1/6-7/11 Bd. Wrkshop
SJR Technical Report
Deadline: 12/6/10 by 12 noon

california water impact network

California Sportfishing Protection Alliance

"An Advocate for Fisheries, Habitat and Water Quality"

6 December 2010

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SWRCB EXECUTIVE

Jeanine Townsend
Clerk of the Board,
State Water Resources Control Board
Cal/EPA Headquarters
1001 "I" Street, 1st Floor
Sacramento, CA 95814
Sent via email to commentletters@waterboards.ca.gov

Subject: SJR Technical Report Comments

Dear Ms. Townsend, and Board Members:

The California Sportfishing Protection Alliance (CSPA) and California Water Impact Network (C-WIN) have reviewed the State Water Resources Control Board's (Board) Draft San Joaquin River Technical Report (Technical Report) and appreciate the opportunity to submit comments. Our comments include a review of the Technical Report prepared for CSPA by fishery biologist Carl Mesick, PhD, and supporting documents, including:

Mesick, C. 2010. Comments on the Draft Technical report on the Scientific Basis for Alternative San Joaquin River Flow and South Delta Salinity Objectives, 3 December 2010. 5 pages.

> In his comments, Dr. Mesick states that the State Water Resources Control Board omits from the draft technical report the important role of managing instream flow releases for temperature protection of salmon smolts in San Joaquin River tributaries, the need for fall pulse flows to minimize straying by returning San Joaquin River tributaries' salmonid spawners to Sacramento River basin streams, and to address potential fish losses at the state and federal Delta pumping facilities given that both a physical head of Old River barrier is not an available option any longer, and the bio-acoustic fish fence performed poorly in 2010. The most important flows are in the late winter through early spring period, and if flows need to be reduced for alternatives development by the State Board, then it can be most safely done with respect to salmon outmigration in the months of May and June. In addition, in the fall, pulse flows and Delta export rates should be managed to protect salmon, particularly when escapement numbers are low. Dr. Mesick also recommends flow management procedures for dry and critically dry years when salmon escapement numbers are low, while also balancing base flow releases to provide minimally required habitat for spawning and egg incubation in all years for spring flows and fall pulse flows.

Mesick, C. 2010. The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Merced River due to Insufficient Instream Flow Releases, 30 November 2010, 110 pages.

Mesick, C. 2009. The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases, 4 September 2009, 43 pages.

> These two studies present Dr. Mesick's evaluation of the risk of extinction for natural fall-run Chinook salmon populations in the Tuolumne and the Merced rivers, based on well-established academic literature on fishery biology. His research finds that declines in escapement for the salmon populations on these rivers is due to inadequate minimum instream flow releases from La Grange and Crocker-Huffman dams in late winter and spring during non-flood years when daily maximum water temperatures exceed the USEPA temperature threshold of 59 degrees F for smoltification. Fish that fail to outmigrate typically die from warming waters and disease in these rivers. These studies include extensive supporting databases.

Mesick, C. 2010. Instream Flow Recommendations for the Stanislaus, Tuolumne, and Merced Rivers to Maintain the Viability of the Fall-Run Chinook Salmon Populations, 14 February 2010, 29 pages.

> This paper is CSPA Exhibit 11 from the State Water Resources Control Board's Delta flow criteria proceeding last winter, and is accessible at the Board's web page supporting the proceeding. The exhibit provides instream flow recommendations specific to the Stanislaus, Tuolumne, and Merced rivers by water year type as inflow to the mainstem San Joaquin River.

United States Environmental Protection Agency, Office of Water. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002, April 2003, 57 pages.

> Dr. Mesick's recommendations and comments on the draft staff technical report point to Table 1 (page 16) as scientifically comprehensive guidance for managing instream flows to protect salmon smolts.

United States Fish and Wildlife Service. 2005. Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin, 27 September 2005, 31 pages.

> These recommended flow schedules were modeled and written by Dr. Mesick during his employment with the US Fish and Wildlife Service. It presents ten analyses used to justify and determine flow schedules for the Stanislaus, Tuolumne, and Merced Rivers that would be needed to achieve the Anadromous Fish Restoration Program's goal to double salmon and other fish populations relative to their 1967-1991 average population

> levels, pursuant to the Central Valley Project Improvement Act of 1992. These flow recommendations span the February through May period, and cover wet, normal, and dry water year types for all four major rivers in the San Joaquin River Basin.

National Marine Fisheries Service. 2009. Endangered Species Act Section 7 Consultation. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. June 2009, 219 pages composed of excerpted sections 1 and 6.6.

> These excerpts of the NMFS 2009 salmon biological opinion on the state and federal Operations Criteria and Plan (OCAP) are resubmitted as part of Dr. Mesick's and C-WIN and CSPA's comments because it still represents the best summarization of the endangered status of salmonids and anadromous fish (including steelhead and green sturgeon), as well as of Delta inflows by water year types, of Delta export rates by facility and water year type, and of fish entrainment operational dynamics and magnitudes based on modeling of Old and Middle River flows (using both particle tracking and CalSIM II). NMFS analyses provide much-needed context for Mesick's recommendations concerning the importance of timing pulse flows and temperature management to benefit smolt outmigration and survival through what is at present an exceedingly hostile and highly altered estuarine environment in the Delta.

National Marine Fisheries Service. 2010. Letter to USEPA: Comment on the State Water Resources Control Board's "Do Not List either the San Joaquin River or its tributaries, the Merced, the Tuolumne and the Stanislaus for Temperature, 15 November 2010, ten pages.

Lee, G. Fred. 2010. Comments on Water Quality Issues Associated with SWRCB's Developing Flow Criteria for Protection of the Public Trust Aquatic Life Resources of the Delta, 11 February 2010, 5 pages.

> This paper is CSPA Exhibit 22 from the State Water Resources Control Board's Delta flow criteria proceeding last winter, and is accessible at the Board's web page supporting the proceeding. The exhibit is included to highlight the total absence of any discussion in the Technical Report regarding the effects of flow on the concentration and residence time of pollutants in the San Joaquin River and Delta estuary, with the exception of salt. Salt is a conservative constituent and cannot be employed as a surrogate for the universe of impairing and bioaccumulating pollutants.

Our comments, in addition to the above cited comments and attachments, are as follows:

Purpose and Use of the Report

The Introduction to the Technical Report states that the Board is reviewing the objectives and program of implementation for San Joaquin River flow and southern delta salinity contained in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan) and will be considering amendments to the Bay-Delta Plan. The Board will comply with CEQA by preparing a Substitute Environmental Document (SED). The purpose of the Technical Report is to serve as the information and tools to provide the Board with the scientific information and methodology necessary to establish San Joaquin River flow and southern Delta salinity objectives and a program of implementation to achieve the objectives.

The Technical Report is, however, unclear as to exactly how the Board will use it. Is it a scoping document pursuant to the California Environmental Quality Act? Is it intended to help provide a factual basis, in tandem with the eventual release of the SED for upcoming evidentiary hearings? Is it intended to support replacement for the Vernalis Adaptive Management Plan or new salinity standards in the Delta? How does it fit into the schedule leading up to the eventual adoption of a revised Bay-Delta Water Quality Control, scheduled for 2012? At what point does the State Board intend to finalize this report? The Technical Report needs to include more specific information regarding its purpose and the procedures and timelines involved in preparing and considering potential amendments to the Bay-Delta Plan.

Problem Statement

The Technical Report's problem statement concerning fisheries is inadequate and incomplete. There is little discussion of historical fisheries, a chronology of their decline or a river-by-river analysis regarding the effects that dams and diversions have had had on the hydrograph, water quality and