity in Montezuma Slough, salinity standards have been met with less frequent gate operation. In 2006 and 2007, the gates were operated periodically between 10-20 days annually. This level of operational frequency (10-20 days per year) can generally be expected to continue in the future except perhaps during the most critical hydrologic conditions.

Table 13-21 Suisun Marsh Channel Water Standards 1/

Compliance Location	Interagency Station Number 2	Description	Time Period	Value (EC)
EASTERN MARSH				
Sacramento River at Collinsville	C-2 (RSAC081)	Progressive Daily Mean = mean of daily average high-tide EC of the month.. See Article I.Y for the mathematical equation.	**All Water Year Types**	
Montezuma Slough at National Steel	S-64 (SLMZU25)		October	19.0
Montezuma Slough near Beldon Landing	S-49 (SLMZU11)		November - December	15.5
			January	12.5
			February - March	8.0
			April - May	11.0
WESTERN MARSH		Progressive Daily Mean	**All Water Year Types**	
Chadbourne Slough at Sunrise Duck Club	S-21 (SLCBN1)		October	19.0
Suisun Slough, 300 feet south of Volanti Slough	S-42 (SLSUS12)		November	16.5
			December	15.5
			January	12.5
			February - March	8.0
			April - May	11.0
			Deficiency Period	
			October	19.0
			November	16.5
			December - March	15.6
			April	14.0
			May	12.5

1. From SWRCB D-1641 Table 3 Water Quality Objectives for Fish and Wildlife Uses
2. Parenthetical contains the River Kilometer Index station number. See Figure 1 for locations.

The SMSCG does not directly affect delta smelt in any measurable way. It is possible, however, for delta smelt and other fishes to be entrained into Montezuma Slough and Suisun Marsh when the SMSCG is fully operational. Fish may enter Montezuma Slough from the Sacramento River when the gates are open to draw freshwater into the marsh and then may not be able to move back out when the gates are closed. However, the degree to which movement of delta smelt is constrained is unknown. It is also unknown if there are differences in habitat conditions that may affect delta smelt that are temporarily forced to remain in Suisun Marsh. It is possible that if delta smelt are indeed entrained into Montezuma slough and Suisun Marsh that they may be more vulnerable to water diversion such as those of the MIDS. Entrainment into MIDS from the Sacramento River may be unlikely though because particle tracking studies have demonstrated low entrainment vulnerability for particles released at random locations throughout Suisun Marsh (3.7%), and almost no vulnerability (<0.1%) to particles released at Rio Vista (Culberson et al. 2004). Moreover, DWR staff monitored fish entrainment from September 2004 to June 2006 at MIDS to evaluate entrainment losses at the facility.

Monitoring took place over several months under various operational configurations to provide data on the site-specific impact of the MIDS diversion with a focus on delta smelt and salmonids. Over 20 different species were identified during the sampling, yet only two fall-run sized Chinook salmon (south intake, 2006) and no delta smelt from entrained water were caught. Indirectly, operations of the SMSCG may influence delta smelt habitat suitability and entrainment vulnerability. When the SMSCG are opened, the draw of freshwater into the marsh effectively moves the Suisun Bay salinity field upstream. In some years, the salinity field indexed by X2 may be shifted as far as 3 km upstream. Thus, depending on the tidal conditions during and after gate operations, X2 may be transported upstream nominally about 20 days per year. The consequence of this shift decreases smelt habitat and moves the distribution of smelt upstream (Feyrer et al. 2007; see smelt habitat effects section). Because juvenile smelt production decreases when X2 moves upstream during the fall (Feyrer et al. 2007), any attributable shift in X2 between September to November (December during low outflow years) caused by operations of SMSCG can be a concern.

During January through March, most delta smelt move into spawning areas in the Delta. Grimaldo et al (in review) found that prior to spawning entrainment vulnerability of adult delta smelt increased at the SWP and CVP when X2 was upstream of 80 km. Thus, any upstream shift in X2 from SMSCG operations may influence entrainment of delta smelt at the CVP and SWP, especially during years of low outflow or periods of high CVP/SWP exports. However, between January and June the SWP and CVP operate to meet the X2 standards, thus the impacts of the SMSCG on X2 during this period are mostly negligible. Therefore, SMSCG operations from January to May are not likely to impact entrainment vulnerability. In addition, because delta smelt move upstream between January and March, operations of the SMSCG are unlikely to adversely affect delta smelt habitat suitability during this period.

Morrow Island Distribution System

The 1997 FWS BO issued for dredging of the facility included a requirement for screening the diversion to protect delta smelt. Due to the high cost of fish screens and the lack of certainty surrounding their effectiveness at MIDS, DWR and Reclamation proposed to investigate fish entrainment at the MIDS intake with regard to fishery populations in Goodyear Slough and to evaluate whether screening the diversion would provide substantial benefits to local populations of listed fish species. DWR staff monitored fish entrainment from September 2004 to June 2006 at the MIDS in Suisun Marsh (Figure 1) to evaluate entrainment losses at the facility. Monitoring took place over several months under various operational configurations to provide data on the site-specific impact of the MIDS diversion with a focus on delta smelt and salmonids. Over 20 different species were identified during the sampling, yet only two fall-run sized chinook salmon (south intake, 2006) and no delta smelt from entrained water were caught. Two species that associate with instream structures, threespine stickleback and prickly sculpin, comprised most of the entrained fish. DWR and Reclamation staff will continue coordination with the fishery agencies to address the screening requirement.

Reclamation and DWR continue to coordinate with the FWS, NMFS, and DFG regarding fish entrainment at this facility. The objective remains to provide the greatest benefit for aquatic species in Suisun Marsh. Studies suggest that GYS is a marginal, rarely used habitat for special-status fishes. Therefore, implementation and/or monitoring of a tidal restoration project elsewhere is emerging as the most beneficial and pratical approach (in lieu of installing and maintaining fish screens). Restoration of tidal wetland ecosystems is expected to aid in the recovery of several listed and special status species within the marsh and improve food availability for delta smelt and other pelagic organisms.

Effects on Critical Habitat

The USFWS designated delta smelt critical habitat to include "areas of all water and all submerged lands below ordinary high water and the entire water column bounded by and constrained in Suisun Bay (including the continguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the Delta." (U.S. Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants: Critical habitat determination for the delta smelt. December 19, 1994. Federal Register 59(242): 65256-65279 [Rule]). Both direct and indirect effects described here for the CVP and SWP upon delta smelt take place within these geographical boundaries. Present and future operations described in studies 6.1, 7.0, and 7.1 are likely to affect the primary constituent elements of delta smelt critical habitat as follows.

Habitat

As described by the Rule, delta smelt require "shallow, fresh or slightly brackish backwater sloughs and edgewaters for spawning. To ensure egg hatching and larval viability, spawning areas also must provide suitable water quality (i.e., low concentrations of pollutants) and substrates for egg attachment (e.g., submerged tree roots and branches and emergent vegetation)." In recent years the densest spawning aggregations of adult delta smelt have been found in the Cache Slough/Sacramento Deepwater Ship Channel complex in the north Delta, with delta smelt also distributed at lower densities in the central and occasionally the south Delta. Current and future CVP and SWP operations described in studies 7.0, 7.1, and 8.0 are unlikely to affect spawning habitat in the interior and north Delta because the projects do not contribute pollutants or otherwise physically or chemically disturb this habitat. During the spawning months, delta outflow is typically high enough that salinity intrusion into areas where delta smelt spawn is unlikely to occur. Moreover, the need to protect the quality of exported water would likely prevent the water projects from causing salinity intrusion into areas where delta smelt are spawning regardless of hydrologic conditions. Water project operations might adversely affect spawning habitat in the west Delta and Suisun Marsh if persistently elevated salinities in those regions resulted in changes in the quality of edgewater habitat and spawning substrate through changes in the plant and animal assemblages that occur there. The extent to which such changes might reduce the overall availability of good-quality spawning habitat is unknown, but given historical geographical patterns of delta smelt is likely to be small.

River Flow

As described in the Rule, to ensure transport of delta smelt larvae from the areas where they hatch to productive rearing or nursery habitat, "the Sacramento and San Joaquin Rivers and their tributary channels must be protected from physical disturbance…and flow disruption (eg. water diversions that result in entrainment and in-channel barriers or tidal gates). Adequate river flow is necessary to transport larvae from upstream spawning areas to rearing habitat in Suisun Bay. Additionally, river flow must be adequate to prevent interception of larval transport by the State and Federal water projects…" Both current and future CVP and SWP operations described in this Biological Assessment are likely to adversely affect larval and juvenile transport by flow disruption and interception (and subsequent entrainment) of fish. The zone of entrainment, in which interception of larval transport occurs, is affected by export rates and especially the degree of upstream flow in Old and Middle Rivers (OMR flow, PE Smith, unpublished analysis, Grimaldo et al. in press, Kimmerer and Nobriga 2008). Disruptive effects associated with negative OMR flow often extend north and east to the San Joaquin River, and sometimes extend far enough north to affect the Sacramento River. While the evidence from the POD investigation principally implicates direct entrainment of adults, larvae, and early juveniles as possible contributing causes of the recent decline of delta smelt, late emerging juvenile delta smelt have historically also been entrained in relatively large numbers during May—July of some years. Increases in the strength of negative OMR flow in June and especially July that are predicted under all model scenarios may have a significant effect in years when the spawning distribution of delta smelt intrudes farther than usual southeast.

The Rule also states that "[a]dult delta smelt must be provided unrestricted access to suitable spawning habitat in a period that may extend from December to July. Adequate flow and suitable water quality may need to be maintained to attract migrating adults in the Sacramento and San Joaquin River channels and their associated tributaries, including Cache and Montezuma sloughs and their tributaries. These areas also should be protected from physical disturbance and flow disruption during migratory periods." As described above and in Chapter 7, water project operations affect delta hydrodynamics during this period by creating a zone of upstream flows north of the facilities, causing water to move south in OMR under most circumstances. Export pumping levels described in Study 6.1 during the winter and spring may have contributed to the Pelagic Organism Decline. Alterations of those levels in studies 7.0, 7.1, and 8.0 provide more protective flow conditions in general during winter and early spring (with exceptions in March, and June), but OMR flow modeling predicts conditions in most of the winter and spring to cause some entrainment of adults, larvae, and juveniles present in the central Delta and areas north of it in June and July.

Water and Salinity

According to the Rule, "[m]aintenance of the 2 ppt isohaline according to the historical salinity conditions…and suitable water quality (low concentrations of pollutants) within the Estuary is necessary to provide delta smelt larvae and juveniles a shallow, protective, food-rich environment in which to mature to adulthood. This placement of the 2 ppt isohaline also serves to protect larval, juvenile, and adult delta smelt from entrainment in the State and Federal water projects." As discussed above and in Chapter 7, changes in X2 alter the distribution and availability of pelagic habitat suitable for delta smelt. Upstream X2 movements of several kilometers predicted for the fall months in studies 7.0, 7.1, and 8.0, relative to Study 6.1, are expected to be associated with a reduction in the quality and availability of rearing habitat.

Cumulative Effects

Cumulative effects include the effects of future State, Tribal, local, or private actions affecting listed species that are reasonably certain to occur in the area considered in this biological assessment. Future Federal actions not related to this proposed action are not considered in determining the cumulative effects, because they are subject to separate consultation requirements pursuant to section 7 of the Act. Any continuing or future non-Federal diversions of water that may entrain adult or larval fish are not subject to ESA Section 7 and might contribute to cumulative effects to the smelt. Water diversions might include municipal and industrial uses, as well as diversions through intakes serving numerous small, private agricultural lands contribute to these cumulative effects. However, a recent study by Nobriga et al. (2005) suggested that these diversions entrain few delta smelt. Nobriga et al. reasoned that the littoral location and low-flow operational characteristics of these diversions reduced their risks. A study of the Morrow Island Distribution System by DWR produced similar results, with one demersal species and one species that associates with structural environmental features together accounting for 97-98 percent of entrainment, and only one delta smelt observed during the two years of the study (DWR 2007).

State or local levee maintenance may also destroy or adversely modify spawning or rearing habitat and interfere with natural long term habitat-maintaining processes. Operation of flow-through cooling systems on electrical power generating plants that draw water from and discharge into the area considered in this biological assessment may also contribute to cumulative effects to the smelt.

Additional cumulative effects result from the impacts of point and non-point source chemical contaminant discharges. These contaminants include but are not limited to free ammonium ion, selenium, and numerous pesticides and herbicides, as well as oil and gasoline products associated with discharges related to agricultural and urban activities. Implicated as potential sources of mortality for smelt, these contaminants may adversely affect fish reproductive success and survival rates.

Two wastewater treatment plants, one located on the Sacramento River near Freeport and the other on the San Joaquin River near Stockton have received special attention because of their discharge of ammonia. The Sacramento Regional County Sanitation District wastewater treatment facility near Freeport discharges more than 500,000 cubic meters of treated wastewater containing more than 10 tonnes of ammonia into the Sacramento River each day (http://www.sacbee.com/378/story/979721.html). Preliminary studies commissioned by the IEP POD investigation and the Central Valley Regional Water Quality Control Board are evaluating the potential for elevated levels of Sacramento River ammonia associated with the discharge to adversely affect delta smelt and their trophic support. The Freeport location of the SRCSD discharge places it upstream of the confluence of Cache Slough and the mainstem Sacramento River, a location where delta smelt have been observed to congregate in recent years during the spawning season. The potential for exposure of a substantial fraction of delta smelt spawners to elevated ammonia levels has heightened the importance of this investigation. Ammonia discharge concerns have also been expressed with respect to the City of Stockton Regional Water Quality Control Plant, but its remoteness from the parts of the estuary frequented by delta smelt suggest that it is more a potential issue for migrating salmonids than for delta smelt.

Other cumulative effects could include: the dumping of domestic and industrial garbage may present hazards to the fish because they could become trapped in the debris, injure themselves, or ingest the debris; golf courses reduce habitat and introduce pesticides and herbicides into the environment; oil and gas development and production may affect habitat and may introduce pollutants into the water; agricultural activities including burning or removal of vegetation on levees reduce riparian and wetland habitats; and grazing activities may degrade or reduce suitable habitat, which could reduce vegetation in or near waterways.

The effects of the proposed action are not expected to alter the magnitude of cumulative effects of the above described actions upon the critical habitat's conservation function for the smelt.

CVP and SWP Delta Effects on Steelhead, Chinook Salmon, and Green Sturgeon

This section addresses the effects associated with Delta pumping on winter-run Chinook, yearling and young-of-the-year (yoy) spring-run Chinook, steelhead and green sturgeon. Fish monitoring programs for CVP and SWP facilities are described, and salvage and loss estimates provided by species and life stage. Instream temperature effects on salmonids resulting from CVP and SWP operations were discussed in Chapter 11, and addressed separately in the effects determination.

CVP and SWP South Delta Pumping Facilities

Winter-run and spring run Chinook losses are seasonal; primarily December through May. The majority of winter-run losses occur December through April (Figure 13-39), yearling spring run surrogate losses December through March, and yoy spring run losses January through May. Distinguishing the four runs of Chinook is difficult; therefore we use a couple of different methods to estimate run losses. Winter run loss is based on length/date criteria (or growth rate criteria) developed by FWS in the upper Sacramento River. Yearling spring run loss is based on using Coleman Hatchery late-fall juveniles as surrogates for yearling spring run. Young-of-the-year spring loss is based on using the entire yoy loss as a relative index of yoy spring run loss. Yoy loss includes both fall-run and spring-run Chinook salmon.

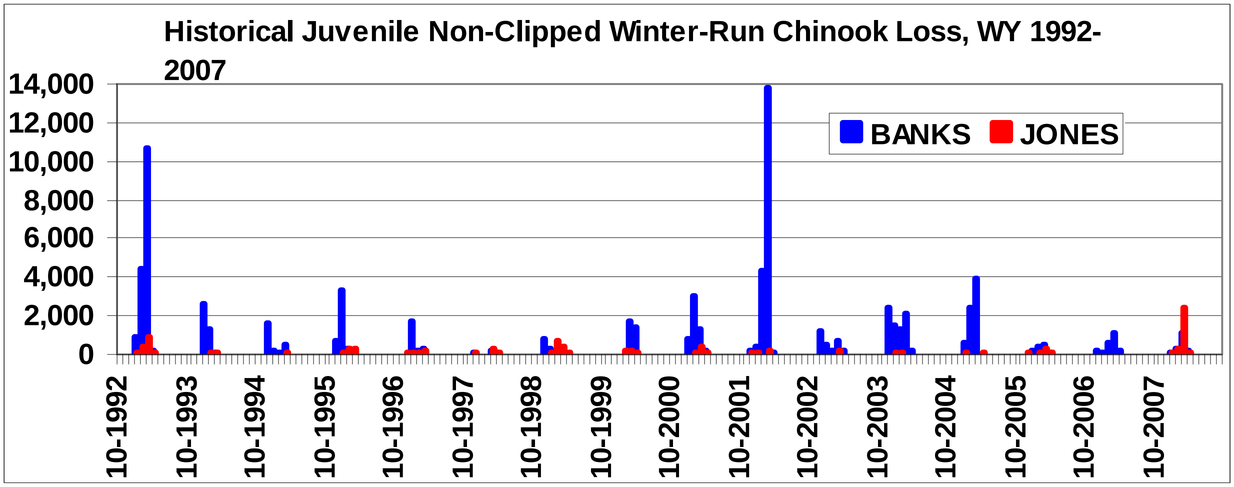


Figure 13-39 Historical juvenile non-clipped winter-run Chinook loss, WY 1992-2007.

Regressions of monthly older juvenile Chinook salmon against exports resulted in significant relationships; more so at the SWP than CVP (Figure 13-40). The months of December through April resulted in most informative relationship based on the historical number of older juvenile

Chinook salvaged each month and the relationship of each month between salvage and exports. Regressions of monthly young-of-the-year (YOY) Chinook salmon against exports did not result in significant relationships at either SWP or CVP (Figure 13-40). Export reductions for VAMP occur during the peak emigration of YOY Chinook which may skew the regression. In all of the graphs, the slope is so small it would necessitate reducing pumping altogether to affect a change in Chinook loss.

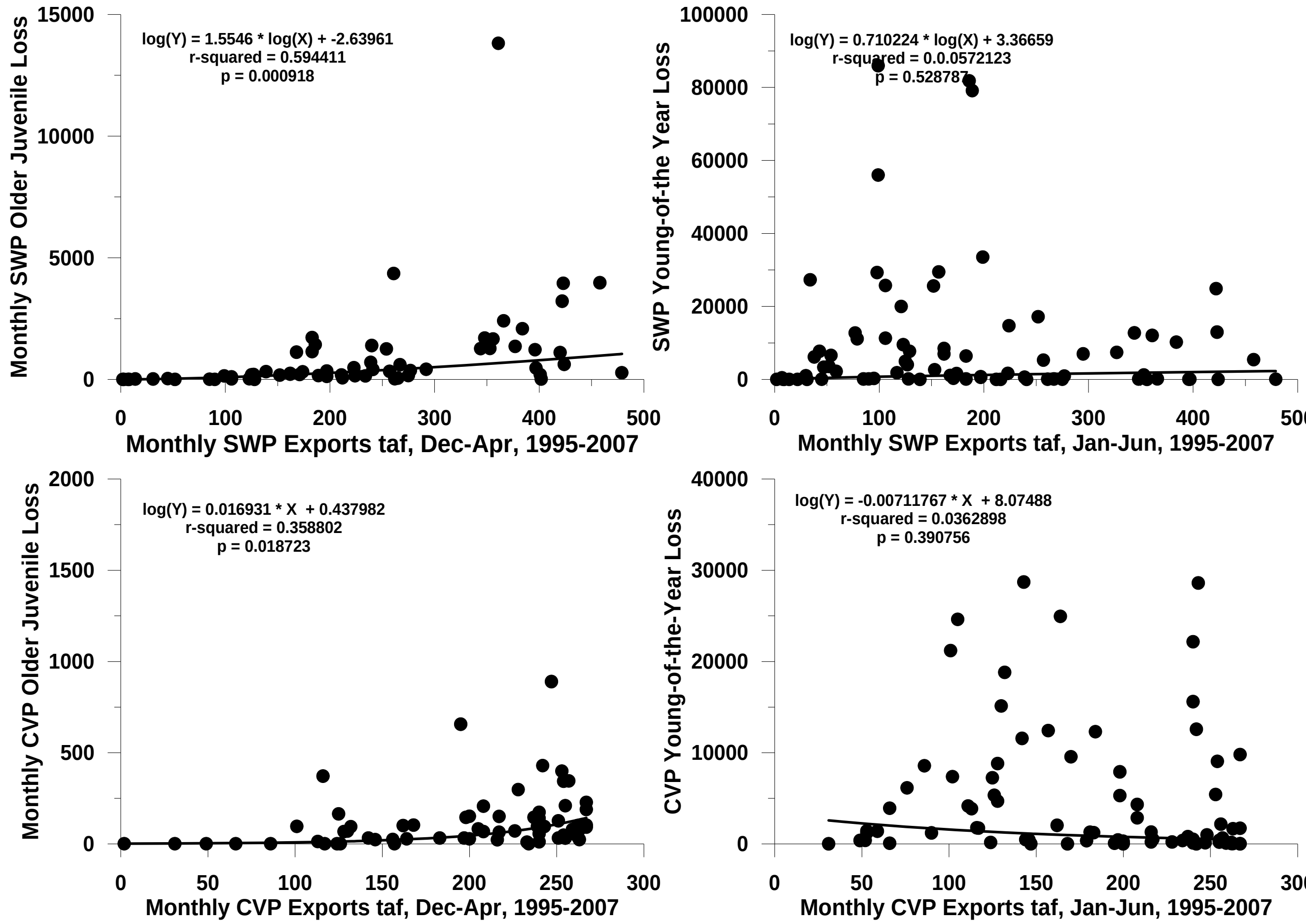


Figure 13-40 Monthly juvenile Chinook loss versus average exports, December through June, 1993 through 2006, at each facility; SWP and CVP.

Regressions of monthly older juvenile Chinook loss against Export/Inflow ratio (EI) between December and April however did not result in significant relationships at the SWP and CVP (Figure 13-40). Regressions of monthly YOY Chinook loss against EI between January and June resulted in a significant relationship for CVP but not SWP (Figure 13-40). In all of the graphs, the slope is so small it would necessitate reducing pumping altogether to affect a change in Chinook loss. There are two regression lines and equations in Figure 13-40, the black lines and equations represent the months of December through April for older juvenile Chinook and January through June for YOY Chinook (similar to the salvage and export graphs in Figure

13-41, and the red lines and equations represent the month of January alone. The regressions of monthly loss against January alone did not result in any significant relationships. Since most of the loss occurs in months other than it would take a large amount of change in EI ratio to affect a small reduction in Chinook loss.

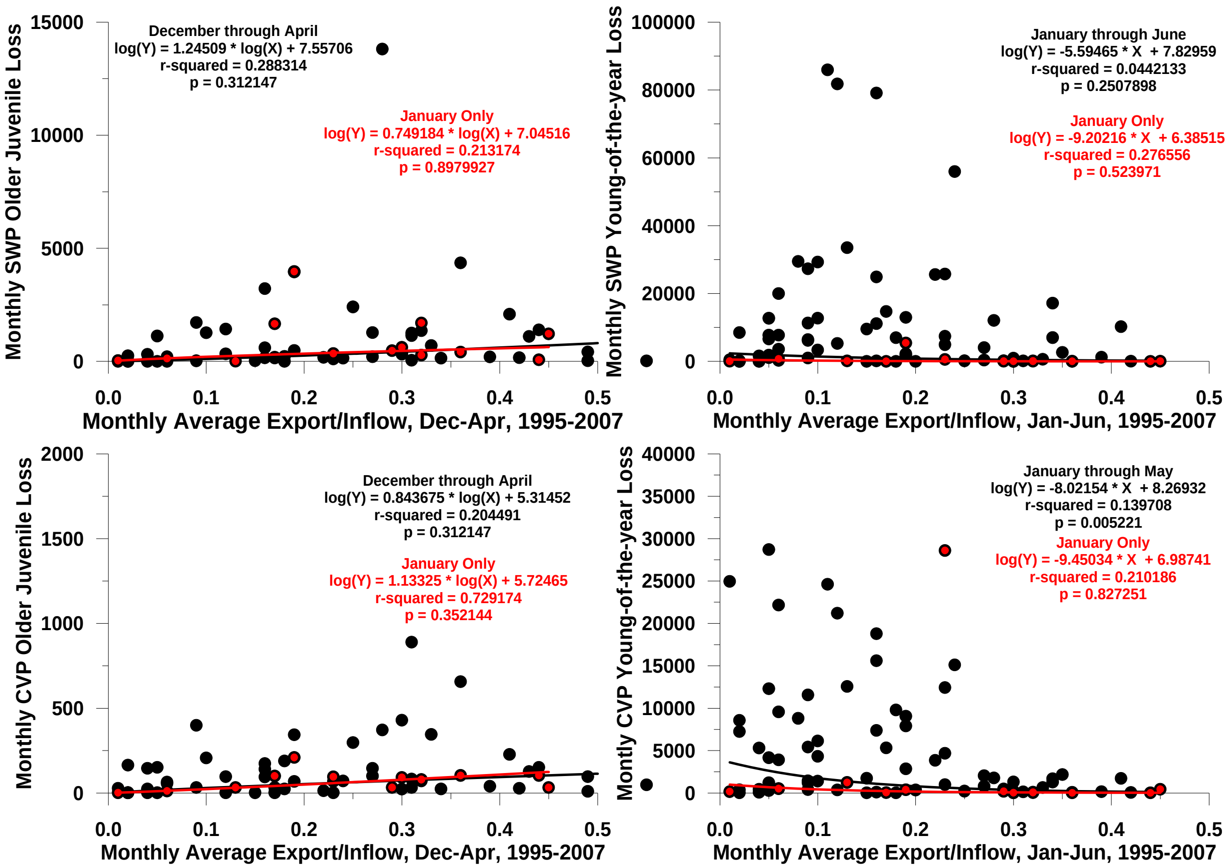


Figure 13-41 Monthly juvenile Chinook loss versus average Export/Inflow ratio, December through June, and January alone, 1993 through 2006, at each facility; SWP and CVP.

Figure 13-42 is an illustration of winter-run Chinook juvenile loss at the SWP and CVP Delta export facilities effect on a winter-run population growth rate parameter, cohort replacement rate (CRR). The CRR is simply the adult escapement one year divided by the adult escapement three years earlier. In Figure 13-42, the regression is a positive relationship between juvenile winter run loss and winter run CRR; meaning as juvenile loss increases, the CRR, or population growth rate, increases. This was not the intuitively expected results. But the regression is driven by one data point, 2003, when the loss and CCR were very high. With just one data point at the high values, there is no way to estimate variation at the high values. For this reason, if we exclude the 2003 data point. Without the 2003 data point, juvenile winter-run loss doesn't explain the variation in the CCR and the regression is not significant. Based on this analysis, winter-run

Chinook juvenile loss at the SWP and CVP Delta export facilities isn't driving the winter-run Chinook population growth rate.

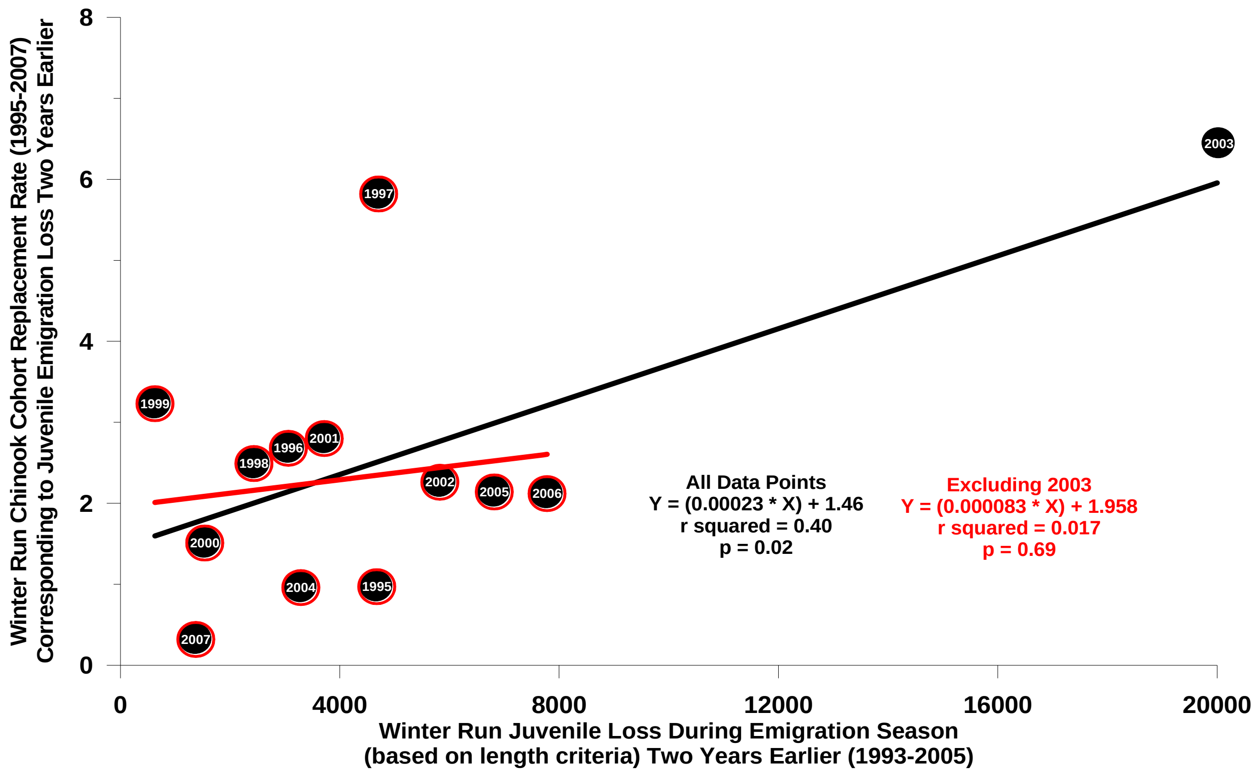


Figure 13-42 Regression of winter-run Chinook cohort replacement rate (population growth rate) to winter-run Chinook juvenile loss at the SWP and CVP Delta exports, 1993-2007.

Similarly, Figure 13-43 is an illustration of spring-run Chinook surrogate loss at the SWP and CVP Delta export facilities effect on a spring-run Chinook population growth rate parameter, cohort replacement rate (CCR). In Figure 13-43, the regression is not significant and spring-run Chinook surrogate loss doesn't explain the variation in the CCR. Based in this analysis, spring-run Chinook surrogate loss at the SWP and CVP Delta export facilities isn't driving the spring-run Chinook population growth rate.

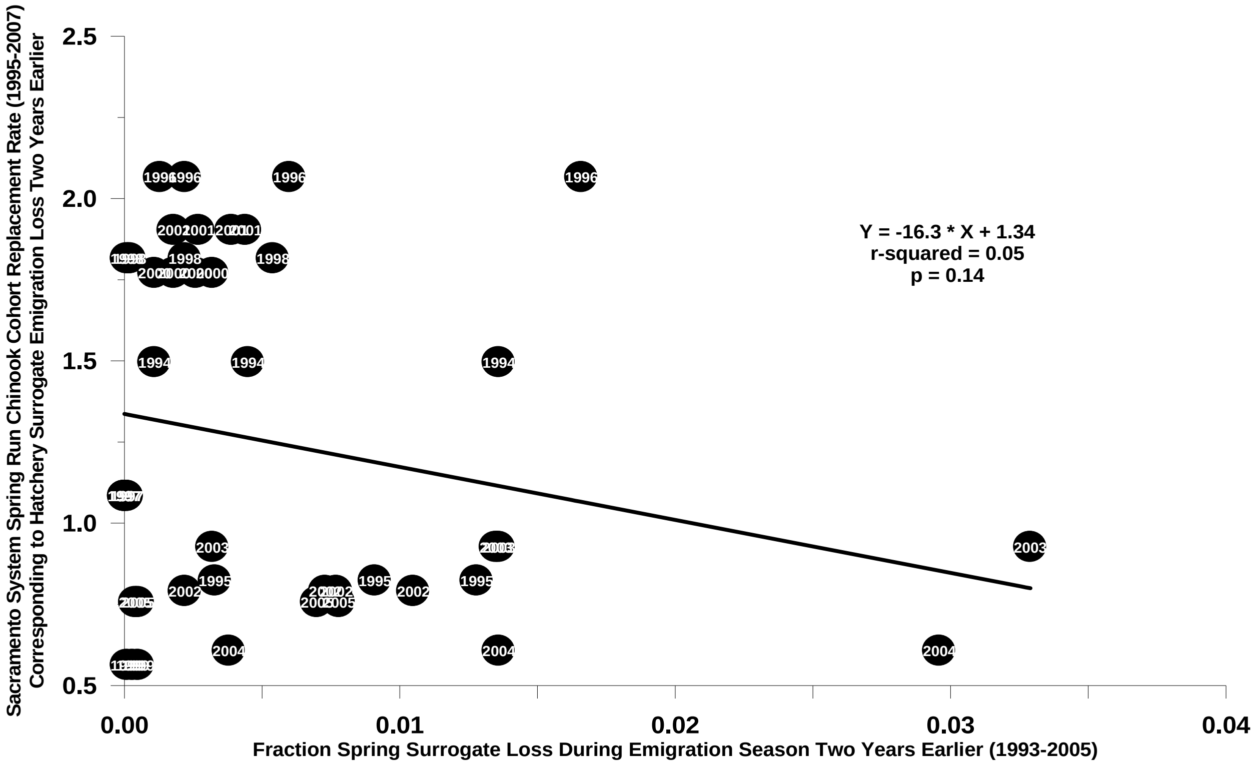


Figure 13-43 Regression of spring-run Chinook cohort replacement rate (population growth rate) to spring-run Chinook surrogate loss at the SWP and CVP Delta exports, 1993-2007.

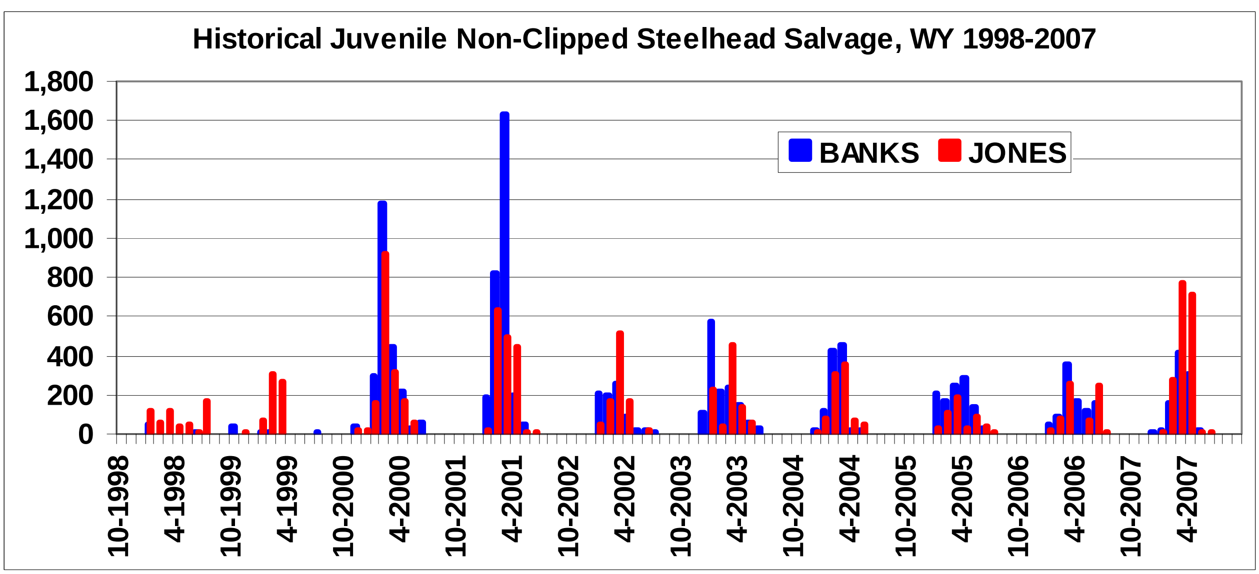


Figure 13-44 Historical Juvenile Non-Clipped Steelhead Salvage, WY 1998-2007.

Regressions of monthly steelhead salvage against exports resulted in significant relationships; more so at the SWP than CVP (Figure 13-45). The months of January through May resulted in most informative relationship based on the historical number of steelhead salvaged each month and the relationship of each month between salvage and exports; December and June both had a very small proportion of the steelhead salvage and very poor and insignificant relationships to exports. Of the four graphs in Figure 13-45, only the SWP clipped steelhead salvage relationship to exports is of interest; the slope actually changes noticeably over the export range; at the high end. In the other three graphs, the slope is so small it would necessitate reducing pumping altogether to affect a change in steelhead salvage.

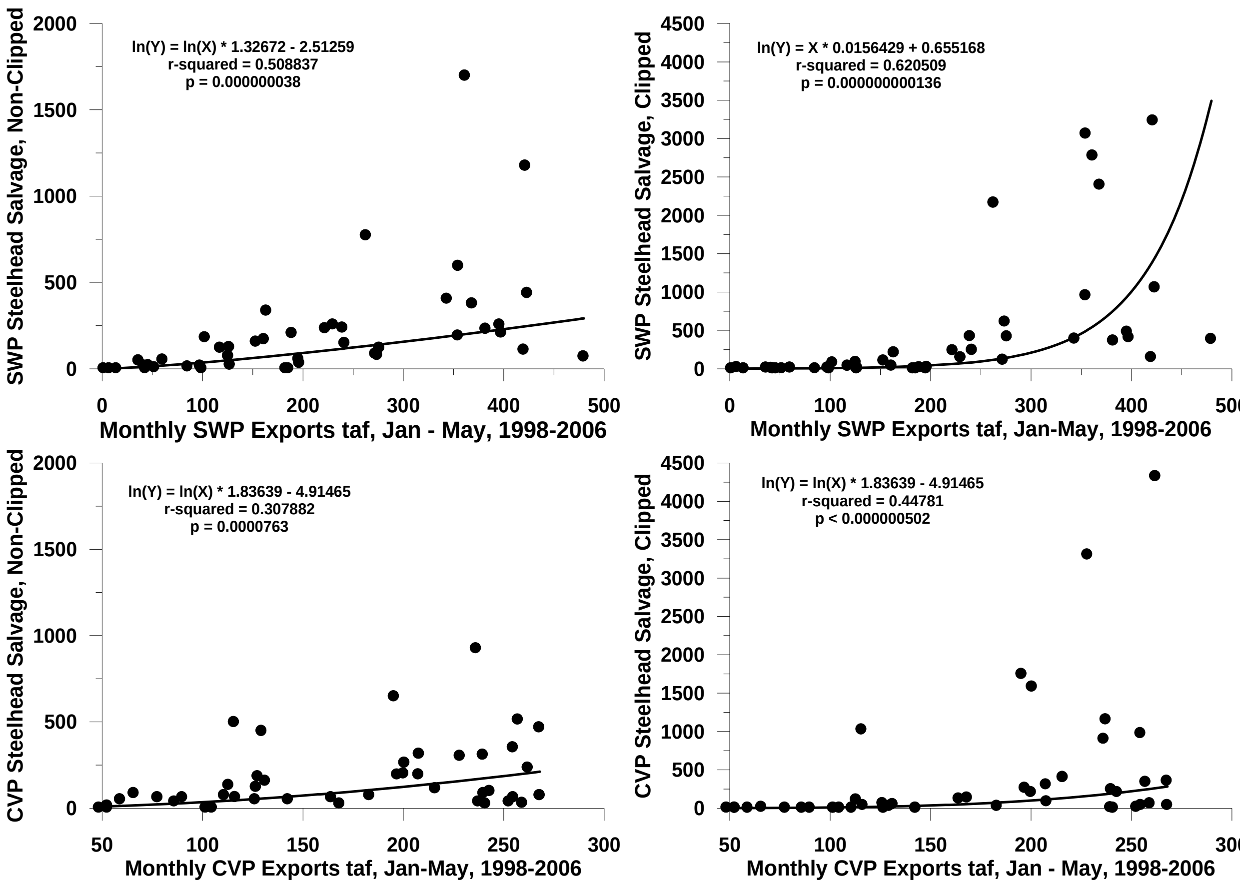


Figure 13-45 Monthly steelhead salvage versus average exports, January through May, 1998 through 2006, at each facility; SWP and CVP.

Regressions of monthly steelhead salvage against Export/Inflow ratio (EI), again, resulted in significant relationships at the SWP and CVP (Figure 13-46). The equations were very similar; not surprising since exports and EI ratio are related. The **r-squared** values were consistently smaller; therefore salvage, not EI ratio, is the better parameter. Of the four graphs in Figure 13-45, only the SWP clipped steelhead salvage relationship to EI ratio is of interest; the slope actually changes noticeably over the EI ratio range; at the high end. In the other three graphs, the slope is so small it would necessitate reducing pumping altogether to affect a change in steelhead salvage. There are two regression lines and equations in Figure 13-46, the black lines and equations represent the months of January through May (similar to the salvage and export graphs in Figure 13-45), and the red lines and equations represent the month of January alone. In three of the graphs in Figure 13-46, the January alone equations had smaller r-squared values and the equations were not significant, which is typical since there were fewer data points. In the remaining graph, SWP clipped steelhead salvage versus EI ratio, the **r-squared** value and was higher for the month of January alone compared to the months of January through May, and the equation was significant. But the slope of the equation is smaller because the most of the higher SWP clipped salvage occurred in months other than January, therefore for the month of January; it would take a large amount of change in EI ratio to affect a small reduction in SWP clipped steelhead salvage.

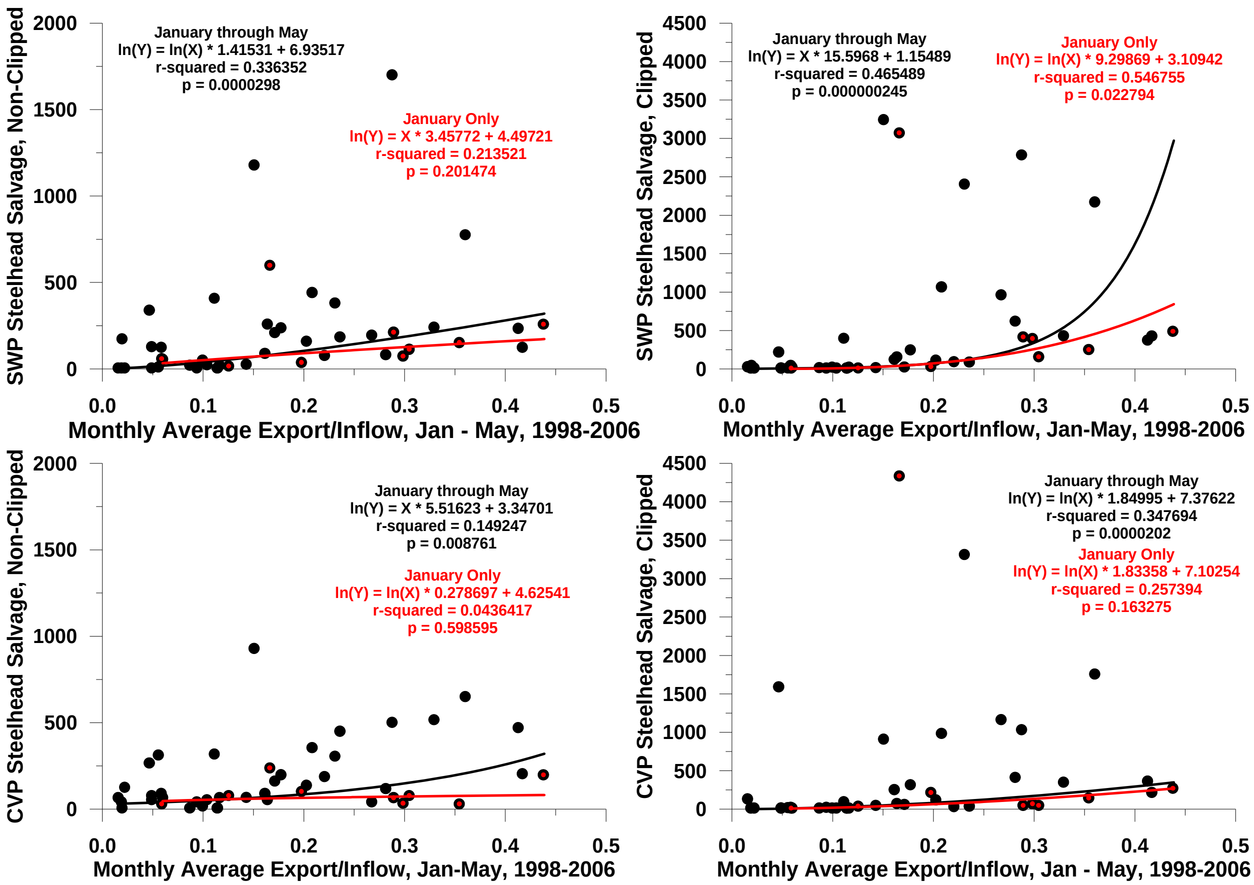


Figure 13-46 Monthly steelhead salvage versus average Export/Inflow ratio in taf, January through May, and January alone, 1998 through 2006, at each facility; SWP and CVP.

Green sturgeon salvage is low; therefore seasonal trends are difficult to determine (Figure 13-47).

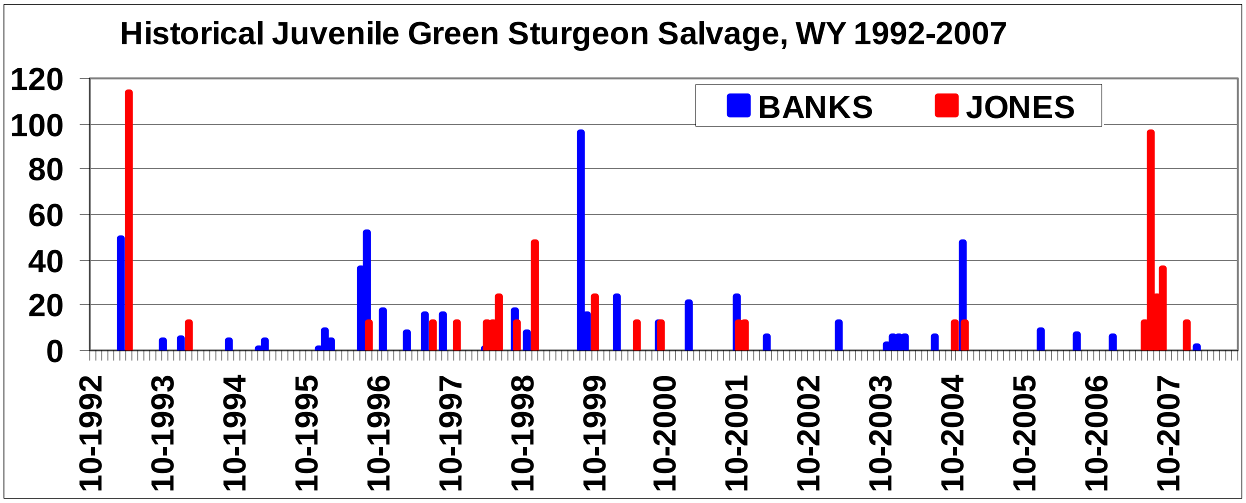


Figure 13-47 Historical juvenile green sturgeon salvage, WY 1992 – 2007.

Figure 13-48 and Figure 13-49 are the green sturgeon salvage grouped by water year type and month at each facility. At Banks, there is a slight trend of higher salvage in wet and critical years, and earlier salvage in wet years than critical years. This trend doesn't occur at Jones.

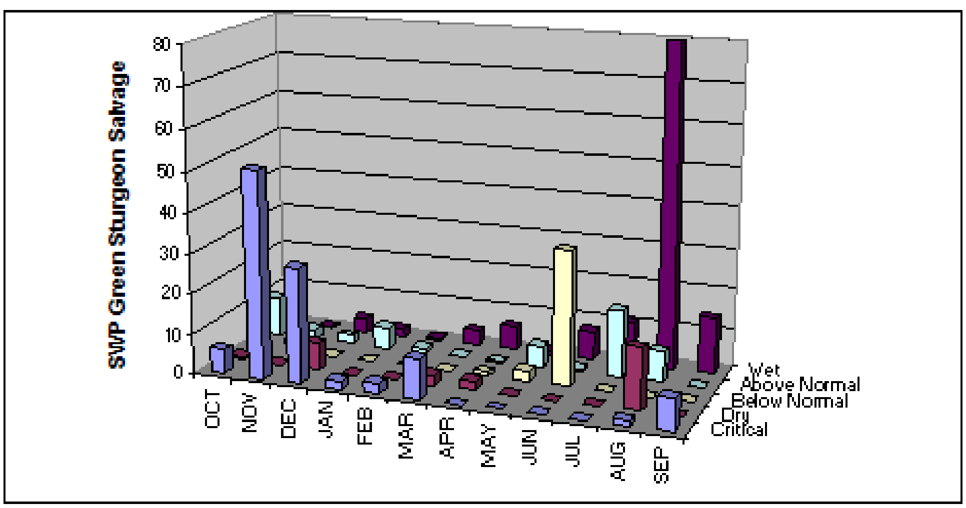


Figure 13-48 Green sturgeon salvage at Banks grouped by water year type and month

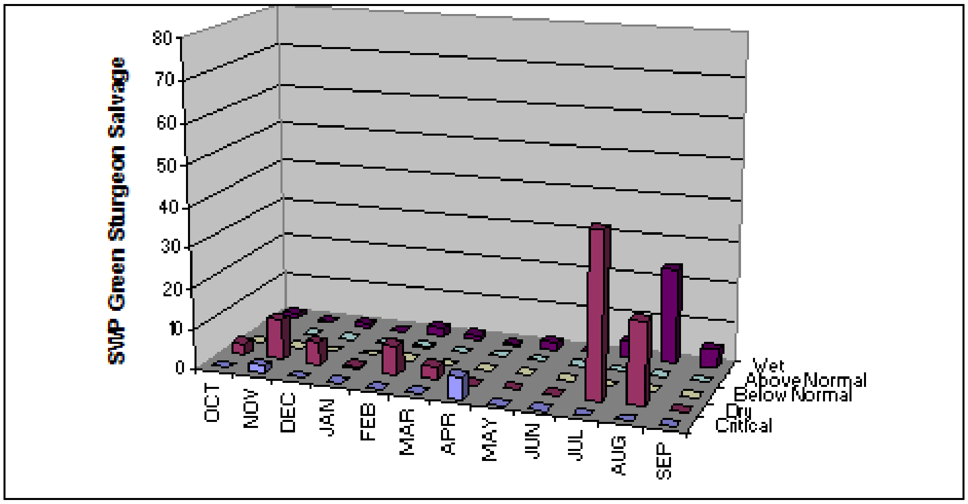


Figure 13-49 Green sturgeon salvage at Jones grouped by water year type and month

Direct Losses to Entrainment by CVP and SWP Export Facilities

Table 13-22 is the average loss of winter-run Chinook, yearling spring-run Chinook, and average salvage of steelhead and green sturgeon used in the effects analysis grouped by water-year type and month. We used Chinook loss data starting from 1993 through 2007 because 1993 was the first year for which adipose fin clip was recorded in the salvage database. Prior to that year, we can not distinguish clipped Chinook from non-clipped Chinook. We used steelhead salvage data starting from1998 because 1998 was the first year for which all hatchery steelhead were clipped. Prior to that year, we can not distinguish clipped from non-clipped steelhead. Loss for winter-run and spring-run was calculated using the Four Pumps Mitigation Agreement method. We used green sturgeon salvage data starting from 1981 because prior to that year green sturgeon were not separated from white sturgeon at Jones. For all species the below normal water year type did not fall into the period of record and was not included in Table 13-22.

Table 13-22 Average loss of winter-run, yearling-spring-run and young-of-the-year spring-run Chinook, and steelhead and green sturgeon salvage by export facility, water-year type and month.

NOTE: Winter run loss was based on non-clipped juveniles in the winter run length range using the Delta Model length criterion from 1993 - 2007. Clipped winter-run loss was based on Livingston Stone Hatchery winter-run from 1999-2007. Yearling spring run loss was based on Coleman Hatchery late-fall hatchery surrogates as described in the Salmon Protection Plan 1995-2007. Young-of-the-year spring run loss was based on total, non-clipped young-of-the-year juvenile loss as a surrogate 1993-2007. Steelhead salvage was based on non-clipped and clipped salvage from 1998 – 2007. Green sturgeon average salvage was calculated from , 1981 – 2007, and categorized into water year types.

BANKS YEARTYPE	SPECIES	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Critical	NC Winter	0	0	1630	168	145	482	16	4	4	0	0	0
Dry	NC Winter	0	0	370	366	1810	4895	140	8	0	0	0	0
Below	NC Winter	*	*	*	*	*	*	*	*	*	*	*	*
Above	NC Winter	0	0	584	1653	1866	1155	125	0	0	0	0	0
Wet	NC Winter	0	0	258	826	247	539	264	4	0	0	0	0
Critical	CL Winter	*	*	*	*	*	*	*	*	*	*	*	*
Dry	CL Winter	*	*	*	*	0.01%	0.07%	0.00%	0	0	0	0	0
Below	CL Winter	*	*	*	*	*	*	*	*	*	*	*	*
Above	CL Winter	*	*	*	*	0.05%	0.09%	0.01%	0	0	0	0	0
Wet	CL Winter	*	*	*	*	0	0.02%	0.02%	0	0	0	0	0
Critical	SR Yearlings	*	*	*	*	*	*	*	*	*	*	*	*
Dry	SR Yearlings	0	0	0.13%	0.09%	0.13%	0.04%	0.00%	0	0	0	0	0
Below	SR Yearlings	*	*	*	*	*	*	*	*	*	*	*	*
Above	SR Yearlings	0	0.01%	0.20%	0.24%	0.12%	0.03%	0	0	0	0	0	0
Wet	SR Yearlings	0	0	0.04%	0.10%	0.03%	0.00%	0	0	0	0	0	0
Critical	F/SR YOY	0	0	0	0	0	0.01	0.12	0.86	0.01	0	0	0
Dry	F/SR YOY	0	0	0	0	0	0.17	0.54	0.28	0.01	0	0	0
Below	F/SR YOY	*	*	*	*	*	*	*	*	*	*	*	*
Above	F/SR YOY	0	0	0	0	0.06	0.11	0.44	0.29	0.10	0	0	0
Wet	F/SR YOY	0	0	0	0.03	0.03	0.05	0.32	0.37	0.20	0.01	0	0
Critical	NC Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Dry	NC Steelhead	0	0	8	133	400	691	153	27	5	3	0	0
Below	NC Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Above	NC Steelhead	0	18	57	438	695	342	184	42	41	0	0	0
Wet	NC Steelhead	10	0	0	80	67	151	113	66	49	2	1	0
Critical	CL Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Dry	CL Steelhead	0	0	0	186	1220	1159	79	3	0	0	0	0
Below	CL Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Above	CL Steelhead	0	0	28	1753	2079	349	60	2	5	0	0	0
Wet	CL Steelhead	0	0	0	63	156	101	38	3	0	0	0	0
Critical	Grn Sturgeon	0	0	0	6	10	37	0	0	0	0	0	0
Dry	Grn Sturgeon	3	0	20	0	0	7	6	0	0	0	45	0
Below	Grn Sturgeon	*	*	*	*	*	*	*	*	*	*	*	*
Above	Grn Sturgeon	1	1	2	4	9	0	0	0	0	2	0	0
Wet	Grn Sturgeon	0	2	23	2	3	13	35	0	1	7	19	7

JONES YEARTYPE	SPECIES	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Critical	NC Winter	0	0	59	14	85	341	114	0	0	0	0	0
Dry	NC Winter	0	0	39	77	351	486	59	0	0	0	0	0
Below	NC Winter	*	*	*	*	*	*	*	*	*	*	*	*
Above	NC Winter	0	0	23	38	118	159	39	8	3	0	0	0
Wet	NC Winter	0	0	22	43	47	138	39	1	0	0	0	0
Critical	CL Winter	*	*	*	*	*	*	*	*	*	*	*	*
Dry	CL Winter	*	*	*	*	0.003%	0.005%	0.001%	0	0	0	0	0
Below	CL Winter	*	*	*	*	*	*	*	*	*	*	*	*
Above	CL Winter	*	*	*	*	0.003%	0.008%	0	0	0	0	0	0
Wet	CL Winter	*	*	*	*	0.004%	0.006%	0	0	0	0	0	0
Critical	SR Yearlings	*	*	*	*	*	*	*	*	*	*	*	*
Dry	SR Yearlings	0	0	0.01%	0.01%	0.01%	0.00%	0.00%	0	0	0	0	0
Below	SR Yearlings	*	*	*	*	*	*	*	*	*	*	*	*
Above	SR Yearlings	0	0	0.026%	0.022%	0.010%	0.00%	0	0	0	0	0	0
Wet	SR Yearlings	0	0.001%	0.006%	0.007%	0.002%	0	0	0	0	0	0	0
Critical	F/SR YOY	0	0	0	0	0	0.05	0.82	0.12	0.01	0	0	0
Dry	F/SR YOY	0	0	0	0	0.01	0.24	0.60	0.13	0.02	0	0	0
Below	F/SR YOY	*	*	*	*	*	*	*	*	*	*	*	*
Above	F/SR YOY	0	0	0	0	0.15	0.11	0.37	0.33	0.04	0	0	0
Wet	F/SR YOY	0	0	0	0.06	0.09	0.10	0.26	0.37	0.11	0	0	0
Critical	NC Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Dry	NC Steelhead	0	0	3	41	345	531	349	19	12	0	0	0
Below	NC Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Above	NC Steelhead	0	12	12	194	484	386	151	60	0	0	0	0
Wet	NC Steelhead	0	3	0	60	138	208	17	52	73	48	0	0
Critical	CL Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Dry	CL Steelhead	0	0	0	55	1440	914	128	9	0	0	0	0
Below	CL Steelhead	*	*	*	*	*	*	*	*	*	*	*	*
Above	CL Steelhead	0	0	42	2309	1021	220	71	0	0	0	0	0
Wet	CL Steelhead	0	0	0	66	198	505	19	2	0	0	0	0
Critical	Grn Sturgeon	0	7	0	0	0	0	23	0	0	0	0	0
Dry	Grn Sturgeon	9	31	17	2	22	0	9	0	0	108	61	0
Below	Grn Sturgeon	*	*	*	*	*	*	*	*	*	*	*	*
Above	Grn Sturgeon	0	0	0	0	4	0	0	0	0	0	0	0
Wet	Grn Sturgeon	8	1	4	0	12	8	1	12	3	27	147	31

Table 13-23 is the average change in Banks and Jones Pumping grouped by water year type comparing Study 7.1 to Study 7.0, and Study 8.0 to Study 7.0. The relative change in fish loss and salvage will be based on the relative change in pumping.

Table 13-23 Average change in Banks and Jones pumping grouped by water year type.

Facility	WaterYearType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Study 7.1 compared to 7.0													
Banks	Critical	7.7%	-8.2%	-6.1%	15.5%	18.2%	8.7%	6.4%	8.8%	25.1%	-7.0%	-11.9%	-13.1%
Banks	Dry	0.2%	-5.3%	7.2%	10.5%	0.0%	4.7%	10.3%	12.4%	3.5%	-8.4%	1.1%	-12.8%
Banks	Bl Normal	11.4%	-4.1%	6.6%	6.1%	-2.4%	7.2%	14.0%	34.3%	6.9%	14.4%	0.9%	-8.3%
Banks	Ab Normal	14.5%	-5.5%	8.3%	-0.3%	7.3%	4.3%	13.1%	42.2%	13.4%	32.5%	-8.5%	-10.2%
Banks	Wet	6.1%	-3.1%	6.6%	5.3%	4.9%	-0.2%	19.2%	20.9%	1.2%	4.2%	-7.8%	-2.9%
Jones	Critical	8.5%	6.2%	15.1%	1.0%	7.9%	16.4%	8.2%	28.6%	-1.0%	-16.6%	-1.7%	-4.3%
Jones	Dry	3.8%	4.5%	11.9%	17.2%	5.1%	-4.2%	6.3%	32.3%	3.9%	7.8%	-13.5%	-7.7%
Jones	Bl Normal	7.5%	6.1%	19.7%	15.0%	-3.4%	-15.7%	-4.3%	5.3%	-2.3%	24.3%	6.6%	-7.5%
Jones	Ab Normal	-0.5%	8.3%	20.6%	15.5%	-1.5%	-13.6%	-9.0%	6.9%	1.2%	9.3%	13.6%	3.3%
Jones	Wet	6.2%	9.0%	18.4%	15.1%	-0.1%	-25.9%	-2.3%	-1.1%	-2.5%	4.5%	5.7%	3.3%
Study 8.0 compared to 7.0													
Banks	Critical	4.8%	-17.5%	-8.7%	-2.9%	20.3%	7.4%	6.7%	13.8%	-11.9%	-22.0%	-17.1%	-2.9%
Banks	Dry	0.3%	-7.8%	8.1%	12.4%	-1.8%	5.3%	8.2%	18.5%	-8.3%	-8.8%	-2.4%	-7.0%
Banks	Bl Normal	7.0%	-5.6%	3.4%	9.9%	-3.1%	1.5%	13.9%	31.3%	9.3%	22.3%	12.9%	-0.2%
Banks	Ab Normal	4.8%	-10.1%	4.4%	4.6%	8.1%	4.8%	12.2%	43.1%	16.9%	51.9%	17.3%	-5.3%
Banks	Wet	2.5%	-4.7%	6.8%	6.1%	5.1%	2.7%	19.2%	20.9%	4.0%	16.1%	-3.8%	-2.7%
Jones	Critical	11.6%	-4.6%	17.5%	9.9%	4.8%	23.4%	5.9%	22.0%	-10.1%	-31.4%	-19.8%	-16.5%
Jones	Dry	8.1%	6.1%	11.9%	17.1%	5.9%	-6.6%	4.2%	29.1%	-3.8%	-0.4%	-29.3%	-8.3%
Jones	Bl Normal	13.8%	7.7%	20.2%	15.6%	-1.6%	-12.9%	-7.2%	-2.6%	-4.2%	19.8%	3.8%	-5.1%
Jones	Ab Normal	-1.6%	4.9%	24.2%	11.2%	11.0%	-7.9%	-8.4%	5.3%	1.2%	7.4%	-0.7%	13.4%
Jones	Wet	8.6%	11.5%	17.9%	13.1%	-1.4%	-20.3%	-1.5%	-0.1%	-1.0%	-8.1%	5.5%	5.1%
Study 6.1 compared to 7.0													
Banks	Critical	3.2%	-9.0%	-18.1%	8.0%	5.5%	-1.5%	-13.4%	-5.5%	-17.8%	-13.5%	-16.6%	20.0%
Banks	Dry	-0.7%	-6.2%	-6.1%	4.1%	-8.1%	-5.0%	-20.9%	25.2%	-10.4%	-1.8%	18.5%	5.3%
Banks	Bl Normal	9.5%	-1.0%	-2.6%	-2.8%	-6.6%	-7.7%	1.0%	4.0%	-8.6%	17.6%	11.8%	13.3%
Banks	Ab Normal	3.8%	-3.6%	-6.7%	2.7%	-6.8%	-6.4%	0.3%	1.5%	4.8%	45.6%	12.1%	6.1%
Banks	Wet	1.4%	-5.6%	-6.9%	-10.2%	-9.1%	-15.5%	-2.2%	-2.6%	1.9%	20.2%	2.5%	2.4%
Jones	Critical	7.3%	1.5%	4.1%	-4.1%	-18.5%	-3.5%	-15.3%	0.0%	19.5%	5.8%	27.9%	-8.3%
Jones	Dry	1.8%	-0.4%	0.2%	4.2%	2.7%	4.7%	-13.4%	16.8%	-2.8%	-7.1%	-11.3%	1.5%
Jones	Bl Normal	5.4%	2.9%	1.4%	-0.6%	7.3%	1.0%	1.1%	-3.1%	-4.1%	-2.1%	-0.1%	-2.1%
Jones	Ab Normal	-1.6%	3.0%	5.3%	-0.9%	4.4%	4.3%	-3.8%	10.9%	2.7%	9.7%	-1.1%	4.3%
Jones	Wet	8.3%	4.0%	3.8%	-0.1%	-6.8%	-2.6%	-3.3%	14.5%	-0.5%	-12.4%	1.1%	2.6%

Table 13-24 represents potential loss and salvage changes for both non-clipped and clipped winter-run, yearling and yoy spring run, non-clipped and clipped steelhead and green sturgeon comparing operations today to future operations (Model 7.1 vs 7.0, model 8.0 vs 7.0) if we assumed that salvage is directly proportional to the amount of water exported (i.e. doubling the amount of water exported doubles the number of fish salvaged). Because there is not a direct method to estimate yoy spring run loss, we used the combination of yoy fall- and spring-run losses as a surrogate for you spring run loss and reported just the percentage change for yoy spring run loss. The highlight cells represent just a visual inspection of the months and water year types with the relatively largest changes in loss or salvage. The values in each table are different because they are in terms of the take statement in the current Biological Opinion (BO). Take for non-clipped winter-run is in terms of loss, for hatchery winter-run (clipped) and yearling spring run are in terms of the percentage of released hatchery juveniles subsequently lost at the Delta pumping facilities, steelhead and green sturgeon are in terms of salvage. Take for young of the year spring run isn't defined in the current BO because there is no method to identify spring run available for management use. Since the values or metrics are different for each species, the values from one table (or species) aren't relative to another table or species.

Table 13-24 Average change in winter run, yearling spring run and young-of-the-year spring run loss, and steelhead and green sturgeon salvage by species, model, facility, water-year type and month assuming a direct relationship between monthly exports and monthly salvage.

NOTE: Winter run loss was based on non-clipped juveniles in the winter run length range 1993 - 2007. Clipped winter-run loss was based on Livingston Stone Hatchery winter-run from 1999-2007. Yearling spring run loss was based on Coleman Hatchery late-fall hatchery surrogates as described in the Salmon Protection Plan 1995-2007. Young-of-the-year spring run loss was based on total, non-clipped young-of-the-year juvenile loss as a surrogate 1993-2007. Steelhead salvage was based on water years 1998 – 2007. Green sturgeon average salvage was based on salvage from 1981 -2007, and categorized into all 5 water year types.

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Model 7.1 compared to 7.0														
Winter Loss	Banks	Critical	0	0	-100	26	26	42	1	0	1	0	0	0
Winter Loss	Banks	Dry	0	0	27	39	0	230	14	1	0	0	0	0
Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Banks	AbNormal	0	0	49	-5	135	50	16	0	0	0	0	0
Winter Loss	Banks	Wet	0	0	17	44	12	-1	51	1	0	0	0	0
Winter Loss	Jones	Critical	0	0	9	0	7	56	9	0	0	0	0	0
Winter Loss	Jones	Dry	0	0	5	13	18	-20	4	0	0	0	0	0
Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Jones	AbNormal	0	0	5	6	-2	-22	-4	1	0	0	0	0
Winter Loss	Jones	Wet	0	0	4	7	0	-36	-1	0	0	0	0	0
Model 8.0 compared to 7.0														
Winter Loss	Banks	Critical	0	0	-142	-5	29	36	1	1	-1	0	0	0
Winter Loss	Banks	Dry	0	0	30	45	-33	261	11	1	0	0	0	0
Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Banks	AbNormal	0	0	26	76	151	55	15	0	0	0	0	0
Winter Loss	Banks	Wet	0	0	18	50	13	15	51	1	0	0	0	0
Winter Loss	Jones	Critical	0	0	10	1	4	80	7	0	0	0	0	0
Winter Loss	Jones	Dry	0	0	5	13	21	-32	2	0	0	0	0	0
Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Jones	AbNormal	0	0	6	4	13	-13	-3	0	0	0	0	0
Winter Loss	Jones	Wet	0	0	4	6	-1	-28	-1	0	0	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Model 6.1 compared to 7.0														
Winter Loss	Banks	Critical	0	0	-295	13	8	-7	-2	0	-1	0	0	0
Winter Loss	Banks	Dry	0	0	-22	15	-146	-245	-29	2	0	0	0	0
Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Banks	AbNormal	0	0	-39	45	-126	-74	0	0	0	0	0	0
Winter Loss	Banks	Wet	0	0	-18	-84	-22	-84	-6	0	0	0	0	0
Winter Loss	Jones	Critical	0	0	2	-1	-16	-12	-17	0	0	0	0	0
Winter Loss	Jones	Dry	0	0	0	3	9	23	-8	0	0	0	0	0
Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Winter Loss	Jones	AbNormal	0	0	1	0	5	7	-1	1	0	0	0	0
Winter Loss	Jones	Wet	0	0	1	0	-3	-4	-1	0	0	0	0	0
Model 7.1 compared to 7.0														
CL Winter Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	Dry	*	*	*	*	0.000%	0.003%	0.001%	0	0	0	0	0
CL Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	AbNormal	*	*	*	*	0.002%	0.007%	0.003%	0	0	0	0	0
CL Winter Loss	Banks	Wet	*	*	*	*	0.000%	0.000%	0.003%	0	0	0	0	0
CL Winter Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	Dry	*	*	*	*	0.00%	0.00%	0.00%	0	0	0	0	0
CL Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	AbNormal	*	*	*	*	0.000%	-0.002%	0.000%	0	0	0	0	0
CL Winter Loss	Jones	Wet	*	*	*	*	0.000%	-0.002%	0.000%	0	0	0	0	0
Model 8.0 compared to 7.0														
CL Winter Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	Dry	*	*	*	*	0.000%	0.004%	0.000%	0	0	0	0	0
CL Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	AbNormal	*	*	*	*	0.002%	0.008%	0.003%	0	0	0	0	0
CL Winter Loss	Banks	Wet	*	*	*	*	0.000%	0.001%	0.003%	0	0	0	0	0
CL Winter Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	Dry	*	*	*	*	0.000%	0.000%	0.000%	0	0	0	0	0
CL Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	AbNormal	*	*	*	*	0.001%	-0.001%	0.000%	0	0	0	0	0
CL Winter Loss	Jones	Wet	*	*	*	*	0.000%	-0.001%	0.000%	0	0	0	0	0
Model 6.1 compared to 7.0														
CL Winter Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	Dry	*	*	*	*	0.00%	0.003%	0.00%	0	0	0	0	0
CL Winter Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Banks	AbNormal	*	*	*	*	-0.002%	-0.02%	0.00%	0	0	0	0	0
CL Winter Loss	Banks	Wet	*	*	*	*	0.00%	-0.001%	0.00%	0	0	0	0	0
CL Winter Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	Dry	*	*	*	*	0.00%	0.00%	0.00%	0	0	0	0	0
CL Winter Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Winter Loss	Jones	AbNormal	*	*	*	*	0.00%	-0.001%	0.00%	0	0	0	0	0
CL Winter Loss	Jones	Wet	*	*	*	*	-0.001%	-0.001%	0.00%	0	0	0	0	0
Model 7.1 compared to 7.0														
YRL Spring Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	Dry	0	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	AbNormal	0	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
YRL Spring Loss	Banks	Wet	0	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	Dry	0	0.00%	0.002%	0.002%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	AbNormal	0	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Wet	0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
Study 8.0 compared to 7.0														
YRL Spring Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	Dry	0	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	AbNormal	0	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Wet	0	0.003%	0.01%	0.001%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	Dry	0	0.00%	0.002%	0.002%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	AbNormal	0	0.00%	0.001%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Wet	0	0.00%	0.001%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
Study 6.1 compared to 7.0														
YRL Spring Loss	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	Dry	0	0	-0.01%	0.003%	-0.01%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Banks	AbNormal	0	0	-0.01%	0.01%	-0.01%	-0.003%	0.00%	0	0	0	0	0
YRL Spring Loss	Banks	Wet	0	0	-0.003%	-0.01%	-0.002%	-0.001%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	Dry	0	0	0.00%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
YRL Spring Loss	Jones	AbNormal	0	0	0.001%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
YRL Spring Loss	Jones	Wet	0	0	0.00%	0.00%	0.00%	0.00%	0.00%	0	0	0	0	0
Model 7.1 compared to 7.0														
F/S YOY Loss	Banks	Critical	0	0	0	15.5%	18.2%	8.7%	6.4%	8.8%	25.1%	0	0	0
F/S YOY Loss	Banks	Dry	0	0	0	10.5%	0.0%	4.7%	10.3%	12.4%	3.5%	0	0	0
F/S YOY Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
F/S YOY Loss	Banks	AbNormal	0	0	0	-0.3%	7.3%	4.3%	13.1%	42.2%	13.4%	0	0	0
F/S YOY Loss	Banks	Wet	0	0	0	5.3%	4.9%	-0.2%	19.2%	20.9%	1.2%	0	0	0
F/S YOY Loss	Jones	Critical	0	0	0	1.0%	7.9%	16.4%	8.2%	28.6%	-1.0%	0	0	0
F/S YOY Loss	Jones	Dry	0	0	0	17.2%	5.1%	-4.2%	6.3%	32.3%	3.9%	0	0	0
F/S YOY Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
F/S YOY Loss	Jones	AbNormal	0	0	0	15.5%	-1.5%	-13.6%	-9.0%	6.9%	1.2%	0	0	0
F/S YOY Loss	Jones	Wet	0	0	0	15.1%	-0.1%	-25.9%	-2.3%	-1.1%	-2.5%	0	0	0
Study 8.0 compared to 7.0														
F/S YOY Loss	Banks	Critical	0	0	0	-2.9%	20.3%	7.4%	6.7%	13.8%	-11.9%	0	0	0
F/S YOY Loss	Banks	Dry	0	0	0	12.4%	-1.8%	5.3%	8.2%	18.5%	-8.3%	0	0	0
F/S YOY Loss	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
F/S YOY Loss	Banks	AbNormal	0	0	0	4.6%	8.1%	4.8%	12.2%	43.1%	16.9%	0	0	0
F/S YOY Loss	Banks	Wet	0	0	0	6.1%	5.1%	2.7%	19.2%	20.9%	4.0%	0	0	0
F/S YOY Loss	Jones	Critical	0	0	0	9.9%	4.8%	23.4%	5.9%	22.0%	-10.1%	0	0	0
F/S YOY Loss	Jones	Dry	0	0	0	17.1%	5.9%	-6.6%	4.2%	29.1%	-3.8%	0	0	0
F/S YOY Loss	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
F/S YOY Loss	Jones	AbNormal	0	0	0	11.2%	11.0%	-7.9%	-8.4%	5.3%	1.2%	0	0	0
F/S YOY Loss	Jones	Wet	0	0	0	13.1%	-1.4%	-20.3%	-1.5%	-0.1%	-1.0%	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Study 6.1 compared to 7.0														
F/S YOY Loss	Banks	Critical	0	0	0	8.0%	5.5%	-1.5%	-13.4%	-5.5%	-17.8%	0	0	0
F/S YOY Loss	Banks	Dry	0	0	0	4.1%	-8.1%	-5.0%	-20.9%	25.2%	-10.4%	0	0	0
F/S YOY Loss	Banks	Bl Normal	*	*	*	-2.8%	-6.6%	-7.7%	1.0%	4.0%	-8.6%	*	*	*
F/S YOY Loss	Banks	AbNormal	0	0	0	2.7%	-6.8%	-6.4%	0.3%	1.5%	4.8%	0	0	0
F/S YOY Loss	Banks	Wet	0	0	0	-10.2%	-9.1%	-15.5%	-2.2%	-2.6%	1.9%	0	0	0
F/S YOY Loss	Jones	Critical	0	0	0	-4.1%	-18.5%	-3.5%	-15.3%	0.0%	19.5%	0	0	0
F/S YOY Loss	Jones	Dry	0	0	0	4.2%	2.7%	4.7%	-13.4%	16.8%	-2.8%	0	0	0
F/S YOY Loss	Jones	Bl Normal	*	*	*	-0.6%	7.3%	1.0%	1.1%	-3.1%	-4.1%	*	*	*
F/S YOY Loss	Jones	AbNormal	0	0	0	-0.9%	4.4%	4.3%	-3.8%	10.9%	2.7%	0	0	0
F/S YOY Loss	Jones	Wet	0	0	0	-0.1%	-6.8%	-2.6%	-3.3%	14.5%	-0.5%	0	0	0
Model 7.1 compared to 7.0														
Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	Dry	0	0	1	14	0	32	16	3	0	0	0	0
Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	AbNormal	0	-1	5	-1	50	15	24	18	6	0	0	0
Steelhead Slvg	Banks	Wet	1	0	0	4	3	0	22	14	1	0	0	0
Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	Dry	0	0	0	7	17	-22	22	6	0	0	0	0
Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	AbNormal	0	1	2	30	-7	-52	-14	4	0	0	0	0
Steelhead Slvg	Jones	Wet	0	0	0	9	0	-54	0	-1	-2	2	0	0
Model 8.0 compared to 7.0														
Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	Dry	0	0	1	17	-7	37	13	5	0	0	0	0
Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	AbNormal	0	-2	2	20	56	16	22	18	7	0	0	0
Steelhead Slvg	Banks	Wet	0	0	0	5	3	4	22	14	2	0	0	0
Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	Dry	0	0	0	7	21	-35	15	5	0	0	0	0
Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	AbNormal	0	1	3	22	53	-30	-13	3	0	0	0	0
Steelhead Slvg	Jones	Wet	0	0	0	8	-2	-42	0	0	-1	-4	0	0
Model 6.1 compared to 7.0														
Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	Dry	0	0	0	6	-32	-35	-32	7	0	0	0	0
Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Banks	AbNormal	0	-1	-4	12	-47	-22	1	1	2	0	0	0
Steelhead Slvg	Banks	Wet	0	0	0	-8	-6	-23	-2	-2	1	0	0	0
Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	Dry	0	0	0	2	9	25	-47	3	0	0	0	0
Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Steelhead Slvg	Jones	AbNormal	0	0	1	-2	22	17	-6	7	0	0	0	0
Steelhead Slvg	Jones	Wet	0	0	0	0	-9	-5	-1	8	0	-6	0	0
Model 7.1 compared to 7.0														
CL Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	Dry	0	0	0	20	0	54	8	0	0	0	0	0
CL Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	AbNormal	0	0	2	-5	151	15	8	1	1	0	0	0
CL Steelhead Slvg	Banks	Wet	0	0	0	3	8	0	7	1	0	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
CL Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	Dry	0	0	0	9	73	-38	8	3	0	0	0	0
CL Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	AbNormal	0	0	9	358	-16	-30	-6	0	0	0	0	0
CL Steelhead Slvg	Jones	Wet	0	0	0	10	0	-131	0	0	0	0	0	0
Model 8.0 compared to 7.0														
CL Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	Dry	0	0	0	23	-22	62	6	1	0	0	0	0
CL Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	AbNormal	0	0	1	81	169	17	7	1	1	0	0	0
CL Steelhead Slvg	Banks	Wet	0	0	0	4	8	3	7	1	0	0	0	0
CL Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	Dry	0	0	0	9	86	-60	5	2	0	0	0	0
CL Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	AbNormal	0	0	10	259	112	-17	-6	0	0	0	0	0
CL Steelhead Slvg	Jones	Wet	0	0	0	9	-3	-102	0	0	0	0	0	0
Model 6.1 compared to 7.0														
CL Steelhead Slvg	Banks	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	Dry	0	0	0	8	-99	-58	-16	1	0	0	0	0
CL Steelhead Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Banks	AbNormal	0	0	-2	48	-141	-22	0	0	0	0	0	0
CL Steelhead Slvg	Banks	Wet	0	0	0	-6	-14	-16	-1	0	0	0	0	0
CL Steelhead Slvg	Jones	Critical	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	Dry	0	0	0	2	39	43	-17	1	0	0	0	0
CL Steelhead Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
CL Steelhead Slvg	Jones	AbNormal	0	0	2	-21	45	9	-3	0	0	0	0	0
CL Steelhead Slvg	Jones	Wet	0	0	0	0	-13	-13	-1	0	0	0	0	0
Model 7.1 compared to 7.0														
Grn Sturgeon Slvg	Banks	Critical	0	0	0	1	2	3	0	0	0	0	0	0
Grn Sturgeon Slvg	Banks	Dry	0	0	1	0	0	0	1	0	0	0	0	0
Grn Sturgeon Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Banks	AbNormal	0	0	0	0	1	0	0	0	0	1	0	0
Grn Sturgeon Slvg	Banks	Wet	0	0	2	0	0	0	7	0	0	0	-1	0
Grn Sturgeon	Jones	Critical	0	0	0	0	0	0	2	0	0	0	0	0

Species	Fac	WYType	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Slvg														
Grn Sturgeon Slvg	Jones	Dry	0	1	2	0	1	0	1	0	0	8	-8	0
Grn Sturgeon Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Jones	AbNormal	0	0	0	0	0	0	0	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Wet	0	0	1	0	0	-2	0	0	0	1	8	1
Model 8.0 compared to 7.0														
Grn Sturgeon Slvg	Banks	Critical	0	0	0	0	2	3	0	0	0	0	0	0
Grn Sturgeon Slvg	Banks	Dry	0	0	2	0	0	0	1	0	0	0	-1	0
Grn Sturgeon Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Banks	AbNormal	0	0	0	0	1	0	0	0	0	1	0	0
Grn Sturgeon Slvg	Banks	Wet	0	0	2	0	0	0	7	0	0	1	-1	0
Grn Sturgeon Slvg	Jones	Critical	0	0	0	0	0	0	1	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Dry	1	2	2	0	1	0	0	0	0	0	-18	0
Grn Sturgeon Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Jones	AbNormal	0	0	0	0	0	0	0	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Wet	1	0	1	0	0	-2	0	0	0	-2	8	2
Model 6.1 compared to 7.0														
Grn Sturgeon Slvg	Banks	Critical	0	0	0	0	1	-1	0	0	0	0	0	0
Grn Sturgeon Slvg	Banks	Dry	0	0	-1	0	0	0	-1	0	0	0	8	0
Grn Sturgeon Slvg	Banks	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Banks	AbNormal	0	0	0	0	-1	0	0	0	0	1	0	0
Grn Sturgeon Slvg	Banks	Wet	0	0	-2	0	0	-2	-1	0	0	2	0	0
Grn Sturgeon Slvg	Jones	Critical	0	0	0	0	0	0	-3	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Dry	0	0	0	0	1	0	-1	0	0	-8	-7	0
Grn Sturgeon Slvg	Jones	Bl Normal	*	*	*	*	*	*	*	*	*	*	*	*
Grn Sturgeon Slvg	Jones	AbNormal	0	0	0	0	0	0	0	0	0	0	0	0
Grn Sturgeon Slvg	Jones	Wet	1	0	0	0	-1	0	0	2	0	-3	2	1

The months of greatest changes in loss or salvage between the base case (Study 7.0) and the future (Studies 7.1 and 8.0) are December through June for salmonids. Green sturgeon change is too irregular to summarize.

Indirect Losses to Entrainment by CVP and SWP Export Facilities

The FWS Service has conducted juvenile Chinook survival experiments in the Delta for many years. They have conducted yoy fall-run survival experiments in the spring months on the Sacramento and San Joaquin rivers, and late-fall run survival experiments in the fall and winter months on the Sacramento River using hatchery reared juvenile Chinook. One of the purposes of these experiments has been to try to determine the "indirect" effects of Delta exports on juvenile Chinook survival as they emigrate through the Delta. Ken Newman (2008) published analyses of all these data sets. The results as quoted from the executive summary are:

> **Results**
>
> For the most part, the substantive conclusions from the Bayesian Hierarchical Model (BHM) analyses, summarized below, were consistent with previous USFWS analyses.
>
> **Delta Cross Channel:** There was modest evidence, 64 to 70% probability, that survival of Courtland [above DCC] releases, relative to the survival of Ryde [below DCC] releases, increased when the gate was closed.
>
> **Interior:** Survival for the interior Delta releases was estimated to be about 44% of the survival for the Sacramento River releases.
>
> **Delta Action 8:** There was a negative association between export volume and relative [interior Delta] survival, i.e., a 98% chance that as exports increased, relative [interior Delta] survival decreased. Environmental variation in the relative survival was very large, however; e.g., for one paired release the actual relative survival at a low export level could with high probability be lower than relative survival at a high export level for another paired release.
>
> **VAMP:** (a) The expected probability of surviving to Jersey Point was consistently larger for fish straying I the San Joaquin River (say passing Dos Reis) than fish entering Old River, but the magnitude of the difference varied between models somewhat; (b) thus if the HORB effectively keeps fish from entering Old River, survival of out-migrants should increase; (c) there was a positive association between flow at Dos Reis and subsequent survival from Dos Reis and Jersey Point, and if data from 2003 and later were eliminated from analysis the strength of the association increased and a positive association between flow in Old River and survival in Old River appeared; (d) associations between water export levels and survival probabilities were weak to negligible. Given complexity and number of potential models for the VAMP data, however, a more thorough model selection procedure using Reversible Jump MCM is recommended.

From Newman's results, we conclude fish emigrating from the Sacramento River through the interior Delta survive about half as well as fish emigrating down the mainstem Sacramento River, but exports affect the change in relative interior survival by about -5 percent per 1,000 cfs increase in exports between 2,000 cfs and 4,000 cfs, and by about -2.75 percent per 1000 cfs increase in exports between 8,000 cfs and 10,000 cfs (Figure 13-50). For fish emigrating from the San Joaquin River through the south Delta, the effect of exports on survival was weak to negligible.

FIGURE 24. DA 8: Posterior means (solid) and medians (dashed line) for θ from the BHM (with log transformed θ and uniform priors on standard deviations of random effects) plotted against export levels. The 2.5% and 97.5% intervals are indicated by vertical lines.

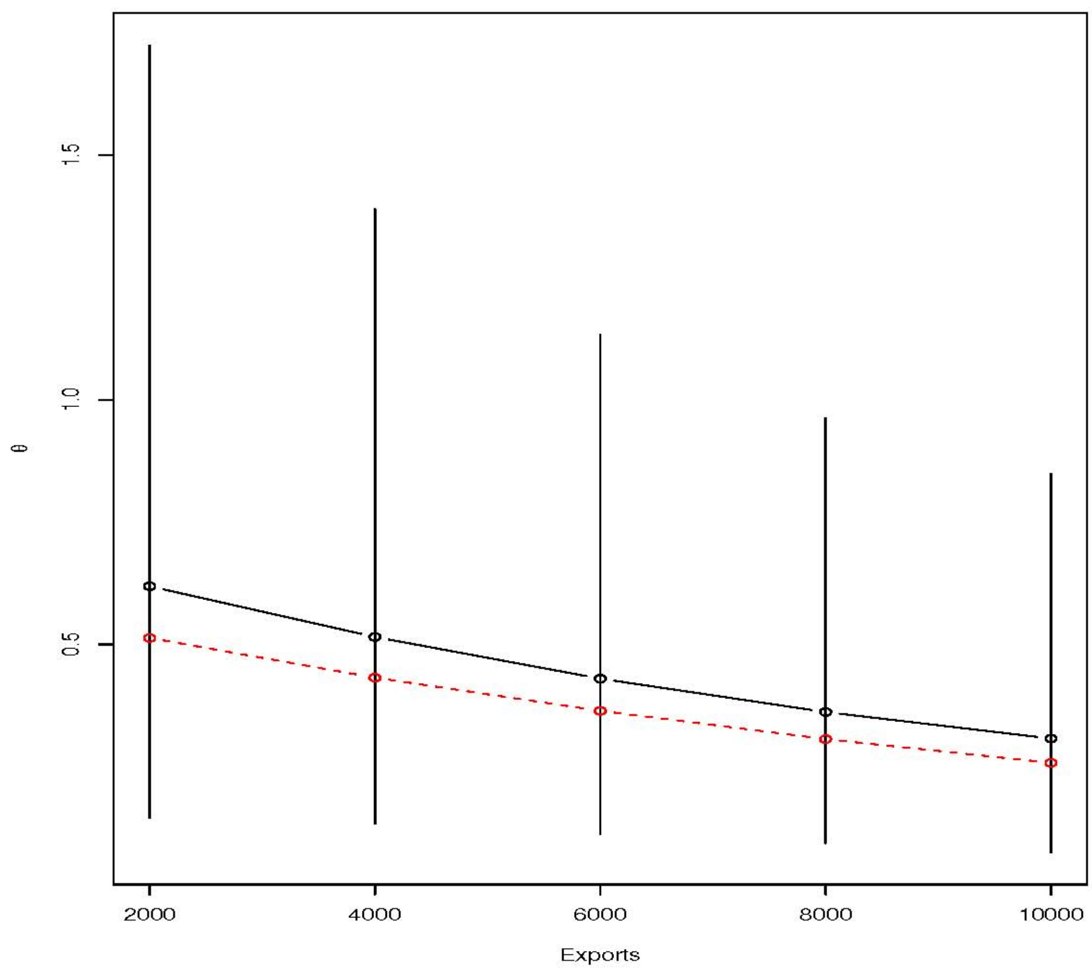


Figure 13-50 Posterior means and medians

Steelhead Predation Study

Steelhead entrained in the Forebay are subject to predation, synonymous with pre-screen loss, as they traverse the Forebay toward the John E. Skinner Fish Protective Facility (SFPF). DWR conducted a study in 2005, 2006, and 2007 to assess and quantify steelhead pre-screen losses within Clifton Court Forebay. The investigation was developed to provide useful information that could serve to reduce the potential vulnerability of steelhead to predation mortality within Clifton Court Forebay. A final report will be available in the fall of 2008.

Preliminary results suggest that the pre-screen loss rate was 82 ±3% (mean ± 95% confidence interval) in 2007. This result is similar to previous pre-screen loss studies of other fish species including Chinook salmon and juvenile striped bass (Schaffter, 1978; Hall, 1980; and Kano, 1985). In contrast, the SFPF loss rate was 26 ±7% (mean ± 95% confidence interval). Statistical analysis showed that pre-screen loss rate did not differ by month of release. However, the time to salvage was greater for PIT tagged steelhead released at the radial gates in February than those released in January or April. Data analysis concluded that there was no correlation between steelhead movement rates and water temperature, export rate, turbidity, radial gate water velocities, or light intensity. However, steelhead movement rates were correlated to the length of time spent within Clifton Court Forebay. The longer steelhead remained within the Forebay the less they moved.

500 CFS Increased Diversion to Provide Reduced Exports Taken to Benefit Fish Resources Effects on Salmonids and Green Sturgeon

Clifton Court Forebay (CCF) is typically operated at or near the rates defined in the USACE Public Notice 5820A, Amended, unless otherwise restricted. Public Notice 5820A, Amended, requires that daily summer diversions into CCF not exceed 13,870 AF and a three-day average not to exceed 13,250 AF. Banks Pumping Plant is operated to the available physical capacity, as constrained by CCF operations. Banks Pumping Plant is also adjusted to assist in maintaining velocity criteria at Skinner Fish facility as exports allow. Maximum average monthly SWP summer exports from Banks Pumping Plant are 6,680 cfs.

Under the 500 cfs increased diversion, the maximum allowable daily diversion rate into CCF during the months of July, August, and September would increase from 13,870 AF up to 14,860 AF and three-day average diversions would increase from 13,250 AF up to 14,240 AF. This increased diversion over the three-month period would result in an amount not to exceed 90,000 AF each year. Maximum average monthly SWP exports during the three-month period from Banks Pumping Plant would increase to 7,180 cfs. Variations to hydrologic conditions coupled with regulatory requirements may limit the ability of the SWP to fully utilize the proposed increased diversion rate. Also, facility capabilities may limit the ability of the SWP to fully utilize the proposed increased diversion rate.

Water exported under the 500 cfs increased export limit would first be used to recover export reductions taken during the VAMP period (assumed mid-April to mid-May) or applied to the “shoulder” periods preceding or following the VAMP period. Any remaining water could be applied to other export reductions for fish protection during that calendar year or be stored in San Luis Reservoir to be applied to export reductions for the subsequent calendar year. As the SWP share of San Luis Reservoir is filled, there is a risk that this water would be “spilled” from the reservoir. “Spilling” the stored water would result in lower exports from the Delta during the time the reservoir is filling. Normally, this would occur during December – March. The fishery agencies would decide whether to implement an export reduction in the fall or winter time period equivalent to the water stored in the reservoir or assume the risk that the water would be spilled later on. Additional details regarding the implementation of the 500 cfs increased diversion are contained in Chapter 2.

Analyses Contained in the Initial Study

Much of the information in this discussion is taken from the *Initial Study for the 2005 – 2008 State Water Project Delta Facility Increased Diversion to Recover Reduced Exports Taken to Benefit Fish Resources* (DWR 2004). The operation analyzed in the Initial Study and implemented in 2005 – 2008 is slightly different than the operation contained in this project description. The difference is the ability to carry over water exported under the 500 cfs increased diversion limit into the subsequent calendar year. The operation analyzed in the Initial Study and implemented through 2008 does not allow carry over of the exported water. The operation to begin in 2009 allows carry over of the exported water as long as it does not affect the ability to fill the SWP share of San Luis Reservoir. Water exported under the 500 cfs export limit is to be used only for export reductions to benefit fish resources.

The Initial Study uses a comparative analysis to quantify the impacts of the 500 cfs increased diversion (Project) compared to a no-project (Base) condition. The range of potential impacts is defined by modeling two hydrologies: a year of low delta inflow, and a year of high delta inflow. The hydrologies are used as input for the DWRDSM2 HYDRO and QUAL studies, which evaluate changes in flow, stage, velocity, and salinity. Tidally averaged comparisons of water quality, flow, stage, and velocities for all the locations studied are in Appendix II of the Initial Study (DWR 2004). The modeling assumptions for the Project include the following:

- Two 30-day periods to reduce diversions to benefit fish resources are chosen: May 15-June 15, and November 15–December 15. The total reduction in diversions cannot exceed 90 TAF.
- The operations of the SWP and CVP must comply with existing Bay-Delta requirements of the SWRCB Decision 1641. Operations are assumed to comply with the ESA, and other regulatory and contractual requirements related to the Sacramento-San Joaquin River Delta.
- Current SWP operations allow a maximum three-day average diversion rate of 6,680 cfs during July, August, and September. Project diversions during that period must exceed the maximum three-day average diversion rate of 6,680 cfs to constitute a with-Project condition since diversions less than that amount are already permitted in the base condition.
- The increased diversions during July, August, and September of any calendar year equals the amount of reduced diversions during that calendar year.

The historic hydrologies were examined to find a representative period and a high and low inflow year. The representative period is from1987 to 1999 and the low and high inflow years are 1992 and 1997. The reasons for selecting 1992 and 1997 are discussed below.

1992, Low Delta Inflow Year

Two difficulties in selecting a year of low delta inflow occurred. Exports in years of low delta inflow during each of the two 30-day periods, (May 15-June 15, and November 15-December 15) typically did not exceed 90 TAF. Current constraints on export/inflow ratios were instituted in 1995 under the Bay-Delta Accord. All years since 1995 have been classified as wet years (up to the year 2000). Therefore, historic operations during a year of low delta inflow with current regulatory constraints did not exist at the time of the study.

Three years of low delta inflow were considered: 1987, 1988, and 1992. In 1987 and 1988, exports during the two 30-day periods, (May 15-June 15, and November 15-December 15) could be reduced by 90 TAF. However, operations prior to 1995 were not subject to existing regulatory requirements, and thus the export/inflow ratios during 1987 and 1988 exceeded existing export/inflow requirements of the SWRCB. In 1987, daily exports exceeded present requirements by an average of 2744 cfs, and a maximum of 6146 cfs. Therefore, 1987 and 1988 were eliminated from consideration.

In 1992, exports during the two 30-day periods, May 15-June 15, and November 15-December 15, were approximately 46 TAF and 66 TAF, respectively. Therefore, exports could not be reduced by the full proposed amount of 90 TAF. Although export/inflow ratios exceeded existing requirements, the existing requirements could be met with minor adjustments to the historic inflow. In 1992, present export/inflow ratio requirements could be met by increasing Sacramento River inflow by an average of 11 cfs. For these reasons, 1992 was selected as the year to represent conditions of low Delta inflow.

1997, High Delta Inflow Year

Current constraints on export/inflow ratios were instituted in 1995 and delta inflow during the subsequent years was high. Therefore, several years of historic operations with high delta inflow and current regulatory constraints exist. Thus, 1995-1999 were considered. SWP exports during May 15-June 15 exceeded 90 TAF in 1995, 1996, and 1997. In 1998 and 1999, SWP exports during May 15-June 15 were only 78 TAF and 71 TAF, respectively, which would not allow a reduction for the full proposed amount of 90 TAF. 1995 was not chosen because SWP exports during the November 15 to December 15 period were only 6,210 AF. 1996 was not chosen because SWP exports during May 15-June 15 were 294 TAF, and this was not considered a representative year. In 1997, SWP exports during May 15-June 15 and November 15 to December 15 period were 100 TAF and 644 TAF, respectively.

Historic vs. Base Hydrologies

The historic hydrologies were modified so the base hydrologies would comply with the initial assumptions explained above and repeated below:

- The operations of the SWP and CVP must comply with existing requirements of SWRCB Decision 1641, with the ESA, and other regulatory and contractual requirements related to the Sacramento-San Joaquin River Delta.
- Current SWP operations allow a maximum three-day average diversion rate of 6,680 cfs during July, August, and September. Project diversions during that period must exceed the maximum three-day average diversion rate of 6,680 cfs because diversions less than this base condition are already permitted.

Sacramento River flows were also modified from historic conditions. When export/inflow ratios exceeded existing requirements, Sacramento River flows were increased until existing constraints were met. When exports were modified, Sacramento River flows were modified to maintain the net delta outflow. Thus, the SWP was simply changing the time when storage in Oroville was being moved to San Luis Reservoir.

The potential changes in diversion rate into CCF will affect fish salvage at the SWP. To determine the impact of such export changes, historic salvage data from 1992 and 1997 (representative low and high Delta inflow years used in the modeling) were used to estimate the impact of the Project on fish salvage. Historic salvage density was used to estimate salvage under the different export scenarios through extrapolation as shown in the tables below.

Potential Impacts of Water Quality and Flow on Fish

Potential impacts to 10 species, including delta smelt, salmon, steelhead and sturgeon, were examined by two methods. First, the water quality and flow modeling results were examined to determine if they posed potential impacts to fish. Second, historic salvage data was examined to determine if the Project posed potential impacts to delta smelt, salmon, steelhead and sturgeon salvage.

The modeling results predicted minor changes in water quality, which would result in no impacts to salmon, steelhead and sturgeon.

The changes in flow predicted by the modeling suggest that there will be no significant negative impacts to salmon, steelhead and sturgeon distribution. The largest changes in flow occurred during the spring pumping reduction. Flows towards CCF decreased by as much as 2,250 cfs. Decreased flows towards CCF may decrease the potential vulnerability of salmon, steelhead and sturgeon to SWP salvage. The modeling results predicted that flows only slightly increased towards CCF during the increased pumping period, suggesting there will be no impact on salmon, steelhead and sturgeon distribution and subsequent vulnerability to SWP salvage.

Potential Impacts to Fish Salvage

Historic salvage data for ten sensitive fish species or runs, including salmon, steelhead and sturgeon, were analyzed to determine the impact of the proposed project. The fish species may occur in the project area during the project period.

The potential changes in diversion rate into CCF will affect fish salvage at the SWP. To determine the impact of such export changes, historic salvage data from 1992 and 1997 (representative low and high Delta inflow years used in the modeling) were used to estimate the impact of the Project on fish salvage. Historic salvage density was used to estimate salvage under the different export scenarios through extrapolation.

The difference in fish salvage between the base and Project conditions was used as the effect of the Project on fish salvage. Base (No-Project) salvage was calculated as the product of historic salvage density (number of fish salvaged per AF diverted) and modeled base exports. Project salvage was calculated as the product of historic salvage density and modeled Project exports. The effect of the Project on fish salvage was the difference between the Project and base salvage estimates.

For example:

historic salvage / historic AF diverted = historic salvage density (HSD)

HSD x base exports = estimated base salvage (BS)

HSD x Project exports = estimated Project salvage (PS)

PS – BS = estimated difference in salvage from the base caused by the Project.

The results of this analysis (see following tables) suggest that salvage of Chinook salmon and steelhead is likely to be reduced while there will be no substantial change in salvage of green sturgeon. The studies can be used to draw conclusions about other potential operations. Consider a scenario in which the export reduction is taken only in May 1997 (48 taf), 90 taf were exported in July-September, and the remaining 42 taf applied as reduced exports in December. This scenario results in the following estimates of changes in salvage:

	May	Jul-Sept	Dec	Total
Chinook Salmon	-1817	+4	-46	-1859
Steelhead	-14	0	-3	-17
Sturgeon	0	+1	0	+1

The results of this scenario supports the conclusion above, that salvage of Chinook salmon and steelhead is likely to be reduced while there will be no substantial change in salvage of green sturgeon.

NOTE: Row headers for the following tables are as follows:

Historic exports	=	Actual SWP exports for given month (AF).
Historic salvage	=	Actual SWP salvage for given month.
Historic salvage density	=	Historic salvage ÷ historic exports (number of fish per AF).
Base exports	=	Modeled SWP base exports for given month.
Base salvage	=	Historic salvage density x modeled base exports.
Project exports	=	Modeled SWP exports for given month which includes the 500 cfs increased export limit.
Project salvage	=	Historic salvage density x modeled project exports.
Percent change	=	Estimated percent change in salvage caused by the project.
	=	(Project salvage – Base salvage)x100%/Base salvage

Table 13-25 Chinook Salmon

Spring 1992	May	Jun	Jul	Aug	Sep	Total
Historic exports	42,376	57,220	25,689	90,836	161,905	378,026
Historic salvage	2,365	0	0	0	6	2,371
Historic salvage density	0.0558	0.0000	0.0000	0.0000	0.0000	-
Base exports	15,099	56,040	410,018	410,018	396,792	1,287,968
Base salvage	843	0	0	0	15	857
Project exports	0	25,469	425,732	425,732	411,036	1,287,969
Project salvage	0	0	0	0	15	15
Percent change	-100%	0	0	0	0	-98%

Fall 1992	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	25,689	90,836	161,905	62,303	168,276	509,009
Historic salvage	0	0	6	0	160	166
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0010	-
Base exports	410,018	410,018	396,792	66,651	35,531	1,319,011
Base salvage	0	0	15	0	34	48
Project exports	432,852	432,852	417,390	35,917	0	1,319,011
Project salvage	0	0	15	0	0	15
Percent change	0	0	0	0	-100%	-69%

Spring 1997	May	Jun	Jul	Aug	Sep	Total
Historic exports	78,236	153,854	321,231	269,918	341,334	1,164,573
Historic salvage	2,962	635	30	0	9	3,636
Historic salvage density	0.0379	0.0041	0.0001	0.0000	0.0000	-
Base exports	47,995	153,058	410,018	410,018	396,792	1,417,882
Base salvage	1,817	632	38	0	10	2,498
Project exports	0	111,953	440,708	440,708	424,512	1,417,882
Project salvage	0	462	41	0	11	514
Percent change	-100%	-27%	8%	0	10%	-79%

Fall 1997	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	321,231	269,918	341,334	292,036	419,732	1,644,251
Historic salvage	30	0	9	4	463	506
Historic salvage density	0.0001	0.0000	0.0000	0.0000	0.0011	-
Base exports	410,018	410,018	396,792	292,923	196,804	1,706,556
Base salvage	38	0	10	4	217	270
Project exports	440,708	440,708	424,512	245,403	155,224	1,706,556
Project salvage	41	0	11	3	171	227
Percent change	8%	0	10%	-25%	-21%	-16%

Table 13-26 Steelhead

Spring 1992	May	Jun	Jul	Aug	Sep	Total
Historic exports	42,376	57,220	25,689	90,836	161,905	378,026
Historic salvage	33	0	0	0	0	33
Historic salvage density	0.0008	0.0000	0.0000	0.0000	0.0000	-
Base exports	15,099	56,040	410,018	410,018	396,792	1,287,968
Base salvage	12	0	0	0	0	12
Project exports	0	25,469	425,732	425,732	411,036	1,287,969
Project salvage	0	0	0	0	0	0
Percent change	-100%	0	0	0	0	-100%

Fall 1992	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	25,689	90,836	161,905	62,303	168,276	509,009
Historic salvage	0	0	0	0	16	16
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0001	-
Base exports	410,018	410,018	396,792	66,651	35,531	1,319,011
Base salvage	0	0	0	0	3	3
Project exports	432,852	432,852	417,390	35,917	0	1,319,011
Project salvage	0	0	0	0	0	0
Percent change	0	0	0	0	-100%	-100%

Spring 1997	May	Jun	Jul	Aug	Sep	Total
Historic exports	78,236	153,854	321,231	269,918	341,334	1,164,573
Historic salvage	23	0	0	0	0	23
Historic salvage density	0.0003	0.0000	0.0000	0.0000	0.0000	-
Base exports	47,995	153,058	410,018	410,018	396,792	1,417,882
Base salvage	14	0	0	0	0	14
Project exports	0	111,953	440,708	440,708	424,512	1,417,882
Project salvage	0	0	0	0	0	0
Percent change	-100%	0	0	0	0	-100%

Fall 1997	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	321,231	269,918	341,334	292,036	419,732	1,644,251
Historic salvage	0	0	0	0	30	30
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0001	-
Base exports	410,018	410,018	396,792	292,923	196,804	1,706,556
Base salvage	0	0	0	0	14	14
Project exports	440,708	440,708	424,512	245,403	155,224	1,706,556
Project salvage	0	0	0	0	11	11
Percent change	0	0	0	0	-21%	-21%

Table 13-27 Green Sturgeon

Spring 1992	May	Jun	Jul	Aug	Sep	Total
Historic exports	42,376	57,220	25,689	90,836	161,905	378,026
Historic salvage	0	0	0	0	0	0
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0000	-
Base exports	15,099	56,040	410,018	410,018	396,792	1,287,968
Base salvage	0	0	0	0	0	0
Project exports	0	25,469	425,732	425,732	411,036	1,287,969
Project salvage	0	0	0	0	0	0
Percent change	0	0	0	0	0	0

Fall 1992	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	25,689	90,836	161,905	62,303	168,276	509,009
Historic salvage	0	0	0	0	1	1
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0000	-
Base exports	410,018	410,018	396,792	66,651	35,531	1,319,011
Base salvage	0	0	0	0	0	0
Project exports	432,852	432,852	417,390	35,917	0	1,319,011
Project salvage	0	0	0	0	0	0
Percent change	0	0	0	0	0	0

Spring 1997	May	Jun	Jul	Aug	Sep	Total
Historic exports	78,236	153,854	321,231	269,918	341,334	1,164,573
Historic salvage	0	0	0	0	18	18
Historic salvage density	0.0000	0.0000	0.0000	0.0000	0.0001	-
Base exports	47,995	153,058	410,018	410,018	396,792	1,417,882
Base salvage	0	0	0	0	21	21
Project exports	0	111,953	440,708	440,708	424,512	1,417,882
Project salvage	0	0	0	0	22	22
Percent change	0	0	0	0	1%	1%

Fall 1997	Jul	Aug	Sep	Nov	Dec	Total
Historic exports	321,231	269,918	341,334	292,036	419,732	1,644,251
Historic salvage	0	0	18	0	0	18
Historic salvage density	0.0000	0.0000	0.0001	0.0000	0.0000	-
Base exports	410,018	410,018	396,792	292,923	196,804	1,706,556
Base salvage	0	0	21	0	0	21
Project exports	440,708	440,708	424,512	245,403	155,224	1,706,556
Project salvage	0	0	22	0	0	22
Percent change	0	0	5%	0	0	5%

Clifton Court Forebay Aquatic Weed Control Program

The Department of Boating and Waterways (DBW) prepared an Environmental Impact Report (2001) for a two-year Komeen research trial in the Delta. They determined there were potential impacts to fish from Komeen treatment despite uncertainty as to the likelihood of occurrence. Uncertainties exist as to the direct impact that Komeen and Komeen residues may have on fish species. “The target concentration of Komeen is lower than that expected to result in mortality to most fish species, including delta smelt (Huang and Guy 1998). However, there is evidence that, at target concentrations, Komeen could adversely impact some fish species. The possibility exists that Komeen concentrations could be lethal to some fish species, especially during the first nine hours following application. Although no tests have examined the toxicity of Komeen to Chinook salmon or steelhead, LC50 data for rainbow trout suggest that salmonids would not be affected by use of Komeen at the concentrations proposed for the research trials. No tests have been conducted to determine the effect of Komeen on splittail, green sturgeon, pacific lamprey or river lamprey.” (DBW, 2001).

In 2005, no fish mortality or stressed fish were reported during or after the treatment. The contractor, Clean Lakes, Inc was looking for dead fish during the Komeen application. In addition, no fish mortality was reported in any of the previous Komeen or Nautique applications. In 2005, catfish were observed feeding in the treatment zone at about 3 pm on the day of the application (Scott Schuler, SePro). No dead fish were observed. DWR complied with the NPDES permit that requires visual monitoring assessment.

Due to the uncertainty of the impact of Komeen on fish that may be in the Forebay, we will assume that all winter- and spring-run Chinook salmon, steelhead, and delta smelt in the Forebay at the time of application are taken. There has been only one green sturgeon at the SWP, 6/26/1996, in the salvage record during the April through June period. Figure 13-51 and Figure 13-52 are illustrations of the total (all runs) Chinook salmon loss at the SWP BPP during the period two weeks before and after Komeen or Nautique treatments from 1995 to 2006. The daily loss values vary greatly within treatments, between months and between years.

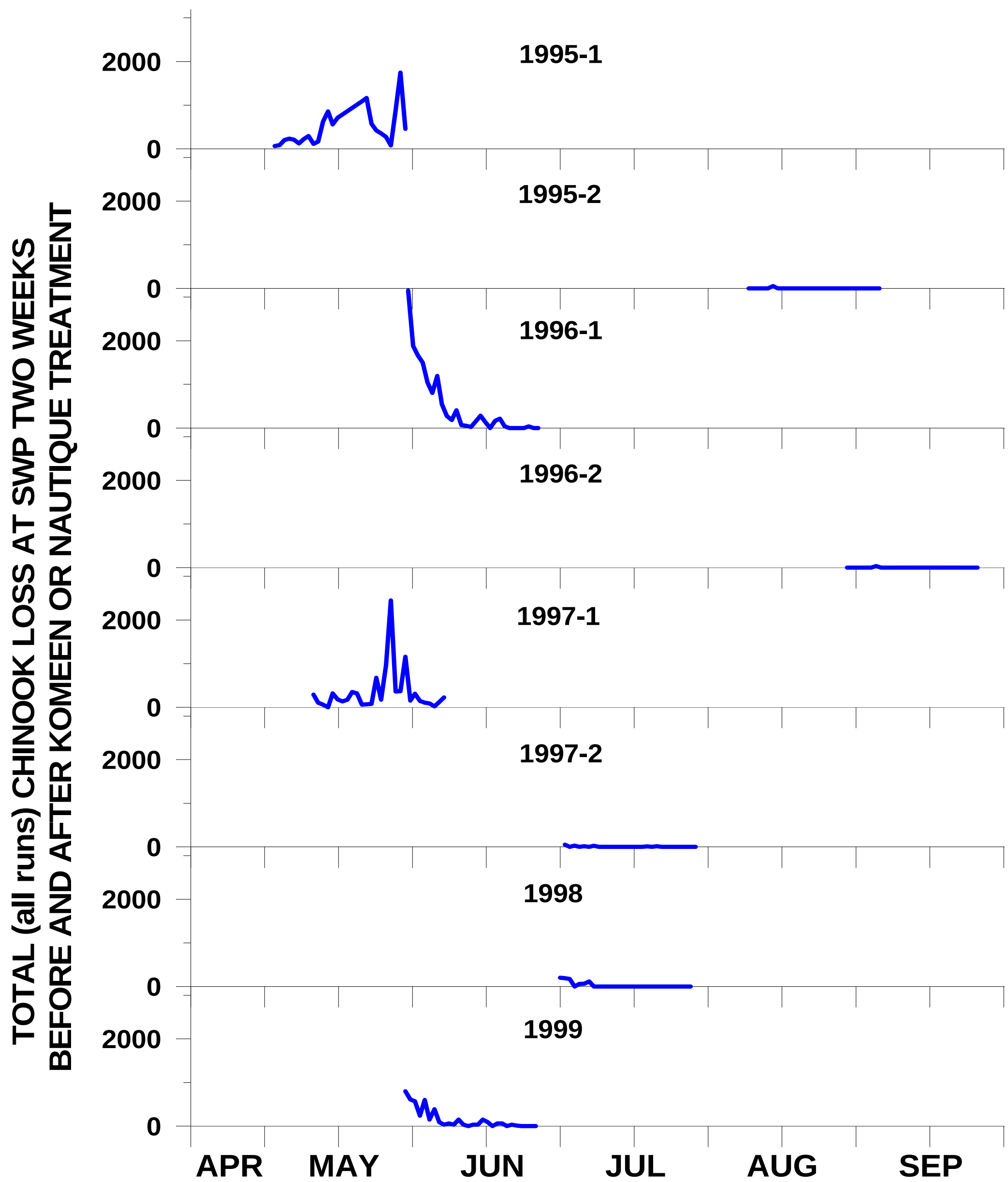


Figure 13-51 Total (all four runs) Chinook loss at the SWP Banks Pumping Plant two weeks before and after Komeen or Nautique aquatic weed treatment, 1995 – 1999.

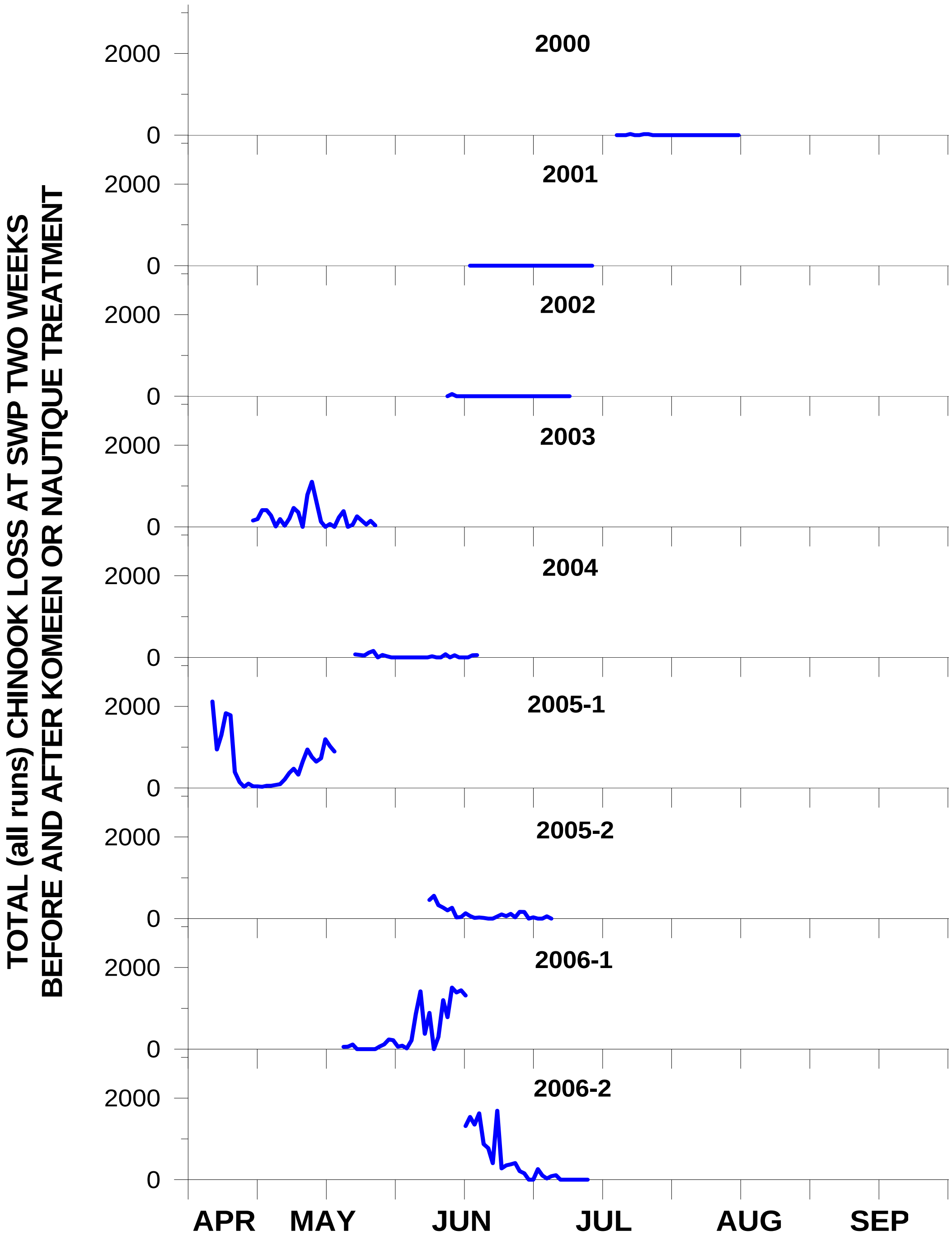


Figure 13-52 Total (all four runs) Chinook loss at the SWP Banks Pumping Plant two weeks before and after Komeen or Nautique aquatic weed treatment, 2000 - 2006.

Figure 13-53 and Figure 13-54 are illustrations of the steelhead salvage at the SWP BPP during the period two weeks before and after Komeen or Nautique treatments from 1995 to 2006. The salvage values vary greatly within treatments, between months and between years.

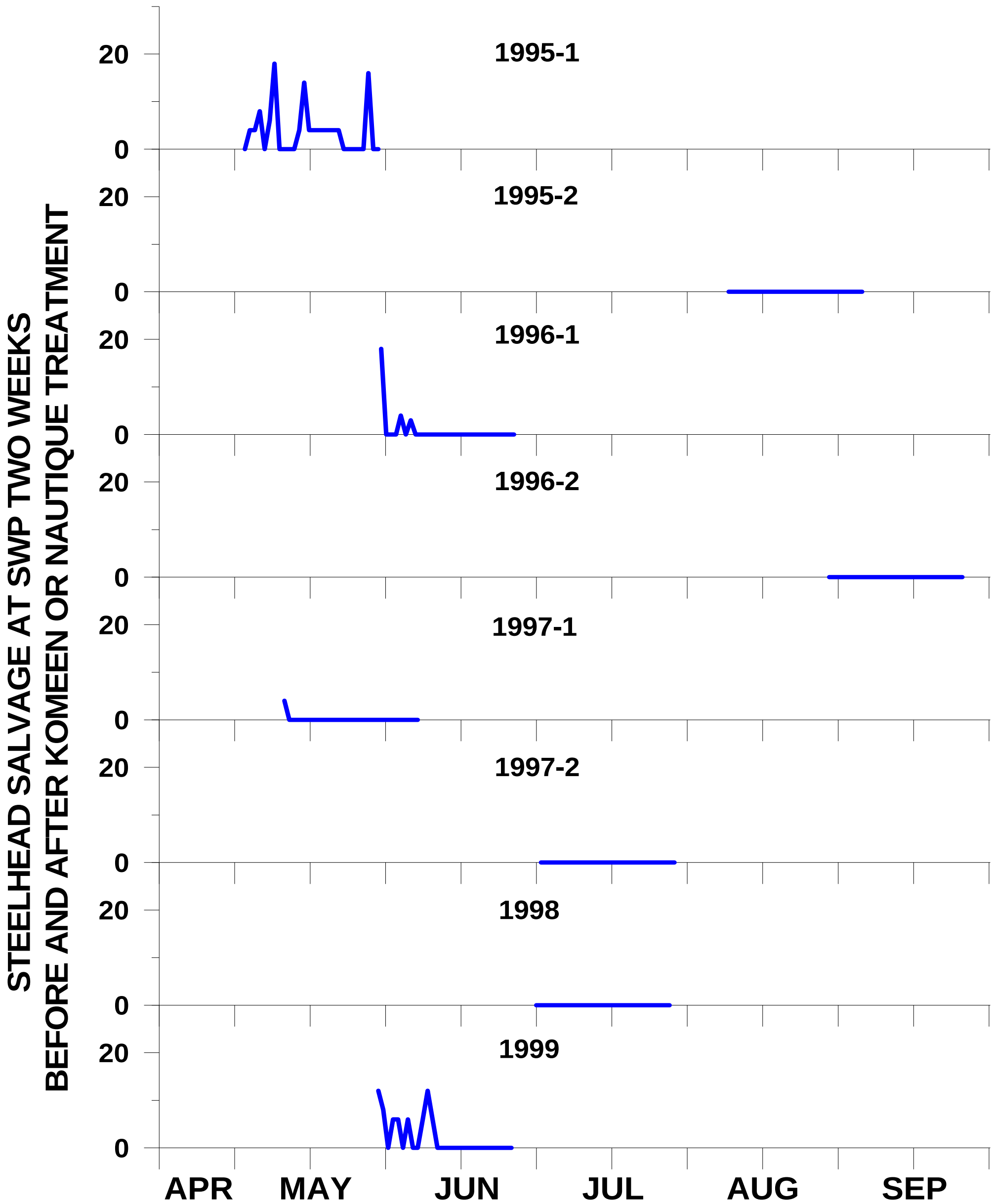


Figure 13-53 Steelhead salvage at the SWP Banks Pumping Plant two weeks before and after Komeen or Nautique aquatic weed treatment, 1995 – 1999.

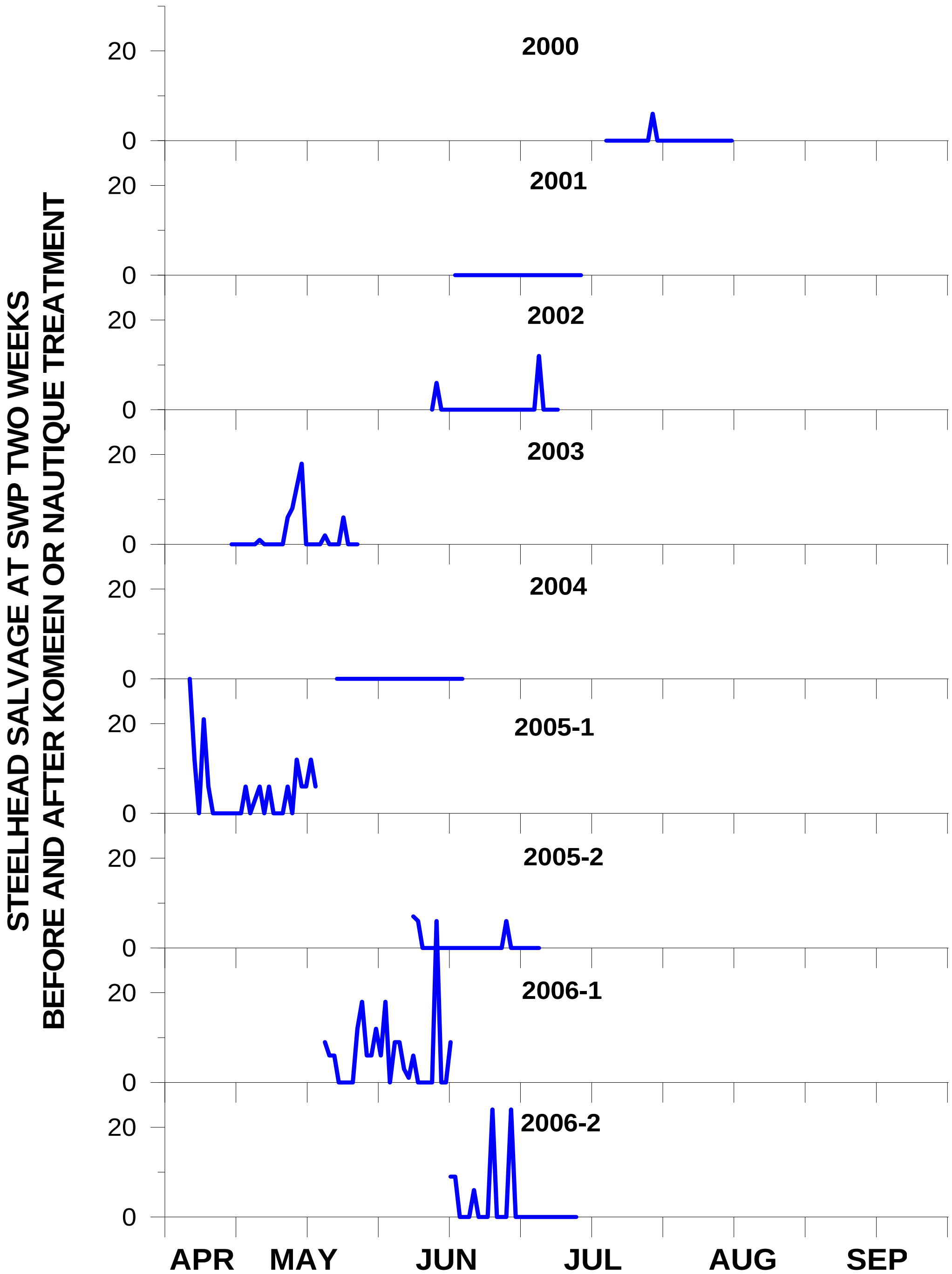


Figure 13-54 Steelhead salvage at the SWP Banks Pumping Plant two weeks before and after Komeen or Nautique aquatic weed treatment, 2000 – 2006.

To estimate the loss of listed Chinook salmon, winter and spring run, at the salvage facilities during Komeen or Nautique treatments, we used genetic characterization. The four Chinook runs look alike at the juvenile lifestage; therefore we used the average fraction of genetically identified winter- and spring-run Chinook lost at the SWP Salvage Facilities, during the historical treatment periods to extrapolate to the actual treatment times. The averages for winter run were 0 percent from the last half of April through July, and for spring run: last half of April – 1 percent, May – 5 percent, June – 1 percent, and July 0 percent. Table 13-28 is the fraction of genetically identified winter and spring-run Chinook lost at the SWP salvage facilities during the historical Komeen or Nautique treatment periods.

Table 13-28 Fraction of salvage sampled, fraction winter run of total Chinook loss based on genetic characterization, and fraction spring run of total Chinook loss based on genetic characterization. Time intervals are two weeks starting Mid-April and ending July.

		later April					
Year	Facility	Fraction Sampled	Fraction WinterRun	Fraction SpringRun			
1997	SWP	0.21	0.00	*			
1999	SWP	0.04	0.00	*			
2000	SWP	0.05	0.00	*			
2006	SWP	0.99	0.00	0.00			
2007	SWP	0.99	0.00	0.02			
Average			0.00	0.01			
		earlier May			later May		
Year	Facility	Fraction Sampled	Fraction WinterRun	Fraction SpringRun	Fraction Sampled	Fraction WinterRun	Fraction SpringRun
1997	SWP	0.19	0.00	*	0.21	0.00	*
1999	SWP	0.08	0.00	*	0.10	0.00	*
2000	SWP	0.07	0.00	*	0.05	0.00	*
2006	SWP	0.98	0.00	0.00	1.00	0.00	0.06
2007	SWP	0.97	0.00	0.06	0.87	0.00	0.00
Average			0.00	0.03		0.00	0.03
		earlier June			later June		
Year	Facility	Fraction Sampled	Fraction WinterRun	Fraction SpringRun	Fraction Sampled	Fraction WinterRun	Fraction SpringRun
1997	SWP	0.33	0.00	*	0.30	0.00	*
1999	SWP	0.17	0.00	*	0.37	0.00	*
2000	SWP	0.00	*	*	0.00	*	*
2006	SWP	1.00	0.00	0.01	0.97	0.00	0.01
2007	SWP	1.00	0.00	0.00	*	*	*
Average			0.00	0.01		0.00	0.01
		earlier July			later July		
Year	Facility	Fraction Sampled	Fraction WinterRun	Fraction SpringRun	Fraction Sampled	Fraction WinterRun	Fraction SpringRun
1997	SWP	0.00	*	*	0.00	*	*
1999	SWP	0.00	*	*	*	*	*
2000	SWP	0.00	*	*	0.00	*	*
2006	SWP	0.91	0.00	0.00	*	*	*
2007	SWP	*	*	*	*	*	*
Average			0.00	0.00		*	*

To estimate the take of listed Chinook salmon and steelhead associated with Komeen or Nautique treatments, we estimated the total (all runs) Chinook salmon and steelhead in the Forebay from 1995 to 2006 during treatment times. We averaged the loss and salvage densities over the week prior to treatment, adjusted the total Chinook loss by the fractions of winter and spring run based on genetic identification, and extrapolated the loss and salvage densities to the approximate volume of water in the Forebay at treatment time. Table 13-29 is the estimated take of listed Chinook salmon and steelhead in the Forebay during Komeen or Nautique treatments.

Table 13-29 Estimated take of listed Chinook (winter and spring run), and steelhead in the Forebay during Komeen or Nautique aquatic weed treatments, 1995 – 2006.

Date	Total Chinook Take In Forebay	Winter Chinook Take In Forebay	Spring Chinook Take In Forebay	Steelhead Take In Forebay
5/15/1995	2084.46	0.00	0.00	12.54
8/21/1995	0.00	0.00	0.00	0.00
6/11/1996	264.43	0.00	0.00	0.00
9/10/1996	1.59	0.00	0.00	0.00
5/23/1997	2010.80	0.00	0.00	0.00
7/14/1997	0.00	0.00	0.00	0.00
7/13/1998	0.00	0.00	0.00	0.00
6/11/1999	520.77	0.00	0.01	32.39
7/31/2000	5.88	0.00	0.00	1.24
6/29/2001	0.00	0.00	0.00	0.00
6/24/2002	0.00	0.00	0.10	0.00
5/12/2003	2923.82	0.00	0.00	9.59
6/3/2004	24.63	0.00	0.53	0.00
5/3/2005	846.09	0.00	0.00	17.64
6/20/2005	71.94	0.00	0.53	0.00
6/1/2006	554.64	0.00	0.40	53.44
6/28/2006	1089.62	0.00	0.00	13.21

Delta Cross Channel

Juvenile salmon survival is higher when the fish remain in the Sacramento River, than when they migrate through the interior (Newman 2008), but the effect of the Delta Cross Channel (DCC) gate position is only modest. Newman's results are quoted below:

> **Results.**
>
> For the most part, the substantive conclusions from the Bayesian Hierarchical Model (BHM) analyses, summarized below, were consistent with previous USFWS analyses.
>
> **Delta Cross Channel:** There was modest evidence, 64 to 70% probability, that survival of Courtland releases, relative to the survival of Ryde releases, increased when the gate was closed.
>
> **Interior:** Survival for the interior Delta releases was estimated to be about 44% of the survival for the Sacramento River releases.

This has not been studied for steelhead, but they are likely affected in a similar manner, although to a lesser extent because steelhead emigrants are larger than Chinook. SWRCB D-1641 provides for closure of the DCC gates from February 1 through May 20. During November through January, the gates may be closed for up to 45 days for the protection of fish. The gates may also be closed for 14 days during the period May 21 through June 15. Reclamation shall determine the timing and duration of the closures after consultation with FWS, DFG, and NMFS. Consultation with the CALFED Operations Group will also satisfy the consultation requirement. The CALFED Ops Group has developed and implemented the Salmon Protection Decision Process. The Salmon Protection Decision Process depends on identifying the time when young salmon are likely entering the Delta and taking actions to avoid or minimize the effects of DCC and other Project operations on their survival in the Delta. The decision process identifies "Indicators of sensitive periods for salmon" such as hydrologic changes, detection of spring–run or spring–run surrogates at monitoring sites or the salvage facilities, and turbidity increases at monitoring sites. These actions should provide protection to both steelhead and Chinook salmon for much of their peak emigration period. Figure 13-55 and Figure 13-56 show the percent of the Sacramento River flow passing through the DCC and through Georgiana Slough during critically dry years. Figure 13-57 shows the percent continuing on down the main Sacramento River channel. During the other water year types a lower percentage of flow passes through the DCC with the lowest percentage occurring in wet years. The percentage passing through the DCC increases in the future in July through December. The increased flow through the DCC occurs when few juvenile salmon or steelhead are present in the Delta. The cross channel gate closure in February through May and low percentage passing through the channel in December and January avoids the majority of salmon and steelhead emigrating from the Sacramento system.

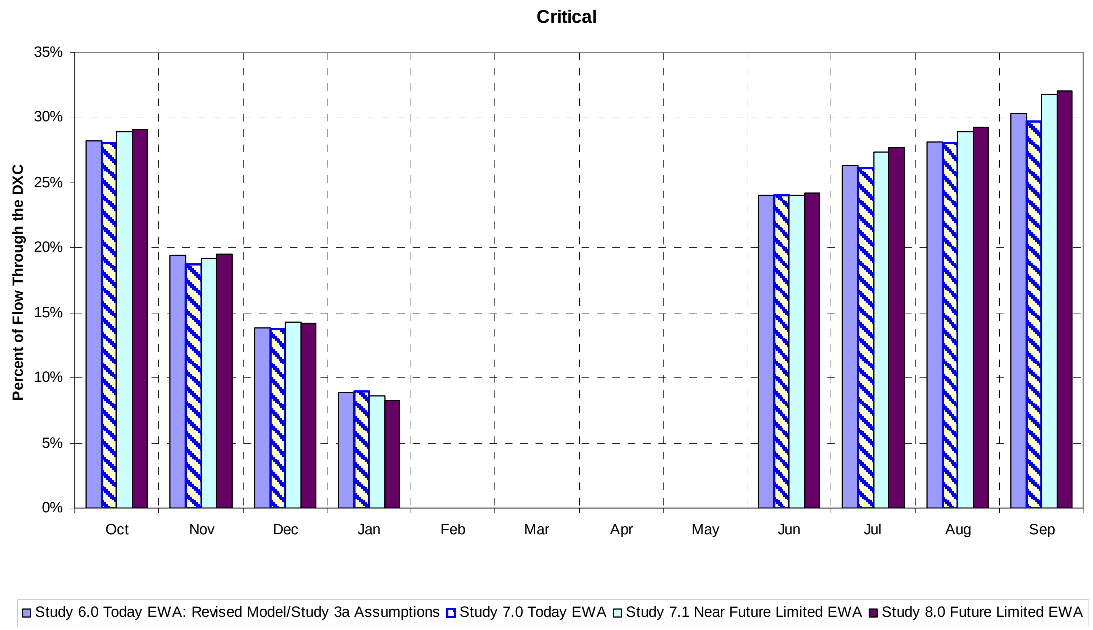


Figure 13-55 Percent of Sacramento River flow passing through the DCC during critically dry years under the three scenarios.

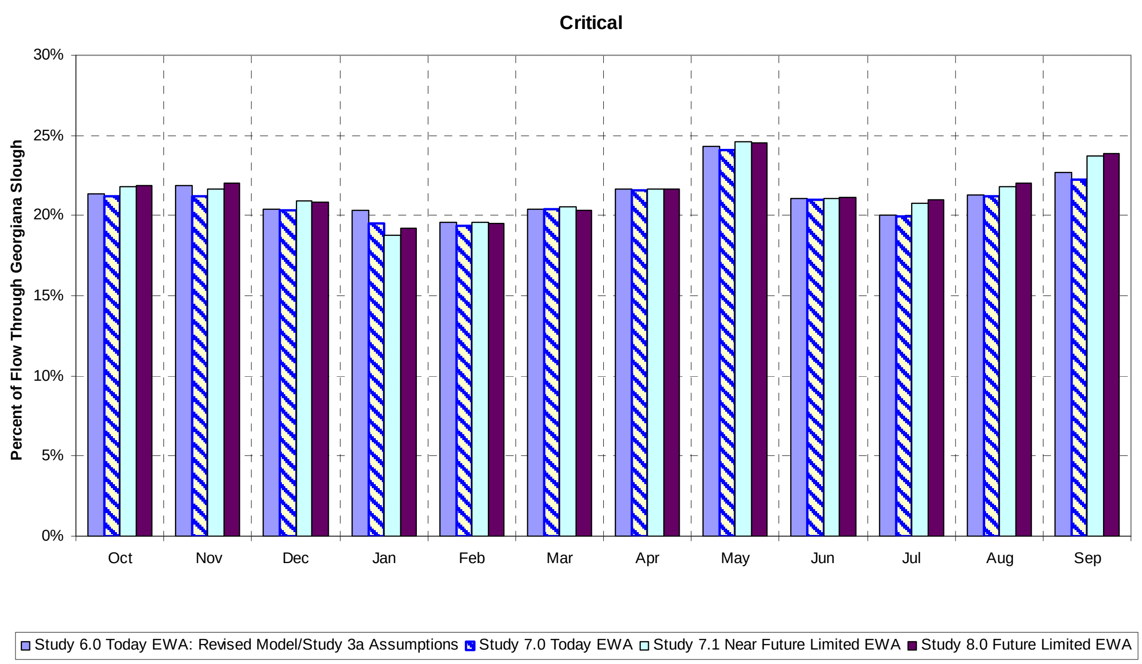


Figure 13-56 Percent of Sacramento River flow passing through Georgiana Slough during critically dry years under the three scenarios.

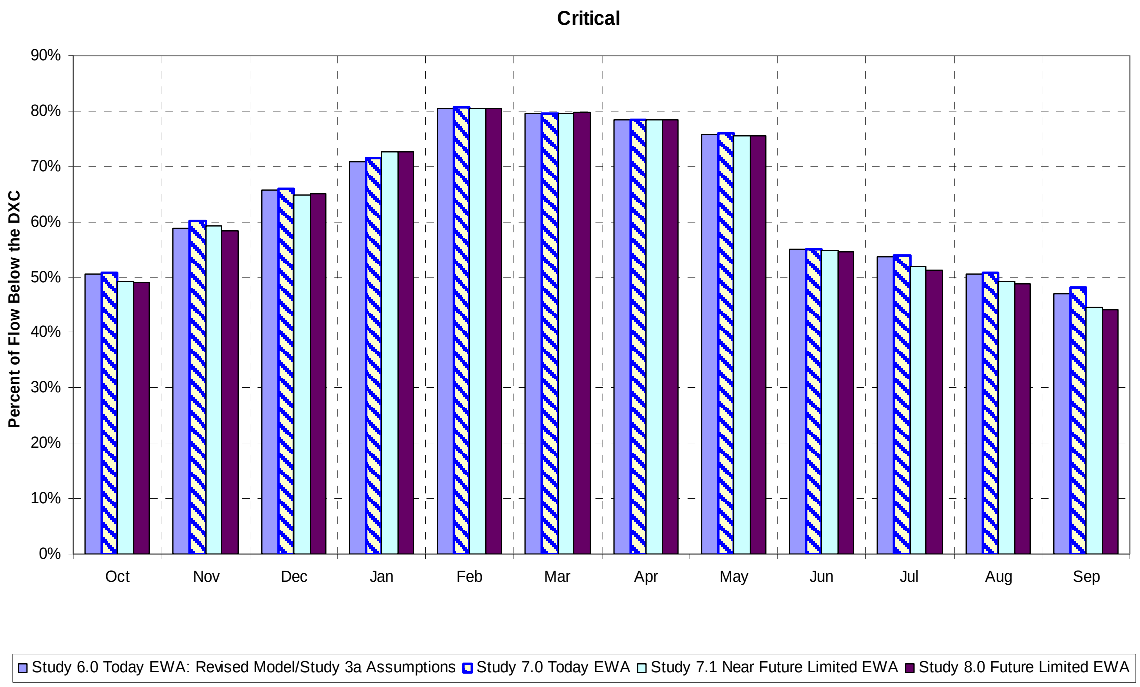


Figure 13-57 Percent of Sacramento River flow continuing down the main Sacramento River channel past the DCC and Georgiana Slough during critically dry years under the three scenarios.

North Bay Aqueduct

The maximum pumping capacity of the NBA facility is 175 cfs, but the mean is typically lower. The NBA facility has positive barrier fish screens built to DFG specifications to exclude juvenile salmon. The screens have approach velocities ranging between 0.2 and 0.4 feet per second. DFG has determined this is sufficient to prevent entrainment of juvenile salmonids. The facility is located at the end of Barker Slough, more than 10 miles from the mainstem Sacramento River. There is no information on salmonids migrating up Barker Slough.

Sommer et al. (2001b) reported the 1998 and 1999 Chipps Island survival indices were comparable to or higher for CWT Chinook released into Yolo Bypass than for fish released simultaneously in the Sacramento River. Similarly, Brandes and McLain (2001) found survival indices were higher for CWT Chinook that passed through the Steamboat-Sutter slough complex than for fish that traveled down the mainstem Sacramento River. Both Yolo Bypass and Steamboat Slough empty into Cache Slough placing fish closer to the NBA pumping plant than they would have been had they remained in the main river channel. This suggests the NBA facility does not significantly adversely impact juvenile salmonids traveling in the river or Cache Slough. The higher survival of Steamboat-Sutter smolts does not affect the conclusions of the Newman and Rice analyses.

Rock Slough Intake

CCWD diverts water from Old River via Rock Slough into the Contra Costa Canal at the Rock Slough Intake. The diversion is presently unscreened. Reclamation, in collaboration with CCWD, is responsible for constructing a fish screen at the Rock Slough Headworks under the Central Valley Project Improvement Act and under the 1993 USFWS Biological Opinion for the Los Vaqueros Project. Reclamation has received an extension on fish screen construction until December 2008, and is preparing to request a further extension until at least 2013 because the requirements for screen design will change as CCWD proceeds with its project to replace the earth-lined portion of the canal with a pipeline.

Before 1998, the Rock Slough Intake was CCWD's primary diversion point. It has been used less since 1998 when Los Vaqueros Reservoir and the Old River Pumping Plant began operating. The diversion at the headworks structure is currently sampled with a sieve net three times per week from January through June and twice per week from July through December. A plankton net is fished at the headworks structure twice per week during times larval delta smelt could be present in the area (generally March through June). A sieve net is fished at Pumping Plant #1 two times per week from the time the first Sacramento River winter-run Chinook salmon is collected at the CVP and SWP (generally January or February) through June. Numbers of listed fish species captured during monitoring are shown in Table 13-30.

The extrapolated numbers of steelhead entrained by the facility between 1994 and 1996 were low, ranging from 52 to 96 per year (Morinaka 1998). The extrapolated numbers of juvenile Chinook salmon (all races) entrained by the facility between 1994 and 1996 ranged from 262 to 642 per year (Morinaka 1998). Entrainment has decreased since Los Vaqueros Reservoir and the Old River Intake came on line in 1998 and Rock Slough Intake diversion decreased significantly. CCWD estimated entrainment levels based on salvaged fish numbers per amount of water pumped at the CVP and SWP from 1998 to 2008. They estimated entrainment within the Contra Costa Canal assuming diversions within Rock Slough of 37,700 acre feet per year for juvenile winter-run salmon are 8 per year and for juvenile spring-run salmon are 25 per year.

The Contra Costa Canal Replacement Project will replace the 4-mile unlined section of canal from Rock Slough to Pumping Plant #1 with a pipeline. ESA consultations have been completed for construction (NMFS issued its concurrence letter on June 11, 2007 and USFWS issued a BO on June 21, 2007) and the first phase of the project is scheduled to begin in the Fall of 2008. When completed, the Canal Replacement project will eliminate tidal flows into the Canal intake section and should significantly reduce entrainment impacts and improve the feasibility of screening Rock Slough.

Because most diversions at the Rock Slough intake now occur during the summer months when salmon and steelhead are not present in the vicinity of the diversion and because very few listed fish species (one winter–run Chinook, 14 spring-run sized Chinook, 6 unclipped steelhead, and one delta smelt) have been captured during monitoring from 1998 to 2008, the Rock Slough diversion is not believed to be a significant source of mortality for any of the listed species. No green sturgeon have been captured at the site.

It is expected that entrainment in the future will be reduced with the addition of CCWD's Alternative Intake Project because CCWD diversions in general during the migration period will be reduced, with most of that reduction taking place at the Rock Slough intake. (See the July 3, 2007 NMFS biological opinion on the Alternative Intake Project). Few listed runs have been captured in sampling since 1996 so take of listed runs is expected to be very low, probably fewer than 50 spring–run, 50 winter–run, and 20 steelhead. Estimates of future losses of spring-run Chinook salmon and winter-run Chinook salmon at the Rock Slough Intake with the Alternative Intake Project in service have been made assuming future CCWD demands of 188,000 af/year. Based on average densities of the salmon in channels (from monitoring programs over the past 10 years), losses were estimated at about 5 winter-run and 16 spring-run juveniles per year.

Table 13-30 Sumary of listed fish captured at the Rock Slough Headworks and Pumping Plant 1 and amount of water diverted each year, 1998 – 2008.

Summary of Sieve Net and Plankton Net Monitoring Conducted at the Rock Slough Headworks and Pumping Plant 1 (PP1) from August 1998 through March 2008.

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Totals
Months Monitoring Occurred	**Aug-Dec**	**Mar-Dec**	**Mar-Dec**	**Jan-Aug**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Mar**	
Amount of Water Diverted at Rock Slough Acre Feet	68,683	43,037	51,421	26,749	35,904	27,302	31,283	35,686	43,273	39,366	5,848	408,552
Number of Headworks &PP1 Sieve Net Surveys	Unknown	Unknown	Unknown	Unknown	Unknown	35	102	131	133	107	54	**562**
Number of Headworks Plankton Net Surveys	Unknown	Unknown	Unknown	Unknown	10	0	34	26	15	23	10	**118**
Winter-run Chinook	Dec=1	0	0	0	0	0	0	0	0	0	0	**1**
Spring-run Chinook	0	0	0	0	0	0	Mar=1 Apr=5	May=4	May=4	0	0	**14**
Central Valley steelhead (unclipped)	0	0	0	0	0	0	0	Mar=2 Apr=1	Jan=1 Mar=1	May=1	0	**6**
Central Valley steelhead (clipped)	0	0	0	0	0	0	0	0	0	0	Feb=6 Mar=2	**8**
Central Valley steelhead (unknown)	0	0	0	0	0	0	0	Feb=1	0	0	0	**1**
Fall run/late fall run Chinook (unclipped)	0	0	May=3	0	0	0	Mar=2 Apr=3 May=1	Apr=2 May=6 Jun=1	May=1	0	0	**19**
Fall run/late fall run Chinook (clipped)	0	0	0	0	0	0	May=1	May=1	0	0	0	**2**
Green sturgeon	0	0	0	0	0	0	0	0	0	0	0	**0**
Delta smelt	0	0	0	0	0	0	0	Feb=1*	0	0	0	**1**
Longfin smelt	0	0	0	0	0	0	0	0	0	0	Mar=1**	**1**

South Delta Temporary Barriers Project (TBP)

The following evaluation is limited to the operational effects of these projects on Chinook salmon, steelhead and green sturgeon. Section 7 consultation for the construction and operation of the TBP through 2010 has been completed with NMFS. The operation effects of the TBP are being consulted upon with FWS through this OCAP BA. The construction effects requiring ESA consultation with FWS will be evaluated in a separate consultation process.

Simulation modeling completed for this OCAP Biological Assessment incorporates the effects of the South Delta Temporary Barriers Project and the 500 cfs increased export in Studies 6.1 and 7.0. The SDIP Stage 1, the 500 cfs increased export, and the CVP aqueduct intertie are incorporated into Studies 7.1 and 8.0. The Temporary Barriers are not included in Studies 7.1 and 8.0. Full evaluation of the combined effects of these elements on Chinook salmon, steelhead and green sturgeon are presented in Chapter 13. Because the simulation models examined the combination of these elements, it is not possible to separate and examine the effects of any single project element by itself. Therefore, the effects analysis for these individual projects is taken largely from prior Biological Assessments and other related consultations. These documents include: *DWR 2000 Proposed Mitigated Negative Declaration and Initial Study Temporary Barriers Project 2001-2007 and 2007 Supplemental Biological Assessment South Delta Temporary Barriers Project*. Because the modeling for these documents was conducted a few years ago, it naturally differs to some degree from what was conducted for the current OCAP Biological Assessment. However, the differences are not such that would alter any interpretation of the likely general effects of these projects individually. For clarity, provided below are brief descriptions of the projects, details of the modeling approaches for the former documents, and an assessment of likely effects.

The following information is from the 2007 Supplemental Biological Assessment. This supplement to the 2000 TBP Biological Assessment presents information and results of analyses to assess the impacts of the TBP on special status species in light of recent ESA listings by the NMFS and their subsequent request for re-initiation of consultation. This supplemental biological assessment serves to update permits prior to the installation of the temporary barriers in 2007, as required by NMFS. New permits, permit extensions and project approval were needed to continue the TBP for a fourth operation interval that began in 2008. DWR has already obtained a DFG Streambed Alteration Agreement and Incidental Take permit extending the TBP through 2010. NMFS has issued a Biological Opinion and Incidental Take permit covering the TBP from 2008 through 2010. The FWS has issued a statement extending their previous Biological Opinion and Incidental Take permit for the TBP through 2008 and will apply the OCAP BA as their basis for extending operations of the TBP beyond 2008. However the FWS will require separate consultation on the installation and removal impacts of the TBP to cover ESA beyond 2008. The US Army Corps of Engineers have issued permits based upon the NFMS and FWS responses extending the TBP through 2010.

Hydrodynamic Effects

The TBP causes changes in the hydraulics of the Delta, which may pose impacts to fish. The TBP does not alter total Delta outflow, thus the position of X2, the linear position where bottom salinity measures two parts per million in the estuary, is not affected by the project. However, the TBP does cause hydrodynamic changes within the interior of the Delta. When the barrier at the head of Old River is in place, most water flow is effectively blocked from entering Old River. This in turn increases the flow in Turner and Columbia Cuts, two major central Delta channels that flow towards the south Delta. The underlying result of this hydrodynamic change is that there is an increase in reverse flow in these and other interior Delta channels. In most instances, net flow is directed towards the CVP and SWP pumps. The directional flow towards the pumping facilities may increase the vulnerability of fish to entrainment by the pumps and local agricultural diversions. Larval and small fishes are especially susceptible to these flows.

Unfortunately, the varying operational configurations of the TBP, natural variations in fish distribution, and a number of other physical and environmental variables prohibit statistical confidence in assessing fish salvage when the TBP is operational versus when it is not. The most effective direct method for examining the effect of the hydrodynamic consequences of the TBP on fish is by examining real-time fish salvage, however statistical results are lacking.

Nobriga and others (2000) and Grimaldo (unpublished data) found that under certain conditions, salvage of delta smelt could increase dramatically when the TBP is operational. In 1996, the installation of the spring barrier at the head of Old River caused a sharp reversal of net flow in the south Delta to the upstream direction. Coincident with this change was a strong peak in delta smelt salvage. This data indicates that short-term salvage, especially that of delta smelt and other small species and juveniles can significantly increase when the TBP is installed in such a manner that causes a sharp change or reversal of positive net daily flow in the interior south and central Delta. Tidally averaged daily flow data for the south Delta was obtained from the U.S. Geological Survey to look for similar phenomena in previous years for a variety of fish species, however nothing was found to be as dramatic as that which occurred in 1996.

The Vernalis Adaptive Management Plan (VAMP), initiated in 2000 as part of the State Water Resources Control Board's Decision 1641, is a large-scale, 12-year, interdisciplinary experimental program designed to protect juvenile Chinook salmon migrating from the San Joaquin River through the Delta. VAMP is studying how salmon survival rates change in response to alterations in San Joaquin River flows and SWP/CVP exports with the installation of the barrier at the head of Old River. VAMP employs an adaptive management strategy to use current knowledge of hydrology and environmental conditions to protect Chinook salmon smolts, while gathering information to allow more efficient protection in the future (USFWS 2007). In each year, VAMP schedules and maintains pulse San Joaquin River flows and reduced project exports for a one month period, typically from April 15 - May 15 (May 1-31 in 2005/06). Tagged salmon smolts released in the San Joaquin River are monitored as they move through the Delta in order to determine their fate. While VAMP studies attempt to limit project impacts to salmonids, the associated reduction in exports reduces the upstream flows that occur in the south and central Delta. This reduction limits the southward draw of water from the central Delta, and thus shortens the Projects' zone of influence with regard to the passive entrainment of fishes.

Impacts to Fish

The assessment of potential impacts to fishes is based upon the current understanding of the biology of those species that may be affected. However, as will become apparent, there are gaps in this knowledge that raise the level of uncertainty when attempting to determine project impacts. In some instances, the degree of a potential impact can not be positively determined because quantification is impossible due to the lack of critical data. The potential impacts to green sturgeon, steelhead and spring-run Chinook salmon are discussed below.

Temporary Barriers Fish Monitoring

In 1992, DFG initiated the TBP Fish Monitoring Program in order to examine the impacts of the TBP on resident fish communities in the south Delta. Ten permanent sites within the south Delta have been sampled with electrofishing and gill nets to study resident fish community composition and distribution (DWR 1998). Unfortunately, a lack of pre-project monitoring data and gear type makes an analysis of overall project impacts impossible. In addition, the gear types used are very inefficient for sampling juvenile salmonids, two of the three species of concern for this BA. This data can only be used to provide simple descriptive species presence/absence information. Similarly, a number of other fish monitoring and special study program data sets were used to assess potential impacts of the TBP. Because these other programs were not designed to specifically test TBP impacts, analysis from these data are also largely descriptive.

Since data concerning the occurrence of green sturgeon in the south Delta is greatly lacking, DWR will add a monitoring section to the annual report beginning in 2009 that would serve to help quantify the presence of salmonids and green sturgeon in the immediate vicinity of the TBP barriers. More specifically, the degree to which juvenile salmonids and green sturgeon are entrapped between the spring HOR BARRIER and the three agricultural barriers would serve to better examine potential project impacts to these fishes. The NMFS has also required a study be developed and implemented to collect this information as part of their Biological Opinion. DWR is working with NMFS on a study plan to be implemented in 2009.

Passage Impacts to Fish

Green Sturgeon. There are no data indicating which areas are used by adult and juvenile green sturgeon but salvage data does indicate they are found in the South Delta year-round and are therefore expected to be exposed to the effects of the temporary barriers over their entire eight-month installation period. Although the effects of the TBP operations on green sturgeon are not understood or predictable, it is likely that green sturgeon may become redirected by these operations, though the effect of this on their behavior, success at foraging, and susceptibility to predation is unknown. Operation of the TBP could impact on green sturgeon by restricting or altering flows which may be used as cues for spawning adults and emigrating or rearing juveniles. While the barriers could constrain movement, they do not preclude juvenile and adult green sturgeon migration into the Sacramento River and out to the Pacific Ocean. Assessing the impacts of flows resulting from the barriers requires a better understanding of sturgeon responses to flows. However, any green sturgeon caught in the interior of the south Delta during the installation of the barriers has the potential to be exposed to lowered water quality until they found their way out of the south Delta or the barriers are removed in the fall. No estimates of the number of individuals rearing in the South Delta are available so the population level impact is unknown.

Spring-run Chinook Salmon. Adult spring-run Chinook salmon migrate through the estuary and into the Sacramento River Basin to spawn from March-September (Moyle 2002). Although their timing overlaps the TBP operating period of April-November, they are unlikely to use the interior Delta as a migration corridor, and therefore are not expected to be impacted by the project. In 2001 and 2003 the DFG tracked tagged fall-run Chinook salmon as they migrated out of the estuary. While most stayed within the Sacramento River, a few were observed to stray into the central and north Delta before continuing up the Sacramento River. Eight tagged individuals were observed exiting the Delta via the San Joaquin River (DFG 2007). It appears that even San Joaquin River basin fall-run Chinook salmon migrate upstream mainly through the mainstem of the San Joaquin River rather than through Delta sloughs. This may be a result of reverse flow conditions in south Delta channels, including Old River, Middle River, and others that occurs during the TBP operating season (DFG 2007). Hallock and others (1970) found that the majority of San Joaquin River basin Chinook salmon migrated through the mainstem river and not through other Delta channels. Additionally, DFG Fish Monitoring data suggests that adult salmon are rare in the south Delta. Large mesh drift nets were used to monitor the presence of fall- and late fall-run adult Chinook salmon during September 1997 and 1998 at Grant Line Canal, Middle River, and Old River at Tracy. In over 74 hours of sampling, only a single adult Chinook salmon was captured.

Juvenile spring-run Chinook salmon are also unlikely to experience a migration impact caused by the TBP. Although some show up in annual salvage at the south Delta fish facilities, juvenile spring-run originate in the Sacramento River basin and are not likely to occur in the south Delta in numbers significant to their population size. The Delta Cross Channel Gates are currently operated in a manner to greatly minimize the potential for spring-run smolts to enter the central Delta. Thus, direct passage impacts are unlikely for juvenile spring-run Chinook salmon. The section on hydraulic impacts below will further discuss potential impacts to juvenile salmonids out-migrating from the Sacramento River.

Steelhead. The TBP may pose a significant passage problem for steelhead. Several monitoring programs indicate that both adult and juveniles might be present in the south Delta during times when the TBP is operational. However, the degree of impact is difficult to quantify. As aforementioned, San Joaquin basin Chinook salmon are known to migrate predominately through the San Joaquin River rather than other peripheral Delta channels. Although similar information is not available for steelhead, it is likely that they also travel primarily through the San Joaquin River because the DFG TBP Fish Monitoring Program never observed a single steelhead outside of the San Joaquin River in over eight years of sampling. A potential passage problem cannot be ruled out, due to the lack of information on adult steelhead migration routes and timing. However, notches constructed into the barriers for fall-run Chinook salmon passage provide an equal benefit to any adult steelhead that might occur downstream of the barriers during TBP operations in the fall.

The best indicator of juvenile steelhead presence in the south Delta is SWP salvage. Annual steelhead salvage increases slightly in the fall, peaks in January through May, and then declines significantly into the summer (DWR 2000a). Some juvenile steelhead migrating downstream in the San Joaquin River may become temporarily trapped upstream of the agricultural barriers following removal of the spring HOR barrier by June 1 of each year, and in years when the spring HOR barrier is not installed. This blockage is temporal in nature, since the three agricultural barriers are regularly overtopped by higher tide stages, during which time downstream passage is possible. In addition to maintaining adequate upstream water levels, overtopping of the agricultural barriers will also benefit fishes temporarily held upstream by slightly lowering water temperatures and replenishing dissolved oxygen levels until passage is achieved. An inherent risk exists for any outmigrating juvenile salmonids that pass from the San

Joaquin River into Old River and the south Delta due to Delta pumping, regardless of TBP operations. Although the number of juveniles that become temporarily trapped in this area is expected to be insignificant to their numbers in the San Joaquin River, those that pass downstream of the agricultural barriers face additional risks of entrainment by the Projects.

Predation Impacts to Fish

The physical presence of the TBP may attract piscivorous fishes and influence predation on special status fish species. However, past studies by the DFG TBP Fish Monitoring Program has indicated that predation on special status fish species near the Temporary Barriers is negligible (DWR 2000a). The top predatory fish in the Delta, the striped bass, primarily feed on threadfin shad and smaller striped bass, as adults. Having highly opportunistic diets, striped bass are known to consume about anything that is in high abundance (Moyle 2002). Rearing-age green sturgeon and other fish much larger than 10 cm escape predation by most adult striped bass (Nelson et. al. 2006).

Water Quality Impacts to Fish

Monitoring of water quality parameters have been conducted during the DFG TBP Fish Monitoring of the study area and also by DWR as part of the DWR annual TBP Monitoring Reports. These studies have found that water quality is not significantly impacted by the TBP (DWR 2000a). In general, electrical conductivity (EC) is slightly higher upstream of the TBP facilities than downstream. This is mostly due to the fact that Sacramento River water is drawn to the south Delta when the TBP is operational. Sacramento River water has generally lower EC than the San Joaquin River and thus improves water quality within the south Delta, downstream of the TBP facilities. Hydrodynamic and water quality modeling has shown that EC in the south Delta increases when SWP pumping decreases (DWR 2000b). The decreased pumping reduced the draw of Sacramento River water in the south Delta and thus water quality “degraded” in the form of increased EC.

Dissolved oxygen (DO) sags have occurred in the project area during years when the TBP was both operational and when it was not, over the same time period. The DO sags appear to be related to increased water temperatures in the summer and have even occurred in high outflow years such as 1998 (DWR 1999). Data from the 1997 fish monitoring water quality element suggest that the TBP does not promote low DO upstream of the facilities (DWR 1998). At the Old River at Tracy (ORT) barrier from March through August, DO levels above the barrier were lower on the flood tide than they were on the ebb tide. This can occur above the ORT barrier whenever flood tides are not strong enough to push enough water over and through the ORT barrier weir and culverts to increase circulation toward the head of the Grant Line Canal. The ORT barrier height is 2.0 feet MSL, while the other two agricultural barriers are at 1.0 feet MSL, a design meant to force circulation up Old River and down the Grant Line Canal. When flood tides are not strong enough, null zones can occur upstream of the ORT barrier due to a combination of weak tides and agricultural diversions. These null zones are areas of low circulation where EC can increase and DO levels can be lower than on the downstream side of the barrier.

Water impounded upstream of the three agricultural barriers is seasonally warmed into the 70-80+ °F range, depending on location, from May – October. There is a concern that fishes that become trapped upstream of the agricultural barriers and are therefore susceptible to high water temperatures.

According to Mayfield and Cech (2004) 1-3 year old rearing juvenile green sturgeon prefer water at 59-61 ºF, tolerate temperatures up to 65 ºF, and likely perish in water that is 72 ºF or higher. Since green sturgeon occurrence is expected to be rare in the south Delta, they are not expected to be greatly impacted by increased temperatures. Although the HOR BARRIER installation is timed to prevent salmonid smolts from emigrating from the San Joaquin River into the south Delta at Old River, a small limited number are expected to be impacted.

Vulnerability to Local Agricultural Diversions

Fish that may become trapped upstream of the TBP agricultural barriers may suffer increased vulnerability to local agricultural diversions. There are numerous local diversions within the southern Delta that are generally most active from April through October (Cook and Buffaloe 1998), the same time period of TBP operation. However, there are many agricultural diversions on the downstream side of the barriers in the central and northern delta as well, consequently, whether there is a difference in vulnerability upstream versus downstream of the TBP agricultural barriers is unknown.

The Interagency Ecological Program (IEP) conducted a Delta Agricultural Diversion Study from 1993 through 1995 in attempt to determine the impacts of in-Delta diversions on resident and anadromous fish (Cook and Buffaloe 1998). No delta smelt, green sturgeon, or salmonids were captured in the fyke net. Overall, threadfin shad, catfish and sunfish were the dominant species captured, comprising over 99 percent of the total catch.

Similar sampling of diversions in other regions of the Delta (Cook and Buffaloe 1998) has captured small numbers of delta smelt, Chinook salmon, splittail. These data suggest that fish vulnerability, especially delta smelt, to in-Delta diversions increases when fish density is high in the immediate vicinity of the diversion. The fact that presumably no species considered under this supplemental B.A. were entrained in the diversion within the TBP area is probably due to the fact that their densities were extremely low in this area during the study period. It can be expected that a few of these fishes will be entrained into local diversions however; the overall impact is expected to be minimal based upon the results of the IEP study.

Impacts to Potential Fish Prey Items

The conditions posed by the TBP may influence the abundance and distribution of food items used by green sturgeon, steelhead, and juvenile spring- and winter-run Chinook salmon. Although their diet in the Delta has not been extensively studied (Sasaki 1966), steelhead and juvenile Chinook salmon likely feed on a variety of aquatic insects and crustaceans as well as small fish. Green sturgeon feed primarily on benthic crustaceans (i.e. amphipods), shrimp, clams, annelid worms and miscellaneous crabs and fishes (Moyle 2002, Kelly et. al. 2006).

The extent to which the distribution and abundance of these organisms will be influenced by the conditions posed by the TBP is difficult to determine. Orsi and Mecum (1986) found that copepod and cladoceran abundance was correlated with chlorophyll a concentration and temperature, but not with net flow or velocity. Such impacts are expected upstream of operating barriers, where occurrence of green sturgeon and salmonids is not expected. Mysid shrimp abundance is strongly related to temperature, salinity, and food supply (Orsi and Mecum 1986, Obrebski and others 1992, Kimmerer and Orsi 1996). Because the TBP does not influence the position of X2, organisms that exhibit a strong abundance-X2 relationship (i.e. mysid shrimp) (Jassby and others 1995), will not be impacted. These data suggest that the TBP probably will not influence prey populations within the Delta.

Past Measures

Under Terms and Conditions 1 (e) of the USFWS Biological Opinion (4/26/96), DWR was required to install at least three fish screens on agricultural diversions per year in the Delta. To date, DWR has installed a total of 14 screens on agricultural diversions and has capped another diversion at Sherman Island, for a total of 15 screens (3 screens per year for the permit period). DWR also contributed to funding a study that examined the entrainment patterns of two side-by-side screened and unscreened diversions at Sherman Island. DWR will continue the operation and maintenance of all 14 fish screens that have been installed at Sherman Island. The previously mentioned DWR study on the entrainment patterns of two side-by-side screened and unscreened diversions at Sherman Island provided evidence that screens can protect fish from entrainment into agricultural diversions (Nobriga and others 2000).

Under Terms and Conditions 3 of the USFWS Biological Opinion (4/26/96), DWR was required to mitigate for the footprint of the Grant Line Canal barrier. DWR fulfilled this requirement by acquiring a 1:1 ratio of 0.064 acres of riparian scrub, 0.011 acres of shaded mudflat, 0.411 acres of shallow water, and 0.250 acres of intertidal vegetation at Kimball Island.

Under Condition 11 of the DFG 1601 Agreement (5/2/96), DWR was required to mitigate for the impact to shallow water habitat. DFG agreed to credit the Kimball Island mentioned above habitat purchase to satisfy this mitigation requirement.

Under Condition 16 of the DFG 1601 Agreement (5/2/96), DWR was required to screen two agricultural diversions in the Bay-Delta Estuary. The fish screen project at Sherman Island fulfilled this requirement.

An additional conservation measure will be to notch each of the agricultural barriers similar to the HORB fall barrier to provide passage for migrating adult salmon that have strayed into Old and Middle Rivers and Grant Line Canal.

South Delta Improvement Program Operable

The following assessment identifies potential effects of operating the gates with the implementation of Stage 1 of the South Delta Improvements Program (SDIP) on Chinook Salmon, Steelhead and Sturgeon in the Delta. SDIP Stage 1 consists of the installation and operation of gates at four locations in the south Delta. There is no increase in the export diversion rate in Stage 1. Stage 2 includes the operable gates with the increase in exports up to 8,500 cfs.

ESA consultation for the operation of the SDIP gates in Stage 1 is being done within this OCAP BA. ESA consultation for the potential construction-related, predation and passage effects will be done separately. The operational effects are discussed and the other effects summarized in the subsequent text.

Simulation modeling completed for this OCAP BA incorporates the effects of the South Delta Temporary Barriers Project and 500 cfs increased export in Studies 6.1 and 7.0. The SDIP Stage

1, the 500 cfs increased export, and the CVP aqueduct intertie are incorporated into Studies 7.1 and 8.0. A full evaluation of the combined effects of these elements on Chinook salmon, steelhead and green sturgeon are presented in Chapter 13. Because the simulation models examined the combination of these elements, it is not possible to separate and examine the effects of any single project element by itself. Therefore, the effects analysis for the SDIP Stage 1 is taken largely from *South Delta Improvements Program Action Specific Implementation Plan* (DWR and USBR 2006), and the *South Delta Improvements Program EIS/EIR* (DWR and USBR 2006), http://baydeltaoffice.water.ca.gov/sdb/sdip/documents/final_eis_eir.cfm. The effects of operation of the gates are discussed in the following text. Details on the hydrodynamics of the SDIP operable gates are in Appendix Z.

South Delta Improvements Project (SDIP) – Stage 1

Permanent gates would be constructed at the head of Old River and in Middle River, Grant Line Canal, and Old River at the Delta Mendota Canal (DMC). Construction of the gates includes grading the channel bank, dredging the channel bottom, constructing sheet-pile cofferdams or an in–the-wet construction method, driving foundation piles, and placing riprap, concrete, and other materials on the channel bank and bottom.

Dredging for all of the permanent gates would occur between August and November. Cofferdams would also be placed in the channel during the August through November timeframe. Work outside of the channel and within the cofferdams, if used, is assumed to occur during any month.

Dredging of Middle River and portions of Old River would increase the tidal conveyance capacity of the channels. Tidal flow velocity may be slightly reduced in West Canal and, depending on existing channel constrictions, circulation may be increased in Middle River, Old River, and Grant Line Canal.

The operation of the permanent flow control gates on Middle River, Grant Line Canal, and Old River would maintain water surface elevation above 0.0 feet msl during April 15 through November. Under current conditions, tides range from about 1.0 foot below mean sea level to 3.0 feet msl two times each day. The maximum change in SWP pumping (and CCF operations) could reduce the daily higher high tide from about 2.6 to 2.4 feet msl near the CCF gates. The reduction in higher high tide attributable to change in SWP pumping is less with distance from the CCF gates. When closed during tide levels below 0.0 feet msl, the flow control gates block fish passage. When opened during tide levels greater than 0.0 feet msl, fish passage is restored. The volume of water exchanged during each tidal cycle is reduced by about 20% for the channels upstream of the gates on Middle River, Grant Line Canal, and Old River.

During the spring, the head of Old River fish control gate would be operated to block flow and movement of juvenile fall-run Chinook salmon and other fishes from the San Joaquin River into Old River from April 15 through May 15, or other periods as recommended by USFWS, NOAA Fisheries, and DFG. Juvenile Chinook salmon move down the San Joaquin River past Stockton, a pathway believed to enhance survival relative to movement into Old River (Brandes and McLain 2001).

During fall, the head of Old River fish control gate would be operated to increase flow in the San Joaquin River past Stockton from about September 15 through November 30. The increased flow in the San Joaquin River potentially improves water quality, including increased dissolved oxygen (DO), in the San Joaquin River channel near Stockton (Giulianotti et al. 2003). Improved water quality could benefit upstream migrating adult Chinook salmon.

Central Valley Chinook Salmon - Operational and Passage Effects

Effects of Gate Operation on Juvenile and Adult Chinook Salmon Migration

The head of Old River fish control gate would be closed from April 15 to May 15 under both Alternative 1 (No Action) when flow in the San Joaquin River is less than 5,000 cfs and in SDIP Stage 1 (Alternative 2A within the SDIP EIR/EIS) when San Joaquin River flow is less than 10,000 cfs. Under Alternative 1, a temporary fixed barrier is constructed and removed each year. Under SDIP Stage 1, a gate structure would be constructed with operable gates that would allow a range of operations. Gate closure would minimize the movement of juvenile Chinook salmon into Old River. Although the effects of gate closure are similar for both Alternative 1 and SDIP Stage 1, the operable gate constructed under SDIP Stage 1 would provide increased opportunities (i.e., longer closure) for fish protection. The increased flexibility to operate the fish control gate is also considered a beneficial effect.

The head of Old River fish control gate may also provide benefits to adult Chinook salmon during upstream migration in September, October, and November. Hallock (1970) observed that adult Chinook salmon avoided water temperatures greater than 66°F if DO was less than 5 mg/l. Low DO in the San Joaquin River channel near Stockton may delay migration of fall-run Chinook salmon. High San Joaquin River flows past Stockton maintain higher DO levels (Hayes and Lee 2000). Closure of the head of Old River fish control gate increases the San Joaquin River flow past Stockton, but the increase in flow during years with low-to-average flow (less than 1,000 cfs) appears to have minimal effect on DO levels. Available data indicate that the operation of flow control gates could reduce DO in the San Joaquin River near Stockton during the summer, but closure of the head of Old River fish control gate September 15 through November 30 would result in DO levels that are the same for Alternative 1 and SDIP Stage 1. Migration of adult Chinook salmon would be protected. Although the benefit of closing the head of Old River fish control gate to upstream movement of adult fall-run Chinook salmon is uncertain for all flow conditions, an operable gate constructed under SDIP Stage 1 would provide increased opportunities to evaluate the potential effects of increased flow under a wide range of San Joaquin River flow conditions. The increased flexibility of an operable gate is a beneficial effect.

Gates in Middle River, Grant Line Canal, and Old River at the DMC could affect access to rearing habitat in the south Delta channels and passage through the channels by adult and juvenile Chinook salmon during operation from April 15 through November. Operation of the gates, however, generally avoids the period of adult and juvenile Chinook salmon movement through the Delta, except during May and June when juvenile Chinook salmon could be affected. During May, the proposed closure of the head of Old River Gate would transcend the effects of the gates on Middle River, Grant Line Canal, and Old River at the DMC. In addition, the gate operations would have a beneficial effect relative to the existing temporary barriers. The existing temporary barriers are in place from mid-May through September and may also be in place in April to mid-May and in October and November, although the culverts on the Grant Line Canal barrier are tied open. Tidal flow overtops the barriers twice each day during the portion of tide that exceeds 1 foot msl. High tide approaches 3 feet msl, and total tidal volume in the channels upstream of the barriers is reduced by about 50 percent. The gates constructed under SDIP Stage 1 would operate from May through September. The gates would be open at tide elevations between 0.0 feet msl and about 3 feet msl, an increase in the tidal period currently allowed by the temporary barriers. Total tidal volume would approach 80% of the tidal volume without gates in place. Operable gates would have a beneficial effect on movement of adult and juvenile Chinook salmon because of the potential management flexibility and increased period of access to Middle River, Grant Line Canal, and Old River (i.e., passage conditions are provided at water surface elevations exceeding 0 feet msl under SDIP Stage 1 versus passage provided at elevations exceeding 1 foot msl under Alternative 1). The increased flexibility of an operable gate is a beneficial effect.

Effects of Head of Old River Gate Operation on Juvenile Chinook Salmon Entrainment

Closure of the head of Old River fish control gate during April 15th – May15th under SDIP Stage 1 would direct juvenile Chinook salmon down the San Joaquin River during most of the peak out-migration period. Installation of the temporary barrier reduces the number of juvenile Chinook salmon salvaged compared to years when the temporary barrier was not installed (San Joaquin River Group Authority 2003). Although the difference in the estimated survival with and without the gate is not statistically significant, relative survival for juvenile Chinook salmon migrating down the San Joaquin River has been about twice the survival for Chinook salmon migrating down Old River (Brandes and McLain 2001; Baker and Morhardt 2001).

Whether or not the gate alone would substantially minimize entrainment-related losses of juvenile fall-run Chinook salmon from the San Joaquin River, however, is currently not well supported. The gate closure results in additional flow from the San Joaquin River channel into Turner Cut, Middle River, and Old River channels to supply the CVP and SWP pumps. There is currently no clear correlation between SWP and CVP pumping and survival of juvenile Chinook salmon moving through the Delta in the lower San Joaquin River (Baker and Morhardt 2001).

Construction-Related Effects on Chinook Salmon

Chinook salmon rear in the Delta. Construction of the gates in the south Delta and maintenance activities have the potential to permanently modify shallow vegetated areas that may provide rearing habitat for Chinook salmon. The permanent gates constructed under SDIP Stage 1 would have minimal effect on habitat within the construction footprint at the head of Old River, Middle River, and Old River at DMC. Construction of the temporary barriers has previously modified shallow water habitat. Three of the four permanent gates would be constructed in the same location as the temporary barriers and would result in little change in habitat quality and quantity relative to Alternative 1.

Construction of a new gate on Grant Line Canal, which would be located in a different location than the temporary barrier, and the proposed dredging in West Canal, Middle River, and Old River potentially would remove and modify existing shallow vegetated habitat. Relative to historical extent, existing availability of shallow vegetated areas is limited. Therefore loss of additional shallow vegetated area that may represent rearing habitat for Chinook salmon could contribute to the historical loss and to an ongoing adverse effect. The site currently used for the temporary Grant Line Canal barrier will be abandoned which would eventually offset some of the shallow vegetated habitat losses associated with the placement of the permanent operable gate.

Predation Effects on Chinook Salmon

Predation associated with the addition of the operable gates and the agricultural intake extensions to the south Delta channels could cause a small and likely negligible increase in mortality of the juvenile Chinook salmon moving past the structures. The determination is based on several factors. Design elements will minimize turbulence that could disorient fish and increase vulnerability to predation. The structures would not create conditions that could concentrate juvenile Chinook salmon. Flow velocity would be similar to velocities within the channel upstream and downstream of the gates and agricultural intake extensions.

The transition zones between various elements of the gates (e.g., sheetpiles and riprap) could provide low-velocity holding areas for predatory fish. Predatory fish holding near the gates and agricultural intakes could prey on vulnerable species. The additional predator habitat created by the gates and intake extensions would have a minimal effect on juvenile Chinook salmon because the increase in potential predator habitat is small relative to habitat in adjacent areas, including the habitat currently created by the temporary barriers and habitat at the existing agricultural intakes. Disorientation and concentration of juvenile fish would be minimal given the size and design of the gates.

Effects of Head of Old River Gate Operation on Juvenile Central Valley Steelhead Migration

Closure of the head of Old River fish control gate would minimize the movement of juvenile steelhead into Old River. Although the effects of gate closure are similar for both Alternatives 1 and 2A, an operable gate constructed under SDIP Stage 1 would provide increased opportunities for fish protection in response to new information on fish survival for variable flows and migration pathways. The increased flexibility is a beneficial effect.

The head of Old River fish control gate may also provide benefits to adult steelhead during upstream migration in September through November. The head of Old River gate structure is designed with vertical-slot fishway. The fishway would be approximately 40 feet long and 10 feet wide and constructed with reinforced concrete. The ladder would be closed during the spring and opened during the fall, through November. Stoplogs would be used to close the fishway.

The benefits would be similar to those described above for adult Chinook salmon relative to movement in the San Joaquin River past Stockton. An operable gate constructed under SDIP Stage 1 would provide increased opportunities to evaluate the potential effects of increased flow and effects on DO levels under a wide range of San Joaquin River flow conditions. The increased flexibility of an operable gate is a beneficial effect.

Construction Effects on Steelhead

Steelhead rear primarily in natal reaches upstream of the Delta and are not expected to rear for substantial periods in the Delta. Therefore, construction activities in the Delta would not affect steelhead rearing or food resources for steelhead. Contaminants associated with construction activities, including gate construction, placement of riprap, dredging, and maintenance dredging, could be introduced into the south Delta channels and could adversely affect steelhead during migration. However, environmental commitments, including an erosion and sediment control plan, Stormwater Pollution Prevention Plan, hazardous materials management plan, spoils disposal plan, and environmental training, will be developed and implemented before and during construction activities. These environmental commitments would substantially reduce the likelihood of any considerable contaminant input. Construction of the gates would also include placement of sheetpiles and riprap and could directly injure fish present during the time of construction. Dredging could entrain and injure juvenile steelhead. Cofferdams, if used, could trap juvenile steelhead. Steelhead that become trapped inside the cofferdams could be killed during desiccation of the construction area and other construction activities. Direct injury associated with construction and maintenance activities, including dredging, would have a minimal effect on steelhead. This determination is based on the fact that 1) in-water construction, including the construction of a cofferdam, would occur between August and November, 2) the area of construction activity is small relative to the channel area providing passage through the south Delta, 3) in-water construction and dredging would occur over a relatively short period (i.e., about 3 years), and 4) most juvenile and adult steelhead would move away from construction activities and into adjacent habitat of similar quality.

Predation Effects on Steelhead

Construction of gates and extension of agricultural intakes would add permanent structure and cover to the south Delta channels. The addition of structure has the potential to increase the density of predator species and predation on steelhead moving around and past the structure. Predation associated with the addition of the operable gates and the agricultural intake extensions to the south Delta channels could cause a small and likely negligible increase in mortality of the juvenile steelhead moving past the structures. The determination is based on the fact that 1) design elements will minimize turbulence that could disorient fish and increase vulnerability to predation, 2) the structures would not create conditions that could concentrate juvenile steelhead, and 3) flow velocity would be similar to velocities within the channel upstream and downstream of the gates and agricultural intake extensions. The increase in potential predator habitat is small relative to habitat in adjacent areas, including the habitat currently created by the temporary barriers and habitat at the existing agricultural diversion intakes.

Passage Effects on Steelhead

Closure of the head of Old River fish control gate would minimize the movement of juvenile steelhead into Old River. In comparison to the existing temporary barriers, an operable gate would provide increased opportunities for fish protection in response to new information on fish survival for variable flows and migration pathways. The increased flexibility is a beneficial effect. The head of Old River fish control gate may also be available to provide benefits to adult steelhead during upstream migration in September through November. The benefits would be similar to those described for adult Chinook salmon relative to movement in the San Joaquin River past Stockton. Hallock (1970) observed that adult Chinook salmon avoided water temperatures greater than 66°F if DO was less than 5 mg/l. Low DO in the San Joaquin River channel near Stockton may delay migration of fall-run Chinook salmon. High San Joaquin River flows past Stockton maintain higher DO levels (Hayes and Lee 2000). Closure of the head of Old River fish control gate increases the San Joaquin River flow past Stockton, but the increase in flow during years with low-to-average flow (less than 1,000 cfs) appears to have minimal effect on DO levels. The operation of flow control gates could reduce DO in the San Joaquin River near Stockton during the summer, but closure of the head of Old River fish control gate September 15 through November 30 would result in DO levels that are the same for the existing temporary barriers and for the operable gates. Migration of adult Chinook salmon and steelhead would be protected. An operable gate would provide increased opportunities to evaluate the potential effects of increased flow and effects on DO levels under a wide range of San Joaquin River flow conditions. The increased flexibility of an operable gate is a beneficial effect.

Operational Effects on Green Sturgeon

Operational effects on adults that migrate in February or March would be avoided because gate closure would not occur until April 15th. Furthermore, adults that use the San Joaquin River channel as a migration corridor would be unaffected by gate operation during all months because the gates would not affect fish passage in the San Joaquin River. The following assessment, therefore, focuses on the potential effects of the design and operation of the gates on adult and juvenile movement.

The flexible operation of the permanent flow control gates in Middle River, Grant Line Canal, and Old River at DMC will have a beneficial effect on green sturgeon movement relative to the existing temporary barriers. The existing temporary agricultural barriers are in place from mid-May, mid-April if the barrier at the head of Old River is in place, possibly through November. They must be removed by November 30th. They are constructed of rock and include culverts with flap-gates that are pushed open and close under tidal influences. The barriers operate as raised weirs at a fixed elevation that likely block the movement of green sturgeon. Under current operations of the temporary barriers, green sturgeon entrainment upstream of the barriers would only be possible when tidal flows overtop the barriers or if they pass through the culverts. Currently there is no information as to whether or not green sturgeon are capable of migrating over or through the temporary barriers during flood tides.

The permanent gates constructed under the SDIP would be open at tide elevations between 0.0 foot msl and about +3 foot msl, an increase in the tidal period currently allowed by the temporary barriers. Operable gates would have beneficial effects on the movement of adult and juvenile green sturgeon because the period of access to Middle River, Grant Line Canal, and Old River would increase relative to the period of access provided by the existing temporary barriers. Passage of green sturgeon would be expected when the Obermeyer gates are down because the gate panels would sit flat on the channel bottom and sturgeon would have access via articulated concrete mats over the riprap on the upstream and downstream sides of the gate.

The head of Old River gate will be operated from mid-April to mid-May and during June through November. The HOR gate would be operated in the spring as a fish barrier to keep juvenile San Joaquin River fish from entering Old River where they presumably are more vulnerable to entrainment by diversions, including the SWP and CVP pumps. Operation during June through November would be to improve flow in the San Joaquin River to avoid time of low DO. Under baseline conditions, a temporary fixed barrier is constructed each spring and/or fall. Under the SDIP, a gate would be constructed with operable bottom-hinged gates that would allow a range of operations.

Construction Effects on Green Sturgeon

The area of green sturgeon habitat affected by the gate footprints, rip-rapped levee, and dredging may total several acres. However, construction of the permanent gates would have minimal effect on green sturgeon habitat and prey availability within the construction footprint at the head of Old River, Middle River, and Old River near the DMC because construction of the temporary barriers has previously modified channel habitat. Three of the four permanent gates would be constructed in the same location as the temporary barriers and would result in little change in habitat and prey quality and quantity relative to existing conditions. Construction of a new gate on Grant Line Canal and the proposed dredging in West Canal, Middle River, and Old River potentially would remove and modify existing shallow vegetated areas and channel bottom substrate, however the area affected by gate construction and riprap placement is small relative to availability of similar vegetated areas and bottom substrates in adjacent channel reaches. Contaminants associated with construction activities, including gate construction, placement of riprap, dredging, and maintenance dredging, could be introduced into the south Delta channels and could adversely affect adult green sturgeon during migration and juveniles rearing in the Delta. However, Environmental commitments, including an erosion and sediment control plan, Stormwater Pollution Prevention Plan, hazardous materials management plan, spoils disposal plan, and environmental training, will be developed and implemented before and during construction activities. These environmental commitments would substantially reduce the likelihood of any considerable contaminant input. Construction of the gates would also include placement of sheet-piles and riprap and could directly injure fish present during the time of construction. Dredging could entrain and injure green sturgeon. Cofferdams, if used, could trap juvenile and adult green sturgeon. Direct injury associated with construction and maintenance activities, including dredging, would have a minimal effect on green sturgeon. This determination is based on the fact that 1) the area of construction activity is small relative to the channel area in-water construction, 2) dredging would occur over a relatively short period (i.e., about 3 years) and be limited to the August to November timeframe, and 3) most juvenile and adult green sturgeon would move away from construction activities and into adjacent habitat of similar quality.

Predation Effects on Green Sturgeon

Increased predation could be associated with the addition of the operable gates and the agricultural intake extensions to the south Delta channels. Design elements, however, will minimize turbulence that could disorient fish and increase vulnerability to predation. The structures would not create conditions that could concentrate green sturgeon. The increase in potential predator habitat is small relative to habitat in adjacent areas, including the habitat currently created by the temporary barriers and habitat at the existing agricultural diversion intakes. Disorientation and concentration of juvenile fish would be minimal given the size and design of the gates.

Passage Effects on Green Sturgeon

The Sacramento River provides a migration pathway between freshwater and estuarine habitats for green sturgeon, however; there is currently no available data about the migratory paths of adult or juvenile green sturgeon through the Sacramento-San Joaquin Delta. If green sturgeon migrate through the South Delta, the gate closures could restrict the movement of green sturgeon into the Sacramento River and out to the Pacific Ocean. However, closure of the Old River fish control gate would not preclude juvenile and adult sturgeon movement between the San Joaquin River upstream and downstream of Old River and the Sacramento River or Pacific Ocean. Boat locks that are regularly opened at the Head of Old River gate may also provide some passage for sturgeon.

Suisun Marsh Salinity Control Gates

The Suisun Marsh Salinity Control Gates could potentially be operated September through May, overlapping with an expected November through May spring–run Chinook salmon emigration. However, juvenile Chinook salmon of all races are rare in Suisun Marsh and are therefore unlikely to be substantially affected by gate operations. Examination of the UC Davis Suisun Marsh Monitoring databases showed only 257 juvenile Chinook salmon were captured from 1979 through 1997.

The infrequent occurrence of young Chinook in the marsh suggests that predation associated with migration delays is unlikely to significantly affect the spring–run or winter–run population. As support for this hypothesis, only three Chinook salmon were found in the stomachs of striped bass and pikeminnow captured near this facility between 1987 and 1993 (DWR 1997).

Although young Chinook salmon will probably not be significantly affected by gate operations, it is possible upstream passage of adults could be influenced. Adult winter–run and spring–run may pass through the marsh channels from December through May when their migration could potentially be delayed. The SMSCG Steering Group decided based on preliminary results from the modified SMSCG tests that the slots resulted in less adult passage than the original flashboards. The modification made for the 2001-02 control season was to leave the boat lock at the SMSCG open at all times.

SMSCG Fish Passage Study

The SMSCG were constructed and operate under Permit 16223E58 issued by the US Army Corps of Engineers which includes a special condition to evaluate the nature of delays to migrating fish. Ultrasonic telemetry studies in 1993 and 1994 showed that the physical configuration and operation of the gates during the Control Season have a negative effect on adult salmonid passage (Tillman et al 1996: Edwards et al 1996).

The Department coordinated additional studies in 1998 - 1999, and 2001- 2004 to assess potential measures to increase the salmon passage rate and decrease salmon passage time through the gates. Monitoring results from the 1998 and 1999 studies indicate that the flashboards modified with horizontal slots did not improve salmon passage at the SMSCG (Vincik et al., 2003). Results in 2001, 2003, and 2004 indicated that leaving the boat-lock open during the Control Season when the flashboards are in place at the SMSCG and the radial gates are tidally operated provided nearly equivalent fish passage to the Non-Control Season configuration when the flashboards are out and the radial gates are open (Vincik et al., 2005). This approach minimized delay and blockage of adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead migrating upstream during the Control Season while the SMSCG is operating. However, the boat-lock gates would be closed temporarily to stabilize flows to facilitate safe passage of watercraft through the facility.

USBR and DWR are continuing to coordinate with the SMSCG Steering Committee in identifying water quality criteria, operational rules, and potential measures to facilitate removal of the flashboards during the Control Season that would provide the most benefit to migrating fish. However, the flashboards would not be removed during the Control Season unless it was certain that standards would be met for the remainder of the Control Season without the flashboards installed.

The SMSCG could be operated as needed to meet State salinity standards in the marsh September through May, overlapping with an expected January through May peak emigration of steelhead through the Delta. However, young steelhead are rare in Suisun Marsh and are therefore unlikely to be substantially affected by gate operations. Examination of the UC Davis Suisun Marsh Monitoring databases revealed six steelhead were captured from 1979 through 1997. Only two of the six were sub-adult sized fish. The very low number of steelhead in the samples is partly due to poor capture efficiencies of the beach seines and otter trawl used in the UC Davis survey. However, 1,505 splittail greater than 200 mm, were collected by UC Davis sampling during the same period. Both adult splittail and yearling steelhead are excellent swimmers and are inefficiently sampled by the gear types used in this program. The much higher incidence of adult splittail in the samples suggests steelhead are relatively rare in the marsh. Furthermore, the marsh sampling collected more adult steelhead (4) than yearlings (2). The adults are larger and faster and therefore sampled less efficiently, providing additional evidence that yearling steelhead seldom occur in Suisun Marsh. The very infrequent occurrence of steelhead in the marsh suggests predation associated with migration delays is unlikely to significantly affect the steelhead population. As support for this hypothesis, steelhead were not listed as a prey item of striped bass or Sacramento pikeminnow captured near this facility between 1987 and 1993 (DWR 1997).

Morrow Island Distribution System

The 1997 FWS BO issued for dredging of the facility included a requirement for screening the diversion to protect delta smelt. Due to the high cost of fish screens and the lack of certainty surrounding their effectiveness at MIDS, DWR and Reclamation proposed to investigate fish entrainment at the MIDS intake with regard to fishery populations in Goodyear Slough and to evaluate whether screening the diversion would provide substantial benefits to local populations of listed fish species. DWR staff monitored fish entrainment from September 2004 to June 2006 at the MIDS in Suisun Marsh to evaluate entrainment losses at the facility.

Monitoring took place over several months under various operational configurations to provide data on the site-specific impact of the MIDS diversion with a focus on delta smelt and salmonids. Over 20 different species were identified during the sampling, yet only two fall-run sized Chinook salmon (south intake, 2006) from entrained water were caught. Two species that are associated with instream structures, threespine stickleback and prickly sculpin, comprised most of the entrained fish. DWR and Reclamation staff will continue coordination with the fishery agencies to address the screening requirement.

Reclamation and DWR continue to coordinate with the FWS, NMFS, and DFG regarding fish entrainment at this facility. The objective remains to provide the greatest benefit for aquatic species in Suisun Marsh.

Goodyear Slough

Studies suggest that Goodyear Slough is a marginal, rarely used habitat for special-status fishes. Therefore, implementation and/or monitoring of a tidal restoration project elsewhere is emerging as the most beneficial and pratical approach (in lieu of installing and maintaining fish screens). Restoration of tidal wetland ecosystems is expected to aid in the recovery of several listed and special status species within the marsh and improve food availability for other pelagic organisms.

Water Transfers

Water transfers would increase Delta exports by 0 to 360,000 acre-feet (af) in most years (the wettest 80 percent of years) and by up to 600,000 af in Critical and some Dry years (approximately the driest 20 percent years). Most transfers will occur at Banks (SWP) because reliable capacity is not likely to be available at Jones (CVP) except in the driest 20 percent of years. Although transfers can occur at any time of year, the exports for transfers described in this assessment would occur only in the months July-September. Juvenile salmonids are rarely present in the Delta in these months, so no increase in salvage due to water transfers during these months is anticipated. Water transfers could be beneficial if they shift the time of year that water is pumped from the Delta from the winter and spring period to the summer, avoiding periods of higher salmonid abundance in the vicinity of the pumps. Some adult salmon and steelhead are immigrating upstream through the Delta during July through September. Increased pumping is not likely to affect immigrating adults because they are moving in a general upstream direction against the current. For transfers that occur outside of the July through September period, all current water quality and pumping restrictions would still be in place to limit effects that could occur.

Post-processing of Model Data for Transfers

This section shows results from post-processed available pumping capacity at Banks and Jones for the Study 8.0 (Future Conditions - 2030). These results are used for illustration purposes. Results from the Existing Conditions CVP-OCAP study alternatives do not differ greatly from those of Study 8.0, and produce similar characteristics and tendencies regarding the opportunities for transfers over the range of study years. The assumptions for the calculations are:

- Capacities are for the Late-Summer period July through September total.
- The pumping capacity calculated is up to the allowable E/I ratio and is limited by either the total physical or permitted capacity, and does not include restrictions due to ANN salinity requirements with consideration of carriage water costs.
- The quantities displayed on the graph do not include the additional 500 cfs of pumping capacity at Banks (up to 7,180 cfs) that is proposed to offset reductions previously taken for fish protection. This could provide up to a maximum about 90 taf of additional capacity for the July-September period, although 60 taf is a better estimate of the practical maximum available from that 500 cfs of capacity, allowing for some operations contingencies.
- Figure 13-58 and Figure 13-59 show the available export capacity from Study 8.0 (Future Conditions-2030) at Banks and Jones, respectively, with the 40-30-30 water year type on

the x-axis and the water year labeled on the bars. The SWP allocation or the CVP south of Delta Agriculture allocation is the allocation from CalSim-II output from the water year.

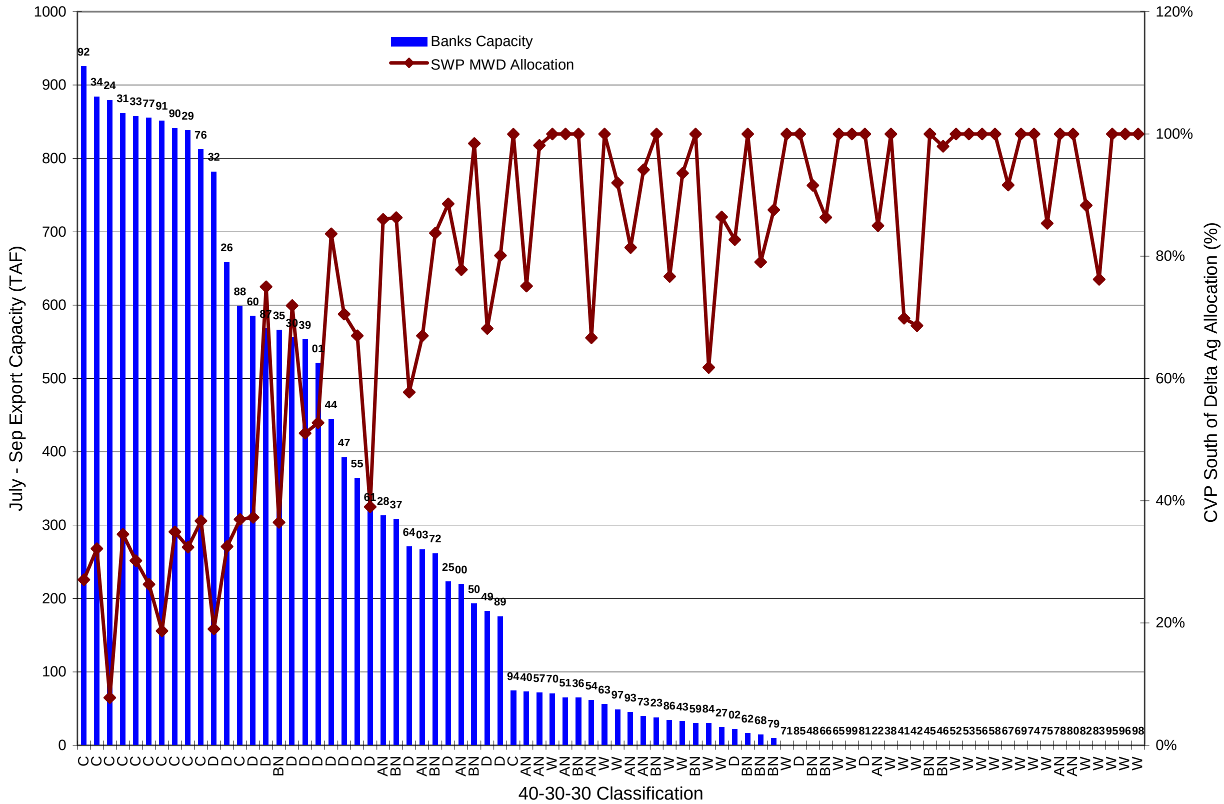


Figure 13-58 Available Export Capacity at Banks Pumping Plant

From Figure 13-58, the most capacity at Banks will be available in Critical and certain Dry years (driest 20 percent of study years) which generally have the lowest water supply allocations, and reflect years when transfers may be higher to augment water supply to export contractors. For all other study years (generally the wettest 80 percent) the available capacity at Banks for transfer ranges from about 0 to 500 taf (not including the additional 60 taf accruing from the proposed permitted increase of 500 cfs at Banks. But, over the course of the three months July-September other operations constraints on pumping and occasional contingencies would tend to reduce capacity for transfers. In consideration of those factors, proposed transfers would be up to 360 taf in most years when capacity is limiting. In Critical and some Dry years, when capacity would not be a limiting factor, exports for transfers could be up to 600 taf (at Banks and Jones combined). Transfers at Jones (Figure 13-59) are probably most likely to occur only in the driest of years (Critical years and some Dry years) when there is available capacity and low allocations.

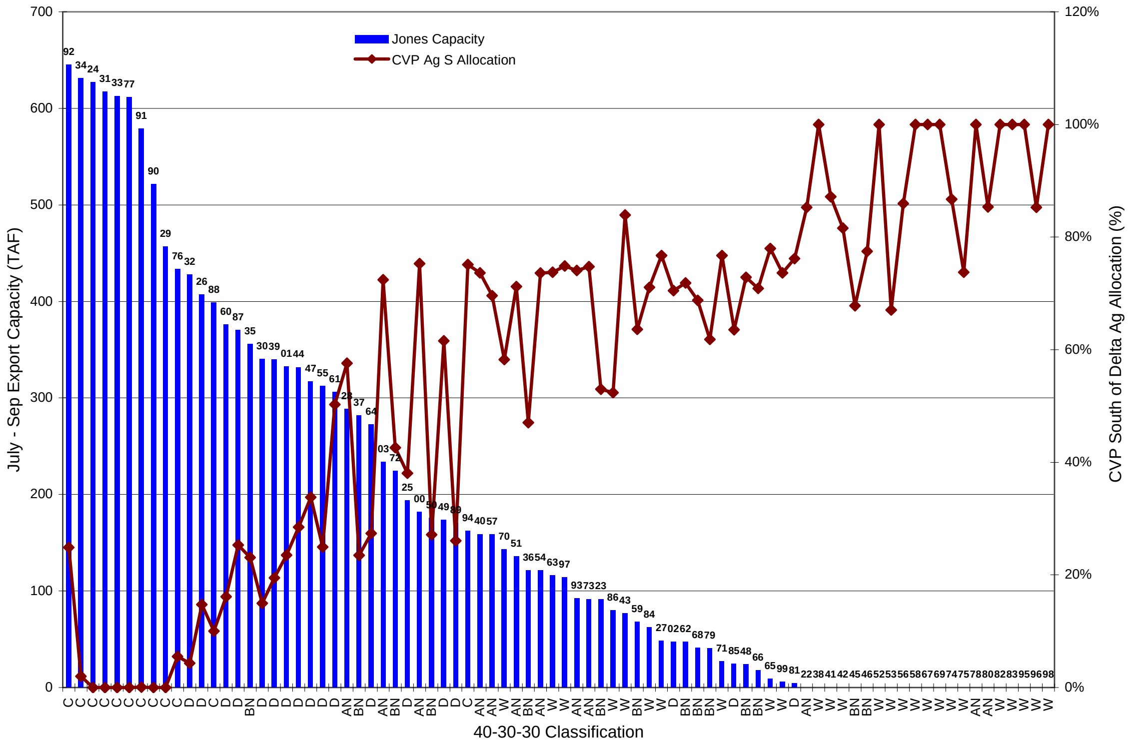


Figure 13-59 Available Export Capacity at Jones Pumping Plant

Limitations

The analysis of transfer capacity available derived from the CalSim-II study results shows the capacity at the export pumps and does not reflect the amount of water available from willing sellers or the ability to move through the Delta. The available capacity for transfer at Banks and Jones is a calculated quantity that should be viewed as an indicator, rather than a precise estimate. It is calculated by subtracting the respective project pumping each month from that project's maximum pumping capacity. That quantity may be further reduced to ensure compliance with the Export/Inflow ratio required. In actual operations, other contingencies may further reduce or limit available capacity for transfers: for example, maintenance outages, changing Delta outflow requirements, limitations on upstream operations, water level protection criteria in the south Delta, and fishery protection criteria. For this reason, the available capacity should be treated as an indicator of the maximum available for use in transfers under the assumed study conditions.

Proposed Exports for Transfers

In consideration of theestimated available capacity for transfers, and in recognition of the many other operations contingencies and constraints that might limit actual use of available capacity, for this assessment proposed exports for transfers (months July-September only) are as follows:

Water Year class	Maximum Amount of Transfer
Critical	up to 600 taf
Consecutive Dry	up to 600 taf
Dry after Critical	up to 600 taf
All other Years	up to 360 taf

Chapter 14 Basic Biology and Life History of Southern Resident Killer Whales, Distribution and Abundance, and Effects of the Proposed Action

Introduction

Three distinct forms of killer whales, termed residents, transients, and off shores, are recognized in the northeastern Pacific Ocean. Resident killer whales in U.S. waters are distributed from Alaska to California, with four distinct communities recognized: Southern, Northern, Southern Alaska, and Western Alaska (Krahn et al., 2002; 2004). Resident killer whales are fish eaters and live in stable matrilineal pods. Of these, only the Southern Resident Distinct Population Segment (DPS) is listed as endangered under the ESA.

Legal Status

The Southern Resident DPS of killer whales was listed as endangered under the Endangered Species Act on November 18, 2005 (NMFS 2005). Killer whales are the world's largest dolphins and the listed Southern Resident DPS overlaps in range in the Northeastern Pacific Ocean with other whale populations classified as transient, resident, and offshore populations. The Southern Resident population consists of three pods designated J, K and L, each containing 24, 22 and 44 members respectively (Ford et al. 2000; Center for Whale Research 2006, unpublished data). These pods generally spend late spring, summer and fall in inland waterways of Washington State and British Columbia. They are also known to travel as far south as central California and as far north as the Queen Charlotte Islands. Winter and early spring movements are largely unknown for this DPS.

Critical habitat for the Southern Resident DPS was designated under the Endangered Species Act on November 29, 2006 (NMFS 2006a). The critical habitat designation encompasses parts of Haro Strait and the waters around the San Juan Islands, the Strait of Juan de Fuca and all of Puget Sound.

General Biology

Wild female Southern Resident killer whales give birth to their first surviving calf between the ages of 12 and 16 years (mean = about 14.9 years) (Olesiuk et al. 1990, Matkin et al. 2003). Females produce an average of 5.4 surviving calves during a reproductive life span lasting about 25 years (Olesiuk et al. 1990). Males become sexually mature at body lengths ranging from 5.2-6.4 meters, which corresponds to between the ages of 10 to 17.5 years (mean = about 15 years) (Christensen 1984, Perrin and Reilly 1984, Duffield and Miller 1988, Olesiuk et al. 1990), and are presumed to remain sexually active throughout their adult lives (Olesiuk et al. 1990).

Most mating of Southern Resident killer whales in the North Pacific is believed to occur from May to October (Nishiwaki 1972, Olesiuk et al. 1990, Matkin et al. 1997); however, conceptions apparently happen year-round because births of calves are reported in all months. Mean interval between viable calves is four years (Bain 1990). Newborns measure 2.2-2.7 m long and weigh about 200 kg (Nishiwaki and Handa 1958, Olesiuk et al. 1990, Clark et al. 2000, Ford 2002). Mothers and offspring maintain highly stable social bonds throughout their lives and this natal relationship is the basis for the matrilineal social structure in the Southern Resident population (Bigg et al. 1990, Baird 2000, Ford et al. 2000).

Most published information on resident killer whale prey originates from a single study (Ford et al. 1998, Ford and Ellis 2005) in British Columbia, including southeastern Vancouver Island. This study focused primarily on Northern Residents and included a relatively small number of observations for Southern Residents. Of the 487 records of apparent fish predation events from 1974-2004, only 68 (14 percent) observations came from Southern Residents. The study recorded surface observations from predation events and also analyzed the stomach contents from stranded killer whales. Southern Resident killer whales are known to consume 22 species of fish and one species of squid (Scheffer and Slipp 1948, Ford et al. 1998, 2000, Ford and Ellis 2005, Saulitis et al. 2000). In recent years additional data has been collected on Southern Residents in parts of Puget Sound (Hanson, et al. 2005, NWFSC unpubl. data). In addition to collections of scales from observed predation events, fecal samples have also been collected for analysis.

Ford and Ellis (2005) found that salmon represent over 96 percent of the prey consumed during the spring, summer, and fall. Chinook salmon were selected over other species, comprising over 70 percent of the identified salmonids taken. This preference occurred despite the much lower abundance of Chinook in the study area in comparison to other salmonids and is probably related to the species' large size, high fat and energy content and year-round occurrence in the area. Other salmonids eaten in smaller amounts include chum (22 percent of the diet), pink (3 percent), coho (2 percent), sockeye (less than 1 percent), and steelhead (less than 1 percent) (Ford and Ellis 2005). This work suggested an overall preference of these whales for Chinook during the summer and fall, but also revealed extensive feeding on chum salmon in the fall.

Rockfish (*Sebastes* spp.), Pacific halibut (*Hippoglossus stenolepis*), and Pacific herring (*Clupea pallasi*) were also observed during predation events (Ford and Ellis 2005). Although it is unclear how important salmon, and southern U.S. salmon in particular, may be as prey while the Southern Resident DPS is offshore, the observed preference for salmon in other areas makes it likely that when available, salmon are taken as prey in ocean waters. A number of smaller flatfish, lingcod (*Ophiodon elongates*), greenling (*Hexagrammos* spp.) and squid have been identified in stomach content analyses of resident killer whales (Ford et al. 1998). Other information raises questions about the preference of Chinook over other prey species, including the abundance of other salmon (particularly sockeye and pink) when Southern Residents are present, the consistency in migratory patterns between Southern Residents and other salmon species, and the greater amount of time whales spend at depths commonly used by species other than Chinook (i.e., less than 30 m) (Baird et al. 2003, 2005; Hoelzel 1993; Ishida et al. 2001; Quinn and terHart 1987; Quinn et al. 1989; Ruggerone et al. 1990), which are usually found at greater depths (25-80 m) (Candy and Quinn 1999). Baird et al. (2005) recently reported a shift to shallower daytime depths among Southern Residents between 1993 and 2002, which possibly reflects a long-term change in prey behavior or selection of prey. Little is known about the winter and early spring diet of Southern Residents or whether individual pods have specific dietary preferences.

NMFS (2008) estimated biological requirements of Southern Resident killer whales including the diet composition and number of salmon the population requires in their coastal range. NMFS estimated the current population of Southern Residents (87) would be required to consume between 392,555 and 470,288 salmon based on diet compositions and bioenergentic needs in their coastal range. These estimated were based on Chinook comprising 70 to 88 percent of their diet.

Based on observations of captive killer whales, studies have extrapolated the energy requirements of wild killer whales and estimate an average size value for the five salmon species combined. Osborne (1999) estimated that adult killer whales would consume 28-34 adult salmon per day, and that younger killer whales (less than 13 years of age) would consume about 15-17 salmon per day to meet their daily energy requirements. By extrapolating these results, we estimate that the Southern Resident population (approximately 90 individuals) would consume about 750,000 to 850,000 adult salmon per year. These estimates are based on two assumptions that could affect the applicability of the results to Southern Resident killer whales in the wild. First, the wild killer whales probably have greater energy requirements than those held in captivity. Second, since salmon differ significantly in size across species and runs, any prey preference among salmon would affect the annual consumption rates, so fewer salmon per day would be required from a larger preferred prey species, such as Chinook salmon while larger numbers of salmon per day would be required for smaller fish, such as chum.

Population Status and Trends

In general, there is little information available regarding the historical abundance of Southern Resident killer whales. Some evidence suggests that, until the mid- to late-1800s, the Southern Resident killer whale population may have numbered more that 200 animals (Krahn et al. 2002). This estimate was based, in part, on a recent genetic analysis of microsatellite DNA, which found that the genetic diversity of the Southern Resident population resembles that of the Northern Residents (Barrett-Lennard 2000, Barrett- Lennard and Ellis 2001), and concluded that the two populations were possibly once similar in size. Recent efforts to assess the killer whale population during the past century have been hindered by an absence of empirical information prior to 1974 (NMFS 2006b). For example, a report by Scheffer and Slipp (1948) is the only pre-1974 account of Southern Resident abundance in the area, and it merely noted that the species was “frequently seen” during the 1940s in the Strait of Juan de Fuca, northern Puget Sound, and off the coast of the Olympic Peninsula, with smaller numbers along Washington’s outer coast. Olesiuk et al. (1990) estimated the Southern Resident population size in 1967 to be 96 animals. At about this time, marine mammals became popular attractions in zoos and marine parks, which increased the demand for interesting and exotic display animals. Between 1967 and 1973, it is estimated that 47 killer whales, mostly immature, were taken from the Southern Resident population for public display. The rapid removal of individual whales caused an immediate decline in numbers (Ford et al. 2000). By 1971, the level of removal decreased the population by about 30 percent, to approximately 67 whales (Olesiuk et al. 1990). In 1993, two decades after the live capture of killer whales ended, the three Southern Resident pods – J, K, and L – totaled 96 animals (Ford et al. 2000).

Over the past decade, the Southern Resident population has fluctuated in numbers. For example, the population appeared to experience a period of recovery by increasing to 99 whales in 1995, but then declined by 20 percent to 79 whales in 2001 (- 3.3 percent per year) before another slight increase to 83 whales in 2003 (Ford et al. 2000; Carretta et al. 2004). NMFS (2008) estimated the 2007 population to be 87 whales. The population estimate in 2006 was approximately 90 animals (+ 3.5 percent per year since 2001) (Center for Whale Research 2006), the decline in the 1990's, unstable population status, and population structure (e.g., few reproductive age males and non-calving adult females) continue to be causes for concern. Moreover, it is unclear whether the recent increasing trend will continue because these observations may represent an anomaly in the general pattern of survival or a longer-term shift in the survival pattern. Several individuals disappeared in the fall of 2006 and one new calf has been identified since the 2006 population estimate.

Range and Distribution

Southern Resident killer whales spend a significant portion of the year in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound, particularly during the spring, summer, and fall, when all three pods are regularly present in the Georgia Basin (defined as the Georgia Strait, San Juan Islands, and Strait of Juan de Fuca) (Heimlich-Boran 1988, Felleman et al. 1991, Olson 1998, Osborne 1999). The Southern Resident population consists of three pods, identified as J, K, and L pods. Typically, K and L pods arrive in May or June and spend most of their time in this core area until departing in October or November. During this time, both pods also make frequent trips lasting a few days to the outer coasts of Washington and southern Vancouver Island (Ford et al. 2000). J pod continues to spend intermittent periods of time in the Georgia Basin and Puget Sound during late fall, winter and early spring.

While the Southern Residents are in inland waters during the warmer months, all of the pods concentrate their activities in Haro Strait, Boundary Passage, the southern Gulf Islands, the eastern end of the Strait of Juan de Fuca, and several localities in the southern Georgia Strait (Heimlich-Boran 1988, Felleman et al. 1991, Olson 1998, Ford et al. 2000). In general, they spend less time elsewhere, including other sections of the Georgia Strait, Strait of Juan de Fuca, and San Juan Islands, Admiralty Inlet west of Whidbey Island, and Puget Sound. Individual pods are similar in their preferred areas of use (Olson 1998), although there are some seasonal and temporal differences in certain areas visited by each pod (Hauser 2006). For example, J pod visits Rosario Strait more frequently than K or L pods (Hauser 2006).

The movements of Southern Resident killer whales relate to those of their preferred prey – salmon. Pods commonly seek out and forage in areas where salmon occur, especially those associated with migrating salmon (Heimlich-Boran 1986, 1988; Nichol and Shackleton 1996). Notable locations of particularly high use include Haro Strait and Boundary Passage, the southern tip of Vancouver Island, Swanson Channel off North Pender Island, and the mouth of the Fraser River delta, which is visited by all three pods in September and October (Felleman et al. 1991, Ford et al. 2000, K.C. Balcomb, unpubl. data). These sites are major corridors for migrating salmon.

Late spring and early fall movements of Southern Residents in the Georgia Basin have remained fairly consistent since the early 1970s, with strong site fidelity shown to the region as a whole (NMFS 2006b). However, some areas of use have changed over time. Visits to Puget Sound have diminished since the mid-1980s, while Swanson Channel has become an area of higher use (K.C. Balcomb, unpubl. data). One possible explanation for these alterations in habitat use may be the long-term differences in the availability of salmon at particular sites (NMFS 2006b). Another possible cause may be the loss of information regarding alternative sites due to the mortality of older, more experienced whales that knew of other good feeding sites, but who can no longer guide their pods to these sites or along favored travel routes (NMFS 2006b).

During late fall, winter, and early spring, the ranges and movements of the Southern Residents are less well known. Throughout this time period, J pod continues to occur intermittently in the Georgia Basin and Puget Sound, but its location during apparent absences is uncertain (Osborne 1999). One sighting of this pod was made off Cape Flattery, Washington, in March 2004 (Krahn et al. 2004). Prior to 1999, K and L pods followed a general pattern in which they spent progressively less time in inland waters during October and November and departed the area entirely by December of most years (Osborne 1999). Sightings of both groups passing through the Strait of Juan de Fuca in late fall suggested that activity shifted to the outer coasts of Vancouver Island and Washington, although it was unclear if the whales spent a substantial portion of their time in this area or were simply in transit to other locations (Krahn et al. 2002). Since the winter of 1999-2000, K and L pods have extended their use of inland waters until January or February each year. Since 1999, both pods are completely absent from the Georgia Basin and Puget Sound only from about early or mid-February to May or June. In recent years between January and March K and L pods have been sighted as far south as Monterey, California. Table 14-1 summarizes the known and potential sightings of Southern Resident killer whales along the California coast.

Table 14-1. Summary of known and potential sightings of Southern Resident killer whales along the California coast.

Date	Location	Pods	Source
Jan. 29, 2000	Monterey Bay	K and L pods	Nancy Black Seen and photographed feeding on fish
Mar. 13, 2002	Monterey Bay	L pod	Nancy Black
Feb. 16, 2005	Farallon Islands	L and K pods	Balcomb, CWR
Jan. 26, 2006	Point Reyes	L pod	S. Allen
Jan. 24, 2007	San Francisco Bay	K pod	Nancy Black
Mar. 18, 2007	Fort Bragg	L pod	Reported on CWR web page
Mar. 24-25, 2007	Monterey	K and L pods	Reported on CWR web page
Jan. 24, 2008	Monterey	L pod	Reported on CWR web page

Effects of the Proposed Action

Project operations have the potential to affect the prey base of Southern Resident killer whales. Chapters 11, 13, and 16 discuss the effects of project operations upon Central Valley steelhead, Sacramento River winter-run Chinook salmon, Central Valley sprint-run Chinook salmon, Southern Oregon/Northern California Coast coho salmon, Central California Coast steelhead, Central Valley fall-run Chinook salmon, and Central Valley late-fall run Chinook salmon. Project operations would only affect Southern Resident killer whales to the extent that the effects of the project operations alter salmonids populations which could indirectly lead to a reduction in prey availability to the Southern Resident killer whales. Reductions in prey availability may force the whales to spend more time foraging, and could lead to reduced reproductive rates and higher mortality.

It is important to note that salmon from streams affected by project operations constitute only a portion of the Southern Resident killer whale prey base; other prey (even assuming all prey are salmon, which is not the case) originate from Puget Sound streams, coastal streams in Washington, Oregon, and California. It is not known what portion of the prey base is composed of salmonids from streams affected by project operations. The spring, summer and fall range of the Southern Resident killer whales includes the inland waterways of Puget Sound, the Strait of Juan de Fuca, and the Southern Georgia Strait, (NMFS 2005). Their wide-ranging migratory patterns put them in the proximity of numerous other stocks of salmon.

The portion of the killer whale prey base that comes from the streams affected by project operations includes both wild and hatchery produced salmon, both ESA-listed and non ESA-listed groups. Salmon distribution and population are also affected by many factors in addition to the proposed actions which include ocean conditions and pollution.

As discussed earlier, little is known about the winter and early spring prey preference of Southern Residents when they are in offshore waters. Studies of resident killer whales indicate that fish, and particularly salmon, are the major prey of resident whales with a reported preference for Chinook salmon (Ford et al. 1998; Ford et al. 2000, Ford et al. 2005). While these studies are predominantly based on observations of Northern Resident whales from May to October in coastal regions of British Columbia, more recent data on Southern Residents in Haro Strait and Puget Sound from May to September also support preference for Chinook (Hanson et al. 2005, NWFSC unpubl. data). Ford et al. (2005) looked at correlations between survival of Northern and Southern Resident killer whales and Chinook stocks from Alaska to Oregon, and reported a strong correlation between changes in overall coast wide Chinook abundance and combined mortalities of both resident communities. There are, however, limitations to applying the analysis and questions regarding the interpretation of the results.

On a local scale, Ford et al. (2005) found a weak correlation between Southern Resident survival and Chinook abundance in Washington and Oregon (R^2 = .115). According to the study, the strongest correlations with Southern Resident killer whale survival were with Chinook in North Coast B.C. (R^2 = .54) and SE Alaska (R^2 = .698). In addition, this study did not analyze the importance of additional Chinook stocks that do appear to be in the range of the Southern Residents, such as those in California. Moreover, the limited information on offshore distribution of Southern Resident killer whales limits our ability to interpret the extent of overlap of the whales and specific Chinook stocks, particularly during winter months. There may also be a correlation with environmental factors common to both Southern Resident killer whales and Chinook salmon, but not necessarily an actual connection between the two species.

Although the importance of salmon to the offshore diet of Southern Residents is not clearly defined, particularly for southern U.S. salmon, the observed preference for salmon in other areas makes it likely that, when available, killer whales take salmon as prey in ocean waters. Chemical analyses of killer whale fatty acids and contaminant ratios are also consistent with a salmon diet (NWFSC unpubl. data).

According to National Marine Fisheries Service (NMFS), "… it appears that the abundance of Washington, Oregon, and California Chinook and coho salmon increased significantly during the period of decline for Southern Resident killer whales between 1996 and 2001. Some studies have evaluated a potential time lag of one or two years between changes in salmon abundance and changes in Southern Resident survival (McClusky 2006). Even accounting for this potential lag time, the available information does not support a strong link between the trends in abundance of these particular salmon stocks and the abundance of Southern Resident killer whales." (NMFS 2007). Generally, there is only a weak correlation between Southern Resident killer whale survival and Chinook salmon abundance in Washington and Oregon (Ford et al. 2005, NMFS 2007).

Salmon originating in California streams are estimated to contribute 3 percent of salmon population off the Washington coast based on Genetic Stock Identification (GSI) of Washington troll catch in May of 1981 and 1982 (Utter et al. 1983). Research in the mid-1970s estimated California's contribution at 5 percent (Wright 1976). More recent data from the Collaborative Research on Oregon Ocean Salmon using GSI estimate 59 percent of salmon analyzed from the Oregon commercial harvest (June – October 2006) were Central Valley fall-run or spring-run Chinook salmon (Project CROOS 2006). It is important to note that these percentages could vary during different years or seasons.

Reclamation funds the operation and maintenance of the Coleman, Livingstone, and Nimbus hatcheries. These hatcheries have a combined yearly production goal of 17,200,000 Chinook salmon smolts. DWR funds the operation of the Feather River Hatcheries for production of approximately 8 million Chinook salmon smolts annually (yearly production goal).

Analysis of Chinook salmon otoliths in 1999 and 2002 found that the contribution of hatchery produced fish (from the Sacramento and San Joaquin River System) made up approximately 90 percent of the ocean fishery off the central California coast from Bodega Bay to Monterey Bay (Barnett-Johnson et al. 2007). Similar studies have not been completed to assess the percentage Central Valley hatcheries contribute to the salmon originating from California off the Oregon and Washington coasts but it suggests that hatchery fish would likely be the majority.

Effects of project operations on juvenile salmon are removed both in time and in place from when and where these salmon potentially become prey for Southern Resident killer whales. Based on data showing that hatchery produced fish make up 90 percent of the ocean fishery off the central California coast it is expected that this trend would carry throughout the range of salmon originating from the Central Valley. Project operations affect juvenile salmon in California Central Valley streams and the Trinity River. Thus any potential effects of the project operations on listed killer whale prey are indirect; are removed in both time and place from the action; represent an unknown portion of the killer whale prey base; are masked by the contribution of hatchery fish; and are intermingled with a host of other factors. Based on this information we have determined that project operations may affect but are not likely to adversely Southern Resident killer whales since the effects are discountable due to the high percentages of hatchery produced fish overshadowing the potential effects of project operations.

Critical Habitat

Critical habitat was designed for Southern Resident Killer Whales on November 29, 2006 (NMFS 2006a). Approximately 2,560 square miles of marine habitat in Washington were designated as critical habitat including portions of Puget Sound, the Strait of Juan de Fuca, Haro Strait, and the waters surrounding the San Juan Islands. Based on the natural history of the Southern Residents and their habitat needs, NMFS determined the following are the physical or biological features essential to conservation (Primary Constituent Elements): (1) Water quality to support growth and development; (2) Prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) Passage conditions to allow for migration, resting, and foraging.

The designated critical habitat does not overlap with the Action Area for this consultation, nor are there any discernible changes to the physical environment that occur within designated critical that could be correlated to project operations. The only potential affect of project operations on the identified physical or biological features essential to conservation would to prey quantity, quality, and availability. Project operations have the potential to affect only a portion of juvenile salmon originating in California Central Valley streams. As discussed earlier, Salmon originating in California streams are estimated to contribute between 3 and 5 percent of salmon population off the Washington coast based on analysis of troll catches. These estimates were made based on data collected during the time of year when the Southern Residents are present. As discussed above, the majority of the fish attributed to California streams that are affected by project operations are expected to be hatchery fish. The effects of the project operations on salmon populations are not likely to adversely affect designated critical habitat since the effects are discountable due to the small percentage of California salmon potentially present in Washington waters identified as critical habitat.

Cumulative Effects

As discussed in the Federal Register listing notice (NMFS 2005), three main human-caused factors that may continue to impede the recovery of this species and have affected the Southern Resident killer whale population, including contaminants, vessel traffic, and reductions in prey availability.

Exposure to contaminants may result in harm to the species. The presence of high levels of persistent organic pollutants (POPs), such as PCBs and DDT, have been documented in Southern Resident killer whales (Ross et al. 2000, Ylitalo et al. 2001, and Herman et al. 2005). These and other chemical compounds have the ability to induce immune suppression, impair reproduction, and produce other adverse physiological effects, as observed in studies of other marine mammals. High levels of "newly emerging" contaminants that may have similar negative effects, such as flame retardants, have been documented in killer whales, and are also becoming more prevalent in the marine environment (Rayne et al. 2004). Although contaminants enter marine waters and sediments from numerous sources, these chemical compounds enter killer whales through their prey. Because of their long life span, position at the top of the food chain, and their blubber stores, killer whales are capable of accumulating high concentrations of contaminants. In addition to reductions in prey abundance, the amount of contaminants in prey may exceed levels that cause mortality or reproductive failure.

Commercial shipping, whale watching, ferry operations, and recreational boat traffic have increased in recent decades. Several studies have linked vessels with short-term behavioral changes in Northern and Southern Resident killer whales (Kruse 1991; Williams et al. 2002a; 2002b; Foote et al. 2004). Although the potential impacts from vessels and the sounds they generate are poorly understood, these activities may affect foraging efficiency, communication, and/or energy expenditure through their physical presence, increased underwater sound level, or both. Collisions with vessels are another potential source of serious injury and mortality and have been recorded for both Southern and Northern Resident whales.

Potential effects of project operations on salmon prey species, in particular, Chinook, could be compounded by ongoing and future effects of other activities including declines due to habitat degradation from development (e.g., agriculture, timber harvest, dam construction, and urban construction), harvest practices, and past hatchery operations. Some historically productive salmon populations are no longer large, whereas other runs may have increased in abundance through hatchery production. Limited evidence indicates that hatcheries do not greatly change the ocean distribution of coho salmon (Weikamp et al.1995), but they can strongly influence the nearshore presence of salmon and thus the overall availability of salmon for predators (Krahn et al. 2002). Historical sources of the Pacific salmon prey base include Alaskan, Canadian, Puget Sound, Columbia Basin and Central California water systems. Specifically, declines in food availability from the Columbia and the California Central Valley are identified by NMFS as major sources for the decline in the Pacific salmon prey base of Southern Resident killer whales. Reductions in prey availability may force the whales to spend more time foraging, and could lead to reduced reproductive rates and higher mortality.

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Chapter 15 Summary of Effects Analysis and Effects Determination

The potential effects of CVP and SWP operations were evaluated into the future by examining and comparing modeled river flows and temperatures to the environmental baseline and how the changes effect the following protected species and their critical habitat (where designated): Central Valley steelhead Distinct Population Segment (DPS), Sacramento River winter-run Chinook salmon Evoluationarily Signficant Unit (ESU),Central Valley spring-run Chinook salmon ESU, Southern Oregon/Northern California Coast coho salmon ESU, Central California Coast steelhead DPS, Southern DPS of North American green sturgeon, delta smelt, and Southern Resident DPS of killer whales. Operation of diversions and facilities affecting migrations were included in the analysis.

The determination of effects for the listed species and their designated critical habitat considers direct and indirect effects of the proposed action on the listed species together with the effect of other activities that are interrelated or interdependent with the action. These effects are considered along with the environmental baseline and the predicted cumulative effects.

Central Valley Steelhead DPS

Upper Sacramento River

Keswick Reservoir releases are expected to provide suitable flows for adult steelhead passage and spawning. The minimum release of 3,250 cubic feet per second (cfs) will sustain the population through dry years. Red Bluff Diversion Dam (RBDD) operations allow most steelhead to pass unimpeded. Those arriving prior to gate opening will use one of the fish ladders or be temporarily delayed. Operations agreements already in place will help to ameliorate effects due to flood control releases should they occur. Water temperatures provided through operation of the Shasta temperature control device (TCD) in the upper Sacramento River will be appropriate for all steelhead life history stages present in the upper river year-round. We project that steelhead populations in the upper Sacramento River will be maintained through continued operation of the project. The steelhead life history includes anadromous and resident forms of the species, allowing populations to persist during periods of poor ocean conditions and periods of low freshwater in streams. The nature of straying allows steelhead to repopulate areas of local disturbance, although no such disturbances requiring straying to repopulate areas are likely to occur as a result of project operations.

Clear Creek

Whiskeytown Reservoir releases will provide adequate flows for passage and spawning in most years. During some years additional Central Valley Project Improvement Act (CVPIA) 3406 (b)(2) water may be used for better attraction and upstream migration conditions for steelhead. Water temperatures should generally be adequate for all steelhead and Chinook life stages throughout the year in the upper river where Whiskeytown releases have the most effect on water temperature. Whiskeytown project releases will not result in scour of redds. Some minor stranding of juveniles could potentially occur, similar to that which occurs in unregulated rivers. We project that steelhead populations in Clear Creek will be maintained through continued operation of the project. CVPIA habitat improvement projects are improving conditions for steelhead. The steelhead life history includes anadromous and resident forms of the species, allowing populations to persist both during periods of poor ocean conditions and periods of low freshwater in streams. The nature of straying allows steelhead to repopulate areas of local disturbance, although no such disturbances requiring straying to repopulate areas are likely to occur as a result of project operations.

Feather River

Flow, habitat, and water temperature conditions should be generally suitable for all steelhead life history stages all year in the low flow channel. The reach below the Thermalito outlet will be less suitable. Water temperatures generally begin exceeding the spawning and emergence recommendations during March; however, this is the latter part of the spawning/emergence season in the Feather River and most spawning occurs upstream. Summer temperatures will generally exceed 65° F below the Thermalito outlet by June, and will remain too warm for steelhead rearing throughout the summer months. Most steelhead rearing occurs in the low flow channel where temperatures are projected to be generally suitable year round and to be slightly improved in the future. We project that steelhead populations in the Feather River will be maintained through continued operation of the project. The steelhead life history includes anadromous and resident forms of the species, allowing populations to persist both during periods of poor ocean conditions and periods of low freshwater in streams. The nature of straying allows steelhead to repopulate areas of local disturbance, although no such disturbances requiring straying to repopulate areas are likely to occur as a result of project operations.

American River

Nimbus Reservoir releases are expected to provide suitable flows for adult steelhead passage and spawning. Operations agreements already in place should ameliorate effects due to flood control releases should they occur. Water temperatures should be generally appropriate for steelhead spawning and emergence from December through March. However, temperatures may be marginal for spawning and emergence during March through May of some years. May through mid-October water temperatures will be marginal for steelhead rearing at times and will be higher in the future. The survival of some juveniles through summer under similar conditions during previous years indicates the conditions are tolerable for some fish. Water temperatures should be appropriate for yearling emigration between December and March. Temperatures will be higher in June through November under the future operations scenario. The steelhead run in the American River will likely continue to be supported primarily by the hatchery, with limited successful in-river smolt production in dry water years.

Stanislaus River

Conditions for steelhead in the Stanislaus River should generally be favorable for completion of the life cycle. Goodwin Dam releases will provide suitable flows for adult steelhead passage and spawning. Water temperatures are suitable for adult migration and spawning and juvenile rearing. Water temperatures between Goodwin Dam and Orange Blossom Bridge should be suitable for all steelhead life history stages present most of the year. Temperatures at and below Oakdale may exceed the preferred range for rearing at times during the summer months, but the presence of a large resident trout population in the river indicates suitable in-river conditions. This resident population will be maintained and provides a source of the anadromous form of the species for those times when San Joaquin River migratory conditions are poor. The steelhead life history includes anadromous and resident forms of the species, allowing populations to persist both during periods of poor ocean conditions and periods of low freshwater in streams. The nature of straying allows steelhead to repopulate areas of local disturbance, although no such disturbances requiring straying to repopulate areas are likely to occur as a result of project operations.

Sacramento-San Joaquin Delta

Previous plans in place to protect spring- and winter-run Chinook salmon and Delta smelt have helped reduce steelhead salvage, and help to minimize CVP and SWP Delta effects on steelhead. The data assessment team (DAT) will continue to monitor conditions in the Delta so that actions can be taken when higher numbers of steelhead are more vulnerable to being taken at the pumps. Projected operation of other Delta facilities (for example, the North Bay Aqueduct, the Delta Cross Channel (DCC), Rock Slough Diversion, and the Suisun Marsh Salinity Control Gates (SMSCG)) are not expected to substantially impact steelhead. Steelhead take at these facilities has historically been low relative to the Central Valley Steelhead population as a whole.

Steelhead Summary

CVP and SWP operations will result in take of some steelhead. The magnitude of effects on population trends are unknown but the effects on the Central Valley steelhead population should be small relative to the population as a whole. Water operations during dry years will reduce steelhead habitat when cold water supplies are not large enough to maintain suitable rearing conditions throughout the habitat generally used by steelhead. However, wild steelhead are consistently captured in smolt outmigration monitoring programs and observed in snorkel surveys, and wild steelhead habitat enhancements have increased since they were listed in 1998, suggesting that protections and enhancements in freshwater habitats and the Delta are sufficient to maintain populations of Central Valley Steelhead at a level similar to the current population. Climate change scenarios include some scenarios where water temperatures in the rivers would be degraded. This would reduce the area of the rivers suitable for steelhead rearing during the summer, potentially decreasing carrying capacity, should these scenarios occur in the future. The steelhead life history includes anadromous and resident forms of the species (O. mykiss), allowing populations to persist both during periods of poor ocean conditions and periods of low freshwater in streams. The nature of straying allows steelhead to repopulate areas of local disturbance, although no such disturbances requiring straying to repopulate areas are likely to occur as a result of project operations.

Determination of Effects to Central Valley Steelhead DPS and their Designated Critical Habitat

Based on the effects analysis we have determined that CVP and SWP project operations are likely to adversely affect the Central Valley steelhead DPS.

Based on the effects analysis we have determined that CVP and SWP project operations are likely to adversely affect Central Valley steelhead designated critical habitat.

Sacramento River Winter–run Chinook ESU, Central Valley Spring–run Chinook Salmon ESU

Upper Sacramento River

Keswick Reservoir releases are expected to provide suitable flows for adult Chinook salmon passage and spawning. The minimum release of 3,250 cfs can sustain the population through dry years if suitable temperatures are maintained in the upper river. Operations agreements already in place will ameliorate effects due to flood control releases when they occur. Water temperatures will be appropriate for most Chinook salmon life history stages year-round during most years in the upper river, but during dry years temperatures during late summer and fall will be above preferred ranges for spawning and rearing so will likely result in lower production than during wet years. Winter–run spawning has shifted upstream with passage enhancements so that although water temperature will be higher, upper river temperatures will maintain incubation conditions down to Balls Ferry in most years. This covers the area where 99 percent of winter–run spawn (based on 2001 – 2005 spawning distribution). The few spring–run that spawn in the Sacramento River spawn further downstream than winter–run, so effects will be greater on them. In addition, winter-run are the primary focus of temperature management so temperatures sometimes warm in the fall during spring-run incubation. During critically dry years most spring–run eggs could suffer mortality due to high water temperature during incubation. A small proportion of the Central Valley spring-run population spawns in the Sacramento River, so overall population effects of low spring run production in the mainstem river will be minor. The entire winter-run population spawns in the upper Sacramento River.

Clear Creek

Whiskeytown Reservoir releases should provide adequate flows for passage and spawning most years. During some years additional CVPIA 3406 (b)(2) water may be needed for better attraction and upstream migration conditions for spring–run and fall–run fish. Summer water temperatures are expected to be suitable for adult holding in the upper river. Water temperatures will be suitable for most life history stages above Igo, but spawning and rearing temperatures near the mouth of the creek will be slightly above the preferred range during the summer. Spring run spawning and rearing habitat is upstream of Igo. A very small proportion of the Central Valley spring-run population enters Clear Creek, but habitat and flow improvements have increased spring run escapements in recent years. These conditions will be maintained with project operations.

Feather River

Flow and water temperature conditions should generally be suitable for all spring–run Chinook salmon life history stages all year in the low flow channel, particularly in the upper low flow channel. However, superimposition on spring–run Chinook salmon redds by fall–run Chinook may continue to be a problem until the Segregation Weir is constructed. The reach below the Thermalito outlet will be less suitable, until a Facility Modification(s) for temperature control is constructed, as water temperatures below Thermalito will be too warm for adult holding and spawning, but will be appropriate for juvenile rearing and emigration during winter and early spring.

Sacramento-San Joaquin Delta

Actions taken in the past to protect winter–run and spring–run Chinook and Delta smelt provide protection during the winter and spring, thereby reducing the impact of CVP and SWP Delta operations. Emigrating yearling Chinook salmon will receive protection from actions triggered through the Salmon Protection Decision Process during the emigration period. The DAT team will continue to watch fish monitoring data throughout the system so that operational adjustments can be made to minimize salvage.

Winter-run and Spring-run Chinook Summary

Chinook losses due to CVP and SWP operations may be substantial. However, the cohort replacement rate methodology discussed in Chapter 4 indicates Chinook salmon populations are generally increasing through 2007. The cohort replacement rate (CRR) data from the Sacramento River, Deer, Mill, and Butte creeks suggest existing protections and enhancements in the upper watershed and the Delta are sufficient to maintain populations of Central Valley winter–run, and Central Valley spring–run Chinook salmon during the continued operations of the CVP and SWP considered in this consultation. The spring-run population uses primarily non-Project tributaries for spawning and rearing, and uses the Sacramento River and Delta as a migratory corridor. Migratory conditions will be adequate to maintain the spring-run and winter-run populations. Climate change scenarios include scenarios with warmer temperatures and decreased precipitation leading to increased water temperatures in the rivers. These scenarios would decrease carrying capacity for winter-run and spring-run Chinook in the future. Ocean conditions will likely continue to produce population fluctuations, and the effects of climate change scenarios on ocean conditions for salmon are still uncertain.

Determination of Effects to Sacramento River Winter-run Chinook Salmon ESU and their Designated Critical Habitat

Based on the effects analysis we have determined that CVP and SWP project operations are likely to adversely affect the Sacramento River winter-run Chinook salmon ESU.

Based on the effects analysis we have determined that CVP and SWP project operations are likely to adversely affect Sacramento River winter-run Chinook salmon designated critical habitat.

Determination of Effects to Central Valley Spring-run Chinook Salmon ESU and their Designated Critical Habitat

Based on the effects analysis we have determined that CVP and SWP project operations are likely to adversely affect the Central Valley spring-run Chinook salmon ESU.

Based on the effects analysis we have determined that CVP and SWP project operations are likely to adversely affect Central Valley spring-run Chinook salmon designated critical habitat.

Southern Oregon/Northern California Coast Coho Salmon ESU

The Southern Oregon/Northern California Coast coho salmon ESU occurs in the Trinity River. Reclamation is implementing higher flows and physical habitat improvements for the Trinity River Restoration Program in the Trinity River. The net effect of future CVP operations on coho salmon in the Trinity River should be a benefit to the population through the habitat values provided as outlined in the Trinity River Restoration Program.

Based on the effects analysis we have determined that CVP and SWP project operations may affect, but are not likely to adversely affect the Southern Oregon/Northern California Coast coho salmon ESU.

Based on the effects analysis we have determined that CVP and SWP project operations may affect, but are not likely to adversely affect Southern Oregon/Northern California Coast coho salmon designated critical habitat.

Central California Coast Steelhead DPS

No adverse effects of the project on Central California Coast steelhead have been identified. The portion of the project area intersecting the CCC steelhead DPS is in the north-western Delta leading to Suisun Creek. Suisun Creek was excluded from the Critical Habitat designation. Effects on this migratory corridor for CCC steelhead are expected to be minimal to water quality and of no measurable effect on VSP parameters for CCC steelhead.

Based on the effects analysis we have determined that CVP and SWP project operations are not likely to adversely affect the Central California Coast steelhead DPS.

Based on the effects analysis we have determined that CVP and SWP project operations are not likely to adversely affect Central California Coast steelhead designated critical habitat.

Delta Smelt

We have considered direct entrainment effects and indirect effects on delta smelt in terms of (1) changes in expected flows at the CVP and SWP export facilities, (2) changes in Old and Middle River flow, and (3) changes in X2 position. These exports, flow and X2 are expected to increase, increasing potential risks for delta smelt. However, the past population effects have been difficult to determine, and DSRAM and EWA-based actions are expected to curtail the exports and flows.

(1) Since exports flows increase under the future scenarios considered, entrainment of unspent adults at the SWP and CVP export facilities may increase in some months, depending on the application of the DSRAM and EWA curtailments. Substantial increases in pumping in some scenarios in one or more months during March to July are likely to increase the entrainment of juvenile delta smelt during drier years. It is important to note here that the beneficial effects of flow and operational restrictions imposed by a federal judge to protect delta smelt from entrainment are not considered in the scenarios.

(2) More negative Old and Middle River flow are predicted in studies 7.0, 7.1, and 8.0 especially for months during drier years when adult, larval and juvenile delta smelt are vulnerable to entrainment. However, other flows and tactical curtailments in exports, and application of DSRAM and EWA curtailments will reduce potential effects of increases in Old and Middle River reversed flows.

(3) Upstream movements of X2 are predicted in studies 7.0, 7.1, and 8.0 with respect to Study 6.0 for the months when delta smelt live in the low salinity zone. Upstream movements of 5 km or more, as projected for some months in late summer and fall, are expected to reduce the availability and quality of delta smelt habitat as defined by salinity, transparency and volume. Such changes may have other effects on the pelagic food web that supports delta smelt. However, the extent of population effects of X2 and entrainment changes are unknown.

Determination of Effects to Delta Smelt and their Designated Critical Habitat

Based on the effects analysis we have determined that CVP and SWP project operations will adversely affect delta smelt.

Based on the effects analysis we have determined that CVP and SWP project operations are likely to advesely affect delta smelt deignated critical habitat.

Southern DPS of North American Green Sturgeon

We have considered (1) Sacramento River flows and water temperature, (2) Red Bluff Diversion Dam Operation, (3) entrainment loss at the CVP and SWP export facilities.

(1) Sacramento River flows provide conditions suitable for adult and juvenile green sturgeon migration. Water temperatures provided for Chinook salmon and steelhead are are suitable for all green sturgeon lifestages in the Sacramento River.

(2) Red Bluff Diversion Dam gate operations have been modified to make downstream passage for green sturgeon safer. Gates under current and near future operations block some late migrating green sturgeon. Future operations will allow unimpeded passage for upstream migrating green sturgeon.

(3) A small number of green sturgeon become entrained in the SWP and CVP Delta export facilities.

At this time, critical habitat for the green sturgeon has not been designated.

Determination of Effects to Southern DPS of North American Green Sturgeon

Based on the effects analysis we have determined that CVP and SWP project operations are likely to adversely affect the Southern DPS of North American green sturgeon.

Southern Resident DPS of Killer Whales

Project operations have the potential to affect the prey base of Southern Resident killer whales. Project operations would only affect Southern Resident killer whales to the extent that the effects of the project operations alter salmonid populations which could indirectly lead to a reduction in prey availability to the Southern Resident killer whales. Reductions in prey availability may force the whales to spend more time foraging, and could lead to reduced reproductive rates and higher mortality.

Determination of Effects to Southern Resident DPS of Killer Whales and their Designated Critical Habitat

Based on the effects analysis we have determined that CVP and SWP project operations may effect but are not likely to adversely affect the Southern Resident DPS of killer whales.

Based on the effects analysis we have determined that the effects of the CVP and SWP project operations on salmon populations are not likely to adversely affect designated critical habitat since the effects are discountable due to the small percentage of California salmon potentially present in Washington waters identified as critical habitat.

Summary of Beneficial Effects

A summary of the CVPIA, Four Pumps Agreement, and CALFED Bay-Delta Program (CALFED) actions is in Chapter 18. CVPIA Section 3406 (b)(2) and Yuba Accord Purchase assist the projects with the VAMP actions. Adaptive Management is summarized in Chapter 2.

Chapter 16 Essential Fish Habitat Assessment

Essential Fish Habitat Background

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) mandates Federal action agencies which fund, permit, or carry out activities that may adversely impact the essential fish habitat (EFH) of Federally managed fish species to consult with the NMFS regarding the potential adverse effects of their actions on EFH (Section 305 (b)(2). Section 600.920(a)(1) of the EFH final regulations state that consultations are required of Federal action agencies for renewals, reviews, or substantial revisions of actions if the renewal, review, or revision may adversely affect EFH. The EFH regulations require that Federal action agencies obligated to consult on EFH also provide NMFS with a written assessment of the effects of their action on EFH (50 CFR Section 600.920). The statute also requires Federal action agencies receiving NMFS EFH Conservation Recommendations to provide a detailed written response to NMFS within 30 days upon receipt detailing how they intend to avoid, mitigate or offset the impact of the activity on EFH (Section 305(b)(4)(B).

The objective of this EFH assessment is to describe potential adverse effects to designated EFH for Federally-managed fisheries species within the proposed action area. It also describes conservation measures proposed to avoid, minimize, or otherwise offset potential adverse effects to designated EFH resulting from the proposed action.

The northern anchovy and starry flounder are managed as “monitored species” by the Coastal Pelagic Species Fishery Management Plan and the Pacific Coast Groundfish Fishery Management Plan of the Pacific Fishery Management Council (PFMC), respectively, and are subject to Essential Fish Habitat consultation as a result (PFMC 1998a, 1998c).

The fall/late fall-run Chinook salmon *Oncorhynchus tschawytscha* is a species of concern and information can be found in the salmon Chapters 5 and 6 of this document for EFH.

Effects on Central Valley spring-run Chinook salmon, Sacramento River winter-run Chinook salmon, Southern Oregon/Northern California Coast coho salmon, Central Valley steelhead, and Central California Coast steelhead habitat are described in this biological assessment in Chapters 11 and 13 and are summarized in Chapter 15.

Identification of Essential Fish Habitat

Essential fish habitat is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of EFH, “waters” include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; “substrate” includes sediment, hard bottom, structures underlying the waters, and associated biological communities; “necessary” means habitat required to support a sustainable fishery and a healthy ecosystem; and “spawning, breeding, feeding, or growth to maturity” covers a species full life cycle. The following important components of EFH must be adequate for spawning, rearing, and migration:

- Substrate composition
- Water quality
- Water quantity, depth, and velocity
- Channel gradient and stability
- Food
- Cover and habitat complexity
- Space
- Access and passage
- Habitat connectivity

The Coastal Pelagic Species Fishery Management Plan has designated EFH for all coastal pelagic species, including the central subpopulation of the northern anchovy (PFMC 1998a). Essential fish habitat is defined to be all marine and estuarine waters along the Pacific coast from Washington to California. The specific limits of this area are defined by temperature-based thermoclines and isotherms, which vary seasonally and annually (PFMC 1998a). The level of EFH information is 1 (Presence/absence distribution data are available) for this species (PFMC 1998a).

Reclamation and DWR's proposed operation is described in Chapter 2 of the BA for the CVP and SWP. The Bay/Delta provides habitat for northern anchovy *Engraulis mordax* and starry flounder *Platichthys stellatus*, which are covered under the EFH provisions of Magnuson-Stevens Act, but are not listed under the ESA.

Description of the Federally-managed Fisheries Species

Northern Anchovy

Description and Life History

Northern anchovies are small, short-lived, fish typically found in schools near the water surface. They are short-lived, rarely exceeding 4 years of age and 7 inches (17.78 cm) in length, although individuals 7 years old and 9 inches (22.86 cm) long have been recorded (Messersmith 1969). Some anchovies reach sexual maturity at the end of their first year of life when 3.5 to 3.9 inches (90 to 100 mm) SL; about 50 percent are mature at 5.1 inches (130 mm) SL when between 2 and 3 years old; all are mature when 5.9 inches (150 mm) SL or 4 years old (Clark and Phillips, 1952). MacGregor (1968) reports that female anchovies, 3.8 to 5.4 inches (97- 138 mm) SL contained 4,023 to 21,297 eggs in an advanced stage of development. This equals 574 per gram of fish or 520 million eggs per short ton of female biomass. He was unable to determine the number of times a female spawns in a season. However, Baxter (1966) reported that although little has been published on the fecundity of the northern anchovy, each large female spawns an estimated 20 to 30 thousand eggs annually and spawns two or three times each year. There is always a reservoir of maturing eggs in the ovary of an adult female in spawning condition. The fraction of one-year-olds that is sexually mature in a given year depends on water temperature and has been observed to range from 47 to 100 percent. They spawn during every month of the year, but spawning increases during late winter and early spring and peaks during February to April. Richardson (1981) reports that peak spawning occurs from January through April when southward current flow is minimal, water temperatures are reaching minimal levels for the year, upwelling is minimal, and day length is at minimum duration. Spawning has been observed over a temperature range of 54 º to 71 º F. Individual females spawn batches of eggs throughout the spawning season at intervals as short as seven to 10 days. This species is a broadcast spawner and females can produce up to 30,000 eggs a year in batches of about 6,000. Most spawning takes place in channels or within 60 miles of the coast in the upper mixed layers at night, in water temperatures of 54º F to 59º F. The San Francisco Bay is thought to provide favorable reproductive habitat for the anchovy because abundant food exists for both adults and larvae and coastal upwelling keeps eggs and larvae in productive areas. Spawning in the bay occurs at higher temperatures and lower salinities than spawning in coastal areas (McCrae 1994, Bergen and Jacobson 2001). In a single year study by McGowen (1986), either eggs or larvae were caught by net in San Francisco Bay every month. Both were most abundant when water temperature was high. Mean egg abundance did not differ among stations but larvae were more abundant within the San Francisco Bay at high and low salinity than near the ocean entrance to the Bay. Larvae longer than 15 mm were collected over the shoals in spring and autumn but were in the channel during winter. Zooplankton and microzooplankton were abundant relative to mean California Current densities. Adult spawning biomass in the Bay was 767 tons in July 1978, based on egg abundance and fecundity parameters of oceanic animals. San Francisco Bay was a good spawning area for northern anchovy because food for adults and larvae was abundant and because advective losses of larvae would have been lower in the Bay than in coastal waters at the same latitude.

Northern anchovy eggs are oval, pelagic, and approximately 1.5 by 0.75 millimeters (mm) in size. Eggs are found near the water surface and require two to four days to hatch, depending on water temperatures. Larvae are also found near the water surface (CDFG 2001). Larvae range in size from 2.5 to 25 mm in length and begin schooling at 11 to 12 mm in length. Juveniles range in size from 25 to 140 mm in length. Some fish mature at less than one year of age (71 to 100 mm) and all are nature at two to three years. Maximum age is seven years, but most live for four years. Maximum size is about 230 mm, although most are not over 158 mm in length (McCrae 1994, Bergen and Jacobson 2001). Ahlstrom (1959) reports that approximately 93 percent of the larvae are taken in water between 14.0 º and 17.4 º C (57.2 º and 67.3 º F) while most eggs are taken between 13.0 º and 17.5 º C (35.4 º and 63.5 º F). Fish-of-the-year apparently tolerate somewhat higher water temperatures than do adults.

Anchovies feed diurnally either by filter feeding or biting, depending on the size of the food (Berkeley Elibrary 2002). Juvenile and adult northern anchovies are considered secondary and higher consumers, selectively eating larger zooplankton, fish eggs, and fish larvae. Baxter (1966) noted that they have been observed to be predatory on small fish at times, even their own kind. He also noted l+-inch fish in the stomachs of 5+-inch anchovies. First-feeding larvae eat phytoplankton and dinoflagellates, while larger larvae pick up copepods and other zooplankton. Female anchovies need to eat approximately 4 to 5 percent of their wet weight per day for growth and reproduction (Goals Project 2000).

All life stages of the northern anchovy are important prey for virtually every predatory fish, bird, and mammal in the California current (Baxter 1967), including California halibut, Chinook and Coho salmon, rockfishes, yellowtail, tunas, sharks, squid, harbor seal, northern fur seal, sea lions, common murre, brown pelican, sooty shearwater, and cormorants. Baxter (1966) reported that anchovies constituted 12.8 percent by volume of the diet of California yellowtail (*SerioZa dorsalis*) (Craig, 1960) and 29.1 percent by volume of the diet of Chinook salmon (*Oncorhynchus tshawytscha*) off San Francisco (Merkel, 1957). Qualitative studies have shown anchovies to be an important constituent in the diets of all of the large predatory game fish off California. Baxter (1966) noted that the Pacific bonito (*Xarda chiliensis*) populations have historically correlated well with Northern anchovy numbers. The breeding success of California brown pelicans and elegant tern production is correlated with anchovy abundance (Bergen and Jacobson 2001; Schaffner 1986). Competitors with the anchovy include sardines and other schooling planktivores, such as jacksmelt and topsmelt. These species are also potential predators on young anchovy life stages (Goals Project 2000).

Distribution

Northern anchovies are pelagic schooling fishes generally found in coastal waters with surface temperatures between 14.5^{o} and 20.0^{o} C (58.1^{o} and 68.O^{o} F) but appear to prefer water temperatures between 14.5 and 18.5ºC (Hart 1973). Anchovies occur from the Queen Charlotte Islands, British Columbia to Cape San Lucas, Baja California. California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys show they are most abundant from San Francisco to Magdalena Bay. North of San Francisco, occasional surveys by the Department of Fish and Game have not found anchovies in abundance (Messersmith et al. 1969). The northern anchovy is one of the most abundant and productive fishes in the San Francisco Bay area (Berkeley Elibrary 2002). The northern anchovy occurs from Suisun Bay to South San Francisco Bay and occasionally in the lower Delta. This species is most abundant downstream of the Carquinez Strait and outside the Bay in the California Current (Herbold et al. 1992, Goals Project 2000).

The east-west geographic boundary of EFH for the northern anchovy is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the exclusive economic zone and above the thermocline where sea surface temperatures range between 10^{o} C to 26^{o} C (50^{o} F to 78.8^{o} F). The southern extent of EFH for the anchovy is the United States-Mexico maritime boundary. The northern boundary of the anchovy's EFH is the position of the 10^{o} C (50^{o} F) isotherm which varies both seasonally and annually (PFMC 1998b). McHugh (1951) concluded that the anchovy population is divided into three subpopulations which do not intermingle completely: (i) British Columbia to northern (California (Monterey Ray), (ii) off southern California and northern Baja California, and (iii) off central and southern Baja California. His conclusions were based on an analysis of meristic data (dorsal, anal, and pectoral fin rays, vertebrae and gill rakers). Hubbs (1925) (as reported in Baxter 1966) described a separate subspecies (*E. nz. nanzis*) which inhabits San Francisco Bay and tolerates much-reduced salinities. In both mean and modal number of vertebrae the bay subspecies has two fewer than the ocean subspecies. It is a much smaller fish, the largest found by Hubbs measured 99 mm TL. Its head averages longer, the body deeper and more compressed. The early development is also apparently more accelerated and transformation from postlarval to juvenile stages occurs at a much smaller size. Similar brackish-water forms also are known for the European anchovy (*E. encrasicholus*) and Australian anchovy (*E. australis*) (Blackburn, 1950). However, no further work has been detected in the literature. Miller (1956), working with age and size compositions of commercial and live-bait catches from central and southern California, aerial surveys, and sea surveys, suggested the possible existence of "local" stocks and the complete separation of central and southern California populations. However, not enough information has been collected to support or refute this (Messersmith 1969).

There is a great deal of regional variation in age composition (number of fish in each age group) and size at age with older fish and larger fish found at relatively offshore and northerly locations. In warm years, relatively old and large fish are found farther north than during cooler years. These patterns are probably due to northern and offshore migration of large fish, regional differences in growth rate, and water temperatures. The adults and juveniles of the northern anchovy are pelagic and form tightly packed schools that range from the water surface to 164 fathoms deep (McCrae 1994). This species is found from seawater to mesohaline (moderately brackish water with salinity range of 5 to 18 ppt) and occasionally found in oligohaline (brackish water with low salinity range of 0.5 to 5 ppt) areas. Adults are found in estuaries, near-shore areas, and out to 300 miles offshore, although most are found within 100 miles of shore (Airame 2000). Juveniles are abundant in shallow near-shore areas and estuaries.

The northern anchovy does not migrate extensively but does have inshore-offshore, along-shore, and daily movements (McCrae 1994). Some exchange of anchovies between major fishing areas does occur. Tagging studies between 1966 and 1968 (Messersmith et al. 1969) indicated that fish from as far away as San Diego and San Francisco do contribute to the Monterey Bay fishery and that fish from Monterey Bay reach southern California. However, to what extent it is unclear.

Habitat Requirements

River

The Northern Anchovy is common in surveys of the lower tidal portions of Sacramento and San Joaquin rivers (Herrgesell 1994). However, because of their salinity requirements, northern anchovy have not been recorded above brackish water within these systems.

Delta

Between 1979 and 1999, northern anchovy made up less than 1% of the total fish captured by otter trawl and beach seine in Suisun Marsh (Matern et al. 2002). However, they were the 4th – most common fish larvae species in the Suisun Bay in a 1991 survey and adults are also common in San Pablo Bay (Herrgesell 1994).

Bay

Although northern anchovy are found in the San Francisco Bay area throughout the year, they tend to peak there from April to October (Goals Project 2000). Larvae numbers are typically found in high density in mid and upper level trawl surveys; so much so, that in a 1992 survey, samples for other species was difficult (Herrgesell 1994). However, by April, larval anchovy numbers appear to diminish. The spring influx to the bay areas may result from higher temperatures and increasing plankton production in the bay and coastal upwelling; the autumn exodus may be linked to cooler temperatures in the bay. Larvae and juveniles that were spawned in late summer tend to overwinter in the bay. In the summer and fall months, anchovy larvae follow the salt wedge into warm, productive shallows of Suisun Bay and the lower Delta (Berkeley Elibrary 2002). Schooling juveniles are found in sea- and freshwater in the

Sacramento-San Joaquin estuary, especially in July and August. During the summer, adults and juveniles have daily movements from 60 to 100 fathoms deep in the day to surface waters at night (Bergen and Jacobson 2001).

The primary fresh water inputs to the San Francisco Estuary are derived from regional precipitation (quantity and form {ie rain or snow]) and to a greater extent, the Sacramento and San Joaquin Rivers (Kimmerer 2002). River inflow is largely regulated by upstream reservoir releases. A significant fraction of this inflow is exported out of the Delta by the CVP and the SWP affecting variation in through-estuary outflow, creating lower winter and higher summer outflow than what occurred historically. This can have a strong influence on the mixing zone (X2), where fresh and salt water collide and overall Estuary salinity (Uncles and Peterson 1996). This mixing zone is a highly productive environment (Kimmerer 2002).

Movement of the mixing zone is complex and dependent upon a number of factors, including tidal cycles (Cloern et al. 1989) and fresh water inflow. Wind wave action can also be important for mixing. Over the course of a year, X2 can range from San Pablo Bay during high flow periods, to well into the Delta during the summer drought. The position of X2 is monitored and maintained by releasing water from upstream reservoirs and operation of manmade barriers (ie Suisun Marsh gates) in anticipation of export demand. This is mandated by in the Vernalis Salinity Standard, which was legally established to maintain habitat quality in the Estuary for wildlife and to prevent salinity from encroaching upstream to the export pumps (Trott 2006). Gravitational circulation causes stratified high salinity water at depth to flow landward while low salinity water on top flows seaward (Monismith 1996). The effect of gravitational circulation may be most pronounced during periods of high fresh water flow, providing a negative feedback for maintaining the salt field and the distribution of pelagic organisms in the Estuary.

Mixing is important at the landward edge of gravitational circulation, often around X2, where the water column becomes less stratified (Burau 1998). A fixed mixing zone occurs at the east end of the Carquinez Strait, where the deep channel becomes dramatically shallower as it enters Suisun Bay (Schoellhamer 2001). Mixing is critical in maintaining salinity such that extremely large inputs of fresh water are required to move X2 a short distance to the west. Mixing also assists pelagic organisms in maintaining position in the Estuary (Kimmerer 2004) and slowing the advection of primary and secondary production out of the system. These relationships appear to have a significant influence on fish species within the Estuary (Feyrer et al. 2007).

Furthermore, phytoplankton, zooplankton, and larval and adult fish can become entrained in the export pumps, causing a potentially significant but unknown impact on the abundance of these organisms. This interaction may have a significant influence on food sources and predators of northern anchovy and starry flounder within the Bay.

Population Trends

Estimates of northern anchovy biomass in the central subpopulation averaged 359,000 tons from 1963 through 1972, increased rapidly to over 1.7 million tons in 1974 and then declined to 359,000 tons in 1978 (CDFG 2001). Since 1978, biomass levels have tended to decline slowly, falling to an average of 289,000 tons from 1986 through 1994 (Jacobson et al. 1994). Total anchovy harvests and exploitation rates since 1983 have been below theoretical levels for maximum sustained yield. Although stock biomass estimates are unavailable for recent years, it is believed that anchovy production is being determined mostly by natural influences, such as ocean temperature (CDFG 2001). Surveys of the South San Francisco Bay (MSI 2002) showed significant decreases in Northern anchovies between 1973 and 2003. According to NOAA (), recent biomass estimates for the central subpopulation (from San Francisco to Baja, California) indicate that biomass averaged 326,000 metric tons until 1970, increased rapidly to 1.6 million metric tons in 1974, and then declined to 521,000 metric tons in 1978. During the early 1990s, biomass declined to about 150,000 metric tons and then increased to 388,000 metric tons in 1995. No new stock assessment has been made, as this species in currently managed based on landings.

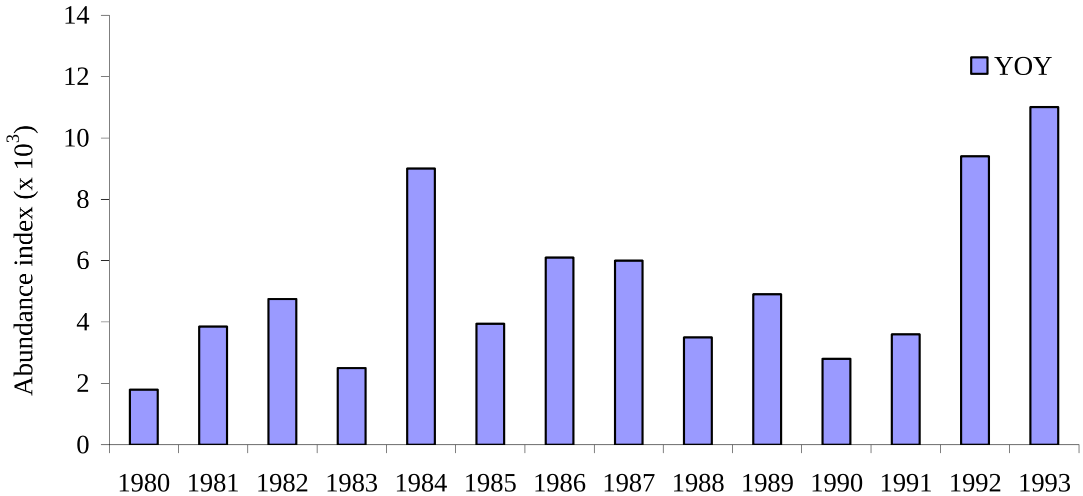


Figure 16-1 The annual abundance indices for northern anchovies are generated from the San Francisco Bay Monitoring Program midwater trawl data.

Data source: California Department of Fish and Game/ Bay Delta Region web page.

(http://www.delta.dfg.ca.gov/baydelta/monitoring/naab.asp)

According to Swanson (2007), although northern anchovy are always found in all sub-regions of the estuary, their abundance differs markedly. For the past 27 years, northern anchovy have been most abundant in Central Bay, least abundant in Suisun Bay, and present at intermediate abundance levels in San Pablo and South Bays (Figure 16-2).

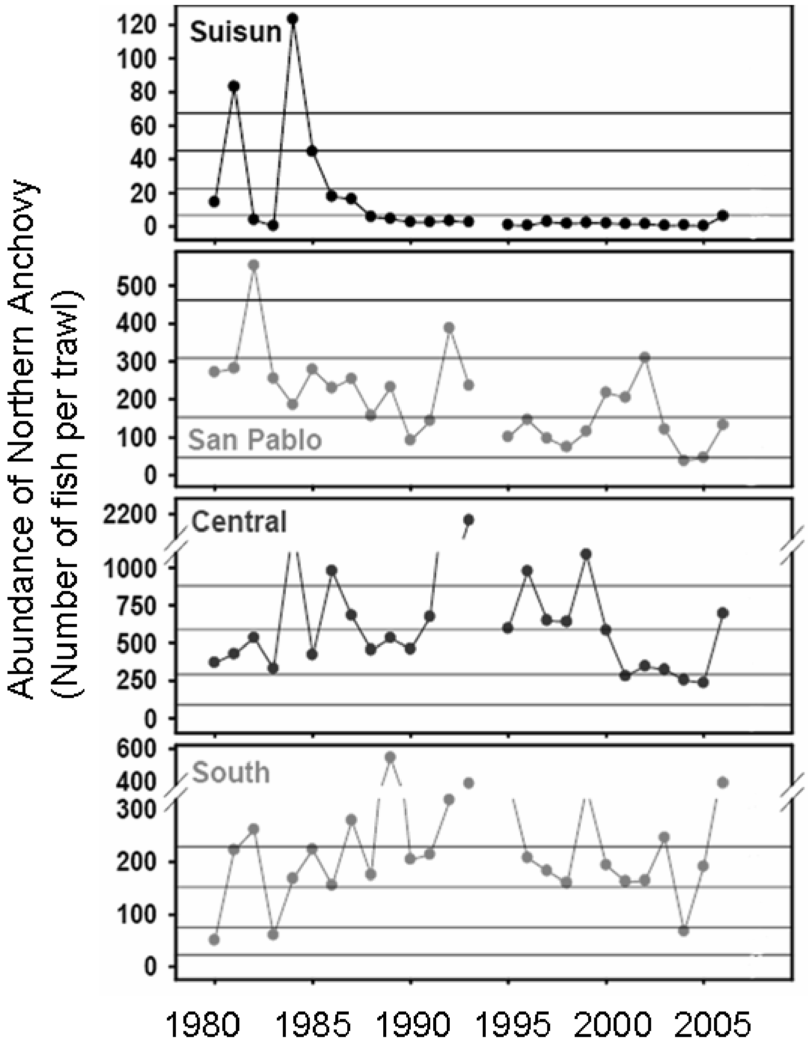


Figure 16-2 Abundance of Northern Anchovy within four sections of the San Francisco Bay, 1980 through 2005. Data Source: CDFG 2005.

Baxter (1966) stated that the California anchovy fishery has been in reality two distinct fisheries, the commercial fishery and that for live bait and both are quite modest compared to anchovy fisheries in other parts of the world. Historically, most of the catch was "reduced" (or processed) into oil and fish meal and sold as a protein supplement for use in poultry feed (Conrad 1991). About 3,000 - 6,000 metric tons (mt) per year are harvested live for use as bait in various sport fisheries, while another 1,000 - 3,000 mt per year are harvested for other commercial products, such as pet food. During its peak years in the mid-1970s the reduction fishery accounted for about 90 percent of the total U. S. harvest. In the 1980s landings for reduction declined below 6,000 mt annually and were exceeded by nonreduction landings for most of the decade. Both have been dropped steadily since the 1970’s (CDFG 2001).

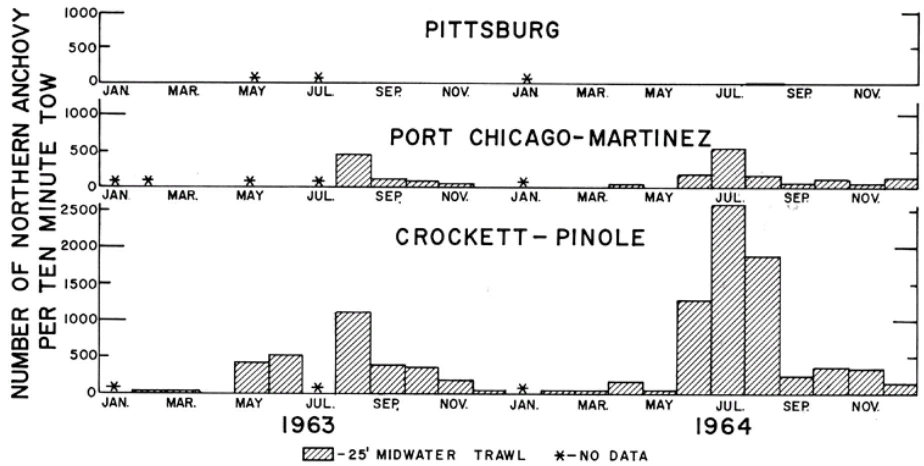


FIGURE 5. Monthly trawl catch of northern anchovy, *Engraulis mordax.*

Figure 16-3 California Department of Fish and Game (1966) Ecological studies of the Sacramento-San Joaquin estuary; Part 1,: Zooplankton, zoobenthos, and fishes of San Pablo and Suisun Bays, zooplankton and zoobenthos of the Delta

Starry Flounder

Description and Life History

The starry flounder, a flatfish also known as rough jacket, belongs to the family Pleuronectidae. According to Moyle (2002), they are characterized by having both eyes on the upper side of the head, a white “belly” with a single pectoral fin in the middle, pelvic fins on the dorsoventral ridge behind the operculum, and dorsal and anal fins that extend around the body on each side. Although they are the only flatfish likely to be found in freshwater, they can be distinguished from other flounders that might occur in brackish water by the distinctive, alternating white to orange and black bands on the dorsal and anal fins, as well as by roughness of their skin, caused by the star-shaped plates (modified scales). Although they belong to the right-eyed flounder family, the eyes may be either side of the head.

Most spawning occurs in shallow waters near the mouths of rivers and estuaries during the winter. In central California, December and January are the peak months of spawning. The number of eggs produced by each female depends on size but a 27-inch fish may produce about 11 million eggs.

Females grow faster and reach larger sizes than males. In central California, most males are sexually mature at two years averaging 14.5 inches; most females at three years and 16 inches. The maximum size reported is 36 inches.

The starry flounder is covered by the West Coast Groundfish Fishery Management Plan (PFMC 1998c). Starry flounder range from the Sea of Japan, north to the Bering Sea and the Arctic coast of Alaska, and southward down the coast of North America to southern California (Haugen and Thomas 2001). Starry flounder can be found in Suisun Bay and the lower portion of the San Joaquin River in the Delta (Figure 16-4). The distribution of the starry flounder tends to shift with growth. Young juveniles are commonly found in fresh or brackish water of Suisun Bay, Suisun Marsh, and the Delta, older juveniles range from brackish to marine water of Suisun and

San Pablo Bays, and adults tend to live in shallow marine waters within and outside the San Francisco Bay before returning to estuaries to spawn (Goals Project 2000).

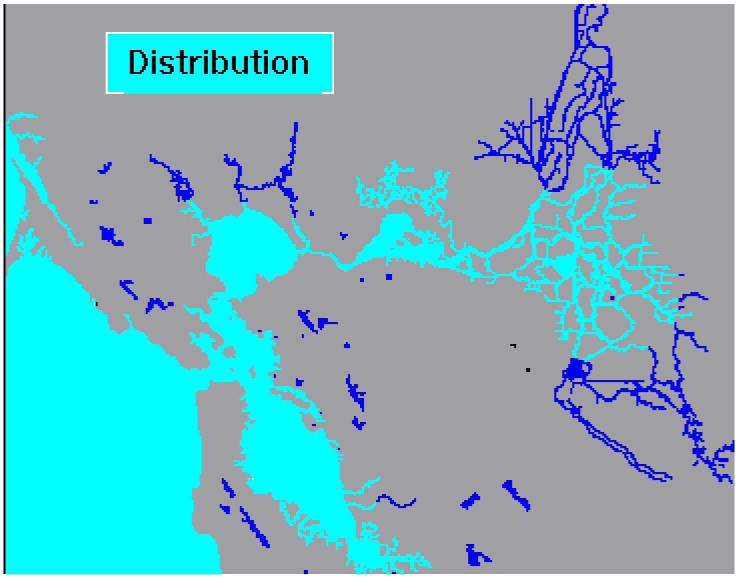


Figure 16-4 San Francisco Bay starry flounder distribution (Source: California Department of Fish and Game/ Bay Delta Region web page (http://www.delta.dfg.ca.gov/baydelta/monitoring/stfl.asp)

Starry flounder is an important member of the inner continental shelf and shallow sublittoral communities, and is one of the most common flatfish in the San Francisco Bay and Delta (Haugen and Thomas 2001). Older juveniles and adults are found from 120 km up coastal rivers to the outer continental shelf at 375 m, but most adults are found within 150 m. Spawning occurs in estuaries or sheltered inshore bays in water less than 45 m deep (Goals Project 2000). Juveniles prefer sandy and muddy substrates and adults prefer sandy and coarse substrates. Eggs are found in polyhaline (brackish water with moderate salinity range from 18 to 30 ppt) to euhaline (brackish water with high salinity range from 30 to 40 ppt) waters; juveniles are found in mesohaline (brackish water with moderate salinity range from 5 to 18 ppt) to fresh waters; adults and larvae are found in euhaline to fresh waters. All life stages can survive and grow at temperatures below 0º C to 12.5º C (32º F to 54.5º F) (Orcutt 1950).

Starry flounder is not considered to be a migratory species. Adults move inshore in winter or early spring to spawn and offshore and deeper in the summer and fall, but these coastal movements are generally less than 5 km. While some starry flounder have shown movements of greater than 200 km, but this is not considered typical. Adults and juveniles are known to swim great distances up major coastal rivers (greater than 120 km) but this is not a migratory trend. Larvae may be transported great distances by oceanic currents (CDFG 2001).

Starry flounder are oviparous; eggs are fertilized externally. Spawning occurs annually in a short time frame in winter and spring, with the exact timing depending on location. In central California, starry flounder spawn from November to February, peaking in December and January (Orcutt 1950). The number of eggs produced by females depends on fish size; a 56 cm fish can produce 11,000,000 eggs (CDFG 2001). Fertilized eggs are spherical and between 0.89 and 1.01 mm in diameter (Orcutt 1950). Eggs hatch in 2.8 days at 12.5º C (54.5º F), 4.6 days at 10.0ºC

(50º F), and 14.7 days at 2.0° C to 5.4º C (35.6º F to 41.7º F). Eggs are pelagic and occur at or near the surface over water 20 to 70 m deep (CDFG 2001).

Eggs and larvae of the starry flounder are epipelagic, while juveniles and adults are demersal. Larvae are approximately 2 mm long at hatching and they start settling to the bottom after two months at approximately 7 mm in length. Metamorphosis to the benthic juvenile form occurs at 10 to 12 mm and sexually immature juveniles range in size from 10 mm to 45 cm, depending on sex (Orcutt 1950). Transforming larvae and juveniles depend on ocean currents to keep them in rearing areas near estuarine areas and the lower reaches of major coastal rivers (Goals Project 2000). Starry flounder tend to rear for up to two years in estuarine areas before moving to shallow coastal marine waters. Adults occur in estuaries or their freshwater sources year-round in Puget Sound. Females begin maturing at 24 cm and three years, but some may not mature until 45 cm and four to six years. Males begin maturing at two years and 22 cm, but some may not reach maturity until four years and 36 cm (Orcutt 1950). Maximum age is reported as 21 years and maximum length is 915 mm.

Starry flounder change their diet as they develop from pelagic to demersal stages (Orcutt 1950). Larvae tend to be planktivorous and eat copepods, amphipods, eggs and nauplii as well as barnacle larvae and diatoms. Juveniles and adults are primary to secondary carnivores on larger benthic invertebrates. Newly metamorphosed juveniles feed on copepods, amphipods, annelid worms, and the siphon tubes of clams. Larger fish with jaws and teeth feed on a wider variety of items, including clams, crabs, polychaete worms, sand dollars, brittle stars, and other more mobile foods (Orcutt 1950). Historically, in San Francisco Bay, small starry flounder fed mainly on opossum shrimp until the invasion of the overbite clam (*Potamocorbula amurensis*) caused a major reduction in shrimp abundance, forcing them to switch to a more diverse diet (Ganssle 1966, Herbold 1987, Feyrer 1999). Moyle (2002) states that in freshwater, starry flounder shift to feeding on insect larvae buried in soft bottoms, such as tipulid larvae (Porter 1964) and annelid worms (Martin 1995) and this may put the flounder under some osmotic stress, because digestion rates are 2-3 times faster in salt water than in fresh (Porter 1964). Starry flounder do not feed during spawning or coldwater periods.

Starry flounder larvae and juveniles are eaten by larger fish, and wading and diving seabirds (e.g., herons and cormorants). Adults are eaten by pinnipeds, larger fishes, sharks and marine mammals.

The starry flounder probably competes with other soft-bottom benthic fishes of estuaries and shallow nearshore bays. Individuals with characteristics intermediate between starry flounder and English sole are evidence of possible hybridization between those species (Haugen and Thomas 2001).

The Pacific Coast Groundfish Fishery Management Plan (PFMC 1998c) has designated EFH for 83 species of groundfish, which taken together include all waters from the high water line, and the upriver extent of saltwater intrusion in river mouths along the coast from Washington to California. Composite habitats most important for the starry flounder are estuarine (for all life stages), non-rocky shelf (for juveniles and adults), and neritic habitats (for eggs and larvae), as defined by the fishery management plan (PFMC 1998d). The level of EFH information is 1 (Presence/absence distribution data are available) for all life stages of this species. When Level 1 information is available, EFH for a species' life stage is its general distribution, the geographic area of known habitat associations containing most (e.g., about 95 percent) of the individuals (PFMC 1998d). The National Marine Fisheries Service is proposing to amend the fishery plan to identify and describe essential fish habitat for each managed groundfish species (PFMC 1998c).

Distribution

The starry flounder is known to occur in coastal waters of the Pacific and Arctic oceans and connecting seas, and rivers within 33 degrees to 73 degrees N. latitude and from 105 degrees W. to 127 degrees E. longitude (Orcutt 1950). Thus it is one of the most widely distributed flounders. In the eastern Pacific the southern limit of its range is at the mouth of the Santa Ynez River at Surf, Santa Barbara County, California. The species becomes more numerous in northern California and is found along the entire Pacific coast of North America from the Santa Ynez River to the Alaskan Peninsula. It occurs along the Aleutian Island chain westward to the Commander Islands and the Kamchatka Peninsula and then extends southward along the east coast of Kamchatka, and Kurile Islands, and the main islands of Japan to Tokyo Bay.

It also occurs in the peripheral seas. It is known from the Sea of Japan south to Obama, Japan and Gensan, Korea; and from the entire Gulf of Tartary. Hubbs and Kuronuma (1942) have mapped it as occurring along all of the shores of Okhotsk Sea although they give no definite locality records and I have been unable to find any elsewhere. Starry flounder have been found along the southern and eastern limits of the Bering Sea and along the northern coast of Alaska and Canada eastward as far as Coronation Gulf. Whether it occurs along the northwestern shores of the Bering Sea is uncertain and there appear to be no records along the arctic coast of Asia.

Habitat Requirements

Although considered a euryhaline fish, Gunter (1942) reported that the starry flounder had been taken 75 miles upstream in the Columbia River. According to Orcutt (1950), a US Fish and Wildlife Service study of salmon and striped bass was conducted with fyke nets fished just below the surface of the water one-half mile below the Antioch Bridge in the San Joaquin River and six miles downstream from Rio Vista in the Sacramento River. Although the collecting nets were not designed or set for the capture of bottom fishes, they took, in addition to the salmon and striped bass, 80 starry flounder in the San Joaquin River. At Antioch the salinity varied from about 0.06 to 9.0 parts per thousand during the period from April through September, in which the flounder were caught; a variation from fresh water to brackish water having a salinity about one-quarter that of the ocean. At Rio Vista the salinity varied from 0.02 to 0.5 parts per thousand and the Sacramento River water could be considered nothing but fresh during the entire period of the experiment. Nevertheless 193 starry flounder were caught at the latter station.

River

In streams, they generally prefer tidal, low-gradient areas that have sandy or muddy bottoms. Most found in fresh water are young-of-the-year. During dry years abundances may be lower but young are more likely to be found farther upstream and to be entrained by the pumps in the south Delta (Moyle 2002). The smallest fish are generally found farthest upstream (Ganssle 1966), and they seek areas with higher salinity as they grow larger (Baxter et al. 1999). Thus, in April-June most young-of-the-year are living in salinities of less than 2ppt, but by July and August they have shifted to salinities of 10-15 ppt (Baxter et al. 1999). Temperatures may also influence distribution because they are usually found at 10-20oC (Baxter et al. 1999). Starry flounders

<20cm TL encountered in freshwater seem to be mostly migrants from salt water, rather than fish that have reared there (Moyle 2002).

Delta

Between 1979 and 1999, starry flounder made up 1% of the total fish captured by otter trawl and beach seine in Suisun Marsh (Matern et al. 2002). Meng et al. (1994) considered starry flounder a seasonal fish species within the marsh.

Bay

In the San Francisco Estuary some smaller flounders may have resulted from spawning in the estuary, but most are apparently carried into San Francisco Bay from nearshore ocean waters by strong tidal currents along the bottom (Baxter et al. 1999). These currents are strongest during years of high outflow from the rivers, and, as a consequence, juvenile starry flounder tend to be most abundant in the estuary during wet years (Jassby et al. 1995, Gunter 1942 as reported in Moyle 2002). Higher abundances may be related to the greater extent of low-salinity rearing areas and the greater abundance of food organisms preferred by small flounders (Herbold et al. 1992). Ralston (2005) showed that the summertime abundance of young-of-the-year(YOY) starry flounder in San Francisco Bay is closely related to discharge into the bay the previous winter, and that the relatively long discharge record can be used to hind-cast starry flounder recruitment.

Population Trends

The starry flounder was a common species in commercial and recreational fisheries of California prior to the 1980s, but has declined dramatically in the 1990s and this trend is mirrored in the CDFG otter trawl data (Figure 16-5). This flounder is generally not targeted by commercial fishers, except in Puget Sound, but is mostly taken as by-catch by bottom trawl, gill nets, and trammel nets. Recreational catch occurs by angling from piers, boats, and shore in estuarine and rocky areas including rocky structures adjacent to Alcatraz Island (PFMC 1998d). Commercial catch trends suggest that populations of this flounder are at extremely low levels, reduced from more than 1 million pounds of annual landings in the 1970s to an average of 62,225 pounds of annual landings in the 1990s (Haugen and Thomas 2001). However, Moyle (2002) suggests that it is unclear whether this decline is related to changing estuary conditions or to changes in fishing regulations that reduce catch (Leet et al. 1992). SWP/CVP fish salvage facilities in the Sacramento-San Joaquin Delta recorded average monthly salvage records for the starry flounder for the period from 1981 to 2002 as 187 fish per month at CVP and 77 at SWP (Foss 2003).

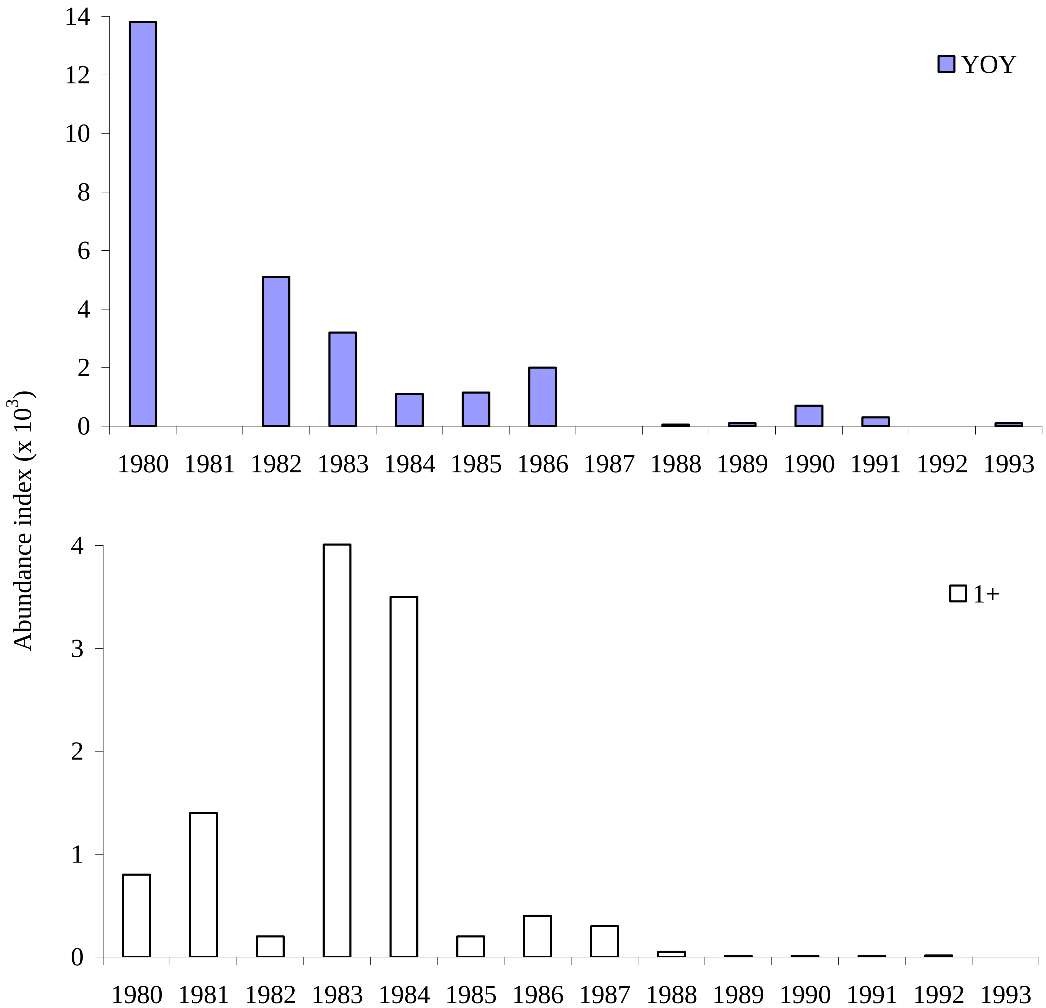


Figure 16-5 Abundance estimates of starrry flounder young-of-the-year (YOY) and age 1+, captured by otter trawl. Data source: California Department of Fish and Game/ Bay Delta Region web page. (http://www.delta.dfg.ca.gov/baydelta/monitoring/stflab.asp)

Potential Effects of Proposed Project

The primary fresh water inputs to the San Francisco Estuary are derived from regional precipitation (quantity and form [ie rain or snow]) and to a greater extent, the Sacramento and San Joaquin Rivers (Kimmerer 2002). River inflow is largely regulated by upstream reservoir releases. A fraction of this inflow is exported out of the Delta by the CVP and the SWP affecting variation in through-estuary outflow, creating lower winter and higher summer outflow than what occurred historically. This can have a strong influence on the mixing zone (X2), where fresh and salt water collide and the overall salinity of the Estuary (Uncles and Peterson 1996). This mixing zone is a highly productive environment (Kimmerer 2002).

Movement of the mixing zone is complex and dependent upon a number of factors, including tidal cycles (Cloern et al. 1989) and fresh water inflow. Wind wave action can also be important for mixing. Over the course of a year, X2 can range from San Pablo Bay during high flow periods, to well into the Delta during the summer drought. The position of X2 is monitored and maintained by releasing water from upstream reservoirs and operation of manmade barriers (ie Suisun Marsh gates) in anticipation of export demand. This is mandated in the Vernalis Salinity Standard, which was legally established to maintain habitat quality in the Estuary for wildlife and to prevent salinity from encroaching upstream to the export pumps. Gravitational circulation causes stratified high salinity water at depth to flow landward while low salinity water on top flows seaward (Monismith 1996). The effect of gravitational circulation may be most pronounced during periods of high fresh water flow, providing a negative feedback for maintaining the salt field and the distribution of pelagic organisms in the Estuary.

Mixing is important at the landward edge of gravitational circulation, often around X2, where the water column becomes less stratified (Burau 1998). A fixed mixing zone occurs at the east end of the Carquinez Strait, where the deep channel becomes dramatically shallower as it enters Suisun Bay (Schoellhamer 2001). Mixing is critical in maintaining salinity such that extremely large inputs of fresh water are required to move X2 a short distance to the west. Mixing also assists pelagic organisms in maintaining position in the Estuary (Kimmerer 2004) and slowing the advection of primary and secondary production out of the system. These relationships appear to have a significant influence on fish species within the Estuary (Feyrer et al. 2007).

Furthermore, phytoplankton, zooplankton, and larval and adult fish can become entrained in the export pumps, causing a potentially significant but unknown impact on the abundance of these organisms. Reduced outflow may have effects on salinity and sediment composition within the Estuary, controlling the size and species composition within this area (Siegfried et al. 1980). Rivers are also one of the largest sources of phosphorous and nitrogen to the ocean environment, having a significant effect on oceanic production (Tyrrell 1999). Potential impacts of river modification include effects on migration patterns, spawning habitat, species diversity, water quality and distribution and production of lower trophic levels in the marine environment (Drinkwater and Frank 1994). Therefore, these interactions may have an influence on prey as well as predators of northern anchovy and starry flounder within the Estuary and potentially along the adjacent coast.

Northern Anchovy

The northern anchovy is primarily a marine and estuarine species. The CVP and SWP operations may have some effects on marine and estuary conditions and it is possible that some adverse effects from the proposed project on northern anchovy EFH may occur within the marine and estuary environment. There are no records of northern anchovy salvage at the CVP or SWP fish salvage facilities and therefore no adverse effects are expected within the river environment.

Starry Flounder

The withdrawal of seawater can create unnatural conditions to the EFH of starry flounder. Various life stages can be affected by water intake operations such as entrapment through water withdrawal and impingement on intake screens. Starry flounder salvage occurs at the CVP and SWP export facilities (Table 16-1). Most salvage occurs in May, June, and July. The salvaged flounder are young of year fish with the largest fish 3 to 4 inches long (Lloyd Hess, pers comm.).

High approach velocities along with intake structures can create unnatural conditions to the EFH of starry flounder. These structures may withdraw most larval and post-larval organisms, and some proportion of more advanced life stages. Periods of low light (e.g., turbid waters, nocturnal periods) may also entrap adult and subadults. Freshwater withdrawal also reduces the volume and perhaps timing of freshwater reaching estuarine environments, thereby potentially altering circulation patterns, salinity, and the upstream migration of saltwater.

Starry flounder is primarily a marine and estuarine species. CVP and SWP operations do not significantly affect marine conditions, although they can affect estuarine conditions and some take occurs at the pumping plants. The proposed CVP OCAP can affect EFH of the starry flounder in the Delta by changing flow and water quality. Starry flounder is a widespread species not directly targeted by commercial fisheries. Effects to starry flounder habitat are minor relative to flounder habitat as a whole and no commercial fisheries will be affected by localized effects on the habitat or population.

Table 16-1 Starry flounder salvage at the SWP and CVP export facilities, 1981 – 2002.

Starry Flounder Salvage at the SWP and CVP Delta Fish Salvage Facilities, 1981 - 2002						
				1 = SWP, 2 = CVP		
Sum of SALVAGE			Sum of SA	FACILITY		
MONTH	Total		MONTH	1	2	Grand Total
1	24		1		24	24
2	181		2		181	181
3	33		3	33		33
4	325		4	294	31	325
5	1733		5	795	938	1733
6	7188		6	6174	1014	7188
7	2242		7	1849	393	2242
8	295		8	154	141	295
9	51		9	27	24	51
10	76		10		76	76
11	6		11	6		6
12	12		12		12	12
Grand Total	12166		Grand Tot	9332	2834	12166

Sum of SALVAGE	MONTH												
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
1981				169	405			48	19				641
1983						60							60
1984						294							294
1985					154	2429	78						2661
1986				31	46	66	615						758
1987				64				168					232
1988		128			49	2707	829						3713
1989					3								3
1990						267	143						410
1991		53			63	43	119			28			306
1992			25	6	29					36		12	108
1994				1	18	24	24						67
1995						12							12
1996						126	170	15	8				319
1997				45	816	854	42	36		12			1805
1998	24				102	80	30		24				260
1999					12	94	96	4			6		212
2000			8	9	24	72	24	24					161
2001							24						24
2002					12	60	48						120
Grand Total	24	181	33	325	1733	7188	2242	295	51	76	6	12	12166

Essential Fish Habitat Conservation Measures

The Coastal Pelagic Species Fishery Management Plan (PFMC 1998a) requires a permit to commercially harvest coastal pelagic finfish species, such as the northern anchovy, south of Point Arena, California. The fishery management plan includes the northern anchovy as a "monitored species" because of low fishery demand and high stock size and thus does not impose harvest limits based on biomass estimates. There is no limit on live bait catch for this species.

The Pacific Coast Groundfish Fishery Management Plan (PFMC 1998c) outlines measures to reduce negative impacts on essential fish habitat. These measures include fishing gear restrictions, seasonal and area closures, harvest limits, among others. There are currently no harvest limits specific to the starry flounder. Conservation measures include recommending that all intake structures be designed to minimize entrainment or impingement of fish, and mitigation should be provided for the net loss of habitat from placement of the intake structure and delivery pipeline.

Conclusion for Northern Anchovy and Starry Flounder

Upon review of the effects of Reclamation's proposed CVP OCAP, the proposed project may affect EFH of the northern anchovy and the starry flounder.

Essential Fish Habitat for Chinook Salmon

Distribution and Status

Note: The following information is background data on fall and late fall-run Chinook salmon *Oncorhynchus tshawytscha*. The effects for these runs are included in chapters 10 and 11 and summarized at the end of this chapter.

On September 16, 1999, NMFS determined that listing was not warranted for this ESU (NMFS 1999). However, sufficient concerns remained to justify adding them to the candidate species list (qualify as species of concern) (NMFS 2004). The ESU includes all naturally spawned populations of fall-run Chinook salmon in the Sacramento and San Joaquin River basins and their tributaries, east of Carquinez Strait, California. Major river basins containing spawning and rearing habitat for this ESU comprise approximately 13,760 square miles in California.

Effects on Central Valley spring-run Chinook salmon, Sacramento River winter-run Chinook salmon, Southern Oregon/Northern California Coast coho salmon, Central Valley steelhead, and Central California Coast steelhead habitat are described in the biological assessment in Chapters 11 and 13 and are summarized in Chapter 15.

Chinook salmon are the largest of the Pacific salmon and are highly prized by commercial, sport, and subsistence fishers. Chinook salmon can be found in the ocean along the west coast of North America from south of Monterey, California, to Alaska, but the southern extent of spawning is in the San Joaquin and Kings rivers (Moyle 2002). The fisheries of healthy Pacific coast Chinook salmon stocks are managed by the Council under the Pacific Salmon Fishery Management Plan. Approximately, 80 percent of the California catch comes from the Central Valley as opposed to the Klammath River system although as much as 90% may be of hatchery origin (Barnett-

Johnson et al. 2007). These stocks include fall and late-fall run Chinook salmon from the Klammath and Central Valley systems. In 2003, preliminary estimates of California coastal community and state personal income impacts of the troll and recreational salmon fishery collectively for the Fort Bragg, and San Francisco/Monterey port areas was $27.0 million and $10.7 million, respectively. Jeffres and Merz (2000) found that salmon sport anglers spent $352 K on a 90 mi section of the Central Delta. Extrapolated to the 1100 miles available to salmon in the Central Valley (Yoshiyama et al. 1996), Chinook salmon sport harvest may be worth another $6.7 million. Historically, fall run Chinook salmon used rivers and their 21 tributaries in the Central Valley from the Kings River in the south to the Pit and McCloud rivers in the north (Schick et al. 2005). Late fall-run Chinook salmon probably used the Sacramento River and tributaries above Shasta Dam (Moyle et al. 1995). The late fall-run was identified as separate from the fall-run in the Sacramento River after the Red Bluff Diversion Dam was constructed in 1966 and fish counts could be more accurately made at the fish ladder there.

Description and Life History

Spawning adult Chinook are the largest of the Pacific salmon, typically, 75-80 cm standard length (9-10 kg), with lengths in excess 140 cm (45 kg)(Moyle 2002). Parr have 6-12 parr marks, each equal to or wider than the spaces between and most extending below the lateral line (Moyle 2002). The parr adipose fin is pigmented on the upper edge but clear at its center and base. Adults are identified from the only other common Pacific salmon in coastal California waters, the coho *O. kisutch* by the Chinook salmon’s black gums on the lower jaw. Because of their large populations and body sizes, Pacific salmon are a major food source for terrestrial and aquatic organisms associated with spawning streams, from bears (*Ursus* spp) to bacteria (Willson et al. 1998; Cederholm et al. 1999; Hilderbrand et al. 1999). Pacific salmon spend most of their life cycles as top predators in the nutrient-rich North Pacific Ocean, where they incorporate carbon, nitrogen, phosphorus, and other micronutrients into their body tissues. These tissues provide an important nutrient and energy subsidy to oligotrophic streams where the salmon spawn and eventually die (Willson and Halupka 1995; Wipfli et al. 1998). Chinook salmon may provide a significant nutrient subsidy to local agricultural interests within the Central Valley where populations still exist (Merz and Moyle 2006). Because of their relatively low abundance in coastal and oceanic waters, Chinook salmon in the marine environment are typically only an incidental food item in the diet of other fishes, marine mammals, and coastal sea birds.

Healy (1991) divided Chinook salmon into two life-history strategies, stream and ocean. Stream-type Chinook salmon have adults that run up streams before they reach full maturity, in spring or summer, and juveniles that spend a long time (usually >1 year) in fresh water (Table 16-2). Ocean-type Chinook salmon have adults that spawn soon after entering fresh water, in summer and fall, and juveniles that spend a relatively short time (3-12 months) rearing in fresh water (Moyle 2002).

Table 16-2 Fall-run and Late Fall-run Life History Traits (Data sources: Moyle et. al. 1995; Moyle 2002).

Trait	Fall-run	Late Fall-run
Spawning migration	June-December	October-April
Spawning period	Late September-December	Early January-April
Juvenile period	March-December	April-June
Juvenile stream residence	1-7 months	7-13 months
Typical ge at spawning	4-5 years	3-4 years
Holding before spawning	Days-weeks	1-3 months

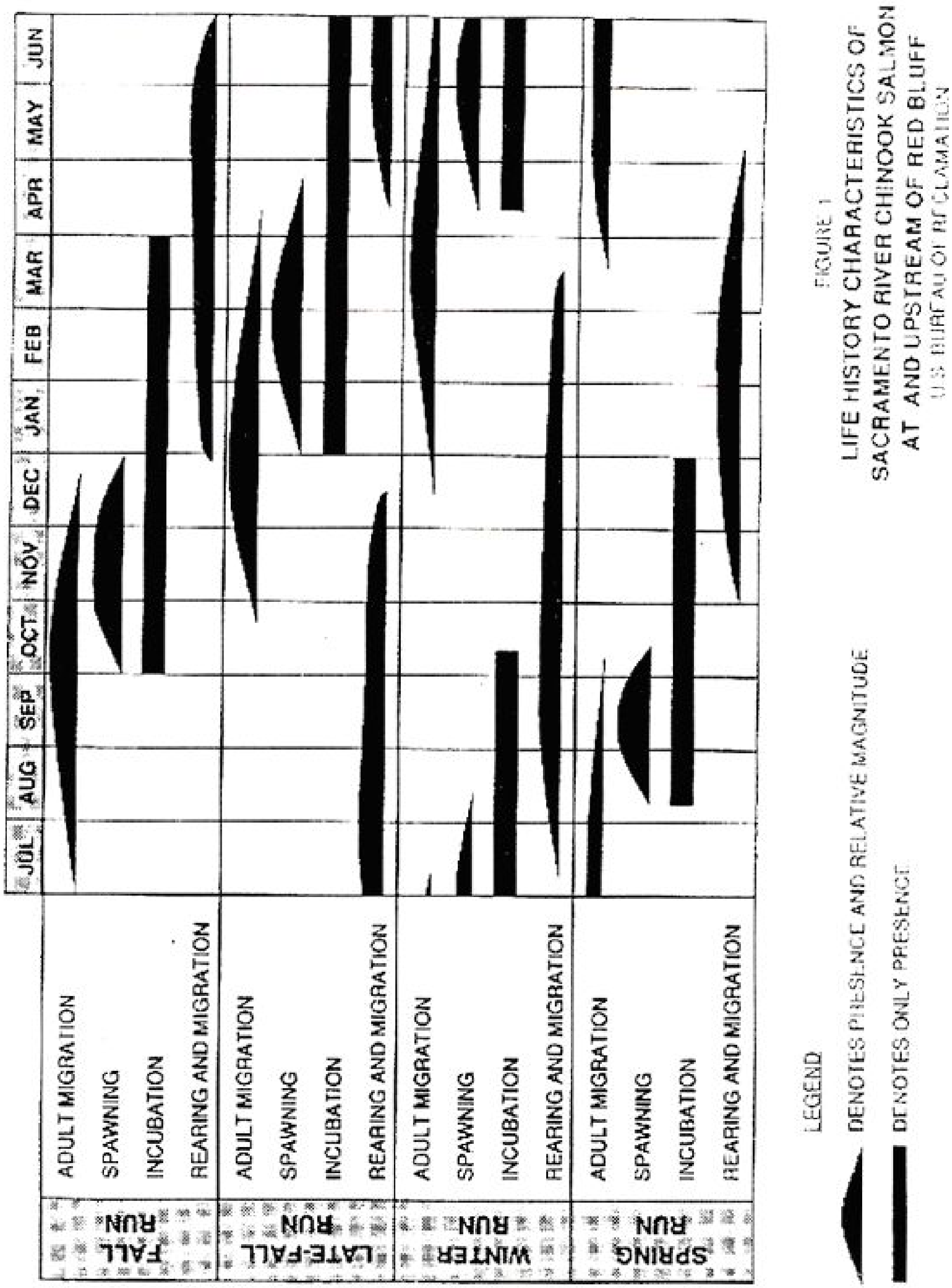


Figure 16-6 Life cycle timing for Sacramento River Chinook salmon. Adapted from Vogel and Marine (1991).

According to Moyle (2002), the fall-run are an unambiguous ocean-type Chinook salmon adapted for spawning in lowland reaches of big rivers and their tributaries. They move up from the ocean in late summer and early fall (Figure 16-6) in mature condition and typically spawn within a few days or weeks of arriving on the spawning grounds. Juveniles typically emerge from the gravel in winter and spring and move downstream within a few months, to rear in mainstem rivers or estuaries before heading to the ocean (Kjelson et al. 1982).

Late-fall-run Chinook salmon are mostly a stream-type salmon found in the Sacramento River today (Moyle 2002). They are the largest and most fecund salmon in California because they historically came in as 4- and 5-year-old fish (Moyle et al. 1995; Fisher 1994). Adults typically hold in the river for 1-3 months before spawning. Juveniles enter the ocean after 7-13 months rearing in fresh water, at 150-170 mm FL, considerably larger and older than fall-run Chinook salmon (Moyle 2002).

Ocean Distribution

Since 1981, Pacific salmon *Oncorhynchus* spp. tagged with coded-wire tags (CWTs) have been recovered in commercial fisheries and research programs in the North Pacific Ocean, Gulf of Alaska, and Bering Sea-Aleutian Islands (Celewycz et al. 2007). The known range of North American Chinook salmon, as shown by tagging experiments, extends across almost the entire Bering Sea, north to 60°03'N and west to 172°12'E. In the North Pacific, the known ocean range of North American Chinook salmon extends north from about 40°N (in the coastal waters just off California) and west to the waters just south of Adak Island in the central Aleutians (176°34'W, 51°29'N)(Celewycz et al. 2007).

Fall-run Chinook salmon normally spend 2-4 years in the ocean although Feather River salmon normally have a 4 to 5 year ocean residency (Moyle 2002). Available data suggest that while in the ocean, fall-run Chinook salmon remain primarily in the coastal waters off California (NMFS 1997).

Along the California coast, adult Chinook salmon are key predators responding in their distribution and abundance to availability of food resources (Adams 2001). Chinook salmon found in the Gulf of the Farallone are predominantly 3-year-old fish preparing to enter the Bay-Delta ecosystem and various tributaries of the Sacramento-San Joaquin River system where they will spawn, and eventually die. They typically move into the Gulf in February and March, and are generally found off the Golden Gate from Bolinas Point in the north to Point San Pedro in the south. Their diets consist of Pacific herring (recently emigrated from November to February spawning in San Francisco Bay) and anchovies. The herring are particularly vulnerable to Chinook predation as they are weakened from spawning. Chinook may move offshore again in April to June to feed on euphausiid shrimp *Thysanoessa spinifera* (krill), crab larvae, and juvenile rockfish; and, the return to the nearshore in July to forage exclusively on anchovy. The distribution of adult Chinook salmon and their stomach contents strongly relates to the availability and composition of food resources, such as anchovy, and the availability of those food resources is related to climatic and ocean conditions.

Anchovies begin to gather in nearshore waters in February and March before their migration into the Bay in April and April represents the transition time in Chinook salmon nearshore and offshore feeding habits. Euphausiids are taken as prey from surface and subsurface swarms that occur over a wide area of the Gulf during April and May (Adams 2001). It is the carotenoid pigment in crustaceans, like euphausiids, that gives the salmon flesh its pink color. Dungeness crab *Cancer magister* megalopa larvae dominate the diets of Chinook salmon for a short time period, during their last pelagic phase in early April. More than 7,000 megalopa have been found in a single Chinook salmon stomach. In May and June, Chinook salmon move further offshore and start feeding on euphausiids and juvenile rockfish. In years when juvenile rockfish are abundant, they are the preferred prey and dominate the Chinook salmon diet, whereas in low-abundance years, Chinook salmon feed mainly on euphausiids. Later in the summer the Gulf water warms due to the absence of upwelling, and anchovies simultaneously move out of the Bay and into the Gulf. This is coupled with a seasonal disappearance of juvenile rockfish, causing the salmon to return to the nearshore and capitalize on the feeding opportunity presented by the anchovies. Diet information has confirmed the salmon's dependence on aggregations of prey, and the prevalence of opportunistic feeding (Adams 2001). This natural concentration of Chinook salmon makes them susseptable to increased angling take (citation). However, the dependence on these traditional prey complexes may be disrupted during strong El Niños or other changes to ocean conditions. When prey aggregations fail to occur, the condition (length-to-weight relationship) may decrease similar to what was recorded during California's commercial salmon catch in El Niños years.

Inland Habitat Requirements and Special Considerations

Specific information on habitat requirements of Chinook salmon in the inland waterways of the California Central Valley is provided in Chapters 5 and 6.

Adult Migration

Specific cues triggering adult fall-run Chinook salmon to return to their spawning grounds from the Pacific Ocean are not well understood. Returning fall-run Chinook salmon average 35.4 inches (90 cm) in length (Moyle 2002). Chinook adults metamorphose from the silvery ocean form into the characteristic dark maroon to olive brown spawning colors. During the upward migration, adults stop feeding as their digestive tract degrades, causing them to live increasingly on body fat reserves. Spawning Chinook salmon are sexually dimorphic, with males darker and typically larger than females. Head and adipose fin to body length is typically greater in males (Merz and Merz 2004). Often the male's back humps and jaw hooks, creating a kype; teeth become more prominent and sharp. As this occurs, both sexes lose their ability to heal injuries and fight disease (Allen and Hassler 1986). The ability for Chinook to find their way back to their home stream in order to spawn is mainly related to the long-term olfaction memory of the salmon, but is also aided by their vision (Healey, 1991) and may be stimulated by higher streamflow and changes in water turbidity, temperature and oxygen content (Allen and Hassler 1986). Migratory routes must be free of barriers that can impede or prevent movement upstream and downstream. Numerous issues, such as predation and water quality can affect the ability of adults to reach spawning areas and complete successful spawning (Goniea et al. 2006; Beamsdorfer 2000; Hillemeier 1999). These are further affected by anthropogenic effects such water diversion; channel modification and water quality controls (Stein xxxx; Hallock et al. 1970). Male salmon often reach the spawning grounds before females to set up territories. Although some feeding has been documented at river mouth entry, in general, Chinook salmon do not eat during their migration to spawning areas or during holding before spawning (Moyle et al. 1995).

Spawning

In general, spawning Chinook salmon require gravel and cobble areas, primarily at the head of riffles, with adequate hyporheic flow to ensure embryo survival (Table 16-3). Chinook salmon select gravel for spawning with a median diameter between 7 and 300 mm (Platts et al. 1979, Reiser and Bjornn 1979, Kondolf 1988). Within this range, the particle sizes used for redd formation can vary with the size of the fish (Burner 1951, Kondolf and Wolman 1993). Kondolf and Wolman (1993) determined that the relation between fish length and gravel size can be described by an envelope curve. In general, fish can spawn in gravels with a median diameter up to about 10% of their body length (Kondolf and Wolman 1993).

Table 16-3 Criteria defining suitable fall-run Chinook salmon spawning habitat (sources: Platts et al. 1979; Reiser and Bjornn 1979; Kondolf 1988; Hanrahan et al. 2004).

Variable	Values
Depth	0.30-9.50 m
Velocity	0.25-2.25 m•s^{-1}
Substrate	7-305 mm
Channel-bed slope	0.0 - 5.0%

Although optimal spawning habitat as defined by habitat suitability models is generally found in riffles, proximity of habitat to structural cover (pools, large woody debris, boulder clusters and overhanging vegetation) and hydrodynamic shear zones provide equally important refuge from predation and resting zones for energy conservation (Wheaton et al. 2004; Merz 2001).

Chinook adults tolerate water temperatures between 51 and 67ºF (10.6 and 19.4ºC) with temperatures between 42°F and 58°F considered most suitable for spawning (Bell 1986). Further discussion of water quality issues are provided in Chapters 5 and 6. CV fall-run Chinook salmon typically spawn within a few days or weeks of arriving at their spawning grounds (Moyle 2002). Spawning takes place between September and early January.

The female Chinook salmon usually chooses a nesting site in gravel deposits at the lower lip of a pool just above a riffle (Burner 1951; Briggs 1953). During spawning, the female makes a redd (an area containing several individual nests) by turning on her side and repeatedly flexing her body and tail to force gravel and fine sediment into the water column; these sediments are deposited a short distance downstream. The completed nest forms an oval depression with a mound of gravel located immediately downstream.

Fecundity varies greatly among Chinook salmon of different populations. For example, fecundity of fall-run Chinook salmon averages 3,634 eggs per female in the Klamath River but 7,295 eggs in Sacramento River fish (Allen and Hassler 1986). Difference in female size alone cannot account for the variation in fecundity (Healey and Heard 1984).

Embryo Development

Optimum substrate for embryos is a gravel/cobble mixture with a mean diameter of 0.5 to 4 inches and a composition including less than 5 percent fines (particles less than 0.3 inch in diameter) (Platts et al. 1979; Reiser and Bjornn 1979 both as cited in DFG 1998). The incubation life stage for fall-run Chinook salmon generally extends from about September through March. The intragravel residence period of incubating eggs and alevins (yolk-sac fry) and egg incubation survival rates and times are highly dependent on water temperature and dissolved oxygen (Merz et al. 2006). Optimal water temperatures for incubation range between 48°F and 58°F (8.9°C to 14.4°C). Incubation temperatures of 62°F to 64°F appear to be the physiological limit for embryo development resulting in 80 to 100 percent mortality prior to emergence (USFWS 1999). Suitable water temperatures for incubation range between 48°F and 58°F. In general, fall-run Chinook salmon fry emerge during December through March (Yoshiyama et al. 1998).

Fry and Juvenile Rearing and Emigration

In the California Central Valley, juvenile Chinook salmon have been reported to emigrate from approximately mid-November through July, with peak emigration occurring from January through March (Painter 1977; DWR 2003). The vast majority of the fall-run Chinook salmon emigrate as fry (Seesholtz et al. 2004), suggesting that rearing habitat is limiting or that conditions later in the season are less suitable. For the most part, fall-run Chinook salmon juveniles rear in tidal freshwater habitats of the Delta. Primary locations where these fish rear are unknown; however, in wetter years it appears that many young salmon rear for weeks to months in the Yolo Bypass floodplain immediately downstream of the Feather River before migrating to the estuary (Sommer et al. 2001). Juvenile fall-run salmon may rear for up to several months within the Delta before entering the ocean (Kjelson et al. 1982; Yoshiyama et al. 1998). Banks et al. (1971) and Rich (1987) report that preferred/optimal water temperatures for juvenile fall-run Chinook salmon rearing are from 54°F to 60°F.

Juvenile Chinook salmon diets often vary by habitat type. Chironomid midges are typically cited as an important prey for juvenile Chinook salmon upstream of the Delta (Sasaki 1966; Merz and Vanicek 1996; Moore 1997; Sommer et al. 2001), whereas crustaceans may be more important in the western Delta (Sasaki 1966; Kjelson et al. 1982). Upstream reservoirs can provide a significant food source to lower rivers, such as zooplankton. Prey size and ingestion rates are also significantly affected by juvenile salmon size and water temperature within the stream (Merz 2002a; Merz 2002b).

Typically, juvenile Chinook salmon do not move into brackish water until they have undergone smoltification, after which they move quickly to the ocean (Reclamation 2004). Scale analysis indicates that fall-run Chinook salmon smolts enter the ocean at an average fork length (FL) of about 85 mm (DFG unpublished data).

Population Trends

Central Valley Chinook salmon constitute the majority of salmon produced in California and at times have accounted for 70 percent or more of the statewide commercial harvest (Yoshiyama et al. 2001). Central Valley populations are monitored in a number of ways. Adult Chinook production is estimated using tributary escapement counts and adding this number to the estimated ocean harvest. Tributary counts come from carcass counts, fish ladder counts, aerial redd surveys, hatchery returns and in-river harvest. The total escapement (in-river plus hatchery) of fall-run Chinook in the Central Valley from 1952-2001 is shown in Figure 16-7.

Figure 16-8 shows Chinook salmon in-river escapement estimates by watershed from 2001-2007. The watershed specific component of the ocean harvest of fall-run Chinook salmon is calculated by multiplying the total ocean harvest by the watershed-specific proportion of the total in-river run size. Tagging programs have not been sufficiently implemented Central Valley wide to provide more exact commercial harvest estimates by watershed. During 1999, ocean harvest accounted for 41 percent (335,700) of the total Central Valley Chinook production of 822,352 (all runs combined). The total production includes both natural in-river and hatchery production estimates.

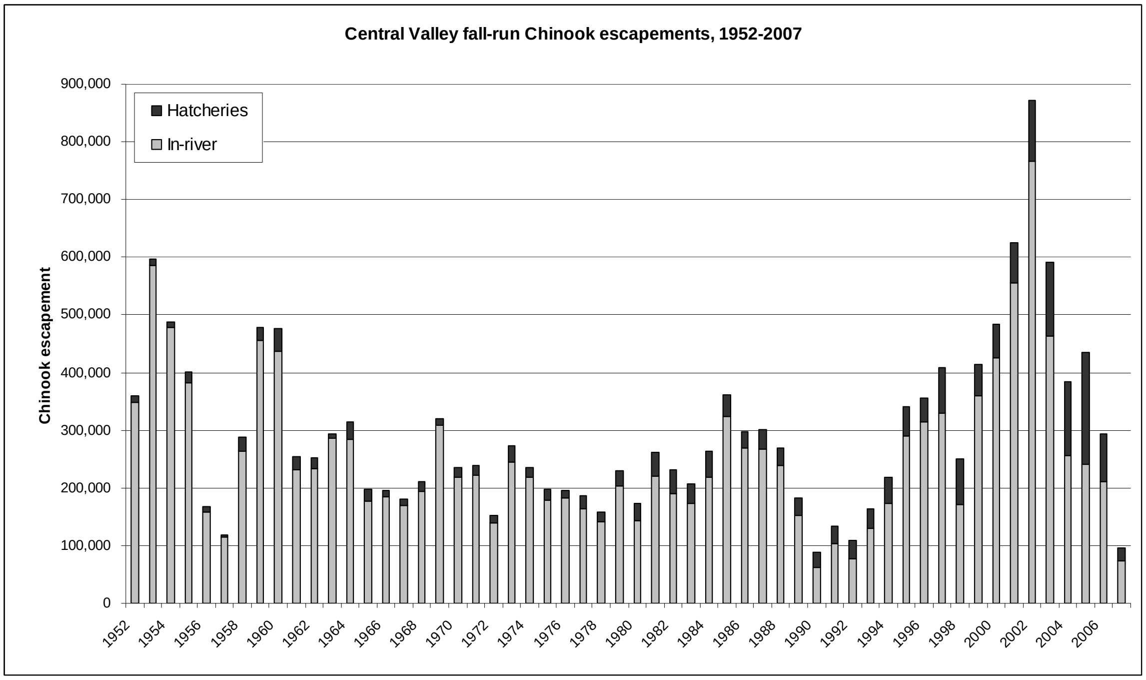


Figure 16-7 Central Valley fall-run Chinook salmon escapements, 1952-2007. Source: DFG data.

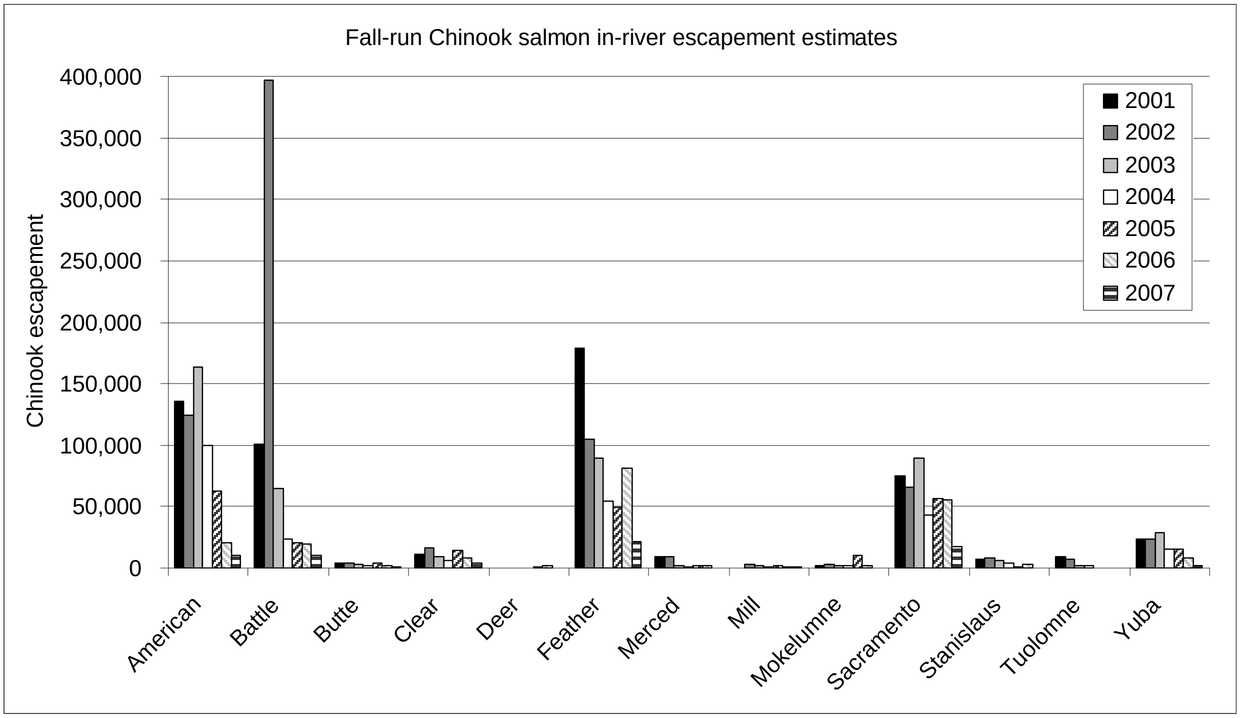


Figure 16-8 Fall-run Chinook salmon in-river escapement estimates in the California Central Valley, 2001-2007. Source: Interior (2008).

The Comprehensive Assessment and Monitoring Program (CAMP) annual report (Interior 2001) summarizes results of monitoring anadromous fisheries production in the Central Valley relative to the CVPIA doubling goal. The CVPIA set the baseline anadromous fisheries production level as the average attained during 1967-91. Progress toward production targets is assessed using a modification of the Pacific Salmon Commission's (1996) rebuilding assessment methods when a minimum of five years of monitoring data is available. Indicator races or species are classified into three categories: (1) those at or above their production target; (2) those meeting their rebuilding schedule; and (3) those not rebuilding. Results based on past escapement estimates need to be qualified due to the vagaries of the estimation methods used over the years (DFG 2003).

Battle Creek, Clear Creek, and Mokelumne River populations of fall-run Chinook salmon and Butte Creek spring-run salmon are classified as meeting restoration goals. Fall-run salmon from the Yuba watershed are classified as Rebuilding. All other races and watershed-specific runs of Chinook salmon are classified as Not Rebuilding, except for American River fall-run salmon classified as Indeterminate. Table 16-4 shows the 1995-99 mean Chinook salmon production expressed as a percent of the goal, which is the mean of the 1967-91 production.

Many variables affect yearly salmon production including ocean conditions and water supplies, which have recently been at good levels for California salmon runs. The 2000, 2001, and 2002 Chinook salmon runs were outstanding in many Central Valley watersheds.

Table 16-4 Status of CAMP-monitored Central Valley stocks of Chinook salmon races using Pacific Salmon Commission methodology.

Watershed	*Race*	*1995-99 mean Chinook production as percent of goal*	*Watershed status through 1999 Chinook run*
American	Fall-run	77 percent	Indeterminate, declines halted
Battle	Fall-run	235 percent	Above goal
Butte	Spring-run	551 percent	Above goal
Clear	Fall-run	218 percent	Above goal
Deer	Spring-run	44 percent	Not Rebuilding
Feather	Fall-run	63 percent	Not Rebuilding
Merced	Fall-run	49 percent	Not Rebuilding
Mill	Spring-run	22 percent	Not Rebuilding
Mokelumne	Fall-run	169 percent	Above goal
Sacramento	Fall-run	48 percent	Not Rebuilding
	Spring-run	2 percent	Not Rebuilding
	Winter-run	5 percent	Not Rebuilding
Stanislaus	Fall-run	17 percent	Not Rebuilding
Tuolumne	Fall-run	30 percent	Not Rebuilding
Yuba	Fall-run	91 percent	Rebuilding, declines halted
Total (all CAMP streams)	Fall-run	66 percent	Not Rebuilding
	Spring-run	22 percent	Not Rebuilding
	Winter-run	5 percent	Not Rebuilding

Trinity River

The Trinity River, a tributary to the Klamath River, is approximately 130 miles (209 km) long with a 2,853 sq mi (7,389 km^2) watershed. Its headwaters are located in northeastern Trinity County, in the Shasta-Trinity National Forest along the east side of the Scott Mountains (Trinity Alps). It flows along the west side of the Trinity Mountains into Clair Engle Reservoir (20 miles (32 km) long) formed by the Trinity Dam, then immediately into the smaller Lewiston Reservoir. From the reservoir it flows past Weaverville and along the southern side of the Trinity Alps. The New River enters the Trinity from the north at Burnt Ranch and the South Fork Trinity River from the south along the Humboldt-Trinity county line. From the confluence with the South Fork it flows through the Hoopa Valley Indian Reservation and joins the Klamath from the south in northern Humboldt County at Weitchpec, approximately 20 miles (32 km) from the Pacific coast. The Trinity Alps watershed generates an average annual water runoff of approximately 1,250,000 acre-feet at Lewiston. Lewiston Dam acts as a storage and diversion facility, sending water through the Clear Creek Tunnel to Judge Francis Carr Powerhouse and Whiskeytown Lake. Since completion of the Trinity and Lewiston Dams in 1963, as much as 90 percent of that water runoff has been diverted from the Trinity River Basin to the San Luis Reservoir.

Trinity River Chinook salmon populations are composed of two races, spring-run and fall-run (Leidy and Leidy 1984). The fall-run Chinook salmon migration begins in August and continues into December (CDFG 1992; CDFG 1994; CDFG 1996). Fall-run Chinook salmon begin spawning in mid-October, activity peaks in November, and continues through December. The first spawning activity usually occurs just downstream from Lewiston Dam. As the spawning season progresses into November, spawning extends downstream as far as the Hoopa Valley (USFWS 1991; HTV 1996).

Emergence of fall-run Chinook salmon fry begins in December and continues into mid-April (Leidy and Leidy 1984). Juvenile Chinook salmon typically leave the Basin (outmigrate) after a few months of growth in the Trinity River. Outmigration from the upper river, as indicated by monitoring near Junction City, begins in March and peaks in early May, ending by late May or early June. Outmigration from the lower Trinity River, as indicated by monitoring near Willow Creek, peaks in May and June, and continues through the fall.

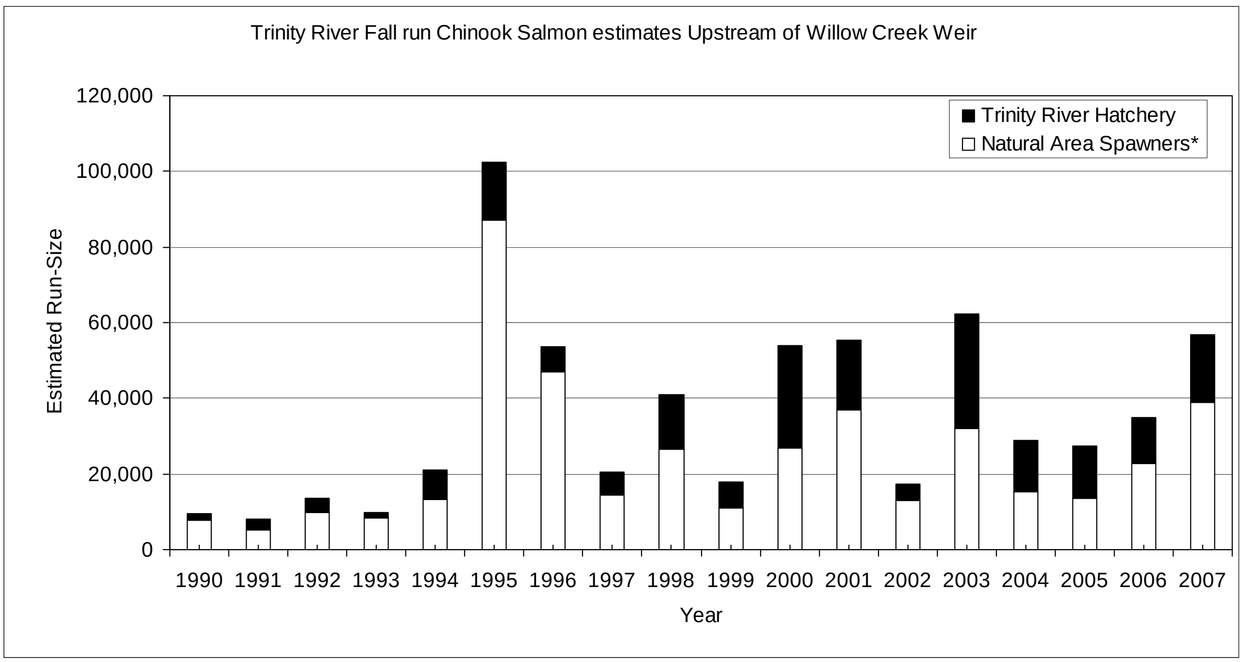
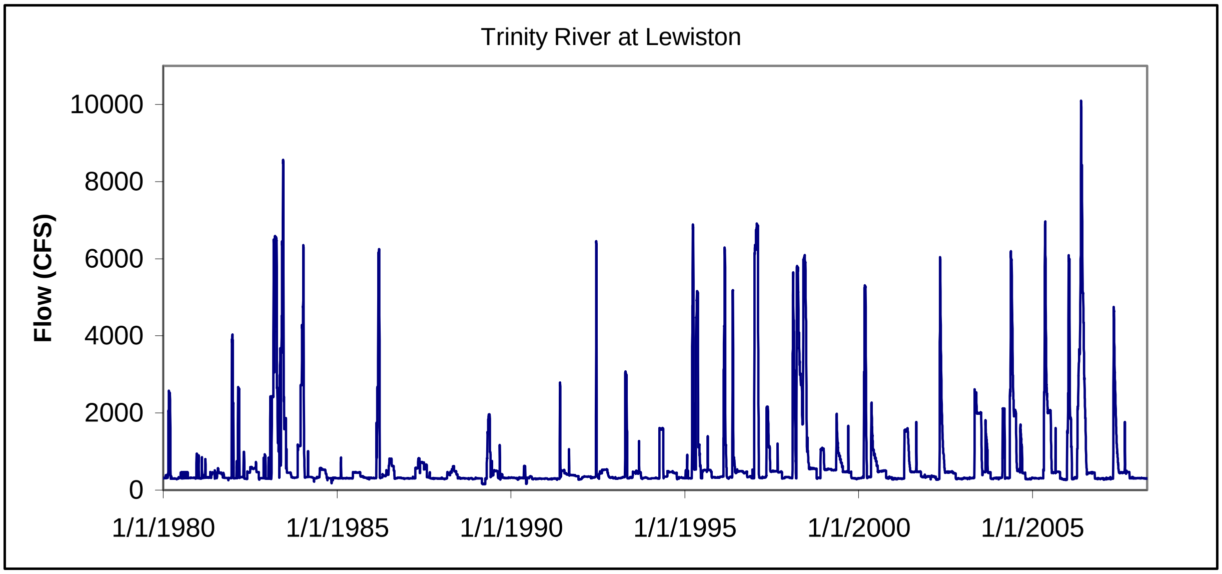


Figure 16-9 Fall-run Chinook salmon run-size for the Trinity River upstream of Willow Creek Weir from 1977 through 2006. *Natural area spawners includes both wild and hatchery fish that spawn in areas outside Trinity River Hatchery.

Hatchery History and Operations

Pre-spawn mortality has been as high as 43.7% for fall-run females (CDFG 1992).

Hydrology



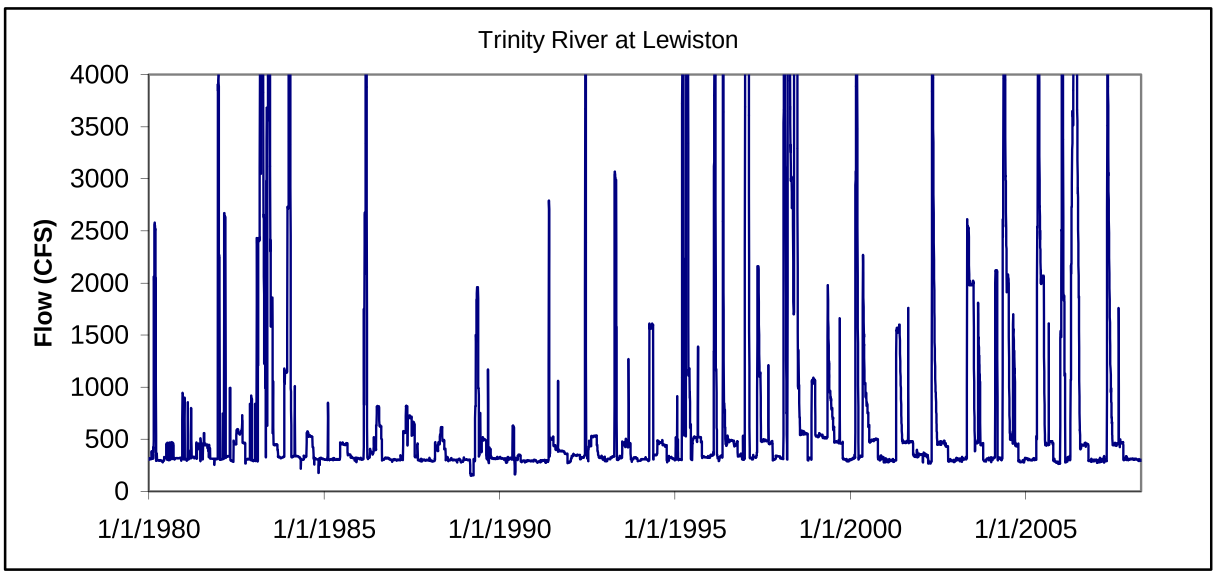


Figure 16-10 Trinity River flows as at the town of Lewiston, 1980-2008. The top chart shows the entire hydrograph. The bottom chart shows a close-up of the 0 to 4000 cfs range.

Clear Creek

Clear Creek originates on the eastern side of the Trinity Alps and flows south to its confluence with the Sacramento River. The Clear Creek watershed is approximately 35 miles long, ranges from five to 12 miles wide, and covers a total area of approximately 249 square miles, or 159,437 acres. Maximum elevation in the watershed is 6,209 feet at the top of Shasta Bally. Clear Creek channel morphology varies from steep confined bedrock reaches above Clear Creek Road bridge to wide meandering alluvial reaches from the bridge to its confluence with the

Sacramento River. Fish passage through ladders on Saeltzer Dam (constructed in 1903), six miles upstream of the Sacramento River confluence, was poor so the dam was removed in 2000. Upstream of Saeltzer Dam at river mile 9.9 and 12 are two series of natural falls which could be barriers to upstream migrants (DFG 1984b).

Fall and late fall-run Chinook salmon use the creek during the fall, winter and spring, when water temperatures are cooler. Therefore, fall and late fall-run Chinook were not as severely impacted by the loss of habitat upstream. In 1995, an unusually large run of 9,298 fall-run Chinook salmon spawned in Clear Creek (Figure 16-11). Increased minimum flow releases are thought to be one factor responsible for the increased number of spawners during that year (Figure 16-12). Late fall-run Chinook spawn in January through April. High seasonal flows and turbid water hinder the ability to conduct escapement surveys during that time of year. Fry and juvenile Chinook rear from January through May. Some late fall-run Chinook juveniles may remain in stream through June, depending on flow and water temperature conditions that occur during the season.

Pulse flows have been proposed for Clear Creek to provide an attraction flow to spring-run Chinook in the mainstem Sacramento River. A release of 1,200 cfs for one day (plus ramping) was proposed in 2000 but was not implemented due to concerns over attracting winter-run into Clear Creek. Because there has been no significant spring-run in Clear Creek in the recent past, pulse flows may aid re-establishment of spring-run in Clear Creek by attracting some fish that would otherwise remain in the Sacramento River.

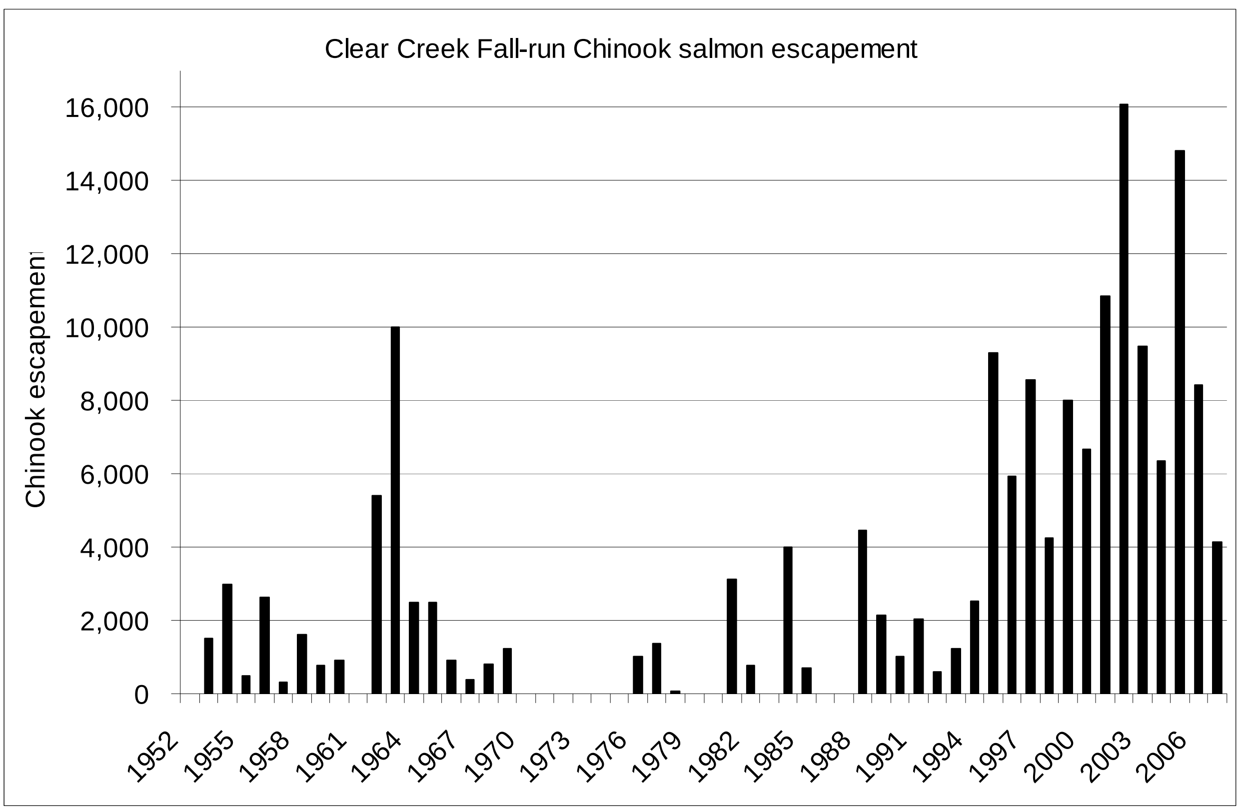


Figure 16-11 Clear Creek fall-run Chinook salmon escapement, 1951-2000. Source: DFG data.

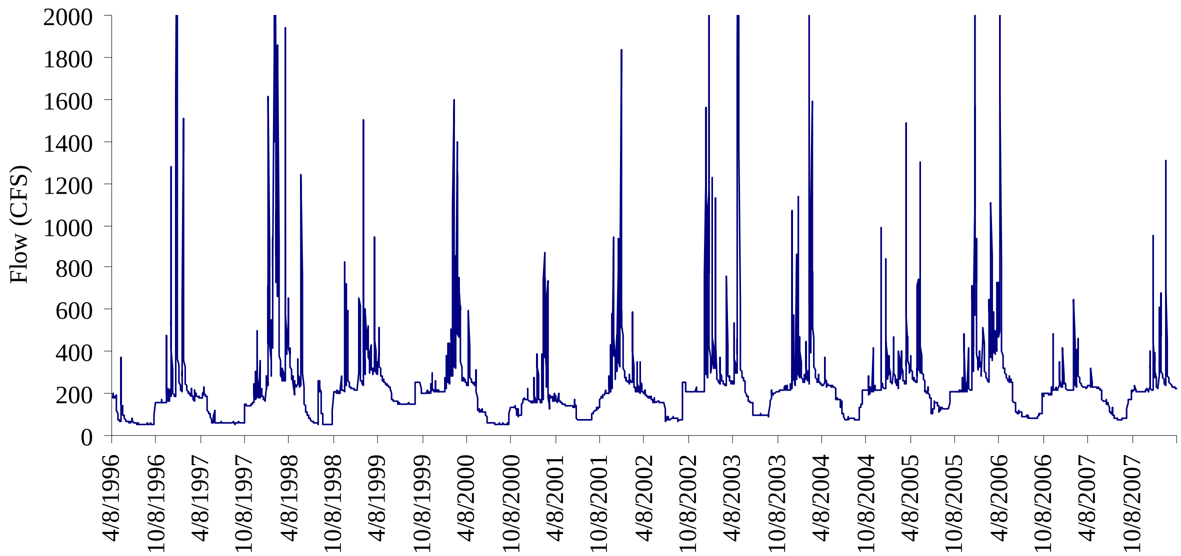


Figure 16-12 Average daily flow in Clear Creek, 1996-2007.

Sacramento River

The Sacramento River drains a watershed area of 21,250 square miles. Keswick Dam at river mile 302 serves as the upstream limit to anadromous habitat. The river is constrained by levees along much of the lower reaches. Stressors identified in the Sacramento River include high water temperatures, a modified hydrograph, simplified instream habitat, diversion dams, predation, and harvest. Water temperature and flow fluctuation are the main short-term factors affected by operation of the water projects.

Escapement of fall-run in the Sacramento River exceeded 100,000 fish every year except one between 1959 and 1970. Escapement has not exceeded 100,000 since 1970. The primary spawning area used by Chinook salmon is in the area from the city of Red Bluff upstream to Keswick Dam. Spawning densities for each of the four runs are generally highest in this reach. This reach is where operations of the Shasta/Keswick and Trinity Divisions of the CVP have the most significant effects on salmon spawning and rearing habitat in the mainstream Sacramento River. Rapid flow fluctuations can dewater edge and backwater habitat and strand fry and juvenile salmon. Redds can also be dewatered as a result of flow fluctuations. Approximately 15 to 30 percent of the total number of fall and late fall-run Chinook spawn downstream of Red Bluff when water quality is good (Vogel and Marine 1991).

Run timing for all Chinook salmon runs and life stages in the Sacramento River is depicted in Figure 16-6. All life stages are present in the river essentially at all times through the year. Abundance of adult Chinook peaks in the fall during the fall-run spawning migrations and then tapers off as fish considered late fall-run spawn. Winter-run enter the river as the late fall-run fish are spawning, starting in January. The winter-run then spawn with the peak in spawning activity in June. Spring-run enter the river soon after the winter run, starting in March and April.

They then hold out until spawning in August and September, during the lowest water flows of the year while temperatures are still relatively high.

Fall-run are entering the river as spring-run are spawning. Fall-run Chinook salmon escapement is shown in Figure 16-13 , the hydrograph since 1993 is in Figure 16-14 .

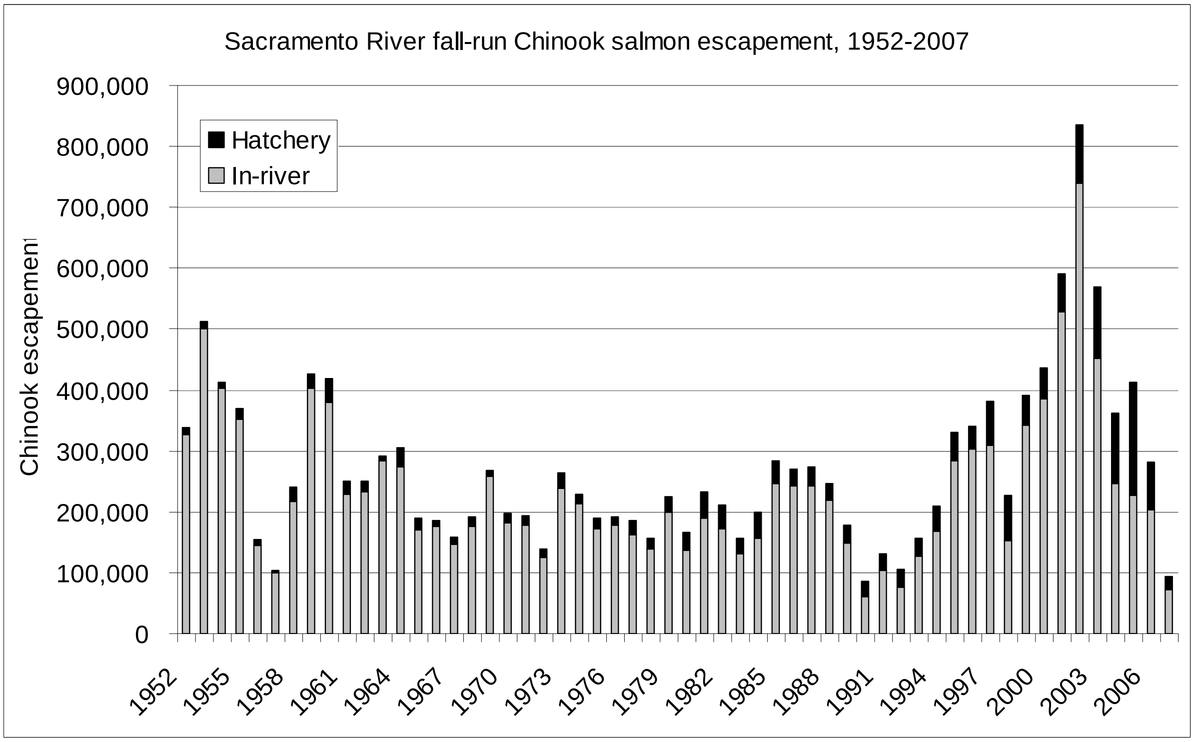


Figure 16-13 Fall-run Chinook salmon escapement in the Sacramento River, 1952-2007.

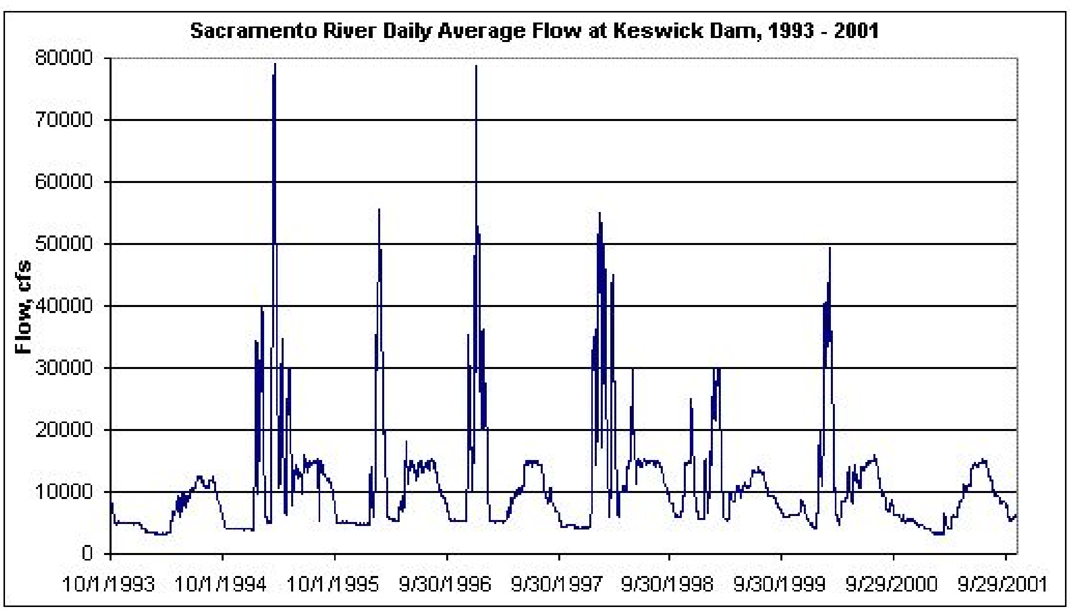


Figure 16-14 Sacramento River daily average flow at Keswick Dam from 1993-2001.

Sacramento River water temperature is controlled primarily by using releases from Shasta Lake through the TCD and also by diversions from Trinity River. The TCD was installed in 1997. Prior to 1997 low level releases were made by opening the lower river outlets, which bypasses power. The TCD enabled power bypasses to be greatly reduced while maintaining desired water temperatures in downstream fish habitat and provides seasonal flexibility to maximize use of cold water volume.

Flows in the Sacramento River generally peak during winter and spring storm events. Sustained moderately high releases (greater than 10,000 cfs) occur during the major irrigation season of June through September. These flows help to meet water temperature criteria for winter-run Chinook spawning and incubation. They also maintain suitable habitat for spring-run and early returning fall-run fish.

American River

The American River drains a roughly triangular watershed covering 1,895 square miles that is widest at the crest of the Sierra Nevada, and narrows almost to the width of the river at its confluence with the Sacramento River at the City of Sacramento. Elevations range from 10,400 feet at the headwaters to about 200 feet at Folsom Dam. Folsom Dam, completed in 1956, provides flood control, hydropower generation and water supply storage. The reservoir is kept partly empty during the winter so that temporary storage is available to regulate the runoff from major storms, preventing flooding in the downstream urban area. Nimbus Dam is seven miles downstream from Folsom Dam. It serves as the limit to upstream migration for anadromous fish. Available anadromous habitat in the American River watershed has been reduced from 161 miles to 23 miles.

Adult Chinook salmon begin to enter the American River in August. Upstream migration peaks in October. Spawning generally commences close to November 1 and peaks in late November. Early spawning success is low if water temperature in early November is above 60° F . American River Chinook salmon escapement has averaged 41,895 since 1952 and ranged from 6,437 to 110,903 (Figure 16-15). Peaks in escapement over 60,000 fish occurred in 1973, 1974, 1981, 1985, 1995, 1996, 1998, and 2000. Low escapements, less than 20,000, fish occurred in 1955, 1956, 1957, 1990, and 1992.

Juvenile Chinook emigration from the American River generally begins in December, peaks in February and March and tails off into June. Nearly all (>99 percent) of the emigrating Chinook salmon from the American River moving past the smolt traps at Watt Avenue are pre-smolts. This suggests that the smolting process is not completed in the lower American River but will continue downstream, likely in the Delta and estuary (Snider and Titus 2000). The 2001 outmigration past Watt Avenue was estimated to be 25 million fish, the largest measured from the American River since rotary screw trapping began (Bill Snider, personal communication, 2001).

The main stressors identified in the American River include an altered flow regime, high water temperatures, hatchery operations and reduced habitat complexity and diversity. The operation of Folsom and Nimbus Dams for water delivery and flood control can affect all of the stressors directly or indirectly.

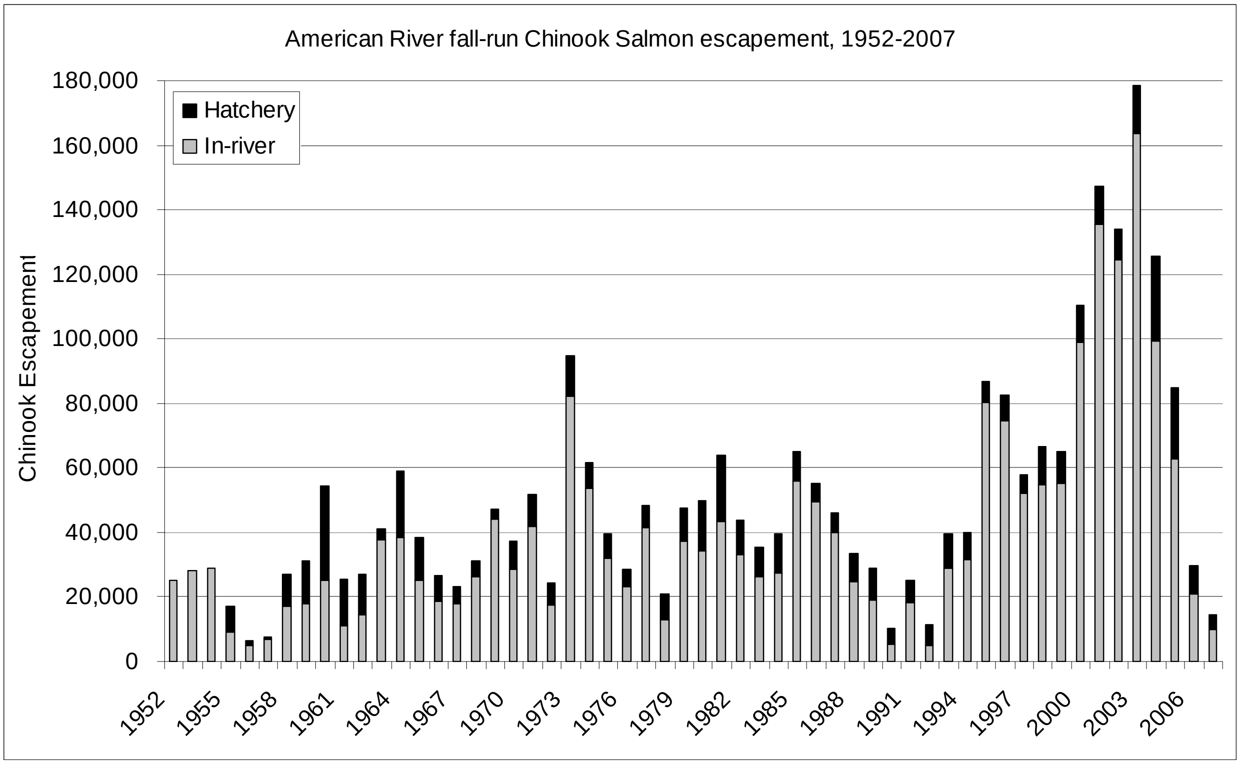


Figure 16-15 American River Chinook salmon escapement estimates, 1952-2007.

Dam operations store water runoff during winter and spring to be released for instream flows, water delivery, and water quality during late spring, summer and fall. Historical high flows in the river have been dampened for flood control and water storage. Moderate flows of around 1,500 to 2,500 cfs have been extended throughout much of the year to provide appropriate instream flows for fish, water quality in the Delta and water for pumping in the Delta. The long-term effect of the lack of high flows is the simplification of instream habitat. High channel forming flows maintain high quality spawning habitat and riparian floodplain conditions. High flows mobilize spawning sized gravels from streambanks and incorporate them into the active channel. Low flows that typically occurred in late summer and fall do not occur because of the dampening effect of the dam operations. High flows are not as high as occurred under natural conditions but the duration of high flows is longer because flood control operations spread them out over time. The longer duration of moderately high flows may be sufficient enough to wash quality spawning gravel out of riffles and deposit it in deeper water where it is unavailable for spawning but not high enough to mobilize new gravel supplies from the extensive gravel bars, banks, and floodplain. Ayres Associates (2001) used detailed topography of the river to model sediment mobilization at various flows in the American River. They found that at 115,000 cfs (the highest flow modeled) particles up to 70 mm median diameter would be moved in the high density spawning areas around Sailor Bar and Sunrise Avenue. Preferred spawning gravel size is 50-125 mm (2-5 inches) in diameter.

Flow fluctuations (below flood release flows) occur as a result of Delta water quality conditions requiring increased releases to maintain water quality for the desired pumping rates. Flow fluctuations can cause stranding of fish and dewatering of redds when the flows are reduced.

Based on cross sections measured in 1998 by the FWS, flow changes of 100 cfs generally change the water depth by about 1 inch in a flow range of 1,000 to 3,000 cfs and by about 0.5 inch in a flow range from about 3,000 to 11,000 cfs. These depth changes vary throughout the river depending on the channel configuration at a location. Decreases in water depth of about 6 inches following spawning can begin to dry up the shallowest redds and will change water velocity over and through the redds.

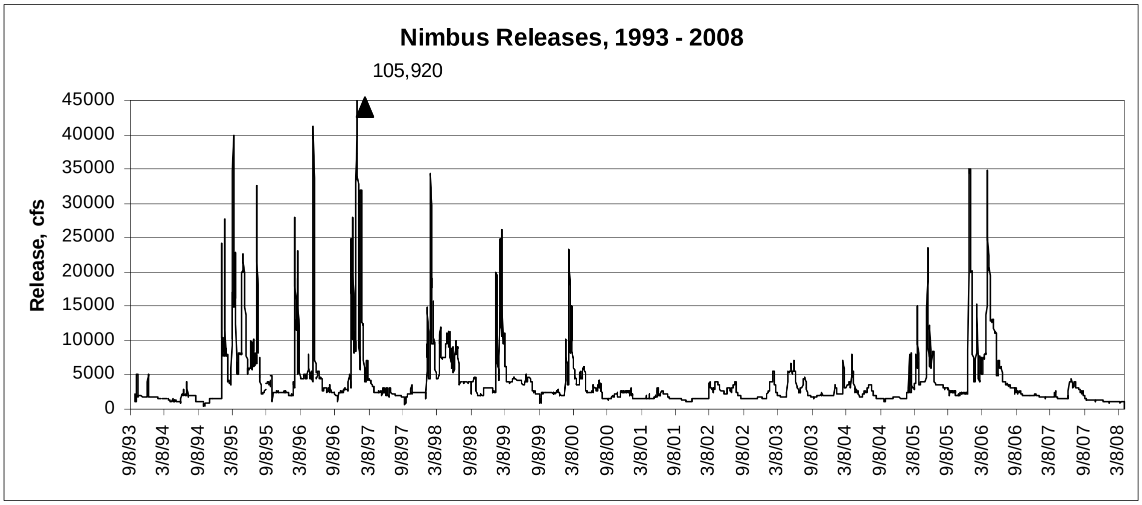
Snider (2001) is evaluating the effects of flow fluctuations on salmon stranding in the American River. Aerial photos and ground truthing were used to measure areas isolated during flow changes. The greatest area isolated occurs at flows around 11,000 cfs (183 acres) and 8,000 cfs (85 acres). Smaller areas of isolation occur around 4,000 cfs (3.6 acres), 3,000 cfs (14.5 acres), 2,000 cfs (13.3 acres), and 1,000 cfs (12.7 acres). Although off-channel areas are important salmon habitat, when salmonids become isolated in off-channel areas for extended periods mortality occurs.

The period of concern for flow fluctuations causing stranding of redds and juvenile Chinook in the American River extends from the initiation of spawning at about the beginning of November until juveniles have emigrated from the river, generally by the end of June. Figure 4–22 shows American River flows from 1993-2001.

FWS (1997) measured 21 cross sections of the American River in high density Chinook spawning areas. They estimated the flows at which the greatest usable spawning area would be available based on water velocity, water depth, and substrate size. Most cross sections showed the greatest usable spawning area available to be in a flow range between 1,600 and 2,400 cfs. Table 16-5shows the average of the weighted usable spawning area from the 21 cross sections expressed as 1,000 square feet of spawning area per 1,000 feet of stream. Weighted usable spawning area peaked at a flow of 1,800 cfs.

In order to maximize survival from egg to fry, flows need to be maintained near or above the level at which spawning occurred. Chinook spawning occurs at water depths greater than about 6 inches. Drops in flow greater than about 500 cfs from the preferred spawning flows following spawning need to be carefully considered. A 500 cfs drop will lower water level in most areas by about 5 inches. Some mortality could occur when water flow over redds drops as flow drops but mortality is greatest when redds begin to become dewatered. Because most Chinook do not spend much time rearing in the American River, spawning habitat may be a limiting factor to Chinook production. Most spawning occurs upstream of the Goethe Park side channels, where river channel gradients are generally higher and riffles more frequent.

Folsom Dam storage capacity is small relative to the annual runoff from the watershed. Because of this, the amount of cold water that can be stored during the winter for release during the summer and fall is limited. Chinook typically begin to show up in the American River in August. Spawning usually initiates about November 1 or when water temperatures fall below a daily average of 60° F . A temperature of 56° F or below is best for survival of incubating eggs. In dry years, such as 2001, water temperature does not reach 60° F until mid-November. A dense school of Chinook holds below the hatchery diversion weir from October until spawning commences. The hatchery opens the fish ladder when water temperature reaches 60° F , typically late October to mid-November. If spawning is delayed past mid-November, the typical peak in spawning, then significant mortality of eggs or pre-spawning mortality may occur. Fish holding in high densities are particularly vulnerable to the effects of high water temperatures, which when coupled with low streamflow can deplete dissolved oxygen and increase disease.



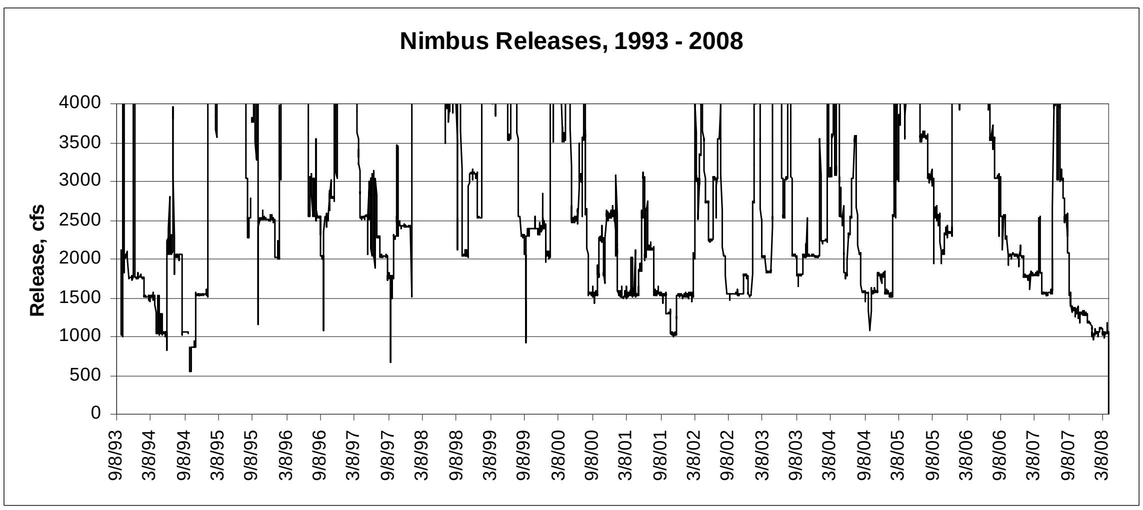


Figure 16-16 American River flows as released from Nimbus Dam, 1993-2008. The top chart shows the entire hydrograph. The bottom chart shows a close-up of the 0 to 4000 cfs range.

Table 16-5 Average weighted usable spawning area in the American River (expressed as 1,000 square feet of spawning area per 1,000 feet of stream) from 21 cross sections measured in 1996. Summarized from FWS 1997.

Flow (cfs)	*Average Weighted Usable Area, 1996*
1000	62
1200	71
1400	78
1600	82
1800	84

Flow (cfs)	*Average Weighted Usable Area, 1996*
2000	83
2200	81
2400	78
2600	74
2800	69
3000	65
3200	60
3400	56
3600	52
3800	48
4000	45
4200	42
4400	38
4600	36
4800	33
5000	31
5200	28
5400	26
5600	25
5800	23
6000	21

American River water temperatures are typically suitable for egg incubation once water temperature cools to 56° F . Before cooling to 56° F , temperature-related mortality of spawned Chinook eggs may occur. Generally temperatures reach 56° F by early December. Cool water temperatures are then sustained through winter egg incubation and juvenile rearing and emigration through the spring.

Efforts are underway by various groups coordinated by the Water Forum to improve American River water temperatures for salmonids. A funding proposal has been submitted for temperature curtains in Lake Natoma. Temperature curtains may lower water temperatures in the river by 3° F during summer and fall. Mechanization and reconfiguration of the temperature shutters on Folsom Dam has also been proposed. The temperature shutter work is expected to improve flexibility in operation of the shutters to spread out cold water availability for a longer period of the year. Construction is underway on Folsom Dam water supply intake to reduce depletions from the coldwater pool. El Dorado Irrigation District is also pursuing a new water intake which would be constructed so that water would not be taken from the cold water pool. Efforts are underway to raise Folsom Dam to provide better flood protection to downstream urban areas. If the dam is raised then the increased storage capacity may alleviate the water temperature concerns in many years.

Reclamation funds operation of Nimbus Salmon and Steelhead Hatchery as mitigation for the habitat blocked by construction of Nimbus and Folsom Dams. An average of 9,370 adults, 22 percent of the average in-river escapement, have been taken at the hatchery each year since 1955.

The hatchery production goal is for 4,000,000 fall Chinook salmon smolts each year. The smolts are released into San Pablo Bay to increase survival over in-river releases. A recent review of hatchery practices in California (DFG and NMFS 2001) recommended discontinuing releases downstream of the American River. They recommended instead to consider releasing Chinook smolts at the hatchery during periods when flow releases can be obtained to maximize smolt survival through the Delta. No consistent coded wire tagging program has been in place so the proportion of the returning salmon that are of hatchery origin v. in-river spawned is unknown. A portion of the release group was coded wire tagged in 2001. This should allow estimates of contribution to commercial and sports fisheries to be made. The proportion of hatchery production contributing to in-river spawning should be able to be determined by comparing the proportion of adipose clipped fish in the carcass mark-recapture survey escapement estimate to the proportion of the release group tagged. Coded wire tagging is recommended to continue to determine contribution to commercial and sports fisheries and survival to spawning.

Stanislaus River

The Stanislaus River is the northern most major tributary to the San Joaquin River. Average monthly unimpaired flows at New Melones Dam are approximately 96,000 af. These flows are reduced to approximately 57,000 af at Ripon, near the confluence with the San Joaquin River, due to flow diversion and regulation at Goodwin Dam.

Goodwin Dam is about 15 miles below New Melones. It serves as the limit to upstream migration for anadromous fish. Anadromous habitat has been reduced from 113 miles to 46 miles. There are approximately forty small, unscreened pump diversions (for agricultural purposes) along the river. New Melones Reservoir is operated to store water during the winter and spring and release it during the summer (San Joaquin River Group Authority 1999).

Adult Chinook salmon begin to return to the Stanislaus River in August with the peak in returns occurring in October. Spawning activity peaks in November and continues into January. Adult Chinook have occasionally been observed in the Stanislaus as early as May. Stanislaus River Chinook escapements have averaged 5,556 and ranged from 0 to 35,000 between 1947 and 2000 (Figure 16-17). Peaks in escapement of over 10,000 fish occurred in the late 1940s, early 50s, late 60s and early 70s, and mid 80s.

The downstream migration of Chinook salmon fry and smolts in the Stanislaus River generally begins in December with newly emergent fry and continues into June. A majority emigrate as fry in January through March. A smaller proportion rear for about one to four months in the river before emigrating. While out-migration of smolts does not appear to be triggered by high flows (Demko et al. 2000), peaks in movement of fry are often correlated with high flow events. When high flow events do not occur, a greater proportion of fry establish rearing territories in the river and remain there longer. Figure 16-18 shows recent Chinook outmigration estimates and prior fall spawning escapement estimates. Higher escapements appeared to result in higher juvenile outmigration until 2001 when outmigration was low. This may be due to the lack of freshets during the outmigration period in 2001 resulting in more fish remaining in the river longer, decreasing in-river survival.

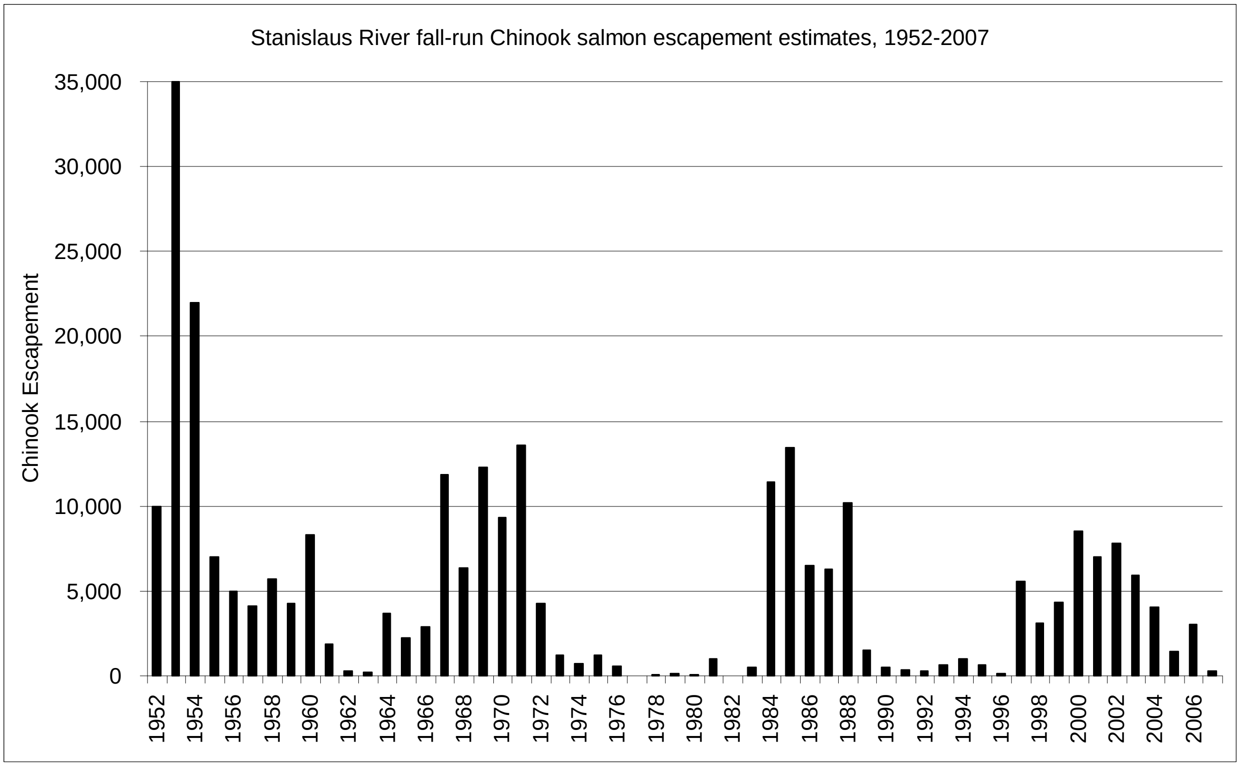


Figure 16-17 Chinook salmon escapement in the Stanislaus River, 1952-2007.

The main Chinook salmon stressors identified in the Stanislaus River include an altered hydrograph lacking peak flows, water temperatures during summer and fall, predation by striped bass and pikeminnows, and a shortage of spawning gravel. Operation of New Melones and Goodwin Dam for water delivery and flood control can affect all of these stressors, directly or indirectly.

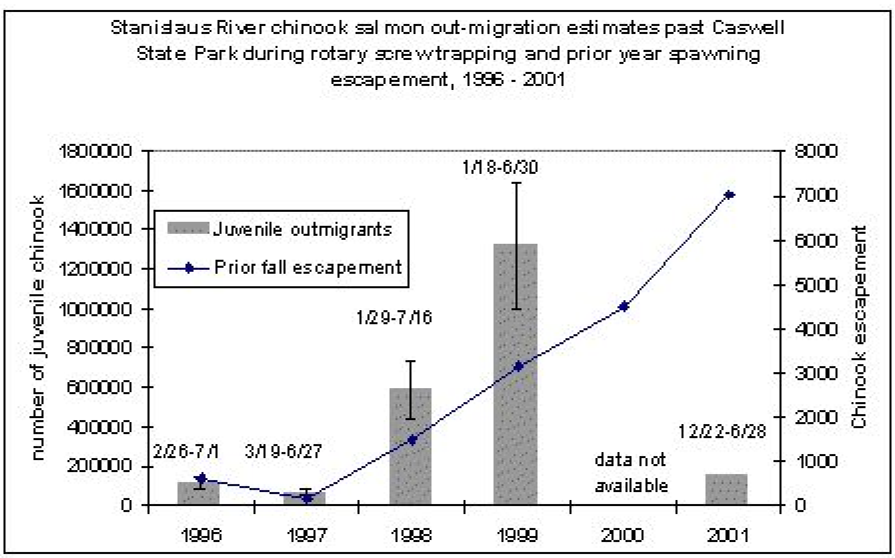
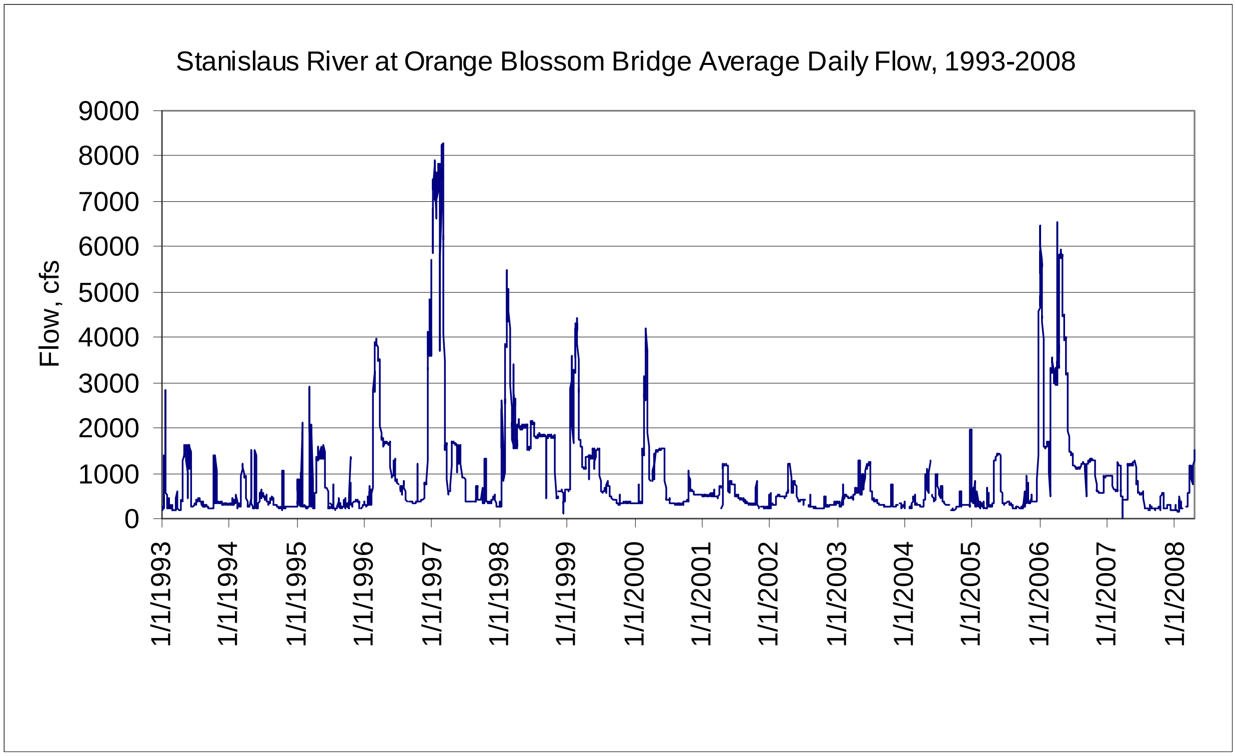


Figure 16-18 Stanislaus River Chinook salmon out-migration estimates past Caswell State Park during rotary screw trapping and prior year spawning escapement, 1996-2001.

Error bars are 95 percent confidence intervals. Dates of trapping are shown above the bars. 1996-97 trapping captured only the latter part of the run. 1996-99 data is from Demko et al. (2000). 2001 estimate calculated from data provided by S.P. Cramer & Associates.

Dam operations store water during winter and spring for releases to irrigators during late spring, summer, and fall. Historical high flows in the river have been dampened for flood control and water storage (Figure 16-19) The 20-year flood flow has been decreased by eight times compared to the historic flow. Moderate flows of around 300-600 cfs have been extended out through much of the year to provide better water quality in the Stanislaus for fish and in the Delta for pumping operations. The long-term effect of the lack of high flows is the simplification of instream habitat. High channel forming flows maintain high quality spawning habitat and riparian floodplain conditions. With reduced flows, riparian vegetation along the banks has become more stable. When high flows do occur they are unable to reshape the channel as occurred historically when high flood flows were more frequent events. High flows mobilize spawning sized gravels from streambanks and incorporate them into the active channel. In the absence of high flows, spawning habitat quality has decreased. In addition, the dams have eliminated recruitment of spawning gravel from upstream sources. Based on an aerial photo analysis 161,400 square feet (30 percent) of spawning gravel was lost between 1961 and 1972 and 150,600 square feet was lost between 1972 and 1994. Spawning gravel additions have occurred regularly in an attempt to maintain good spawning habitat.



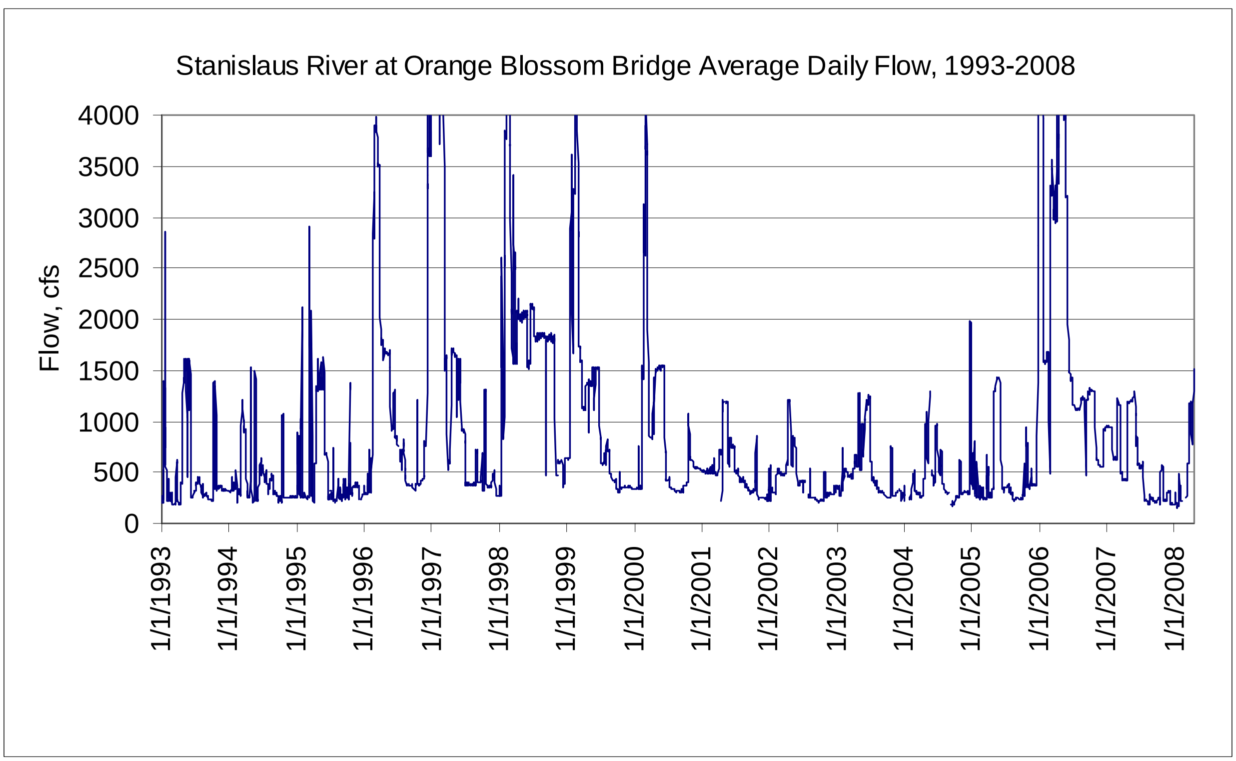


Figure 16-19 Stanislaus River flow at Orange Blossom Bridge, 1993-2008. The top chart shows the entire hydrograph. The bottom chart shows a close-up of the 0 to 4000 cfs range.

Access to upstream habitat, where water temperatures are cooler, has been blocked by the dams. Therefore, cool water temperatures are critical in the available anadromous habitat. The summer time release of water stored in upstream reservoirs provides late summer flows higher than those that occurred historically. These releases have allowed anadromous fisheries populations to persist in the remaining accessible habitat below Goodwin Dam.

Predation by introduced striped bass and native pikeminnows may be a significant stressor to juvenile fish rearing in the river. Cooler water lowers the metabolic rate of predators and likely reduces the effect of predation. Gravel mining along the river has created backwater areas where there is no flow, allowing the water to become warmer. Predators such as striped bass, pikeminnows, and largemouth bass do well in these backwater areas and may use them as refuge habitat from the cooler water areas.

Aceituno (1993) applied the instream flow incremental methodology to the Stanislaus River between Riverbank and Goodwin Dam (24 river miles) to help to determine instream flow needs for Chinook salmon and steelhead. Table 16-6 gives the resulting instream flow recommendations for Chinook salmon.

Studies are underway in the Stanislaus to determine the best spring time flow regimes to maximize survival of juvenile Chinook. The studies utilize survival estimates from marked hatchery fish released at various flows (Table 16-7). These tests took place during the VAMP flows which occur after the peak outmigration period from the Stanislaus River.

Table 16-6 Instream flows (cfs) that would provide the maximum weighted usable area of habitat for Chinook salmon in the Stanislaus River between Goodwin Dam and Riverbank[1].

Life Stage	*Dates*	*Number of days*	*Flow at Goodwin (cfs)*	*Dam release (af)*
Spawning	October 15 - December 31	78	200	46,414
Egg Incubation/Fry Rearing	January 1 - February 15	46	150	13,686
Juvenile Rearing	February 15 - October 15	241	200	95,605
Total		365		155,705

1Source: Aceituno 1993.

Table 16-7 Stanislaus River summary of past smolt survival tests.

Stanislaus River Summary of Past Smolt Survival Tests

Year	tag codes	Rel. Start	Rel. End	Flow at OBB (cfs)	Avg. Temp at Ripon1	Rel. Location	# Released	Release Length (mm)	Recoveries at Oakdale	Survival to Oak RST	Recoveries at Caswell	Survival to Cas RST	Recoveries at Mossdale2	Riverwide Survival
1986		28-Apr	28-Apr	1200	62	Knights Ferry			na	na	na	na		
		28-Apr	28-Apr	1200	62	Naco West			na	na	na	na		0.59
1988	b6-11-05, -06	26-Apr	26-Apr	900	60	Knights Ferry	71,675	75.2	na	na	na	na	278	0.54
	b6-11-03, -04	26-Apr	26-Apr	900	60	Naco West	68,788	79.6	na	na	na	na	828	
1989	b6-14-09,-10	20-Apr	20-Apr	900	64	Knights Ferry	103,863	77.4	na	na	na	na	471	0.37
	b6-01-01, -14-11	19-Apr	19-Apr	900	64	Naco West	74,073	76.5	na	na	na	na	860	
	b6-14-12	3-May	3-May			Naco West	46,169	72.4	na	na	na	na	173	
1999		1-Jun	1-Jun	1300	60	Knights Ferry	25,536		156	0.77	35	0.07		
		1-Jun	1-Jun	1300	60	RM 40	4,975	84.4	na	na	10	0.10		
		2-Jun	2-Jun	1300	60	RM 40	4,403	83.2	na	na	7	0.08		
					60	RM 40 (combined)	9,378	83.8	na	na	17	0.09		
		1-Jun	1-Jun	1300	60	RM 38	4,981	85.3	na	na	8	0.08		
		2-Jun	2-Jun	1300	60	RM 38	5,007	84.8	na	na	8	0.08		
					60	RM 38 (combined)	9,998	85.1	na	na	16	0.08		
2000		18-May	19-May	1500	61	Knights Ferry	77,438		546	0.73	127	0.13		
		20-May	20-May	1500	61	Two Rivers	50,547		na	na	na	na		0.57

1 1986-1989 from CDFG reports. 1999 and 2000 from SPCA Caswell.

2 1988 & 1989 from Demko's files of Mossdale catch.

Feather River

The lower Feather River has two runs of Chinook salmon, the fall-run and spring-run. Adult fall-run typically return to the river to spawn during September through December, with a peak from mid-October through early December. Spring-run enter the Feather River from March through June and spawn the following autumn (Painter et al. 1977). Fry from both races of salmon emerge from spawning gravels as early as November (Painter et al. 1977; DWR unpublished data) and generally rear in the river for at least several weeks. Emigration occurs from December to June, with a typical peak between January and March (Figure 16-20). The vast majority of these fish emigrate as fry (DWR unpublished data), suggesting that rearing habitat is limiting or that conditions later in the season are less suitable. Risks for late migrating salmon include higher predation rates and high temperatures. The primary location(s) where these fish rear is unknown, however in wetter years it appears that many young salmon rear for weeks to months in the Yolo Bypass floodplain immediately downstream of the Feather River before migrating to the estuary (Sommer et al. 2001b).

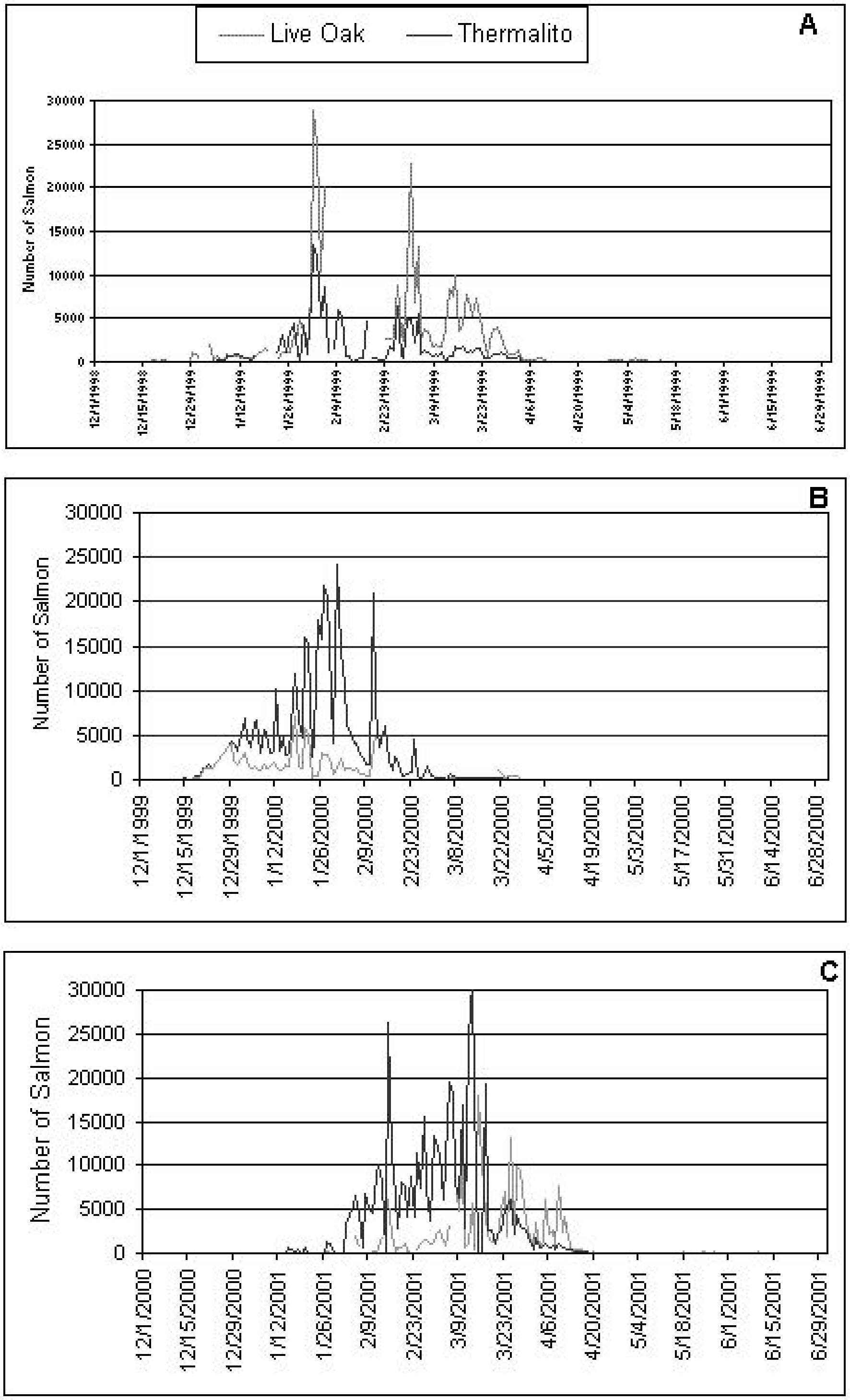


Figure 16-20 Daily catch distribution of fall-run Chinook salmon caught at Live Oak and Thermalito rotary screw traps during 1998, 1999, and 2000 (trapping years a, b, and c, respectively).

Historical distribution and abundance of Chinook salmon in the Feather River is reviewed by Yoshiyama et al. (2001). They note that fall-run historically spawned primarily in the mainstem river downstream of the present site of Lake Oroville, while spring-run ascended all three upstream branches. Fry (1961) reported fall-run escapement estimates of 10,000 to 86,000 for 1940-59, compared to 1,000 to about 4,000 for spring-run. Recent fall-run population trends continue to show annual variability, but are more stable than before Oroville Dam was completed (Figure 16-21). Pre-dam escapement levels have averaged approximately 41,000 compared to about 46,000 thereafter (see also Reynolds et al. 1993). This increase appears to be a result of hatchery production in the system.

Hatchery History and Operations

Feather River Hatchery was opened in 1967 to compensate for the loss of upstream habitat by the construction of Oroville Dam. The facility is operated by the DFG and typically spawns approximately 10,000 adult salmon each year (Figure 16-21). Until the 1980s, the majority of the young hatchery salmon was released into the Feather River (Figure 16-22). However, the release location was shifted to the Bay-Delta Estuary to improve survival. DFG is now considering shifting the release of at least a portion of the hatchery fish back to the Feather River to reduce the potential for straying into other watersheds.

Hydrology

The Feather River drainage is located within the Central Valley, draining about 3,600 square miles of the western slope of the Sierra Nevada (Sommer et al. 2001a). The reach between Honcut Creek and Oroville Dam is of low gradient. The river has three forks, the North Fork, Middle Fork, and South Fork, which meet at Lake Oroville. Lake Oroville, created by the completion of Oroville Dam in 1967, has a capacity of about 3.5 million acre-feet (MAF) of water and is used for flood control, water supply, power generation, and recreation. The lower Feather River below the reservoir is regulated by Oroville Dam, Thermalito Diversion Dam, and Thermalito Afterbay Outlet. Under normal operations, the majority of the Feather River flow is diverted at Thermalito Diversion Dam into Thermalito Forebay. The remainder of the flow, typically 600 cfs, flows through the historical river channel, the “low flow channel” (LFC). Water released by the forebay is used to generate power before discharge into Thermalito Afterbay. Water is returned to the Feather River through Thermalito Afterbay Outlet, then flows southward through the valley until the confluence with the Sacramento River at Verona. The Feather River is the largest tributary of the Sacramento River.

The primary area of interest for salmon spawning is the low flow channel, which extends from the Fish Barrier Dam (river mile 67) to Thermalito Afterbay Outlet (river mile 59), and a lower reach from Thermalito Afterbay Outlet to Honcut Creek (river mile 44). There is little spawning activity in the Feather River below Honcut Creek.

The hydrology of the river has been considerably altered by the operation of the Oroville complex. The major change is that flow that historically passed through the LFC is now diverted into the Thermalito complex. Mean monthly flows through the LFC are now 5 percent to 38 percent of pre-dam levels (Figure 16-23). Mean total flow is presently lower than historical levels during February through June, but higher during July through January.

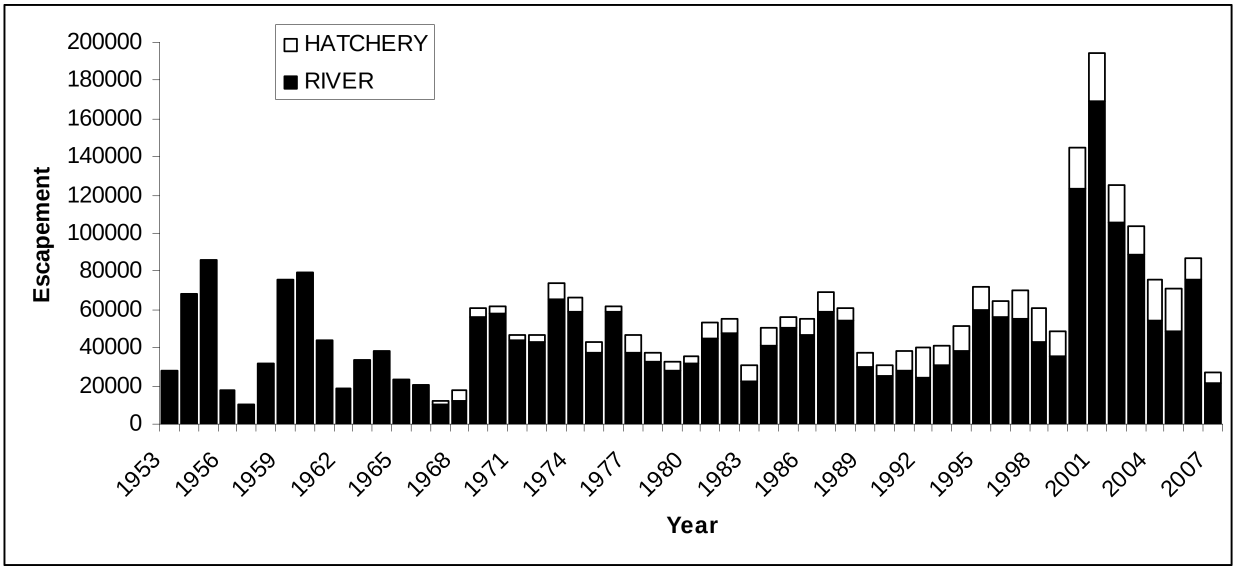


Figure 16-21 Escapement of fall-run Chinook salmon (1953-2007) in the FRH and river.

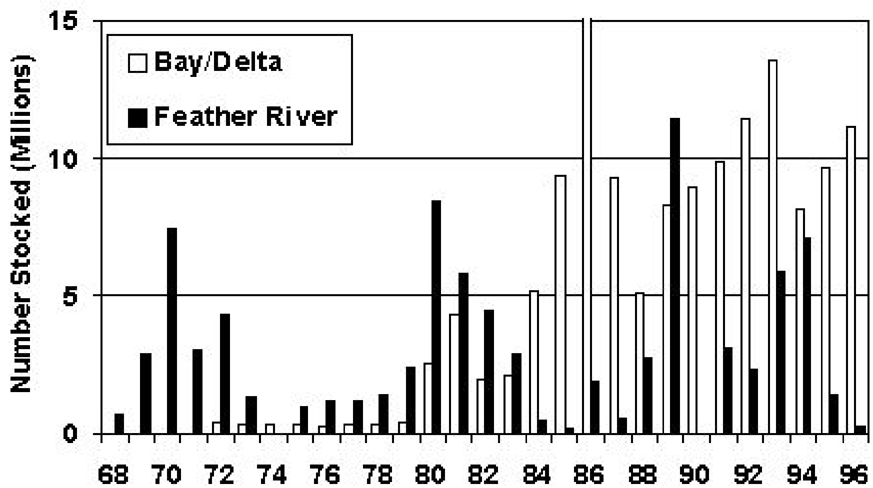


Figure 16-22 Stocking rates of juvenile salmon from the FRH into river and Bay-Delta locations.

Project operations have also changed water temperatures in the river. Compared to historical levels, mean monthly water temperatures in the LFC at Oroville are 2° F to 14° F cooler during May through October and 2° F to 7° F warmer during November through April. Pre-project temperature data are not available for the reach below Thermalito Afterbay Outlet, but releases from the broad, shallow Thermalito Afterbay reservoir probably create warmer conditions than historical levels for at least part of the spring and summer.

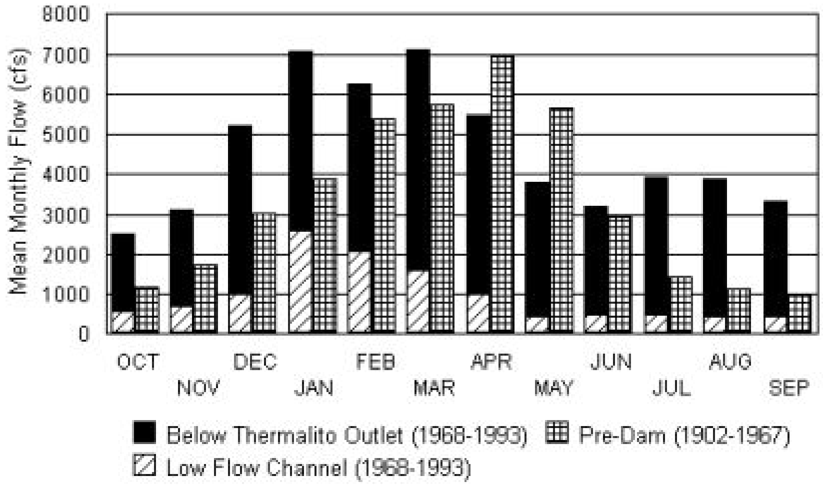


Figure 16-23 Mean monthly flows (cfs) in the Feather River for the pre-Oroville Dam (1902-67) and post-Oroville Dam (1968-93) periods.

Total flow in the post-dam period includes the portion from the low flow channel and the portion diverted through the Thermalito complex.

Spawning Distribution

Since the construction of Oroville Dam and FRH, there has been a marked shift in the spawning distribution of Chinook salmon in the lower Feather River. Salmon have shifted their spawning activity from predominantly in the reach below Thermalito Afterbay Outlet to the LFC (Figure 16-24) (Sommer et al. 2001a).

An average of 75 percent of spawning activity now occurs in the LFC with the greatest portion crowded in the upper three miles of the LFC. While there is evidence that this upper section of the LFC was also intensively used after the construction of the dam and hatchery, the shift in the spawning distribution has undoubtedly increased spawning densities. The high superimposition indices in the LFC suggest that there is not enough spawning habitat for the large numbers of salmon attempt to utilize the area. It must be observed; however, that the very success of the hatchery is responsible for the large population of adult fall-run spawners. Without the production of the FRH it would be impossible for salmon populations to regularly exceed the river's post-dam carry capacity. Therefore, the high density of hatchery produced salmon spawning at the upstream end of the low flow channel may be attributed to hatchery production levels, and potentially, to a tendency among hatchery fish to return to their place of origin.

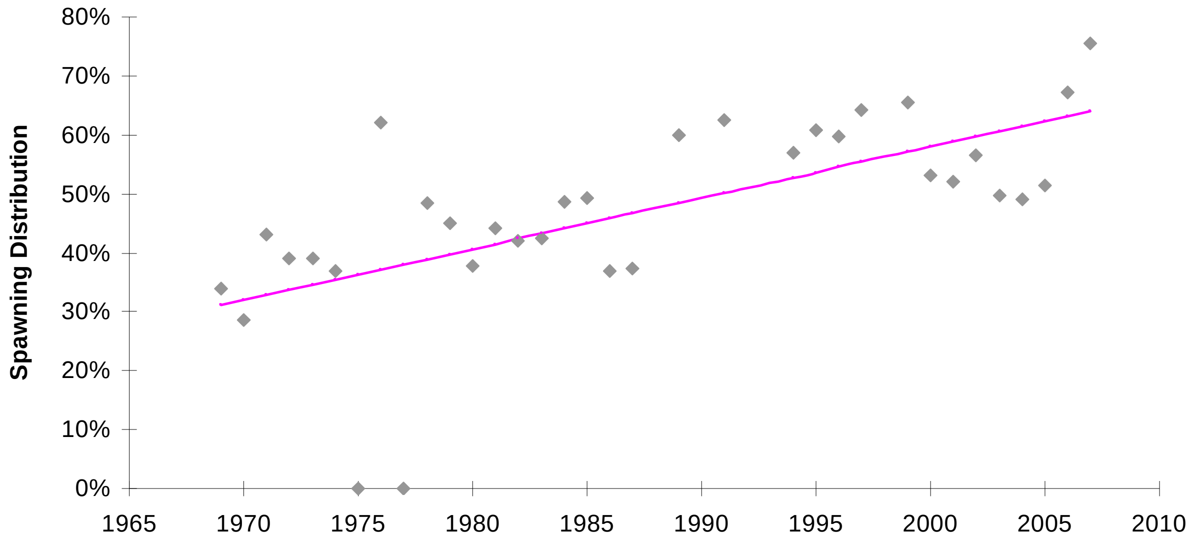


Figure 16-24 The percentage of salmon spawning in the Feather River low flow channel for 1969-2007. The increase is significant at the *P* < 0.001 level.

Currently several studies are underway to evaluate salmon and steelhead populations in the Feather River. Since fall 2000, DWR in cooperation with DFG has conducted salmon spawning escapement data on the Feather River. This survey takes place from September through December. The purpose of this survey is to measure the abundance and distribution of spawning effort among fall-run salmon on the Feather River. The escapement surveys also collects information about the size and sex distribution among the population, and on the rates of pre-spawning mortality among female salmon. DWR staff also operate two rotary screw traps on the Feather River. These traps are located upstream of the Thermalito Outlet and near Live Oak. These traps are operated from November through June and collect information about the abundance of juvenile salmonids and the factors which may influence their migration timing. During the spring and summer DWR also conducts snorkel surveys on the Feather River. The purpose of these surveys is to document abundance, distribution and habitat use among juvenile salmonids during this period of time when the effects of environmental stressors may be most acute.

Summary of effects on EFH for Chinook Salmon

Mortality model outputs for fall run and late fall run Chinook are included at the sections below.

Trinity River

The increased flows in the spring for the restoration program would aid outmigrating Chinook so smolt survival should increase. The habitat benefits provided through more natural geomorphic processes should benefit Chinook salmon.

Temperatures in the Trinity during the fall Chinook spawning period will be slightly increased in the future because more water would be released early in the season. The result will be slight changes in egg mortality based on model results shown in (Figure 16-25).

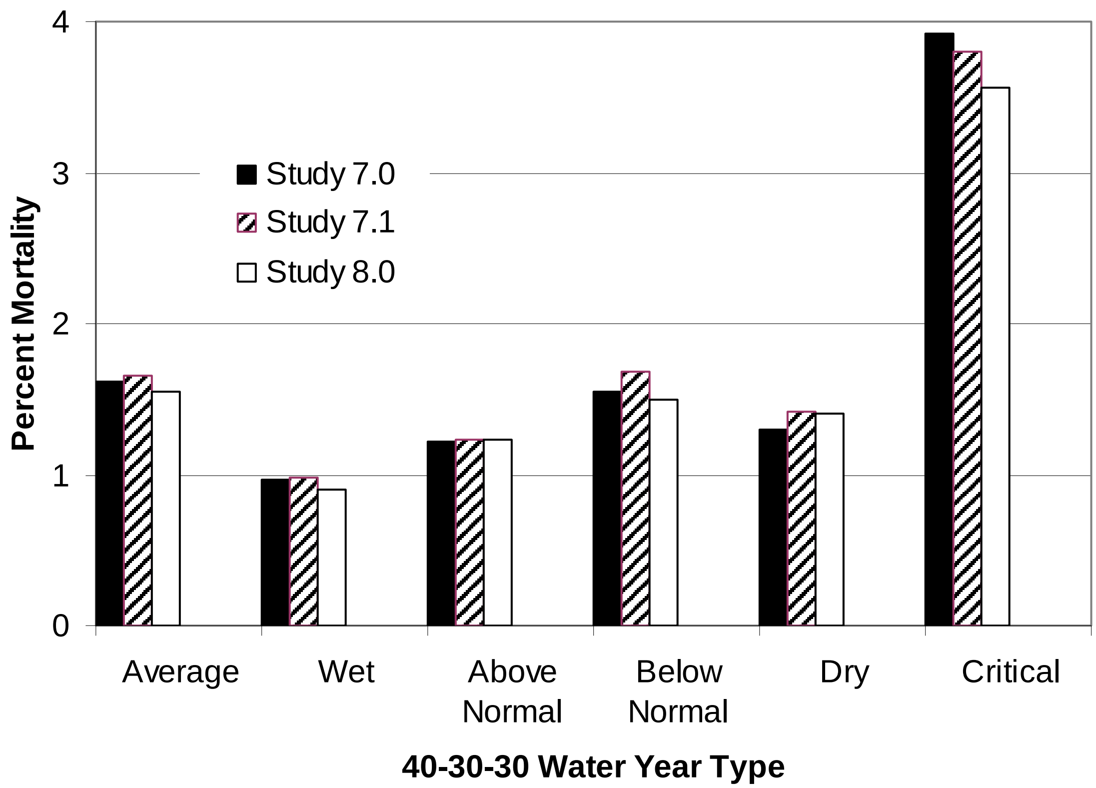


Figure 16-25 Percent mortality of Chinook salmon from egg to fry in the Trinity River based on water temperature by water year type.

Sacramento and San Joaquin Rivers, Delta, San Pablo Bay, and San Francisco Bay

Rearing juveniles migrate down the Sacramento and San Joaquin Rivers and into the Delta and estuaries while rearing. CV fall-run Chinook salmon use the Delta, San Pablo Bay, and San Francisco Bay as a migratory corridor when they move from the ocean to freshwater as adults and from freshwater to the ocean as juveniles. Most movement by adults occurs in deeper channels, while juveniles are more likely to use the shallow habitats, including tidal flats, for feeding. The lower Sacramento and San Joaquin Rivers are used as migratory corridors as the adults move towards their natal streams, which include most tributaries. However, adults use variable paths to reach their spawning grounds depending on time of year and year (McLaughlin and Jeff McLain 2001). Adult migration can be influence by cross-channel operations and salinity gate operations within the Suisun Marsh area (Stein 2000; Vincik 2002).

Upper Sacramento River

Fall/late fall-run spawning in the upper Sacramento River may be affected in some years when flows are dropped off in the fall as water demands decrease. Redd dewatering is possible in some years. This may be the most significant effect of project operations on fall/late fall-run in the upper Sacramento. See Figure 16-26 for Fall-run and Figure 16-27 for late fall-run mortality.

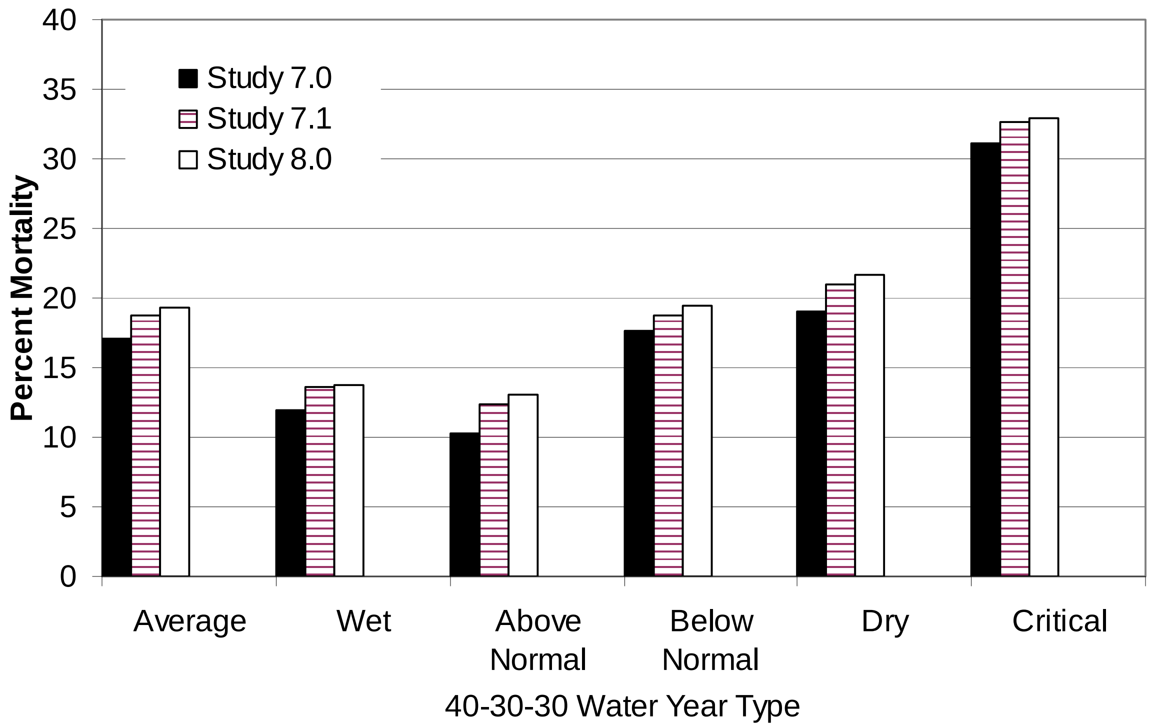


Figure 16-26 Sacramento River Fall-run Chinook Early Life-stage Mortality by Water Year Type

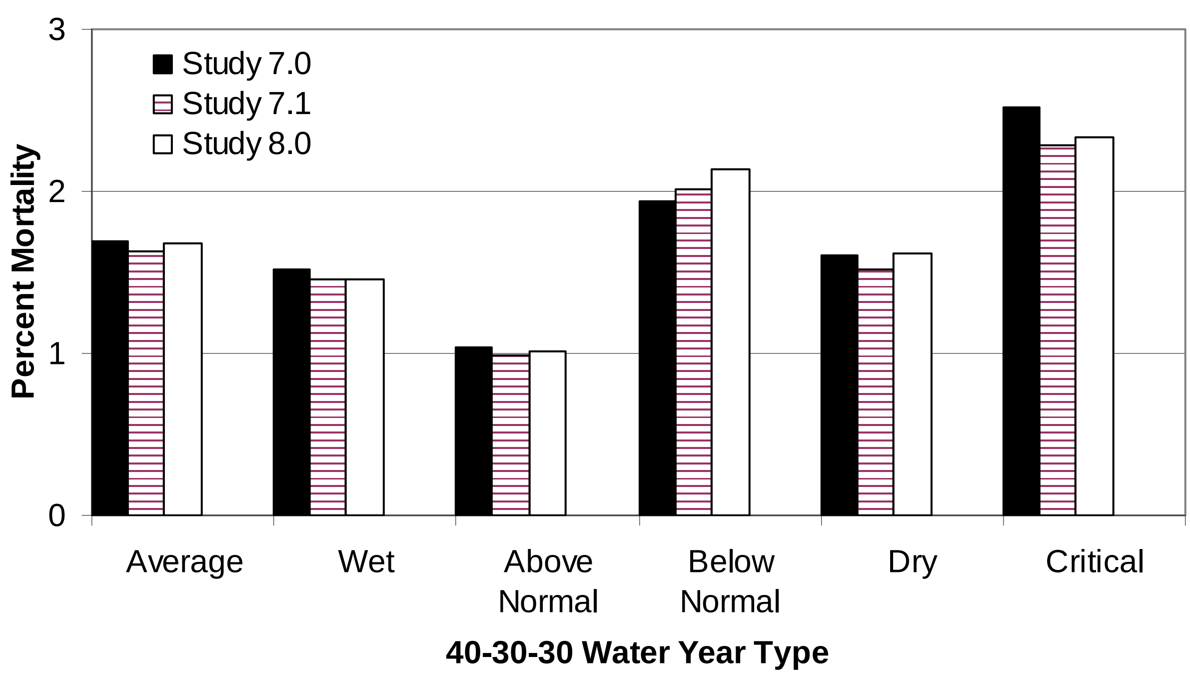


Figure 16-27 Sacramento River Late Fall-run Mortality by Year Type

Clear Creek

Temperatures and flows are generally suitable year round in Clear Creek for fall run Chinook. No adverse effects to EFH for fall run in Clear Creek are anticipated.

Feather River

Flow and water temperature conditions should be generally suitable for all fall–run Chinook salmon life history stages all year in the low flow channel, particularly in the upper low flow channel. Superimposition on spring–run Chinook salmon redds by fall–run Chinook may continue to be a problem. The reach below the Thermalito outlet will be less suitable. Water temperatures below Thermalito will be too warm for adult holding and spawning, but will be appropriate for juvenile rearing and emigration during winter and early spring. See Figure 16-28 .

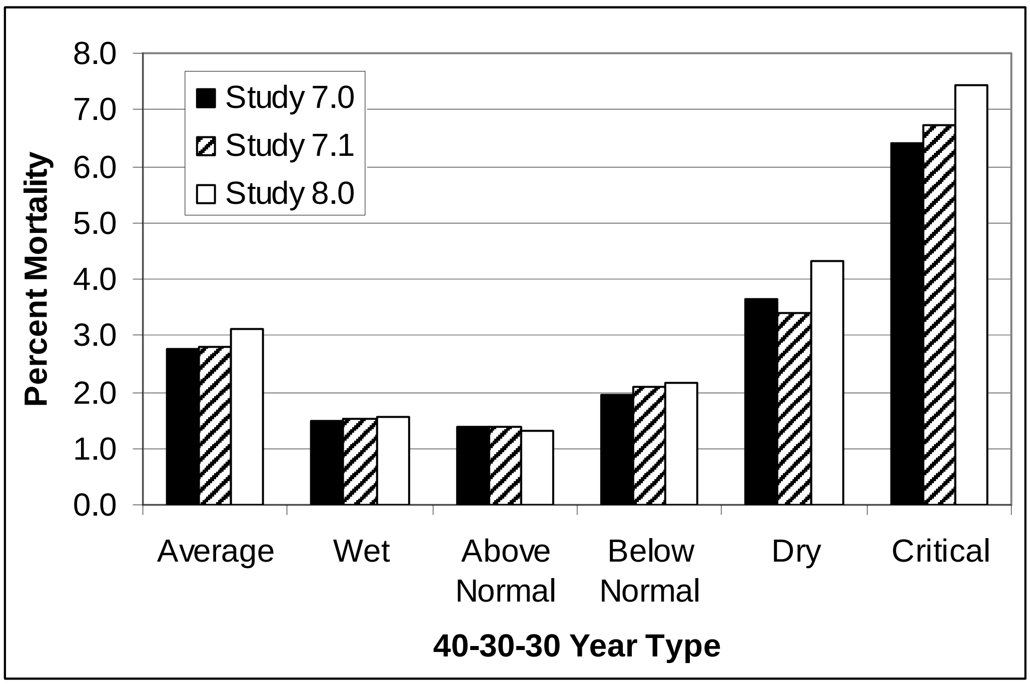


Figure 16-28 Feather River Chinook Salmon Mortality

American River

Flows are projected to be adequate for fall–run Chinook spawning in normal water conditions but if dry conditions occur, flows are projected to provide less than optimal spawning habitat for Chinook. Flows in the spring should be adequate for outmigration. Temperature goals for fall–run Chinook spawning and incubation are projected to be met in November of almost every year but meeting the goals will likely involve trade-offs between providing cool water for better steelhead rearing conditions during the summer and providing it for Chinook spawning in the fall. Water temperatures for Chinook rearing are forecast to exceed the preferred range generally starting in April. Most Chinook leave the river by early April. Temperatures will be higher in

June through November under future operations due to increased upstream diversions, causing more temperature stress on migrating and holding adults in the fall. See Figure 16-29 .

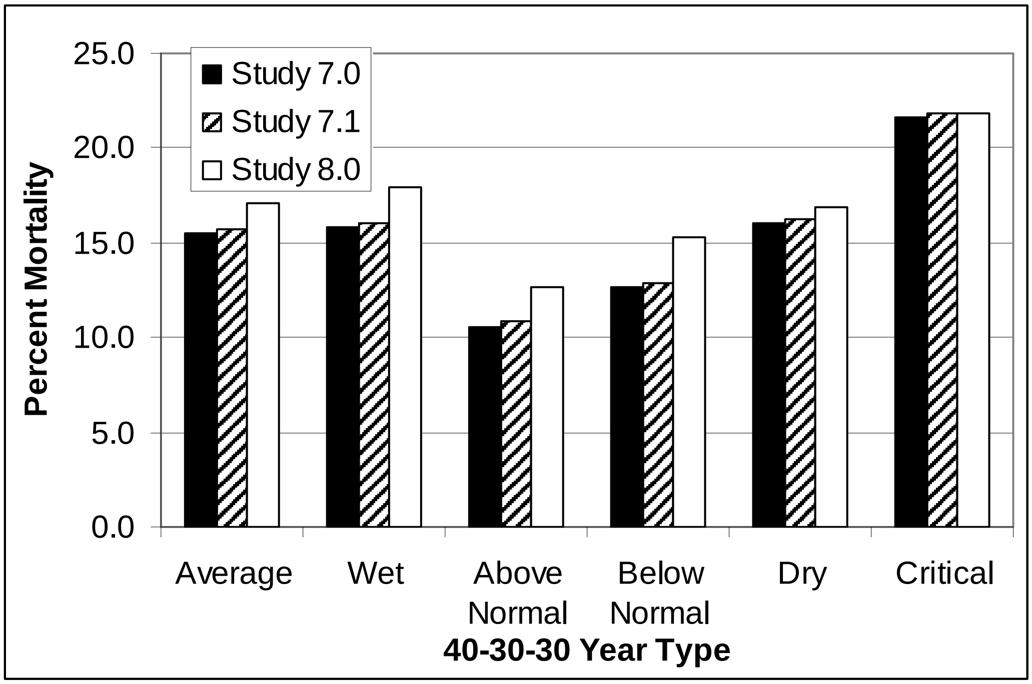


Figure 16-29 American River Chinook Salmon Mortality

Stanislaus River

Flows are projected to be adequate for fall–run Chinook spawning in nearly all years. Water temperatures are generally warm in the lower part of the river during the early part of the immigration period but are they are expected to be suitable for spawning and rearing in the upper river during the entire spawning and rearing period. Temperatures should be suitable for outmigration of fry and smolts, but when dry conditions occur, flows can be less than desired for optimal outmigration prior to the VAMP period. See Figure 16-30 .

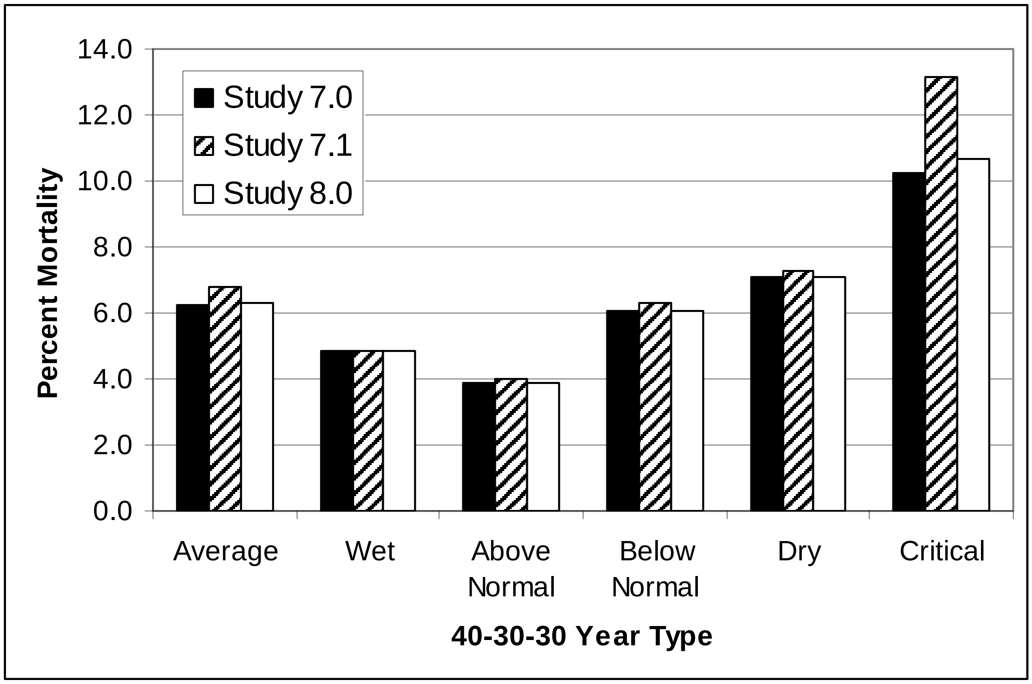


Figure 16-30 Stanislaus River Chinook Salmon Mortality

Delta

Fall and late fall-run Chinook take occurs at the Delta pumping facilities. Protective measures target winter-run and spring-run Chinook salmon, but the VAMP period is intended to focus on the fall and late-fall run through Delta migration peak.

Conclusion Chinook

CVP and SWP operations will adversely affect the EFH of fall run and late fall run Chinook salmon. Chinook salmon EFH in the Trinity River should benefit from the Trinity River ROD flows and other habitat improvement measures.

EFH Conservation Measures for Chinook Salmon

Currently, no recovery plan has been established for Central Valley fall or late fall-run Chinook salmon. However, the following are conservation measures being implemented that could be considered specifically addressing Essential Fish Habitat for Chinook salmon. Additional ongoing measures to improve Chinook salmon habitat are described in chapter 18.

Folsom Dam Temperature Shutter Mechanization

Folsom Dam restricts salmon and steelhead life cycles to the 23-mile lower American River precluding the fish from migrating to their upstream natal spawning grounds. Cold water is necessary to sustain existing spawning and rearing salmon and steelhead populations below the dam. To manage lower American River water temperature, cold water from varying depths in Folsom Lake is withdrawn via shutters located at different elevations on the penstock inlet. The restoration feature would modify and automate the temperature shutters to allow for the flexibility and timeliness needed to optimize management of the coldwater pool to sustain the downstream fishery, including fall-run Chinook. This project was congressionally authorized in 2003 as a part of a multi-purpose (flood control, ecosystem restoration, and dam safety) project and is awaiting appropriations.

Spawning Gravel Enhancement

Reclamation manages spawning gravel injections below CVP dams on the Sacramento, American, and Stanislaus Rivers in cooperation with the Fish and Wildlife Service. This ongoing program is funded yearly and projects are implemented in the three rivers as the need is identified. Gravel augmentation can improve habitat quality for Chinook salmon (Merz and Setka 2004; Merz and Chan 2006; Elkins et al. 2007) and benefits have been documented in each of the rivers. Additionally, monitoring on the Stanislaus has identified benefits of enhanced rearing habitat created by the new gravel for juvenile salmon and steelhead.

Stanislaus Temperature Model

Reclamation cooperates with funding development of a sub-daily water temperature model on the Stanislaus River. The model can be used to identify optimization strategies for coldwater from New Melones Reservoir relative to life cycle needs of salmon and steelhead.

American River Group

Reclamation facilitates the American River Group, a group of stakeholders and biologists who makes recommendations to Reclamation relative to fisheries conditions in the river.

Sacramento River Temperature Control Task Group

This group makes recommendations on how to manage water temperatures throughout the summer in the upper Sacramento River relative to relative to fisheries conditions and coldwater pool storage in Shasta Reservoir.

Chapter 17 Technical Assistance for Longfin Smelt

Longfin Smelt Biology and Population Dynamics

General Biology

Longfin smelt populations occur along the Pacific Coast of North America. Hinchinbrook Island, Prince William Sound, Alaska represents the northernmost documented population and the San Francisco Estuary represents the southernmost population (Lee et al. 1980). Individual longfin smelt have been caught in Monterey Bay (Moyle 2002) but there is no evidence of a spawning population south of the Golden Gate. In California, the largest spawning population is in the San Francisco Estuary. The existence of other spawning populations has been documented or suspected in Humboldt Bay, the Eel River estuary, the Klamath River estuary, the Van Duzen River, the Eel River drainage, and the Russian River (Moyle 2002, Pinnix et al. 2004); most of these populations are small and perhaps ephemeral, if they exist at all. Longfin smelt are periodically caught in nearshore ocean surveys (City of San Francisco 1985). It is possible that longfin smelt individuals may emigrate from or immigrate to the San Francisco Estuary. The degree of demographic and genetic interaction between coastal populations is unknown; however, given their small size and short life span, it is unlikely that the San Francisco Estuary's population size or genetic diversity are supported by regular emigration from other California coastal populations (which are all ephemeral, small, or distant). Longfin smelt are widespread within the San Francisco Estuary and, historically, they were found seasonally in all of its major open water habitats and Suisun Marsh.

In San Francisco Estuary, longfin smelt adults are generally 90-110 mm standard length (SL) at maturity, but some individuals may be up to 140mm SL (Baxter 1999; Moyle 2002). Longfin smelt can be distinguished from other California smelts by their long pectoral fins, incomplete lateral line, weak or absent striations on the opercular bones, low number of scales in the lateral series, low number of scales in the lateral series (54-65) and long maxillary bones. The lower jaw projects forward of the upper jaw when the mouth is closed. Small, fine teeth are present on both jaws, tongue, vomer and palatines. The sides of living fish appear translucent silver while the back has an olive to iridescent pinkish hue. Mature males are usually darker than females, with enlarged and stiffened dorsal and anal fins, a dilated lateral line region, and breeding tubercles on the paired fins and scales (Moyle 2002).

Longfin smelt generally occur in Suisun, San Pablo, and San Francisco bays as well as in the Gulf of the Farallones, just outside San Francisco Bay. Longfin smelt is anadromous and spawn in the Delta in freshwater. Longfin smelt spawn at 2-years of age. Female longfin smelt may live a third year but it is not certain if they spawn again. Most spawning takes place from February through April. The larval longfin smelt move downstream with the tides until they reach favorable rearing habitat near X2 and, later, downstream into Suisun and San Pablo bays. Larger longfin smelt feed primarily on opossum shrimps *Neomysis mercedis* and *Acanthomysis* spp (Feyrer et al. 2003). Copepods and other crustaceans can also be important food items, especially for smaller fish (DFG unpublished).

Legal Status

The San Francisco Estuary population of longfin smelt was recently advanced to candidacy as an endangered species by the California Department of Fish and Game. As a candidate species, it is afforded all of the protections as formally listed species until a decision has been rendered by the Fish and Game Commission on its status. Longfin smelt is also currently proposed for listing under the federal Endangered Species act.

Distribution, Population Dynamics, and Baseline Conditions

Distribution

Longfin smelt in the San Francisco Estuary are broadly distributed both temporally and spatially, and interannual distribution patterns are relatively consistent (Rosenfield and Baxter 2007). Seasonal patterns in abundance indicate that the population is at least partially anadromous (Rosenfield and Baxter 2007). This is indicated by a decrease in density and distribution in San Francisco Bay up to Suisun Marsh after the first winter of the longfin smelt life cycle, which cannot be attributed solely to mortality because both density and distribution increased during the second winter of the life cycle, just before the spawning season. Sampling by the City of San Francisco during several years in the early 1980s detected longfin smelt in the Pacific Ocean, providing additional evidence that some part of this population migrates beyond the Golden Gate Bridge (City of San Francisco and CH2M Hill 1985). Anadromous populations of longfin smelt occur elsewhere in their range, but the duration of this anadromous phase of their life cycle is unstudied as are the ecology and behavior of longfin smelt in marine environments. However, the detection of longfin smelt within the estuary throughout the year suggests that anadromy is just one of potentially several life history strategies or contingents in this population.

There is also a consistent pattern of bathymetric distribution in that postlarval longfin smelt are associated with deep-water habitats (Rosenfield and Baxter 2007). Longfin smelt in the Lake Washington population also display a depth-stratified distribution (Chigbu et al. 1998; Chigbu 2000). Longfin smelt concentration in deepwater habitats combined with migration into marine environments during summer months suggests that longfin smelt may be relatively intolerant of warm waters that occur seasonally in this estuary.

Longfin smelt migrate upstream to spawn in freshwater during late autumn through winter. The general spawning region is believed to be downstream of Rio Vista on the Sacramento River and downstream of Medford Island on the San Joaquin River Sacramento River, to just downstream of the confluence of these two rivers (Moyle 2002). Limited spawning may also periodically occur in the south Bay (DFG unpublished). Larvae are most abundant in the water column usually from January through April (DFG unpublished), and are one of the most common and abundant species encountered during the 20mm Survey (Dege and Brown 2004). The vertical distribution of longfin smelt larvae is highly associated with the upper portion of the water column (DFG unpublished) The geographic distribution of longfin smelt larvae is closely associated with the position of X2; the center of distribution varies with outflow conditions but not with respect to X2 (Dege and Brown 2004). The center of distribution is consistently seaward of X2 (Dege and Brown 2004). This pattern is consistent with juveniles migrating downstream to low salinity habitats for growth and rearing.

Population Abundance Trends

The population size of longfin smelt in the San Francisco Estuary is measured by indices of abundance generated from different sampling programs. The abundance of age-0 and older fish is best indexed by the Fall Midwater Trawl and Bay Study, while the abundance of larvae and young juvenuiles is best indexed by the 20mm Survey (Figure 17-1). The relationship between these indices and actual population sizes are unknown. Furthermore, basic life-history information (mortality and growth rates) and ecological patterns (e.g. the extent, duration, and outcomes of marine migrations) for this population have received little study. As a result, a quantitative assessment of population viability (i.e., with extinction thresholds and probabilities) has not developed.

The abundance of longfin smelt in the Estuary has fluctuated over time but has exhibited a sharp decline since the early 1980's, and was particularly low during the drought of the early 1990's and recent wet years (Figure 17-1) (Rosenfield and Baxter 2007; Sommer et al. 2007). This decline has also been reflected in a reduction in the percent of trawls that catch longfin smelt throughout the Estuary (Rosenfield and Baxter 2007). Thus, longfin smelt have apparently decreased in abundance and are also less common than they have been historically. Also, whereas the Suisun Marsh sampling program commonly caught small numbers of age class 2 longfin smelt in the late-fall and winter, that program has caught very few spawning-age adult longfin smelt since 1990 (Rosenfield and Baxter 2007). More concerning, the 2007 Fall Midwater Trawl index was the lowest (13) recorded since the survey began in 1967. The recent decline in longfin smelt numbers and those of other pelagic fish species such as delta smelt has become known as the Pelagic Organism Decline (Sommer et al. 2007).

Note that in Figure 17-1 the panels from top to bottom are: fall midwater trawl, 20mm survey, bay study midwater trawl, and bay study otter trawl. Values exceeding the vertical scale on the fall midwater trawl are (in chronological order) 81,740, 59,350, 31,184 and 62,905. There is no fall midwater trawl index for 1974, 1976, or 1979. The 20mm survey started in 1995, and the bay study started in 1980. Error bars for the 20mm survey and bay study are one standard error.

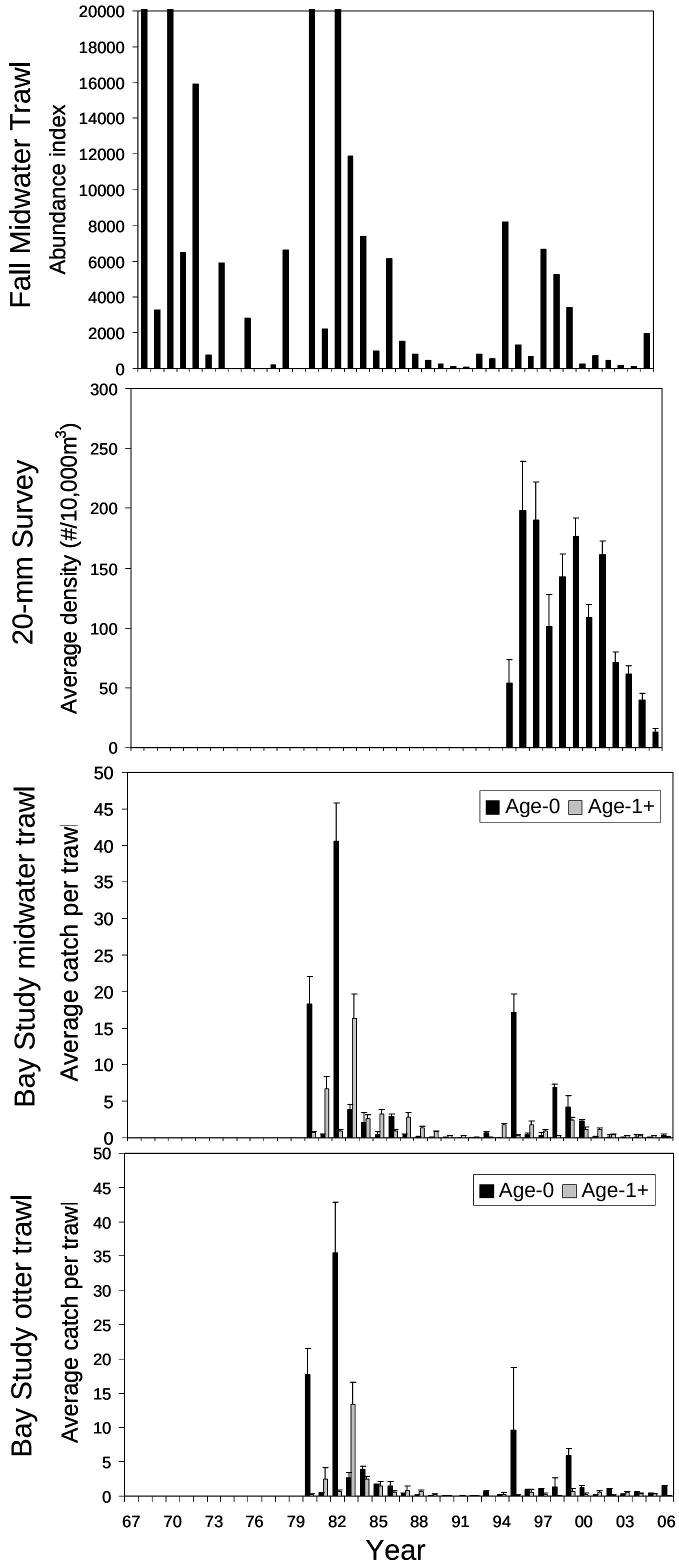


Figure 17-1 Four separate "indices" of longfin smelt abundance in the San Francisco Estuary through 2006.

The Pelagic Organism Decline

The term "Pelagic Organism Decline" (POD) denotes the sudden, overlapping declines of San Francisco Estuary pelagic fishes since about 2002. The POD species include delta smelt, longfin smelt, threadfin shad, and (age-0) striped bass, which together account for the bulk of the pelagic fish biomass in the upper Estuary. The year 2002 is often reckoned as the start of the POD because of the striking declines of three of the four POD species between 2001 and 2002. The POD declines became clearly evident against the high background variability in these species in early 2005, when analysis of the third consecutive year of extremely low numbers in these species made them statistically clear.

Post-2001 abundance indices for the POD species have included record lows for longfin smelt, delta smelt and age-0 striped bass, and near-record lows for threadfin shad. Abundance improved for each species during 2006, but levels for all have remained relatively poor since 2002 for all four species. Low abundance levels have been especially remarkable in that winter and spring river flows into the estuary have been moderate or very wet (2006) during recent years. Moderate to wet conditions have historically usually been associated with at least modest recruitment of most pelagic fish species. Longfin smelt is perhaps the best example of this point as the species shows a very strong relationship with delta outflow. The introduction of the overbite clam (*Corbula amurensis*) in 1986 and associated changes in the food web reduced the magnitude of the response of longfin smelt without altering its slope (Kimmerer 2002). Specifically, the grazing effects from Corbula are thought to have resulted in a substantial decline in phytoplankton and calanoid copepods, the primary prey of early life stages of pelagic fishes. As a consequence, comparable levels of flow did not generate the expected levels of fish biomass (as indexed by abundance) after 1986. During the POD years, the abundance indices for longfin smelt deviated substantially from both the pre-and post-Corbula relationships with outflow. The situation is similar for age-0 striped bass, which has a historical abundance association with outflow that was also altered by *Corbula*, whereas the recent abundance indices were well below expected levels based on outflow. Hence, it appears that the response of these pelagic fishes to environmental conditions has fundamentally changed since the POD (Sommer et al. 2007).

Because of its many management implications, the POD has been the subject of an intensive analytical effort by the Interagency Ecological Program since the POD was recognized in 2005. The POD investigation has greatly improved our understanding of the ecology of pelagic fishes in the Estuary. Content of this chapter and in the formulation of the longfin smelt effects analysis largely reflect changes in our understanding of longfin smelt biology that have emerged from the POD investigation. While mechanisms responsible for POD-era declines of the species probably vary by species, it appears very unlikely that they are independent of one another. Consequently, some of the discussion in the remainder of this chapter involves species other than longfin smelt. This chapter borrows heavily from the text of the 2007 POD Synthesis Report (IEP 2008).

Factors That May Influence the Abundance and Distribution of Longfin Smelt

Numerous factors are hypothesized to have influenced historical population dynamics of longfin smelt (Moyle 2002). Some of these factors (e.g., climatic influences on the physical environment) are thought to exert strong, consistent influences, while others are thought to exert more subtle influences (e.g., factors affecting growth rates), or to be important only under certain conditions (e.g., entrainment losses). Historically, the evidence brought to bear on most mechanistic hypotheses has been based on statistical correlations of abundance and/or survival with environmental variables (Jassby et al. 1995; Moyle 2002; Kimmerer 2002; Sommer et al. 2007; IEP 2007).

For organization we will use the four categories described in the simple conceptual model presented in the POD 2007 Synthesis Report (IEP 2007). Where the POD Team used the model to describe possible mechanisms by which a combination of long-term and recent changes to the ecosystem could produce the observed pelagic fish declines, we use it simply to organize mechanisms that affect abundance and distribution. The conceptual model is rooted in classical food web and fisheries ecology and contains four major components: (1) prior fish abundance, including low-abundance effects that may reduce juvenile production (e.g. stock-recruit effects); (2) habitat, including physical and chemical variables, disease, and localized toxic algal blooms that affect survival and reproduction; (3) top-down effects, including predation, entrainment, and other processes that cause juvenile and adult mortality; (4) bottom-up effects, including food web interactions that affect growth, reproduction, and, indirectly, survival.

Prior Abundance

The relationship between numbers of spawning fish and the numbers of young subsequently recruiting to the adult population is known as a stock-recruit relationship. Stock-recruit relationships have been described for many species and are a central part of the management of commercially and recreationally fished species (Myers et al. 1995). Different forms of stock recruit relationships are possible, including density-independent, density-dependent, and density vague types. The latter refers to situations where there is not a statistically demonstrable stock recruit relationship observable in available data. In any form of a stock-recruit model, there is a point at which low adult stock will result in low juvenile abundance and subsequent low recruitment to future adult stocks even under favorable environmental conditions while the stock ‘rebuilds’ itself.

There has been no demonstrated stock-recruit relationship for longfin smelt in the San Francisco Estuary.

Habitat

Aquatic habitats are the suites of physical, chemical, and biological factors that species occupy (Hayes et al. 1996). The maintenance of appropriate habitat quality is essential to the long-term health of aquatic resources (Rose 2000; Peterson 2003). A key point is that habitat suitability affects most or all other factors affecting abundance and/or distribution. This is because changes in pelagic habitat, to take an example, affect not only affect delta smelt and other pelagic fishes but also their predators and prey.

Habitat for longfin smelt is open water, largely away from shorelines and vegetated inshore areas except perhaps during spawning. This includes large embayments such as Suisun Bay and the deeper areas of many of the larger channels in the Delta. More specifically, longfin smelt habitat is water with suitable values for a variety of physical-chemical properties, especially including salinity, turbidity, and temperature, suitably low levels of contaminants, and suitably high levels of prey production to support growth. Thus, longfin smelt habitat suitability in the estuary can be strongly influenced by variation in freshwater flow (Jassby et al. 1995; Bennett and Moyle 1996; Kimmerer 2004). Several of the POD fishes, including longfin smelt, use a variety of tidally assisted swimming behaviors to maintain themselves within open-water areas where water quality and food resources are favorable (Bennett et al. 2002). The four POD fishes also distribute themselves at different values of salinity within the estuarine salinity gradient (Dege and Brown 2004), so at any point in time, salinity is a major factor affecting their geographic distributions.

Physical Habitat

Changes in longfin smelt habitat quality in the San Francisco Estuary can be indexed by changes in X2. The abundance of many local taxa has tended to increase in years when flows into the estuary are high and the 2 psu isohaline is pushed seaward (Jassby et al. 1995), implying that over the range of historical experience the quantity or suitability of estuarine habitat increases when outflows are high.

Currently, X2 (which is controlled by both climate and water operations) is a strong predictor of the longfin smelt Fall Midwater Trawl index, which suggests flow and its affect on habitat are strong determinants of year class strength for longfin smelt. This is particularly important considering there is no demonstrated stock-recruit relationship for longfin smelt.

Although similar work has not yet been completed for longfin smelt, there has been a long-term decline in fall habitat environmental quality for delta smelt (Feyrer et al. 2007). The long-term environmental quality declines for delta smelt are defined by a lowered probability of occurrence in samples based on changes in specific conductance and Secchi depth. Notably, delta smelt environmental quality declined recently coinciding with the POD (Figure 7-8). The greatest changes in environmental quality occurred in Suisun Bay and the San Joaquin River upstream of Three Mile Slough and southern Delta (Figure 7-9). There is evidence that these habitat changes have had population-level consequences for delta smelt. The inclusion of specific conductance and Secchi depth in the delta smelt stock-recruit relationship described above improved the fit of the model, suggesting adult numbers and their habitat conditions exert important influences on recruitment. Additional discussion pertinent to delta smelt is provided above in the chapter covering delta smelt biology. Given the status of longfin smelt, similar work evaluating their habitat should be initiated immediately.

Contaminants and Disease

In addition to habitat changes from salinity, turbidity and invasive aquatic vegetation such as E. densa, contaminants can change ecosystem functions and productivity through numerous pathways. The trends in contaminant loadings and their ecosystem effects are not well understood. We are currently evaluating direct and indirect toxic effects on the POD fishes of both man-made contaminants and natural toxins associated with blooms of M. aeruginosa (a cyanobacterium or blue-green alga). The main indirect contaminant effect we are investigating is inhibition of prey production.

Although a number of contaminant issues first during the POD years, concern over contaminants in the Delta is not new. There are long standing concerns related to mercury and selenium in the watershed, Delta, and Bay (Linville et al. 2002; Davis et al. 2003). Phytoplankton growth rate may occasionally be inhibited by high concentrations of herbicides (Edmunds et al. 1999). New evidence indicates that phytoplankton growth rate may at times be inhibited by ammonium concentrations in and upstream of Suisun Bay (Wilkerson et al. 2006, Dugdale et al. 2007, Dugdale et al unpublished). Toxicity to invertebrates has been noted in water and sediments from the Delta and associated watersheds (e.g., Kuivila and Foe 1995; Giddings 2000; Werner et al. 2000; Weston et al. 2004). Undiluted drainwater from agricultural drains in the San Joaquin River watershed can be acutely toxic (quickly lethal) to fish and have chronic effects on growth (Saiki et al. 1992). Evidence for mortality of young striped bass due to discharge of agricultural drainage water containing rice herbicides into the Sacramento River (Bailey et al. 1994) led to new regulations for discharge of these waters. Bioassays using caged fish have revealed DNA strand breakage associated with runoff events in the watershed and Delta (Whitehead et al. 2004). Kuivila and Moon (2004) found that peak densities of larval and juvenile delta smelt sometimes coincided in time and space with elevated concentrations of dissolved pesticides in the spring. These periods of co-occurrence lasted for up to 2-3 weeks, but concentrations of individual pesticides were low and much less than would be expected to cause acute mortality. However, the effects of exposure to the complex mixtures of pesticides actually present are unknown.

The POD investigators initiated several studies to address the possible role of contaminants and disease in the declines. Their primary study consists of twice-monthly monitoring of ambient water toxicity at fifteen sites in the Delta and Suisun Bay. In 2005 and 2006, standard bioassays using the amphipod Hyalella azteca had low (<5%) frequency of occurrence of toxicity (Werner et al. unpublished data). However, preliminary results from 2007, a dry year, suggest the incidence of toxic events was higher than in wetter previous years. Parallel testing with the addition of piperonyl butoxide, an enzyme inhibitor, indicated that both organophosphate and pyrethroid pesticides may have contributed to the observed 2007 toxicity. Most of the tests that were positive for H. azteca toxicity have come from water samples from the lower Sacramento River. Pyrethroids are of particular interest because use of these insecticides has increased (Ameg et al. 2005, Oros and Werner 2005) as use of some organophosphate insecticides has declined. Toxicity of sediment-bound pyrethroids to macroinvertebrates has also been observed in watersheds upstream of the Delta (Weston et al. 2004, 2005).

Larval delta smelt bioassays were conducted simultaneously with a subset of the invertebrate bioassays. The water samples for these tests were collected from six sites during May-August of 2006 and 2007. Results from 2006 indicate that delta smelt is highly sensitive to high levels of ammonia, low turbidity, and low salinity. There is some preliminary indication that reduced survival under low salinity conditions may be due to disease organisms (Werner, unpublished data). No significant mortality of larval delta smelt was found in the 2006 bioassays (Werner 2006), but there were two instances of significant mortality in June and July of 2007 (Werner, unpublished). In both cases, the water samples were collected from sites along the Sacramento River and had relatively low turbidity and salinity and moderate levels of ammonia. It is also important to note that no significant H. azteca mortality was seen in these water samples. While the H. azteca tests are very useful for detecting biologically relevant levels of water column toxicity, interpretation of the H. azteca test results with respect to fish should proceed with great caution. The relevance of the bioassay results to field conditions remains to be determined.

POD investigators have also monitored blooms of the toxic cyanobacterium *Microcystis aeruginosa*. Large blooms of *M. aeruginosa* were first noted in the Delta in 1999 (Lehman et al. 2005). Further studies (Lehman et al. in prep.) suggest that microcystins, the toxic chemicals associated with the algae, probably do not reach concentrations directly toxic to fishes, but during blooms, the microcystin concentrations may be high enough to impair invertebrates, which could influence prey availability for fishes. The *M. aeruginosa* blooms peak in the freshwaters of the central Delta during the summer at warm temperatures (20-25°C; Lehman et al. in prep). Delta smelt and longfin smelt are generally not present in this region of the Delta during summer (Nobriga et al. in press; Rosenfield and Baxter 2007) so *M. aeruginosa* toxicity is not likely a factor in their recent decline. However, in the low flow conditions of 2007, blooms of this cyanobacterium spread far downstream to the west Delta and beyond during summer (Lehman, unpublished data), so toxicity may have been a much broader issue than in other years.

The POD investigations into potential contaminant effects also include the use of biomarkers that have been used previously to evaluate toxic effects on POD fishes (Bennett et al. 1995; Bennett 2005). The results to date have been mixed. Histopathological and viral evaluation of young longfin smelt collected in 2006 indicated no histological abnormalities associated with toxic exposure or disease (Foott et al. 2006). There was also no evidence of viral infections or high parasite loads. Similarly, young threadfin shad showed no histological evidence of contaminant effects or of viral infections (Foott et al. 2006). Parasites were noted in threadfin shad gills at a high frequency but the infections were not considered severe. Thus, both longfin smelt and threadfin shad were considered healthy in 2006. Adult delta smelt collected from the Delta during winter 2005 also were considered healthy, showing little histopathological evidence for starvation or disease (Teh et al. unpublished). However, there was some evidence of low frequency endocrine disruption. In 2005, 9 of 144 (6%) of adult delta smelt males were intersex, having immature oocytes in their testes (Teh et al. unpublished).

In contrast, preliminary histopathological analyses have found evidence of significant disease in other species and for POD species collected from other areas of the estuary. Massive intestinal infections with an unidentified myxosporean were found in yellowfin goby *Acanthogobius flavimanus* collected from Suisun Marsh (Baxa et al. in prep.). Severe viral infection was found in inland silverside *Menidia beryllina* and juvenile delta smelt collected from Suisun Bay during summer 2005 (Baxa et al. in prep.). Lastly, preliminary evidence suggests that contaminants and disease may impair striped bass. Ostrach et al. (in prep.) found high occurrence and severity of parasitic infections, inflammatory conditions, and muscle degeneration in young striped bass collected in 2005; levels were lower in 2006. Several biomarkers of contaminant exposure including P450 activity (i.e., detoxification enzymes in liver), acetylcholinesterase activity (i.e., enzyme activity in brain), and vitellogenin induction (i.e., presence of egg yolk protein in blood of males) were also reported from striped bass collected in 2006 (Ostrach et al. in prep.).

Much of the previous discussion about how physical conditions and water quality affect delta smelt and other fishes is also relevant to other aquatic organisms including plankton and the benthos. It is important to keep in mind that river flows influence estuarine salinity gradients and water residence times. The residence time of water affects both habitat suitability for benthos and the transport of pelagic plankton. High tributary flow leads to lower residence time of water in the Delta (days), which generally results in lower plankton biomass (Kimmerer 2004), but also lower cumulative entrainment effects in the Delta (Kimmerer and Nobriga in press). In contrast, higher residence times (a month or more), which result from low tributary flows, may result in higher plankton biomass. This can increase food availability for planktivorous fishes; however, much of this production may be lost to water diversions under low flow conditions. Under extreme low flow conditions, long water residence times may also promote high biological oxygen demand when abundant phytoplankton die and decompose (Lehman et al. 2004; Jassby and Van Nieuwenhuyse 2006). Recent particle tracking modeling results for the Delta show that residence times in the southern Delta are highly variable, depending on Delta inflow, exports, and particle release location (Kimmerer and Nobriga, in press). Very high inflow leads to short residence time. The longest residence times occur in the San Joaquin River near Stockton under conditions of low inflow and low export flow.

Salinity variation can have a major effect on the benthos, which occupy relatively "fixed" geographical positions along the gradient of the estuary. While the distributions of the benthos can undergo seasonal and annual shifts, benthic organisms cannot adjust their locations as quickly as the more mobile pelagic community. Analyses of long-term benthic data for four regions of the upper San Francisco estuary indicate that two major factors control community composition: species invasions, and salinity (Peterson et al. in prep). Specifically, the invasion of the clam *C. amurensis* in the late 1980s resulted in a fundamental shift in the benthic community; however; the center of distribution of *C. amurensis* and other benthic species varies with flow and the resulting salinity regime. So at any particular location in the estuary, the benthic community can change substantially from year to year as a result of environmental variation and species invasions (Figure 7-10). These changes in the benthos can have major effects on food availability to pelagic organisms, including delta smelt.

Few studies have directly addressed how toxic chemicals, disease, and parasites affect longfin smelt. One of the few that does is an unpublished study by Scott Foott (CDFG), who summarizes the work as follows.

> Larval and 0+ juvenile Longfin smelt (LFS) and Threadfin shad (TFS) were collected in 2006 and 2007 from April – November. Over 400 fish / yr were assayed for virus using up to 4 different cell lines. Other fish were processed for histological examination (Davidson's fixative, 6µm paraffin sagittal sections, H&E or PAS stain) of 10 target tissues (gill, liver, kidney, acinar tissue, intestinal tract, heart, brain, eye, olfactory organ, and epidermis). The histological sample set in 2006 was composed of 15 TFS and 142 LFS while 118 TFS and 86 LFS histological specimens were examined in 2007.
>
> Trematodes and cestodes were observed in 8-16% of intestines without associated tissue damage. Varying degrees of hepatocyte vacuolation was observed in a majority of LFS livers (July – November 2006 and 2007). PAS stain showed little glycogen and we speculate the vacuoles primarily contain fat. Fatty change can be associated with contaminate exposure. Interpretation is complicated by signs of tissue hypoxia in many specimens (outcome of capture stress prior to fixation?).
>
> Summary: no significant health problem was detected in either TFS or LFS juveniles in 2006 or 2007. No virus was isolated in over 800 samples and the low incidence of parasitic infection was not associated with tissue damage or inflammation. In both 2006 and 2007, hepatocyte vacuolation was seen in many juvenile LFS livers from fish collected primarily in the fall. It is unknown whether fatty liver is normal for LFS or associated with toxic insults.

Climate Change

There are several reasons we expect future climate change might have negative long-term influences on pelagic habitat suitability for the POD fishes. First, there has been a trend toward more Sierra Nevada precipitation falling as rain earlier in the year (Roos 1987, 1991; Knowles and Cayan 2002, 2004). This increases the likelihood of winter floods and may have other effects on the hydrographs of Central Valley rivers and Delta salinity. Altered hydrographs interfere with pelagic fish reproduction, which is usually tied to historical runoff patterns (Moyle 2002). Second, sea level is rising (IPPC 2001). Sea level rise will increase salinity intrusion unless sufficient freshwater resources are available to repel the seawater. This will shift fish distributions upstream and possibly further reduce habitat area for some species. Third, climate change models project warmer temperatures in central California (Dettinger 2005). As stated above, water temperatures do not currently have a strong influence on POD fish distributions. However, summer water temperatures throughout the upper estuary are fairly high for delta smelt. Mean July water temperatures in the upper estuary are typically 21-24C (Nobriga et al. in press) and the lethal temperature limit for delta smelt is reported to be 25C (Swanson et al. 2000), though entrainment of juvenile delta smelt in spring 2007 continued until central Delta temperatures approached 28C. Thus, if climate change were to result in summer temperatures in the upper Estuary substantially exceeding current levels, suitable habitat during those months could be reduced or, in the worst case, eliminated in some years.

Top-Down Effects

The two most prominent top-down influences on pelagic fishes are entrainment into various water diversions and predation by piscivorous fishes. Major water diversions in the delta include the SWP and CVP export facilities, power plants, and agricultural diversions. The CVP and SWP water export operations include upstream reservoirs, the DCC, the SMSCG, the North Bay Aqueduct facilities (NBA), the Contra Costa Canal facilities (CCC), CCF, the Banks Pumping Plant/Skinner Fish Facilities (hereafter SWP), the South Delta Temporary Barriers (SDTB) and the Jones Pumping Plant/Fish Collection Facilities (hereafter CVP). The description and operation of these facilities was covered in the “Project Description” section of this Biological Assessment.

Water export operations occur primarily at SWP and CVP, with far smaller amounts of water diverted at NBA and CCC. Because of their size, and because of evidence implicating water project operations as contributing causes of the POD, the discussion of them below borrows heavily from the POD analysis.

As described in the “Project Description”, the NBA diversions have fish screens designed to FWS criteria for delta smelt protection. In addition, a larval delta smelt monitoring program occurs each spring in the sloughs near NBA. This monitoring program is used to trigger NBA export reductions when delta smelt larvae are nearby. Because the FWS deems these NBA measures to be adequately protective of delta smelt, the NBA will not be considered further.

Water is also temporarily diverted by two power plants located in the western Delta at Antioch and Pittsburgh. Nonconsumptive water use may reach 3200 cfs during full operation of both plants, which might be enough to create a substantial entrainment risk for fishes residing in the vicinity (Matica and Sommer, in prep.). Studies in the late 1970s indicated that losses of pelagic fishes during such operations can be very high. In recent years these plants have not been operated frequently, and their use appears to be restricted to supplying power only during periods of extreme demand. They are discussed in more detail below.

Entrainment

Because large volumes of water are drawn from the estuary, water exports and inadvertent fish entrainment at the SWP and CVP export facilities are among the best-studied top-down effects in the San Francisco Estuary (Sommer et al. 2007). The export facilities are known to entrain most species of fish in the upper Estuary (Brown et al. 1996), and are of particular concern in dry years, when the distributions of young striped bass, delta smelt, and longfin smelt shift closer to the diversions (Stevens et al. 1985; Sommer et al. 1997). As an indication of the magnitude of the effects, approximately 110 million fish were salvaged at the SWP screens and returned to the Delta over a 15-year period (Brown et al. 1996). However, this number greatly underestimates the actual number of fish entrained. It does not include losses at the CVP. Even for the SWP alone, it does not account for mortality of fish in Clifton Court Forebay and the waterways leading to the diversion facilities, larvae < 20 mm FL are not collected by fish screens, and losses of fish > 20 mm FL that because of inefficiencies are not removed by the louver system.

One piece of evidence that export diversions played a role in the POD is the substantial increases in winter CVP and SWP salvage that occurred contemporaneously with recent declines in delta smelt and other POD species (Grimaldo et al. in review). Increased winter entrainment of delta smelt, longfin smelt and threadfin shad represents a loss of pre-spawning adults and all their potential progeny. Similar increases in the salvage of littoral species including centrarchids and inland silverside were observed during the same period. The littoral species are less influenced by flow changes than the POD fishes. However, the increases in salvage for centrarchids may be at least partially a result of the range expansion of *Egeria densa*, which provides favored habitat. This hypothesis is supported by the observation that the greatest increases in centrarchid salvage occurred at the CVP. The intake of the CVP is located in an area with significant areas of *E. densa* nearby. Nonetheless, the increase in entrainment of both groups of fishes suggests a large change in the hydrodynamic influence of the export diversions during recent winters. Note that winter salvage levels subsequently decreased to very low levels for all POD species during the winters of 2005-2006 and 2006-2007, possibly due to the very low numbers of fish that appear to remain in the estuary.

In trying to evaluate the mechanism(s) for increased winter-time salvage, POD studies by USGS made three key observations (IEP 2005). First, there was an increase in exports during winter as compared to previous years, mostly attributable to the SWP (Figure 7-11). Second, the proportion of tributary inflows shifted. Specifically, San Joaquin River inflow decreased as a fraction of total inflow around 2000, while Sacramento River increased (Figure 7-12). Finally, there was an increase in the duration of the operation of barriers placed into south Delta channels during some months. These changes may have contributed to a shift in Delta hydrodynamics that increased fish entrainment.

These observations led to a hypothesis that the hydrodynamic change could be indexed using net flows through Old and Middle rivers (Figure 7-13), which integrate changes in inflow, exports, and barrier operations (Arthur et al. 1996; Monsen et al. 2007). Net or residual flow refers to the calculated flow when the effects of the tide are mathematically removed. An initial analysis revealed that there was a significant inverse relationship between net Old and Middle rivers flow and winter salvage of delta smelt at the SWP and CVP (P. Smith, unpublished). These analyses were subsequently updated and extended to other pelagic fishes (Figure 7-14, L. Grimaldo, in preparation). The general pattern is that POD species salvage is low when Old and Middle river flows are positive.

The hydrologic and statistical analyses suggest a reasonable mechanism by which winter entrainment increased during the POD years; however, the direct population-level effects of increased entrainment are less clear. As part of the POD investigation, Manly and Chotkowki (IEP 2005; Manly and Chotkowski 2006) used log-linear modeling to evaluate environmental factors that may have affected long-term trends in the Fall Midwater Trawl abundance index of delta smelt. They found that monthly or semi-monthly measures of exports or Old and Middle rivers flow had a statistically significant effect on delta smelt abundance; however, individually they explained a small portion (no more than a few percent) of the variability in the fall abundance index of delta smelt across the entire survey area and time period. Hence, there are other factors that dominate the relationship between exports and delta smelt fall abundance. Similarly, Kimmerer et al. (2001) estimated that entrainment losses of young striped bass were sometimes very high (up to 99%), but they did not find evidence that entrainment losses were a major driver of long-term striped bass population dynamics.

These results do not mean, however, that direct export effects can be dismissed as a contributing cause of the POD. There are two aspects of entrainment that explicitly were not addressed by Manly and Chotkowski (2006) and are not well understood: (1) the possibility that selective entrainment among a heterogeneous population of prespawning adults could produce consequences that do not become manifest until the following year (discussed in the next paragraph), and (2) larval entrainment. Very little is known about historical larval entrainment because larvae are not sampled effectively at the fish screening facilities. To address this shortcoming, Kimmerer and Nobriga (in press) coupled a particle tracking modeling with survey results to estimate larval entrainment. Kimmerer (in press) used data from several IEP monitoring programs to estimate entrainment of delta smelt. These approaches suggest that larval delta smelt entrainment losses could exceed 50% of the population under low flow and high export conditions. Because there are few reliable larval entrainment data, it is not possible to directly address the question of how important these losses were historically.

It has been proposed that losses of larger females and their larvae may have a disproportionate effect on the delta smelt population (B. Bennett, unpublished data). Bennett (unpublished data) proposes that larger females spawn earlier in the season and produce more eggs, which are of better quality, and survivability, as has been noted for Atlantic cod and other commercially harvested species (Marteinsdottir and Steinarsson 1998; Swain et al. 2007). As a consequence, winter and early spring exports, which have continually increased as described above (Figure 7-15), could have an important effect on reproductive success of early spawning female delta smelt. Bennett hypothesizes that the observed reduction in the mean size of adult delta smelt in the early 1990s (Sweetnam 1999) is a result of selective losses of earlier spawning adults and their larvae, thereby selecting for later spawned offspring (that have less time to reach maturity). Under this hypothesis, the most important result of the loss of early spawning females would manifest itself in the year following the loss, and would therefore not necessarily be detected by analyses relating fall abundance indices to same-year (or same-water year) predictors. This hypothesis is presently being evaluated by Bennett's laboratory using otolith methods.

The CVP and SWP export operations are most likely to impact adult delta smelt during their upstream spawning migration between December and April. A significant negative correlation between November-February delta smelt salvage and the residuals from a FMWT index at year one vs. FMWT index at year two stock-recruit relationship is evidence for an influence of adult entrainment on delta smelt population dynamics (Brown and Kimmerer 2001). Delta smelt spawn over a wide area (much of the delta and some areas downstream). In some years a fairly large proportion of the population seems to spawn in or be rapidly transported to the central and southern delta. Presumably, entrainment vulnerability is higher during those years. Unfortunately, it is not currently known what cues decisions about where to spawn.

The CVP and SWP water operations are not thought to have any impact on delta smelt eggs because they remain attached to substrates. Shortly after hatching, larvae are vulnerable to entrainment at all points of diversion, but, as mentioned earlier, are not counted in SWP or CVP fish salvage operations. Juvenile delta smelt also are vulnerable to entrainment and are counted in salvage operations once they reach 20-25 mm in length. Most juvenile salvage occurs from April-July with a peak in May-June (Nobriga et al. 2001).

Salvage of delta smelt population has historically been greatest in drier years when a high proportion of YOY rear in the delta (Moyle et al. 1992; Reclamation and DWR 1994; Sommer et al. 1997; Figure 7-6). In recent years however, salvage also has been high in moderately wet conditions (Nobriga et al. 2000; 2001; springs of 1996, 1999, and 2000) even though a large fraction of the population was downstream of the Sacramento-San Joaquin River confluence. Nobriga et al. (2000; 2001) attributed recent high wet year salvage to a change in operations for the VAMP that began in 1996. The VAMP provides a San Joaquin River pulse flow from mid-April to mid-May each year that probably improves rearing conditions for delta smelt larvae and also slows the entrainment of fish rearing in the delta. The high salvage events may have resulted from smelt that historically would have been entrained as larvae and therefore not counted at the fish salvage facilities growing to a salvageable size before being entrained. However, a more recent analysis summarized in Figure 7-6 provides an alternative explanation. Delta smelt salvage in 1996, 1999, and 2000 was not outside of the expected historical range when three factors are taken into account, (1) delta smelt distribution as indexed by X2 position, (2) delta smelt abundance as indexed by the Townet Survey (TNS), and (3) the amount of water exported. Therefore, it is uncertain that operations changes for VAMP have influenced delta smelt salvage dynamics as strongly as suggested by Nobriga et al. (2000). Nonetheless, it is likely that actual entrainment has decreased since the initiation of the VAMP because of the improved transport flows it provides. In addition, “assets” from CALFED’s Environmental Water Account (EWA) are often used during this time of year to further reduce delta smelt entrainment. Although the population level benefits of these actions are unknown, they appear to have been successful at keeping delta smelt salvage under the limits set by FWS (1993) (Brown and Kimmerer 2002).

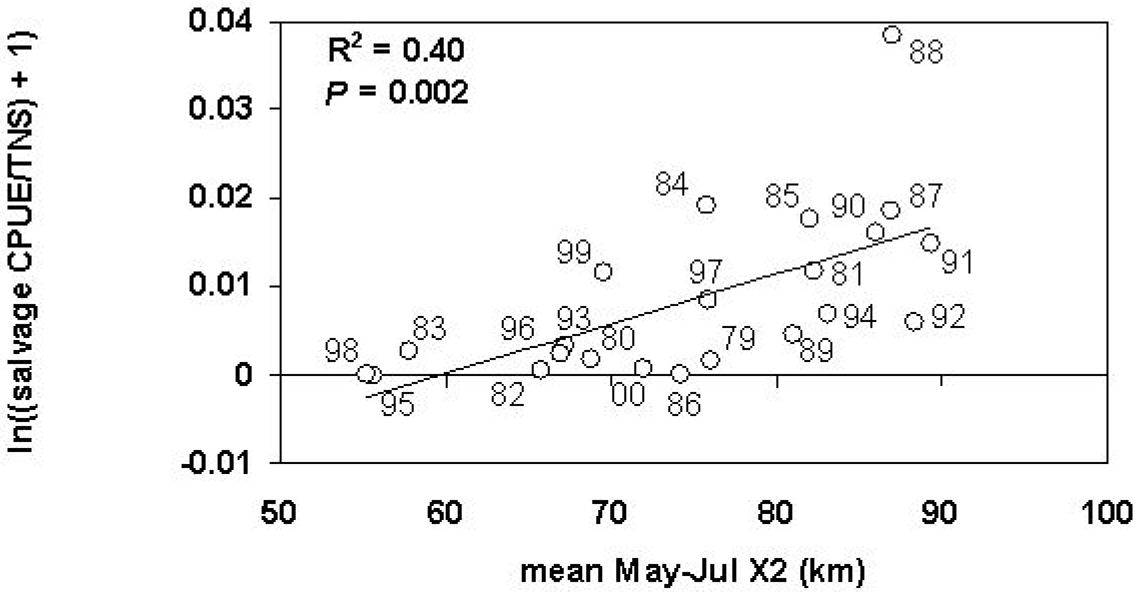


Figure 17-2 Water operations impacts to the delta smelt population.

Another possible effect on delta smelt entrainment is the SDTB. The SDTB are put in place during spring and removed again each fall (see the “Project Description” section of this Biological Assessment for more detail). Computer simulations have shown that placement of the barriers changes south delta hydrodynamics, increasing central delta flows toward the export facilities (DWR 2000). When delta smelt occur in areas influenced by the barriers, entrainment losses could increase.

Predation Effects

Predator-prey dynamics in the San Francisco Estuary are poorly understood, but are currently receiving considerable research attention by the IEP as part of the POD investigation. Studies during the early 1960s found delta smelt were an occasional prey fish for striped bass, black crappie and white catfish (Turner and Kelley 1966). This, coupled with the substantial decline in striped bass abundance has been taken as evidence that delta smelt are not very vulnerable to predation (Sweetnam and Stevens 1993). In recent years, it has become clear that the prey choices of piscivorous fishes switch as the relative abundances of species in the prey field change (Buckel et al. 1999). Even in the 1960s, delta smelt was rare relative to the dominant prey fishes of striped bass (age-zero striped bass and threadfin shad) (Turner and Kelley 1966). Therefore, there should have been no expectation that delta smelt would be commonly found in stomach contents samples. Because delta smelt are still rare relative to currently common prey fishes, the same holds true today (Nobriga et al. 2003). Because of the limitations of using stomach samples, IEP researchers are attempting to model potential impacts of striped bass on delta smelt using bioenergetics and individual-based approaches.

Bennett and Moyle (1996) proposed that inland silverside may be impacting delta smelt through predation (on delta smelt eggs and/or larvae) and competition (for copepod prey). This hypothesis is supported by recent statistical analyses showing negative correlations between inland silverside abundance and delta smelt TNS indices, and two indices of egg and/or larval survival (Brown and Kimmerer 2001). The hypothesis also is consistent with the analysis by

Kimmerer (2002) showing a change in the sign of the delta smelt X2-TNS relationship (described above) because inland silversides began to increase in abundance about the same time the relationship changed sign (Brown and Kimmerer 2001). It should be noted however that since the early 1980s, there also have been increases in other potential larval fish predators such as coded wire tagged Chinook salmon smolts released in the Delta for survival experiments (Brandes and McLain 2001) and centrarchid fishes (Nobriga and Chotkowski 2000). In addition, striped bass appear to have switched to piscivorous feeding habits at smaller sizes than they historically did following severe declines in the abundance of mysid shrimp (Feyrer et al. in press). We suspect that CWT salmon and centrarchid abundance, as well as the striped bass diet switch have covaried with the increase in inland silverside abundance and the declines in phytoplankton and zooplankton abundance mentioned above.

One hypothesis arising from the POD investigation holds that predation effects on delta smelt and other POD species have increased in all water year types as a result of increased populations of pelagic and inshore piscivores. In the pelagic habitat, age-1 and age-2 striped bass appear to have declined more slowly than age-0 striped bass (compare Figure 7-6 with Figure 7-16, CDFG, unpublished data). Adult striped bass abundance increased in the latter 1990s (Figure 7-17) so high striped bass predation pressure on smaller pelagic fishes in recent years is probable. Further, largemouth bass abundance has increased in the Delta over the past few decades (Brown and Michniuk 2007). While largemouth bass are not pelagic, their presence at the boundary between the littoral and pelagic zones makes it probable that they do opportunistically consume pelagic fishes. Analyses of fish salvage data show this increase occurred somewhat abruptly in the early 1990s and has been sustained since (Figure 7-18). The increase in salvage of largemouth bass occurred during the time period when *E. densa*, an introduced aquatic macrophyte was expanding its range in the Delta (Brown and Michniuk 2007). The habitat provided by beds of *E. densa* provide good habitat for largemouth bass and other species of centrarchids. Thus, the increased abundance of this introduced predator was likely caused by an increase in an introduced plant, which provided favorable habitat. The areal coverage of *E. densa* in the Delta continued to expand by more than 10% per year from 2004 to 2006, by infesting a greater portion of channels and invasion of new habitat (E. Hestir et al., U.C. Davis, unpublished data). This suggests that populations of largemouth bass and other species using submerged aquatic vegetation will continue to increase. Although none of the IEP surveys adequately tracks largemouth bass population trends, the Delta has become the top sport fishing destination in North American for largemouth bass, which illustrates the recent success of this species. Each year, lucrative fishing tournaments are held in the Delta to take advantage of the large number of trophy-sized bass in the region. Largemouth bass have a much more limited distribution in the estuary than striped bass, but a higher per capita impact on small fishes (Nobriga and Feyrer 2007). Increases in largemouth bass may have had a particularly important effect on threadfin shad and striped bass, whose earlier life stages occur in littoral habitat (Grimaldo et al. 2004; Nobriga and Feyrer 2007).

A change in predation pressure may, in part, be an effect of interactions between biotic and abiotic conditions. Natural, co-evolved piscivore-prey systems typically have an abiotic production phase and a biotic reduction phase each year (e.g., Rodriguez and Lewis 1994). Changing the magnitudes and durations of these cycles greatly alters their outcomes (e.g., Meffe 1984). Generally, the relative stability of the physical environment affects the length of time each phase dominates and thus, the importance of each. Biotic interactions like predation will have stronger community-structuring influence in physically stable systems (e.g., lakes). Historically in the estuary, the period of winter-spring high flow was the abiotic production phase, when most species reproduced. The biotic reduction phase probably encompassed the low-flow periods in summer-fall. Multi-year wet cycles probably increased (and still do) the overall ‘abiotic-ness’ of the estuary, allowing populations to increase. Drought cycles likely increased the estuary’s ‘biotic-ness’ (e.g., Livingston et al. 1997), with low reproductive output and increased effect of predation on population abundance. Our managed system has reduced flow variation much of the time and in some locations more than others. This has probably affected the magnitudes and durations of abiotic and biotic phases (e.g., Nobriga et al. 2005). In other words, reduced flow variability in the estuary may have exacerbated predation effects. However, there is no clear evidence that such changes have been abrupt enough to account for the POD.

Agricultural Diversions

There are 2,209 agricultural diversions in the Delta and an additional 366 diversions in Suisun Marsh used for enhancement of waterfowl habitat (Herren and Kawasaki 2001). The vast majority of these diversions do not have fish screens to protect fish from entrainment. It has been recognized for many years that delta smelt are entrained in these diversions (Hallock and Van Woert 1959; Pickard et al. 1982). In the early 1980s delta smelt were the most abundant fish entrained in the Roaring River diversion in Suisun Marsh (Pickard et al. 1982), so it is possible the waterfowl diversions are detrimental. However, delta smelt may not be especially vulnerable to Delta agricultural diversions for several reasons. First, adult delta smelt move into the Delta to spawn during winter-early spring when agricultural diversion operations are at a minimum. Second, larval delta smelt occur transiently in most of the Delta. Third, Nobriga et al. (2002; in press) examined delta smelt entrainment at an agricultural diversion in Horseshoe Bend during July 2000 and 2001, when much of the YOY population was rearing within one tidal excursion of the diversion. Delta smelt entrainment was low compared to density estimates from the DFG 20 mm Delta Smelt Survey. Low entrainment was attributed to (1) offshore distribution of delta smelt, and (2) the extremely small hydrodynamic influence of the diversion relative to the channel it was in. Because Delta agricultural diversions are typically close to shore and probably take small amounts of water relative to what is in the channels they draw water from, delta smelt vulnerability may be low despite their modest swimming ability and their poor performance near simulated fish screens in laboratory settings (Swanson et al. 1998; 2002). It should be noted however that DWR screened five agricultural diversions around Sherman Island, an area consistently used by delta smelt of all life stages.

Antioch and Pittsburgh Power Plants

PG&E operates two power generation facilities within the range of delta smelt: Contra Costa Power Plant and Pittsburg Power Plant. Contra Costa Power Plant is about six miles east of the confluence of the Sacramento and San Joaquin rivers. Pittsburg Power Plant is on the south shore of Suisun Bay, in the town of Pittsburg. Each power plant has seven generating units that rely on diverted water for condenser cooling. Cooling water is diverted at a rate as high as about 1,500 cfs for the Contra Costa plant and 1,600 cfs for the Pittsburg plant, forming a thermal plume as it is discharged back into the estuary. Pumping rates are often significantly lower under normal operation. Potential impacts of the power plants fall into two categories - direct and indirect. Previous data on direct and indirect impacts of the power plants were summarized by Reclamation and DWR (1994). However, robust data analyses of population level effects of power plant operation on delta smelt and other fishes have not been performed. Briefly, the direct impact of the power plants comes from the removal of fish during diversion operations. Indirect effects stem from water temperature increases when the cooling water is returned to the estuary. Intakes at all units at both power plants employ a screening system to remove debris, but the screens allow entrainment of fish smaller than about 38 mm and impingement of larger fish.

Since the 1978–79 studies were completed, PG&E has implemented a resource management program to reduce striped bass loss. During the period of peak striped bass entrainment (May to mid-July), power generation units are operated preferentially, using fish monitoring data. This program has reduced entrainment losses of larval and juvenile striped bass by more than 75 percent (PG&E 1992a). Given its timing, this management program also may be beneficial to delta smelt.

In recent years, the plants have been operated only in a “peaking” capacity, and kept in a standby state when regional power consumption is not high. However, although they may not be routinely operated, the plants are most likely to be called into use during the summer, at a time when delta smelt are potentially close to the intake and discharge points, and thus vulnerable to entrainment and other adverse effects.

Bottom-Up Effects

The quality and availability of food may have important effects on the abundance and distribution of delta smelt. Food quality and availability have been highly historically variable, largely because of the lamentable history of exotic species introduction into the Estuary. In this section recent elements of that story are presented to develop the theme of dependency between delta smelt and its trophic support. Because a large part of this discussion has evolved only in the last few years as a result of the POD investigation, this account borrows heavily from the POD work.

Interconnected Recent Changes in Plankton and Benthos

Estuaries are commonly characterized as highly-productive nursery areas for a suite of organisms. Nixon (1988) noted that there actually is a broad continuum of primary productivity levels in different estuaries, which in turn affects fish yield. Compared to other estuaries, pelagic primary productivity in the upper San Francisco estuary is poor and a low fish yield is expected (Figure 7-19). Moreover, there has been a significant long-term decline in phytoplankton biomass (chlorophyll a) and primary productivity to very low levels in the Suisun Bay region and the lower Delta (Jassby et al 2002). Hence, low and declining primary productivity in the estuary is likely a principal cause for the long-term pattern of relatively low and declining biomass of pelagic fishes.

A major reason for the long-term phytoplankton reduction in the upper estuary is filter-feeding by the overbite clam (*Corbula amurensis*), which became abundant by the late 1980s (Kimmerer 2002). The overbite clam was first reported from San Francisco Estuary in 1986 and it was well established by 1987 (Carlton et al. 1990). Prior to the overbite clam invasion, there were periods of relatively low clam biomass in the upper estuary because the Asiatic freshwater clam (*Corbicula fluminea*) colonized Suisun Bay during high flow periods and the native marine clam *Mya arenaria* (also known as *Macoma balthica*) colonized Suisun Bay during prolonged (> 14 month) low flow periods (Nichols et al. 1990). Thus, there were periods of relatively low clam grazing rates while one species was dying back and the other was colonizing. The overbite clam invasion changed this formerly dynamic clam assemblage because the overbite clam, which is tolerant of a wide range of salinity, is now always the dominant clam species in the brackish water regions of the estuary and its grazing influence extends into the Delta (Kimmerer and Orsi 1996; Jassby et al. 2002) beyond the clam's typical range, presumably due to tidal dispersion of phytoplankton-depleted water.

According to recent research, shifts in nutrient concentrations may also contribute to the phytoplankton reduction as well as to changes in algal species composition in the San Francisco Estuary. While phytoplankton production in the San Francisco Estuary is generally considered light limited and nutrient concentrations exceed production limiting levels, nutrients may affect production during times when light conditions are more favorable and also affect species composition. Dugdale et al (2007) and Wilkerson et al (2006) found that high ammonium concentrations prevented the formation of diatom blooms but stimulated flagellate blooms in the lower estuary. Ammonium concentrations in the Delta and Suisun Bay have significantly increased over the last few decades due to increased loading from sewage treatment plants (Jassby, in press, Mueller-Solger, in prep.). Van Nieuwenhuyse (2007), on the other hand, found that a rapid reduction in wastewater total phosphorus loads in the mid-1990s coincided with a similarly rapid drop in phytoplankton biomass at three stations in the upper estuary.

Starting in the late 1980s, a series of major changes was observed in the estuarine food web that negatively influenced pelagic fish (including delta smelt) production. Major step-declines were observed in the abundance of phytoplankton (Alpine and Cloern 1992) and the copepod Eurytemora affinis due to grazing by the clam (Kimmerer et al. 1994). Northern anchovy abandoned the estuary's low salinity zone coincident with the overbite clam invasion, presumably because the sharp decline in planktonic food items made occupation of low-salinity waters unprofitable for this marine fish (Kimmerer 2006). There was also a major step-decline in mysid shrimp in 1987-1988, presumably due to competition with the clam for phytoplankton (Orsi and Mecum 1996). The mysid shrimp had been an extremely important food item for larger fishes like longfin smelt and juvenile striped bass; its decline resulted in substantial changes in the diet composition of these and other fishes (Feyrer et al. 2003). As described above, the population responses of longfin smelt and juvenile striped bass to winter-spring outflows changed after the overbite clam invasion. Longfin smelt relative abundance was lower per unit outflow post-clam (Kimmerer 2002b). Young striped bass relative abundance stopped responding to outflow altogether (Sommer et al. 2007). One hypothesis to explain these changes in fish population dynamics is that lower prey abundance reduced the system carrying capacity (Kimmerer et al. 2000; Sommer et al. 2007).

Several recent studies have shown that pelagic consumer production is limited by low phytoplankton productivity in the San Francisco Estuary (Sobczak et al. 2002, 2004; Mueller-Solger et al. 2002). However, in contrast to the substantial long-term declines in phytoplankton biomass and productivity (Jassby et al. 2002), phytoplankton trends for the most recent decade (1996-2005) are actually positive in the Delta and neutral in Suisun Bay (Jassby, in press). While this does not support the hypothesis that changes in phytoplankton quantity are responsible for the recent declines of delta smelt and other pelagic fishes, phytoplankton may nevertheless play a role via changes in species composition, as will be discussed in the food quality section below.

A notable finding for the POD is that *Pseudodiaptomus forbesi*, a calanoid copepod that has replaced *Eurytemora affinis* as the most common delta smelt prey during summer, continued to decline in the Suisun Marsh and confluence regions from 1995 to 2004, while its numbers increased in the southern Delta (Figure 7-20; Kimmerer et al. in prep., Mueller-Solger et al. in prep.). Although substantial uncertainties about mechanisms remain, this trend may be related to increasing recruitment failure and mortality in Suisun Bay and the western Delta due to competition and predation by the overbite clam, contaminant exposures, and entrainment of source populations in the Delta (Durand et al. in prep., Mueller-Solger et al. 2006). For example, overbite clam abundance and distribution in the Suisun Bay and the western Delta during 2001-2004 was greater than during the 1995-1999 wet period, but similar to abundance indices and distribution patterns during the 1987-1992 drought (IEP 2005, Peterson et al. in prep.). Further, in the two most recent years (2005 and especially 2006), *P. forbesi* has started to rebound substantially in the western Delta (Figure 7-21, Mueller-Solger et al. in prep., Jassby et al. in prep.).

There is also interest in a more recent invader, the cyclopoid copepod *Limnoithona tetraspina*, which significantly increased in the Suisun Bay region beginning in the mid-1990s. It is now the most abundant copepod species in the low-salinity zone (Bouley and Kimmerer 2006). It has been hypothesized that *L. tetraspina* is an inferior food for pelagic fishes including delta smelt because of its small size, generally sedentary behavior, and ability to detect and avoid predators (Bouley and Kimmerer 2006). Experimental studies addressing this issue are ongoing (Sullivan et al., unpublished). *Acartiella sinensis*, a calanoid copepod species that invaded at the same time as L. tetraspina, also reached considerable densities in Suisun Bay and the western Delta over the last decade. Its suitability as food for pelagic fish species remains unclear, but is also being investigated (Sullivan et al., unpublished).

Preliminary information from studies on pelagic fish growth, condition and histology provide additional evidence for food limitation in pelagic fishes in the estuary (IEP 2005). In 1999 and 2004, residual delta smelt growth was low from the Sacramento-San Joaquin confluence through Suisun Bay relative to other parts of the system. Delta smelt collected in 2005 from the Sacramento-San Joaquin confluence and Suisun Bay also had high incidence of liver glycogen depletion, a possible indicator of food limitation. Similarly, during 2003 and 2004 striped bass condition factor decreased in a seaward direction from the Delta through Suisun Bay.

Thus far, there is little evidence that the unusually poor growth rates, health, and condition of fishes from Suisun Bay and western Delta are due directly to the effects of toxic contaminants or other adverse chemical or physical habitat conditions. Therefore, our working hypothesis is that the poor fish growth and condition in the upper estuary are due to food limitation. Note, however that contaminant episodes may be contributing to poor phytoplankton growth (Dugdale et al. 2007) and invertebrate mortality (Werner unpublished data), which could exacerbate food limitation. If fishes are food limited in Suisun Bay and west Delta during larval and/or juvenile development, then we would expect greater cumulative predation mortality, higher disease incidence, and consequently low abundance indices at later times.

Fish Co-Occurrence with Food

The above patterns in fish food have generally been described at rather broad scales. Recently, interest has focused on determining patterns of co-occurrence of fish predators, particularly delta smelt, and their zooplankton prey. The assumption is that predators should co-occur with their prey. This idea was first explored by Nobriga (2002) who showed that delta smelt larvae with food in their guts typically co-occurred with higher calanoid copepod densities than larvae with empty guts. Recently, Kimmerer (in press), Miller and Mongan (unpublished data), and Mueller-Solger (unpublished data) used similar approaches to look at potential co-occurrence of delta smelt and their prey and its effects on survival. Kimmerer (in press) showed that there was a positive relationship between delta smelt survival from summer to fall and zooplankton biomass in the low-salinity region of the estuary (Figure 7-22). Miller and Mongan (unpublished data) have concluded that April and July co-occurrence is a strong predictor of juvenile delta smelt survival. Mueller-Solger (unpublished data) defined delta smelt habitat based on the environmental quality results of Nobriga et al. (in press) and prey spectrum more broadly (as all copepods) compared to Miller and Mongan (unpublished data) and found no long-term decline in the total biomass of copepods potentially available for consumption by delta smelt in midsummer, although species composition has changed considerably (Figure 7-21).

There are two shortcomings of co-occurrence analyses like those described above. First, it is difficult to characterize fish prey suitability. For instance, *E. affinis* and *P. forbesi* are generally believed to be “preferred” prey items for delta smelt (Nobriga 2002; Miller and Mongan unpublished). However, diet data show that delta smelt will actually feed on a wide variety of prey (Lott 1998; S. Slater, California Department of Fish and Game, unpublished; Figure 7-23). Thus, the question of prey co-occurrence involves questions of prey catchability (e.g., Meng and Orsi 1991) and profitability (energy per item consumed and nutritional quality of individual prey items). For example, *L. tetraspina* has a large biomass in the system but individual *L. tetraspina* are smaller and possibly more evasive than the larger calanoid copepods. The energy needed by an individual delta smelt to harvest a similar biomass of *L. tetraspina* compared to the energy needed to harvest a larger species could be very different, as suggested by optimal foraging theory (e.g., Stephens and Krebs 1986). Another major limitation of co-occurrence analyses is that IEP sampling programs sample fish and zooplankton at larger spatial and temporal scales than those at which predator-prey interactions occur. Both fish and copepods are likely to be patchy and the long tows required to collect sufficient numbers of organisms for counting would homogenize such patch structure. Moreover, it is unlikely that the (monthly or even twice monthly) “snapshot” of fish and prey co-occurrence in specific locations or even small regions provided by the IEP surveys is representative of feeding conditions actually experienced by fish on an hourly or daily basis.

The weight of evidence strongly supports bottom-up food limitation as a factor influencing longterm fish trends in the upper estuary. However, the bottom-up hypothesis is unlikely as a single mechanism for the recent pelagic organism declines. Specifically, it is unclear why there has been a substantial recent decline in some Suisun Bay and western Delta calanoid copepod species, but not in phytoplankton chlorophyll a concentration. Also, calanoid copepod densities (especially *P. forbesi*) rebounded substantially in 2006 (Mueller-Solger, unpublished data) while the POD fish abundance indices (especially for delta smelt) remained low. Second, recent *C. amurensis* levels are not unprecedented; they are similar to those found during the 1987-92 drought years, so it is unclear if and why benthic grazing would have a greater effect on the Suisun Bay food web during the POD years than during the earlier drought years. Finally, it is possible that the hypothesis that the San Francisco Estuary is driven by phytoplankton production rather than through detrital pathways (Sobczak et al. 2002, 2004; Mueller-Solger et al. 2002) may have been accepted too strictly. Many zooplankton are omnivorous and can consume microbes utilizing dissolved and particulate organic carbon. This has recently been demonstrated for several zooplankton species in the San Francisco Estuary (Gifford et al. 2007 and references therein). Thus, shifts in availability of phytoplankton and microbial food resources for zooplankton might favor different species. It is possible that a better understanding of shifts in phytoplankton and zooplankton community composition and perhaps related changes in the microbial food web in the Suisun Bay region could explain these apparent inconsistencies.

Food Quality

Studies on food quality have been relatively limited in the San Francisco Estuary, with even less information on long-term trends. However, food quality may be another limiting factor for pelagic zooplankton and their fish predators, including delta smelt.

At the base of the pelagic food web, food quality for consumers is determined by the relative contributions of different phytoplankton and microbial species and detritus to the overall organic particle pool available to primary consumers. For example, diatoms and cryptophytes are thought to be of good food quality for zooplankton, while the nutritional value of cyanobacteria such as *Microcystis aeruginosa* can be very low (Brett and Müller-Navarra 1997), particularly for toxic varieties (Rohrlack et al. 2005). Lehman (1996, 2000) showed shifts in phytoplankton species composition in the San Francisco Estuary from diatom dominated to more flagellate dominated communities. Mueller-Solger et al. (2006) found that in recent years, diatoms were most abundant in the southern San Joaquin River region of the Delta, and Lehman (2007) found greater diatom and green algal contributions upstream and greater flagellate biomass downstream along the San Joaquin River. To date, the *M. aeruginosa* blooms have occurred most intensively in the central Delta, thus POD species that utilize the central Delta such as threadfin shad, striped bass, and the poorly monitored centrarchid populations (largemouth bass and sunfish) would be most likely to suffer any direct adverse effects of these blooms.

In 2007, the *M. aeruginosa* bloom year was the worst on record in the Delta (P. Lehman, in prep.). The highest cell densities were observed near Antioch, i.e. considerably west of the previous center of distribution, and may thus have affected invertebrates and fishes in the confluence and Suisun Bay regions of the upper estuary. In general, phytoplankton carbon rather than the much more abundant detrital carbon are thought to fuel the food web in the San Francisco Estuary (Mueller-Solger et al. 2002; Sobczak et al. 2002, 2004); however, that does not mean the detrital pathways are not significant because many zooplankton are omnivorous and capable of utilizing both pathways. For example, Rollwagen- Bollens and Penry (2003) observed that while heterotrophic ciliates and flagellates were the dominant prey of *Acartia* spp. in the bays of the San Francisco Estuary, diatoms and autotrophic ciliates and flagellates also formed an important part of their diet during phytoplankton blooms. Calanoid copepod and cladoceran growth and egg production may often be limited by low levels of phytoplankton biomass. This appears to be true even for omnivorous calanoids such as *Acartia* spp. Kimmerer et al (2005) found a significant relationship between *Acartia* spp. egg production and chlorophyll a concentration in the San Francisco Estuary, suggesting that *Acartia* spp. likely also derived a large part of carbon and energy from phytoplankton. Bouley and Kimmerer (2006), on the other hand, reported that egg production rates of the cyclopoid copepod *L. tetraspina* were unrelated to chlorophyll a concentrations in the low salinity region of the San Francisco Estuary. *L. tetraspina* digestion rates were highest for ciliates, perhaps suggesting a greater importance of the detrital carbon pathway for this species.

In a study focusing on the nutrition and food quality of the calanoid copepods *E. affinis* and *P. forbesi*, Mueller-Solger et al (2006) found evidence for “trophic upgrading” of essential fatty acids by *E. affinis* and *P. forbesi*, confirming their importance as high-quality food for fish. They also found that *E. affinis* gained the greatest nutritional benefits from varied food sources present in small tidal sloughs in Suisun Marsh. *P. forbesi*, on the other hand, thrived on riverine phytoplankton in the southern Delta, especially diatoms. Diatoms are likely also an important food source for other calanoid copepod species. The relative decrease in diatom contributions to the phytoplankton community in the central Delta and Suisun Bay (Lehman 1996, 2000) is thus a concern and may help explain the declines in *P. forbesi* and other calanoid copepods in these areas.

Mueller-Solger et al. (2006) concluded that areas rich in high-quality phytoplankton and other nutritious food sources such as the southern Delta and small tidal marsh sloughs may be critical “source areas” for important fish prey organisms such as *P. forbesi* and *E. affinis*. This is consistent with results by Durand et al. (unpublished data) who showed that transport from upstream was essential for maintaining the *P. forbesi* population in Suisun Bay. It is possible that the increase in *P. forbesi* densities in the western Delta in 2006 could be related to greater San Joaquin River flows during this wet year, which may have reduced entrainment of *P. forbesi* source populations in the Delta.

As noted in earlier sections, the dichotomy between phytoplankton and detrital/microbial energy pathways supporting zooplankton has probably been applied more stringently than is appropriate. Both are likely important, with the balance between them in specific areas of the estuary likely having affects on the success of particular zooplankton species. Additional research into the detrital pathway might be useful in understanding the factors controlling zooplankton populations, which are critical food resources for pelagic fishes.

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Chapter 18 Ongoing Management Programs that Address State Water Project and Central Valley Project Impacts

The material provided in this chapter is for informational purposes only and provides background and a general summary of the various cooperative management programs that help protect listed species and address effects on critical habitat. Although many of these actions are included as part of the overall project description in Chapter 2, Environmental Species Act (ESA) coverage for these actions is not requested under the Operations Criteria and Plan (OCAP) consultation, but have been addressed under separate Section 7 consultations.

This chapter also summarizes ongoing planning activies that could result in future actions and provides informational needs to benefit listed species. The Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR) are working with U.S. Fish and Wildlife Service (FWS), National Marine Fisheries Service (NMFS), California Department of Fish and Game (DFG), and various stakeholders on multiple actions, and funding frameworks, to mitigate losses of salmon, delta smelt, steelhead and green stergeon. Several agreements and programs are in place that, in combination with the actions described in the Project Desription, help mitigate for direct losses attributable to the State Water Project (SWP) and Central Valley Project (CVP), and help improve and restore fishery resources. Chinook salmon, delta smelt, steelhead and green sturgeon are among the species that benefit from the various actions provided under these agreements and programs.

Central Valley Project Improvement Act

On October 30, 1992, the Reclamation Projects Authorization and Adjustment Act of 1992 (Public Law 102–575) was signed into law, including Title XXXIV, the Central Valley Project Improvement Act (CVPIA). The CVPIA amends the authorization of the CVP to include fish and wildlife protection, restoration, and mitigation as project purposes having equal priority with irrigation and domestic uses, and fish and wildlife enhancement as a purpose equal to power generation. Implementation of CVPIA measures to double anadromous fish populations, improve habitat, and reduce losses of steelhead, spring-run salmon, and other salmon races include habitat restoration, improvement of fish passage, and diversion screening.

DFG has identified the CVPIA as one of the two major restoration plans addressing habitat restoration projects to benefit Chinook salmon, with great potential to successfully fund and implement restoration actions needed to protect and restore the run (DFG, 1998). The other major restoration plan is DFG’s action plan for restoring Central Valley streams (DFG, 1993).

Since passage of the CVPIA, Reclamation and the FWS, with the assistance of the State of California and the cooperation of many partners, have completed many of the necessary administrative requirements, conducted numerous studies and investigations, implemented hundreds of measures, and have generally made significant progress towards achieving the goals and objectives established by the CVPIA. A summary of the actions completed in these past 14 years is provided below in Table 18–1. A more detailed narrative discussion of these efforts and of the progress toward achieving CVPIA goals follows.

CVPIA Sections 3406 (b)(1) through (21) authorize and direct actions that will ultimately assist in protecting and restoring salmon and steelhead. These actions include modification of CVP operations, management and acquisition of water for fish and wildlife needs, and mitigation for pumping plant operations. Also included are actions to minimize and resolve fish passage problems, improve fish migration and passage (pulse flows, increased flows, seasonal fish barriers), replenish spawning gravels, restore riparian habitat, and establish a diversion screening program.

Table 18–1 Summary of CVPIA accomplishments – 1992–2007

PROGRAM OR PROJECT	STATUS
Anadromous Fish – Habitat Restoration	
Anadromous Fish Restoration Program (AFRP)	Developed Restoration Plan to guide implementation efforts, partnered with local watershed groups, acquired over 8,200 acres and enhanced over 1,000 acres of riparian habitat, restored over 16 miles of stream channel, placed 72,600 tons of spawning gravels, and eliminated predator habitat in San Joaquin River tributaries. Between 2002 and 2007, the program reopened nearly 200 miles of river to fish passage through the removal or bypass of 7 fish barriers. The program identified 128 structural and non-structural actions to be taken in support of fish doubling goals (53 structural actions and 75 non-structural actions). The 1992-2007 average natural production for all races of Chinook salmon is 477,312, approximately 48% of the doubling target. However, average Chinook salmon production for the period 1992-2006 has exceeded the doubling goal target on Clear and Butte Creeks where substantial funding for passage or habitat improvements has occurred.
Dedicated CVP Yield	The program manages the dedication of 800,000 AF/year for CVPIA purposes. The target has been met each year since 2000; in 2005 and 2006 (both wet years) a portion of this water was banked for future use. In 2007, Reclamation dedicated 800,000 acre-feet of 2007 water and approximately 195,000 acre-feet of banked 2006 water through the (b)(2) program. Improved stream flows created by the dedicated yield in Clear Creek, Sacramento River, American River and Stanislaus River have resulted in increased survival of juvenile anadromous fish passing through the Delta.
Water Acquisition Program (Anadromous Fish Focus)	On average, the program has achieved approximately 50% of its 200,000 AF/year target for annual instream water acquisitions since 2001. Most of this water was acquired pursuant to the San Joaquin River Agreement. An additional purchase of 35,000 AF in 2007 provided water for the federally-listed delta smelt.

PROGRAM OR PROJECT	STATUS
Clear Creek Fishery Restoration	Reclamation and the Service removed McCormick-Saeltzer Dam in 2000, immediately providing access to upstream reaches. As of 2007, the agencies have restored 1.6 miles (of targeted 2 miles) of stream channel and approximately 68 acres of floodplain. Approximately 103,371 tons of spawning gravel were added to the stream since 1995 to create anadromous fish spawning habitat. Approximately 152 acres of shaded fuelbreak were constructed. 12 miles of roadway were treated to control erosion.
Gravel Replenishment and Riparian Habitat Protection	Since 1997 placed a total of 151,000 cubic yards of gravel on the Sacramento, Stanislaus and American rivers to create anadromous fish spawning habitat. Program monitoring has shown improvement in spawning distribution relative to total escapement (Sacramento and Stanislaus rivers) and redd density per square meter (American River). Salmonids have been observed spawning on the gravel at each of the placement sites on the three rivers. In 2007, environmental permitting was acquired for gravel addition at eight new sites in the Stanislaus River. Aerial photos of the American River reviewed in 2007 showed more anadromous fish than available spawning habitat; data will be used in 2008 for gravel placements.
Trinity River Restoration Program	Since 1997 the program has made significant progress toward goals. The flow evaluation study was completed in 1999 and the Record of Decision (ROD) for the Trinity River Mainstem Fisheries Restoration EIS/EIR was issued in 2000. The program completed an inventory of floodplain structures for more than 500 private parcels, replaced 3 bridges, relocated 1 house, improved 1.5 miles of road accessing private homes, and completed all other necessary infrastructure improvements to allow for peak releases of up to 11,000 cfs in compliance with the ROD. The program also has completed 8 mechanical channel rehabilitation projects and added 12,000 tons of coarse sediment (spawning/rearing gravel) to the river. Reclamation has achieved full ROD flows since 2005 following successful resolution of litigation that initially constrained ROD flows in 2001-2004. Water year types since 2005 have included Normal, Extremely Wet, and Dry, with volumes ranging from 453,000 AF to 815,000 AF. More than 1.5 million additional acre-feet of water have been released into the Trinity River since 2001 than would have been without the ROD.

PROGRAM OR PROJECT	STATUS
Anadromous Fish – Structural Measures	
Jones Pumping Plant Mitigation	As of 2007, the program has completed 10 of the 23 identified actions (43%) related to improving fish protection. 2007 actions include continued study efforts to determine the TFCF's present-day fish salvage efficiency, assessment of above-ground holding tanks in the lab (Denver), re-assessment of the outdated Bates Table used for establishing fish hauling densities during transport, improvement to debris and predator management as well as hydraulic control of the facility, collection of water quality data at the entrance to the DMC, distribution of various Tracy Research Volume Series and publications, and updating of the Tracy Research Web site. Also, Reclamation proceeded with replacement of fish transfer buckets and new fish haul trucks and tanks, and began construction of a new onsite research building. All improvements to date have already significantly improved Reclamation's ability to successfully salvage all species of Delta fish, including anadromous fish, and release them safely back into the Delta Estuary.
Contra Costa Canal Pumping Plant Mitigation	Established cooperative program for fish screen project for Rock Slough intake of Contra Costa Canal (CCC); 90% designs and environmental evaluation completed in 2002; reassessment of design alternatives completed in 2007. Implemented an expanded fish-monitoring program in 2004 to assess the status of the fisheries near the pump; conducted in 2006 a Cumulative Impacts Assessment to serve as the basis for future NEPA documentation, identified existing conditions and potential future alternatives.
Shasta Temperature Control Device (TCD)	Program completed in 1999. TCD approved for operation February 1997; final construction report/closeout of construction contract completed in 1999. The TCD has increased operators' ability to control river temperature, turbidity and dissolved oxygen without bypassing power generation (loss in power generation pre-TCD was $35 million over seven years).
Red Bluff Dam Fish Passage Program	Completed interim actions and modification of Red Bluff Diversion Dam operations to meet needs of fish and water users in 1993; as a result, approximately 20 percent of the adult spring-run Chinook and approximately 50 percent of the green sturgeon achieve passage. Draft EIS/EIR of fish passage alternatives issued in 2006; final EIS/EIR expected 2008. Implemented operational changes in 2007 in response to loss of adult green sturgeon near the dam, preventing further loss. Achieved 100% of 25,000 AF of refuge water conveyance capacity.

PROGRAM OR PROJECT	STATUS
Coleman National Fish Hatchery Restoration and Keswick Fish Trap Modification	Two phases of the nine-phase Station Development Plan (SDP) remain to be implemented and are expected to be complete by 2010. To date, the program has completed the following SDP projects: installed an ozone water treatment system, installed fish trap improvements, improved raceways and barrier weir and ladders, and installed interim screens at intakes.
Anderson-Cottonwood Irrigation District (ID) Fish Passage	Program completed in 2001. Monitoring program of adult passage through fish ladders completed in 2003. Modified dam and operations to improve fish passage; designed new fish ladders and screens.
Glenn-Colusa ID Pumping Plant	Program completed in 2007 Constructed fish screen for 3,000 cubic feet per second (cfs) diversion, completed water control structure and access bridge, completed improvements on side channel, implemented biological and hydraulic testing and monitoring to determine if facility is operating per the design criteria. Mitigating actions to reduce impact on terrestrial species near the pumping plant included transplanting 211 elderberry shrubs; planting 6,718 elderberry bush associate plants; will provide 10 years maintenance and monitoring. The program has screened up to 105,000 AF of firm annual water supply to 20,000 acres of Sacramento NWR lands.
Anadromous Fish Screen Program	Since 1994, the program has worked with the state of California and assisted irrigation districts and water companies with fish screening at 23 diversions ranging from 17 cubic feet per second (cfs) to 960 cfs. Cumulatively, the program has supported/funded the screening of more than 4,200 cfs of diversions. Majority of fish screen projects have been on the Sacramento River; e.g., the Sutter Mutual Water Company (SMWC) Tisdale Positive Barrier Fish Screen Project, which screens the largest unscreened diversion (960 cfs) on the Sacramento River; and the Reclamation District 108 Fish Screen Project, which screens three diversions at a new, consolidated 300 cfs diversion.
Refuges and Waterfowl	
Refuge Water Conveyance/Wheeling	Since 1992, the program has, on average, delivered approximately 75% of Level 2 water (out of a target of 422,251 AF); and has delivered all of the Incremental Level 4 water acquired by the Refuge Water Acquisition program.
Facility Construction/ San Joaquin Basin Action Plan	To date, the programs have completed 31 of 46 actions (structures or projects) identified in the environmental documents and related design and specification documents. The success of the program is measured by the capacity of each refuge to accept Full Level 4 water delivery; 14 of the 19 CVPIA refuges now have sufficient external conveyance capacity to accept Full Level 4 water.

PROGRAM OR PROJECT	STATUS
Refuge Water Acquisition	From 2002 to 2006, the program has acquired 60,000 - 85,000 AF of Incremental Level 4 water, representing approximately 50 percent of the quantity mandated in CVPIA.
Other Fish and Wildlife	
Habitat Restoration Program	The program has funded 89 projects supporting the recovery of threatened and endangered species; program funds have also been used to protect 100,000 acres of native habitat for threatened and endangered species.
Land Retirement Program	Launched the Land Retirement Demonstration Program, a pilot program to study environmental impacts and effective restoration strategies for land retirement. Through the pilot program, acquired 9,203 acres and retired 8,345 acres from agricultural production in the San Joaquin Valley. To date, 4,440 of these acres have been restored through the program.
Monitoring	
Comprehensive Assessment and Monitoring Program	Four annual reports have been produced since 1995 to document monitoring activities and the assessment of the biological results and effectiveness of fish restoration activities. The most recent 1997 annual report provides an overview of population numbers from 1992 to 2006 and discusses relevant anadromous fish production trends.
Studies, Investigations, and Modeling	
Flow Fluctuation	Coordinated management of CVP facilities and developed standards to minimize fishery impacts from flow fluctuation; studies on American and Stanislaus rivers are ongoing; Draft Stanislaus River flow fluctuation study to be completed.
Shasta and Trinity Reservoir Carryover Storage Studies	Biological assessment for the CVP Operations Criteria and Plan (OCAP) completed June 2004; included the analysis of storages in Trinity and Shasta reservoirs; identified requirements to ensure the protection of fisheries resources on the lower American and Stanislaus Rivers.
San Joaquin River Comprehensive Plan	Goal is to reestablish and sustain naturally reproducing salmon in the San Joaquin River below Friant Dam to the confluence with the Sacramento-San Joaquin Delta. An 18-year legal challenge has delayed development of the Plan. In support of the Plan's development, in 2007 initiated organizational and management actions with CVPIA authority and funding including development of a Program Management Plan, public involvement/outreach program, and a process for preparation of technical documents for PEIS/R.

PROGRAM OR PROJECT	STATUS
Stanislaus River Basin Water Needs	Prepared Stanislaus and Calaveras river-water-use program and federal Endangered Species Act (ESA) report; additional studies were performed concurrent with the development of Stanislaus River long-term management plans to assess water temperature parameters, refine analysis of groundwater resources, determine effects of flood-lain development and the relationship between reservoir management and the ecological functioning of the river.
Central Valley Wetlands Water Supply Investigations	Program completed in 2000. Report completed that identified private wetlands and water needs, alternative supplies, and potential water supplies for supplemental wetlands. Developed geographic information system (GIS) database to identify potential water supply sources.
Investigation on Maintaining Temperatures for Anadromous Fish	Program completed in 2001. Completed report in 2001 on maintaining temperatures for anadromous fish; included field investigations on interaction between riparian forests and river water temperatures and on the general effects on water temperature of vegetation, irrigation return flow and sewage effluent discharge. Completed report including investigations on tributary enhancement in 1998 and submitted to Congress in 2000.
Investigations on Tributary Enhancement	Program completed in 1998. Completed report on investigations to eliminate fish barriers and improve habitat on all Central Valley tributary streams.
Report on Fishery Impacts	Program completed in 1995. Completed report describing major impacts of CVP reservoir facilities and operations on anadromous fish.
Ecological and Hydrologic Models	Developed six of nine models designed to evaluate existing and alternative water management strategies and improve scientific understanding of ecosystems in the Sacramento, San Joaquin, and Trinity river watersheds. Since 1998, the Ecological/Water Systems Operations Model Program has provided a high level of support for CALSIM, the integrated CVP/SWP model. CALSIM is available to the public and has been used in many large-scale water supply improvement studies including the CVP OCAP and the CALFED feasibility study for storage and conveyance.
Project Yield Increase (Water Augmentation Program)	Program completed in 1996. Developed least-cost plan considering supply increase and demand reduction opportunities; submitted to Congress.

Tracy Fish Facility Improvement Program

The Tracy Fish Facility Improvement Program (TFFIP) is a component of CVPIA Section 3406(b)(4) and its primary focus is identifying and making physical improvements and operational changes, assessing fishery conditions, and monitoring salvage operations at the TFCF in order to reduce the loss of delta fish species during the salvage and trucking process. Research and evaluation efforts to date have included predator removals, whole facility efficiency estimates for various species of interest, holding tank fish stress and damage analysis, biology and movements of local native species within and around the facility (Chinook salmon, delta smelt, splittail, striped bass, etc), evaluation of debris impacts and recommendations for improvement, water quality monitoring, egg and larvae density studies, improved fish handling, and improved fish identification. Facility improvements have included new fish hauling trucks and fish transfer buckets, new primary louver transition boxes, predator removal operations, improved instrumentation, and surface painting of holding tanks to minimize fish abrasion. All activities accomplished under the TFFIP are documented in Reclamation reports as part of the Tracy report series. To date, approximately 35 reports have been completed or are currently under preparation. Reclamation's research efforts are coordinated with the other water and regulatory agencies through the IEP and CALFED. ESA considerations are covered either through language contained in the biological opinions or application of ESA Section 10 permits.

Reclamation is conducting research efforts on-site at Tracy and in Reclamation's lab in Denver to test and assess similar fishery conditions and demonstrate new technologies to be used in the south Delta for improved fish protection.

Chinook Salmon and Steelhead Benefits

Chinook salmon and steelhead benefit greatly through the efforts of the TFFIP and implementation of measures to reduce their loss during the salvage and trucking process. Examples of where improvements have benefited salmon as well as steelhead include:

Primary Louver Bypass Modification at TFCF

Fish bypass transition boxes have deteriorated and were replaced in May 2004. The new transition boxes were previously modeled in Reclamation's lab in Denver and will be modeled again for velocity field conditions after installation. Additional hydraulic testing was completed in 2005. Field fishery evaluation of the new transition boxes were completed using Sacramento blackfish as a substitute species.

Tracy Fish Screen Debris Studies

The existing TFCF does not handle incoming debris loads very well. Several projects are scheuled over the next several years to improve Reclamatioon's ability to clear debris from the trashrack and louver structures such that they operate more as originally designed.Other research will be conducted on-site to explore improved debris removal at various points in the system.

TFCF Full Facility Evaluation

Reclamation will be conducting full facility evaluations of the TFCF as it relates to the various species of fish entering the facility, especially those that are listed or POD species, and how well the system can effectively louver fish into the holding tanks for release back into the Delta. Research has already been conducted within the secondary louver system for several different species.

Improve Removal Procedures from Fish Holding Tanks

Recently conducted studies indicate that survival of fish in holding tanks could be improved with new fish removal procedures, especially during high debris events. The studies will consider new designs that would have application to both the Tracy and Federal fish facilities. Tank and valve development, fish separation strategies, and consideration of pumping techniques that are less stressful on fish will be analyzed and considered for future modifications.

Delta Fish Agreement Summary

Introduction and Background: Delta Pumping Plant Fish Protection Agreement

On December 30, 1986, the Directors of the California Department of Water Resources (DWR) and the California Department of Fish and Game (DFG) signed an agreement to provide for offsetting direct losses of fish caused by the diversion of water at the Harvey O. Banks Delta Pumping Plant (Delta Pumping Plant). The Agreement is commonly known as the Delta Fish Agreement. Because it was adopted as part of the mitigation package for four additional pumps at the Delta Pumping Plant, it has also been referred to as the Four Pumps Agreement. The 1986 Delta Fish Agreement offsets direct losses of striped bass, Chinook salmon, and steelhead. Among its provisions, the Delta Fish Agreement provides for the estimation of annual fish losses and mitigation credits, and for the funding and implementation of mitigation projects. The Agreement gives priority to mitigation measures for habitat restoration and other non-hatchery measures to help protect the genetic diversity of fish stocks and reduce over reliance on hatcheries. The 1986 Delta Fish Agreement indicates that mitigation for project effects may be quantified in smolt or yearling "equivalents," or may be unquantified recognizing that some benefits are not measurable. In the case of Chinook salmon, priority is given to salmon protection measures in the San Joaquin River system.

The 1986 Delta Fish Agreement has been amended three times to extend the period for expenditure of the $15 Million Lump Sum funding component of the original Agreement, with the most recent extension through December 2007. The other funding component of the Agreement is the Annual Mitigation funding, which has no termination date. Since 1986, approximately $60 million in combined funding from the Annual Mitigation and $15 Million Lump Sum components have been approved for over 40 fish mitigation projects through December 2007. About $47 million of the approved funds have been expended to date and the remaining approved funds are allocated for new or longer term projects. Examples of the types of projects that are ongoing, have been completed, or will be implemented in future years that are funded under the existing 1986 Delta Fish Agreement are: fish screens in Butte Creek, San Joaquin River tributaries, and Suisun Marsh; enhanced law enforcement projects to reduce illegal harvest in the Bay-Delta and upstream in the Sacramento-San Joaquin basins; a seasonal fish barrier on the San Joaquin River; fish ladders in Butte Creek; cost-share funding for Chinook salmon production at the Merced River Fish Hatchery; habitat enhancement and river restoration projects in San Joaquin River tributaries and the upper Sacramento River; and water exchange projects on Deer Creek and Mill Creek.

The 1986 Delta Fish Agreement Article V, Paragraph B states measures to offset direct losses for fish species not targeted by the original Agreement shall be included when more information is obtained to develop effective measures, and provides for the addition of other species to the Agreement. Article VII of the Agreement directs DFG and DWR to develop ways to offset the adverse impacts of the State Water Project (SWP) to fish not addressed in the Agreement, and provides for the resolution of indirect impacts to fish through the existing Agreement.

Description of Delta Fish Agreement 2008 Amendment

On May 7, 2007, DWR and DFG entered into a Memorandum of Understanding (MOU) in order to facilitate and expedite completion of the reinitiated consultation of the federal Biological Opinions (BiOps) on the coordinated SWP and Central Valley Project (CVP) operations, commonly referred to as the Operations Criteria and Plan (OCAP). In Paragraph 7 of the MOU, the parties agreed to begin negotiations to amend the 1986 Delta Fish Agreement to "at least address direct and indirect take of delta smelt and indirect take of salmon and methods to develop mitigation credits for this take."

DWR and DFG are finalizing the 2008 Amendment to the Delta Fish Agreement between DWR and the DFG (hereafter "2008 Amendment"), and anticipate that the Amendment will be executed prior to the issuance of the OCAP BiOps. The mitigation actions currently identified in the draft 2008 Amendment are described in this section as "conservation actions" for the OCAP Biological Assessment and subsequent BiOps issued by U.S. Fish and Wildlife Service (USFWS) and NOAA National Marine Fisheries Service (NMFS). The Amendment sets forth the process which will be used to identify and implement actions to preserve species (hereafter "conservation actions"), and requiring specific evaluations, acceptance, progress review, timing and financing of conservation actions. The Amendment acknowledges that the impact estimates and mitigation requirements will be refined based on the actual Export/Inflow ratio parameters set in the BiOps issued by USFWS and NMFS and that details concerning some of the identified conservation actions that have been identified may be modified or refined; and new conservation actions may be proposed.

The draft 2008 Amendment identifies actions, including habitat restoration, for the preservation of Sacramento River winter-run Chinook salmon (hereafter "winter-run Chinook Salmon"), Central Valley spring-run Chinook salmon (hereafter "spring-run Chinook salmon"), delta smelt, and longfin smelt to address impacts by the operation of the Harvey O. Banks Delta Pumping Plant, Clifton Court Forebay, Skinner Fish Facility, and Barker Slough Pumping Plant (collectively, "SWP Delta Pumping Facilities").

DWR and DFG agree that SWP Delta Pumping Facilities cause direct losses of some species other than those specifically listed in the original Agreement and also cause indirect losses. Pursuant to Article V and VII of the 1986 Agreement, under the 2008 Amendment DWR will mitigate for direct and indirect losses of winter-run Chinook salmon, spring-run Chinook salmon, delta smelt, and longfin smelt (referred to hereinafter as "target species") caused by the SWP Delta Pumping Facilities. Measures provided under this Amendment may also benefit non-target fish species.

In the current draft of the 2008 Amendment to the Delta Fish Agreement, DWR would provide direct and indirect benefits to the target species through restoration of aquatic habitat in the Delta and Suisun Marsh, in the amount determined by the DFG methodology described in the DFG Rationale for Effects of Exports, to mitigate for impacts to surface acres of aquatic habitat in the Delta determined to have been impacted by the SWP Delta Pumping Facilities. DWR would also provide direct and indirect benefits to the anadromous target species through funding of mitigation actions described in this section, or equivalent actions, as determined by DFG.

Commitments, Timing, and Financing

DWR and DFG are finalizing the 2008 Amendment. As per the current draft of the 2008 Amendment, DWR and DFG shall work together, in coordination with the USFWS and NMFS, to implement accepted conservation actions using a phased approach to ensure funding and implementation of actions (Year One), and to provide for the funding and development of additional actions (Years Two to Ten). DFG will use the process outlined in the *Evaluation, Acceptance and Progress Review of Conservation Actions* section below to accept conservation actions. As currently anticipated in the 2008 Amendment, to immediately start mitigation to restore habitats needed to provide sufficient nutrient production, spawning and rearing for target species, during Year One, DWR will fund, plan, and implement to the extent practicable the early implementation actions chosen by DWR and DFG, at an estimated cost of $36 million. These early implementation actions include, but are not limited to, protection and restoration of the Cache Slough Complex with an initial focus on Prospect and Liberty Islands, a fixed cost contribution to the Battle Creek Restoration Project, restoration of Hill Slough West Tidal Marsh, and a one-time contribution to the Delta Smelt Refugium Culture Facility. These actions, which are described in greater detail under *Early Implementation Actions* in the Delta Fish Agreement Appendix Y, will be part of the Year One commitments with a funding commitment of $36 million. These actions will be subject to final agreement on the 2008 Amendment to the Delta Fish Agreement by DWR and DFG, DFG acceptance of these actions, and completion of all necessary environmental review and permitting. DWR will also continue funding and implementation of several ongoing annual conservation actions described in detail under *Ongoing Actions* in the Delta Fish Agreement Appendix Y.

Potential additional conservation actions for Years Two to Ten include, but are not limited to, projects in the Yolo Bypass, Sacramento Basin, the Delta, Suisun Marsh, and Cache Slough Complex that are determined by DFG to provide direct and indirect benefits to the target species. These actions are also described in greater detail under *Other Potential Conservation Actions* in the Delta Fish Agreement Appendix Y. These potential additional actions will be identified by DFG and DWR with assistance from USFWS and NMFS and submitted for final acceptance to DFG.

Year One Commitments and Financing

As currently anticipated in the 2008 Amendment, in Year One DWR will initiate or continue implementation of conservation actions identified by DFG and DWR as early implementation actions. DWR will also continue funding and implementation of the following ongoing actions, which are annual conservation actions under the existing Delta Fish Agreement: Salmon Stock Ocean Harvest Inland Escapement Data Processing Program; Deer Creek Flow Enhancement

Program; Mill Creek Water Exchange Program; Butte Creek Fish Passage Monitoring and Maintenance Program; Spring-run Chinook Salmon Warden Protection Program.

DWR will initiate or continue early implementation conservation actions identified above (and possibly others), including several ongoing annual conservation actions under the existing Delta Fish Agreement. DWR will fund the early implementation conservation actions specified above, in Year One, at an estimated cost of $36 million through direct implementation or as cost-share partners in the project. During the first six months, DFG and DWR shall develop an Implementation Schedule and Plan that will identify conservation actions, costs, targeted acreage, and a timeline for DWR's implementation over the term of the Amendment. Pursuant to the 2008 Amendment, plans for individual conservation actions shall include DWR funding sufficient to accomplish full implementation of the action, which may include restoration planning, environmental review, permitting, interim management prior to restoration, restoration implementation, operation and maintenance activities, and monitoring to evaluate project success in meeting the planned restoration objectives.

Years Two through Ten Commitments and Financing

As currently anticipated in the 2008 Amendment, in Years Two through Ten, DWR will work with DFG to initiate or continue implementation of conservation actions identified by DFG in Year One and through the Implementation Plan and Schedule. DWR and DFG will follow the Implementation Plan and Schedule to mitigate the impacts to in-Delta aquatic habitat until the required mitigation acreage is met. Pursuant to the 2008 Amendment DWR will reimburse DFG's staffing costs to plan and implement mitigation actions including tracking compliance with the Implementation Schedule, negotiating land transfer agreements, managing transferred lands, assessing and evaluating results, and helping develop adaptive management plans.

Evaluation, Acceptance and Progress Review of Conservation Actions

The conservation actions, including but not limited to those described in *Early Implementation Actions*, *Ongoing Actions*, and *Other Potential Conservation Actions* in the Delta Fish Agreement Appendix Y, will be identified by DFG and DWR with assistance from USFWS and NMFS and submitted for final acceptance to DFG. Conservation actions could include any of the following, subject to the process outlined below: Ecosystem Restoration Program (ERP) Directed Actions; Ecosystem Restoration Program Proposal Solicitation Process (PSP); DWR sponsored projects; purchase of credits at mitigation banks; cost-share projects or other actions mutually agreed upon by DWR and DFG. DWR and DFG will comply with the California Environmental Quality Act (CEQA) for proposed projects under the Amendment. The process for accepting, implementing, and reviewing conservation actions is outlined below.

Additional Delta Fish Agreement 2008 Amendment information such as the descriptions of proposed conservation actions; action areas; best management practices; avoidance and minimization measures; adaptive management strategy; status of the species; effects of the proposed actions on federally listed species; cumulative effects; determinations; and references are all included in the Delta Fish Agreement Appendix Y.

A. Conservation Action Development and Evaluation Process:

1. Conservation actions will be developed by DFG and DWR in cooperation with USFWS, NMFS, and other responsible regulatory agencies.

2. DFG and DWR shall evaluate each proposal following the guidelines set forth in the Agreement and the criteria set forth in Section B below.

3. Proposed conservation actions will be evaluated using the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) conceptual models and peer reviewed through the ERP Directed Action Process.

4. Proposed mitigation actions will be submitted to the Delta Fish Agreement Advisory Committee for review and comment.

5. Proposed mitigation actions may be modified by input which includes, but is not limited to, that from the public, the Delta Fish Agreement Advisory Committee, or the DRERIP evaluation.

6. The finalized proposal will be submitted to DFG for acceptance of the proposed mitigation action.

B. Criteria: DFG will accept mitigation actions using the following process and criteria:

1. Aquatic habitat actions in the Delta and Suisun Marsh, primarily for the benefit of pelagic target species, which will focus on restoration of intertidal, shallow subtidal, floodplain, and adjacent open water habitats. The acres of habitat restored or enhanced are expected to provide both direct and indirect benefits by enhancing spawning and rearing habitat, increasing primary and secondary productivity in the Delta, and providing export of nutrients to adjacent openwater habitats. These habitat actions are expected to mitigate for productivity impacts which occur as a result of SWP Delta Pumping Facilities exports and support higher larval and juvenile fish survival and increased fitness of spawning adults by improving conditions for the production of forage species. Restored intertidal or shallow subtidal habitats will be expected to: a) provide net export of nutrients to adjacent open water (pelagic) habitat; b) have appropriate hydrodynamic and/or salinity and water quality characteristics to minimize or discourage invasion by non-native submerged aquatic vegetation (*e.g. Egeria*) and *Microcystis* blooms; and/or c) function as spawning and/or rearing habitats for the target species; and d) be located in areas not subject to the near-field effects of SWP Delta Pumping Facilities.

2. Conservation actions primarily for the benefit of the salmonid target species includes, a) provision of flows in tributary streams to enhance upstream passage, over-summering, spawning and rearing habitat, b) barrier removal which improves access to suitable

habitat described above, and/or c) restoration of functional stream geomorphology and floodplain which provides spawning habitat and rearing habitat for out-migrating smolts. These actions are expected to increase available spawning habitat, improve over-summering adult survival, increase spawning success, and increase juvenile survival and fitness.

3. DFG will use its Habitat Management Land Acquisition Checklist to evaluate the acceptability of any property to be transferred as part of its consideration of the proposed conservation action.

C. Review of Progress – DFG will monitor for the effectiveness of the conservation actions towards meeting the criteria in Section B, as follows:

1. The results of mitigation actions will be evaluated by an independent science panel or advisor as agreed to by DWR and DFG at Years Five and Eight of the Amendment, or earlier if necessary, in order to determine if the mitigation actions are meeting intended mitigation criteria for target species.

2. DFG, in coordination with DWR, will review implementation of mitigation actions after Year Four of the Amendment and each two years thereafter, to determine progress towards achieving mitigation acreage.

3. If the review of progress indicates that mitigation actions are not performing adequately, DWR and DFG will implement adaptive management measures as necessary.

D. Mitigation Acreage:

1. As part of its review and acceptance of each conservation action, DFG will determine the amount of acreage to be credited to DWR. The amount of acreage credit will be based upon the criteria in Section B (above) and the evaluation conducted in Section A (above).

2. For cost-share conservation actions, acreage credit will be pro-rated based on DWR's funding contribution towards the implemented action. DFG will determine the pro-ration of acres by using the percentage of funding contributed towards the conservation action by DWR through this Amendment. Or if the action contains distinct elements, DFG will credit the acreage of those elements to the extent funded by DWR through this Amendment. For each individual conservation action, DFG will determine the appropriate method of pro-ration based on which method is more beneficial to the resource.

E. Notwithstanding the foregoing, DFG may accept proposals for mitigation from DWR without reference to the process and criteria set forth above, upon DFG first determining in its sole discretion that circumstances regarding the status of the target species warrant such action. Such mitigation may include, without limitation, the funding of actions or the provision of assets, provided that DFG determines that the action or assets will provide mitigation benefit to the target species. In such event, DFG will credit mitigation acreage to DWR in the amount determined to correspond to the mitigation benefit provided. DFG will advise DWR of the amount of acreage to be credited prior to the funding or implementation of the action.

CALFED Bay-Delta Program

State and federal agencies in the CALFED Bay-Delta Program adopted a Record of Decision (ROD) for the Programmatic Environmental Impact Statement and Report (EIS/EIR) in August 2000. This action committed the Program to a 30-year plan to meet objectives for levee system integrity, ecosystem restoration, water supply reliability and water quality. The agencies also agreed to a preferred program alternative – including moving water across the Delta in what is known as “through-Delta conveyance” – and required an evaluation of its performance at the end of the ROD’s first seven years (Stage 1) of the 30-year proposed plan of action.

The CALFED Program has made progress toward meeting its objectives during the first seven years, particularly in areas outside the Delta, however progress within the Delta has been limited. In the past four years there has been a dramatic decline in abundance of the pelagic (open water) species in the Delta, including the threatened delta smelt, which has reached its lowest recorded levels. This decline, combined with increasing knowledge and awareness of future challenges, including climate change and sea level rise, seismic risk and population growth, calls into question whether current uses of the Delta are sustainable. It further leads to the conclusion that the preferred program alternative for conveyance – through-Delta conveyance as originally envisioned – is unlikely to achieve its objectives.

The four CALFED Program objectives outlined in the ROD remain valid for all efforts to develop and manage a sustainable Delta. The End of Stage 1 Report evaluates progress across all areas of the CALFED Program and outlines a plan to build on the interagency cooperation and work already under way, and incorporate the direction provided by the Governor’s Delta Vision, the BDCP and other initiatives to help implement a long-term management plan for a sustainable Delta.

The following conclusions have been reached based on the results of Stage 1 implementation and information that is now available:

California’s population and demand for water are increasing. Forecasts indicate that California’s population may reach 90 million by 2100. More people will mean more demand for water, greater impacts to existing water resources and an increasing strain on Delta resources. California’s existing water infrastructure is struggling to meet the State’s current needs and will not be able to meet the demands of the future. Californians will need to support a comprehensive plan that includes improved conveyance of Delta waters, increased surface and groundwater storage, and programs aimed at increasing regional self-sufficiency.

Climate change and sea level rise will increase the risk to the State's water supplies. Climate change and the corresponding rise in sea level will have significant adverse impacts in the Delta. Scientists expect California's climate to become warmer during this century. Storm runoff is likely to become more intense, with higher snow lines causing more winter precipitation to fall in the mountains as rain rather than snow. Average winter flows to the Delta are likely to become larger in the future, which will cause more flooding. As sea level rises and winter storms become more intense, fragile Delta levees will be overwhelmed. This will result in the loss of Delta islands to flooding and will put the State's largest water supply at risk.

Seismicity and risk of levee failures. A growing body of information supports the fact that Delta levees are at risk of failure due to earthquakes on faults in or near the western Delta. Such a failure would lead to near-instant contamination of the State's water supply from saltwater intrusion, a disruption in operation of state and federal pumps, and shutdown of the Delta infrastructure of highways, railroads, navigation channels, ports and utility supply lines. Homes, business, and agricultural lands would be flooded and recovery would take years and cost billions.

Restoring ecosystem function in the Delta remains a challenge. Large scale restoration of upstream tributaries and floodplains has been initiated and is continuing successfully. In the Delta, emphasis on targeted research has greatly increased understanding of Delta ecosystem processes, but restoration solutions remain elusive. As in the years preceding CALFED, there remains a conflict between water exports and ecosystem protection in the Delta. The decline in pelagic fishes has highlighted this conflict and the uncertainty surrounding any proposed solutions. Major investments in large-scale experimentation and adaptive management may be needed to clarify how ecosystem function can be improved, given the highly-altered nature of the Delta.

Species invasions need to be controlled. Non-native invasive species constitute one of the greatest obstacles to recovering native species in the Delta. Preventing new invasions and containing and managing existing invasions are essential if viable populations of some native species are to be sustained. Containing aquatic invasive species is particularly challenging. Current scientific thinking is that managing the Delta to increase spatial and temporal habitat variability may improve conditions for native species. While undoubtedly posing trade offs for other Delta constituencies, including agriculture.

Through-Delta Conveyance needs to be reassessed. A growing body of information related to risk of levee failure, water quality, fish losses at export pumps, and rising sea level raises questions about the ability of through-Delta conveyance to meet future water and environmental management objectives. Alternative conveyance methods need to be identified and their costs and benefits assessed to ensure that the water management infrastructure is able to meet future needs of water supply and water quality.

CALFED anticipated a reevaluation of the preferred alternative at the end of Stage 1. In doing so, it allowed for the possibility for changes in programs and projects that would best enable the agencies to meet the still-valid CALFED goals of a reliable supply of water from the Delta, improved water quality for both the ecosystem and for drinking, a restored ecosystem and improved levee stability. Two major efforts now underway will set the stage for how we move forward in the Delta. The challenges of managing a sustainable Delta and providing for the state's water future will be met through cooperative commitment of state and federal CALFED agencies and collaborative efforts with Delta landowners.

Highlights of Accomplishments in Years 1-7

CALFED Program funding has totaled approximately $2.8 billion for water supply reliability projects and programs. Since the ROD was signed, more water has been reliably delivered than in the years of crisis that led to the establishment of the CALFED Program. New groundwater storage and recycling projects are expected to provide a projected 687,000 to 860,000 acre-feet of new water. Favorable hydrology and implementation of projects to increase operational flexibility have resulted in meeting the target of 65 to 70 percent of contract amounts for water deliveries to the Central Valley Project (CVP) south-of-Delta water users in most years since the ROD was signed. In urban areas, investments in water use efficiency, recycling and storage have helped stabilize demand for Delta water. Surface storage feasibility studies are continuing on four potential projects that could increase the State's water storage capacity and add flexibility needed to protect at-risk species, meet water quality standards, and ensure reliable water supplies to cities and farms. Much has been learned about the Bay-Delta system relevant to water supply reliability.

One of the cornerstones of the CALFED Ecosystem Restoration Program (ERP) has been the development of a common vision or single "blueprint" for ecosystem restoration. The ERP was also instrumental in developing a framework for adaptive management. Numerous important projects have been implemented, ranging from targeted research to full-scale restoration. Significant investments in fish screens, temperature control, fish passage improvements and improvements in upstream habitats have improved the outlook for most salmon populations throughout the Central Valley. CALFED ERP agencies have been successful at acquiring and protecting important lands in the Delta and along its tributary rivers and streams.

CALFED-funded research on the Delta has fundamentally changed how scientists now understand Delta functioning. During Stage 1 understanding of the problem of species and ecosystem restoration in the Delta has become clearer, but practical solutions remain elusive. To date, more than 130,000 acres of habitat targeted for important species have been enhanced, protected or restored. More than 54,000 acres of agricultural lands have been protected for their value as habitat. ERP funding has neared the $1 billion ROD target, totaling approximately $900 million and funding an estimated 550 projects.

The CALFED Water Quality Program set as a goal the continuous improvement of Delta water quality for all uses, including in-Delta, drinking water, environmental and agricultural uses. Since the CALFED ROD was signed, drinking water quality standards at the tap have generally been met, but little or no improvement has yet occurred in Delta source water quality. Advances in treatment technology have allowed water users to remain in compliance despite an increasingly challenging water quality and regulatory environment. Research has resulted in a better understanding of how mercury is methylated in the Bay-Delta system and how this affects wildlife and human health. CALFED agencies made progress in understanding and reducing the impacts to water quality from low-dissolved oxygen in the San Joaquin River deep-water ship channel near Stockton, pesticides and toxicity and the bioaccumulation of selenium. Despite meeting current regulatory standards, risks to human health from Delta drinking water remain. It seems likely that regulatory standards for drinking water will become progressively stricter so that future provision of safe and affordable drinking water will depend on improved source water quality. Actual spending during Stage 1 from State and federal sources was approximately $125 million in water quality programs.

The Levee System Integrity Program funds earmarked for levee improvements in State Propositions 13 and 50 were used to replace the State's share of levee maintenance. As a result levee maintenance programs were funded, but long-term levee improvements defined under the CALFED ROD were under funded. Funding to reimburse local maintenance districts for eligible expenditures has reduced the rate of catastrophic levee failure during Stage 1. Substantial progress has been made for reusing dredge material to help stabilize Delta levees and improving the Delta Emergency Response Plan. A Levee Risk Analysis was conducted and resulted in the launching of a study called Delta Risk Management Strategy, which is now underway and shows promise of providing important information on statewide risks associated with Delta levee failure. Program funding from state and federal sources was approximately $140 million, with a Federal share of $1.4 million. Of the state's contribution, approximately $60 million was spent to reimburse local districts for about half of their expenditures on levee maintenance.

Delta Vision – One Vision for the Delta

Delta Vision is a broad initiative designed to study the Delta from all perspectives – not only as a source of water or a unique ecosystem. It was created by Executive Order of the Governor and given the ultimate task of developing a strategy for the Delta's sustainable future by the end of 2008.

The Sacramento-San Joaquin Delta is a unique natural resource of local, State, and national significance. Although it builds on work done through the CALFED Bay-Delta Program, Delta Vision has broadened the focus of past efforts within the Delta to recommend actions to address the full array of natural resource, infrastructure, land use, and governance issues necessary to achieve a sustainable Delta. Delta Vision is based on a growing consensus among scientists, and also supported by recent legislation and other information, indicating that:

- Environmental conditions and current Delta "architecture" are not sustainable.
- Current land and water uses and related services dependent on the Delta are not sustainable based on current management practices and regulatory requirements.
- There is growing consensus that the Delta is dependent upon a levee system that is aging and deteriorating.
- Factors outside of our control will significantly change the Delta during the coming decades. These include seismic events, land subsidence, sea level rise, increasing temperature, more intense winter storms, species invasions and population growth.
- Current fragmented and complex governance systems within the Delta are not conducive to effective management of its fragile environment in the face of the cumulative threats identified above.
- Failure to act to address identified Delta challenges and threats will lead to potentially devastating environmental and economic consequences of statewide and national significance.

A key component of Delta Vision was the appointment of an independent Blue Ribbon Task Force by the Governor that is responsible for recommending future actions to achieve a sustainable Delta. The Task Force has extensively evaluated the existing and proposed land and water uses, ecosystem functions and processes, and management practices in the Delta. Alternative Delta management scenarios are being identified and evaluated. By applying the best available scientific information, and input provided by experts and the public during its open meetings, the Task Force has recommended natural values and functions, services and management practices that should be considered priorities for future management as part of a sustainable Delta.

The Strategic Plan that emerges from Delta Vision will identify and evaluate alternative measures and management practices that would be necessary to implement Delta Vision recommendations. These implementation recommendations will involve considering changes in the use of land and water resources, services to be provided within the Delta, governance, funding mechanisms, and ecosystem management practices. The final Task Force Strategic Plan recommendations will be submitted to the public and the Delta Vision Committee by October 31, 2008. The Delta Vision Committee will submit its report on the final Delta Strategic Plan to the Governor and Legislature by December 31, 2008.

The Delta Vision Strategic Plan will define actions including those that will be implemented in Stage 2 of the CALFED Program.

Bay-Delta Conservation Plan – Conservation Planning

State and federal agencies, along with stakeholders, are developing a conservation plan for the Delta. The Bay-Delta Conservation Plan (BDCP) is intended to provide state and federal endangered species authorizations for the state and federal water projects and their contractors. The BDCP is being developed by a steering committee of state and federal water management and resource agencies, water contractors and non-governmental organizations. When approved, it will provide for conservation of the covered species, water supply reliability, regulatory assurances and funding assurances for implementation of conservation actions. These actions would contribute to implementation of many parts (water quality, supply and ecosystem) of the CALFED Bay-Delta Program. While not intended to be a comprehensive approach to ecosystem restoration of the Delta, the BDCP is focused on the conservation of species closely associated with aquatic habitats that may be affected by water conveyance through the Delta.

On October 6, 2006, DWR and DFG, along with the California Resources Agency, Reclamation, FWS, the NMFS, seven water agencies and other Delta water users, and four non-governmental organizations, signed the BDCP Planning Agreement. Consistent with the NCCP Act, the Planning Agreement recognized that the parties could “elect to preserve, enhance, or restore, either by acquisition or other means, aquatic and associated riparian and floodplain habitat in the Planning Area that support native species of fish, wildlife, or natural communities prior to approval of the BDCP” and that DFG, FWS, and NMFS could agree, if appropriate, to “credit such resources toward the land and water acquisition or habitat protection, enhancement, and restoration requirements of the BDCP.”

The completed BDCP is expected to cover a subset of species and habitats within CALFED's purview and provide a mechanism with which to address improvements. A BDCP Planning Agreement has been completed and a draft BDCP is scheduled for completion in late 2008.

Appendices are delivered on CDROM or available for download at
http://www.usbr.gov/mp/cvo/ocapBA_SEP_2008.html

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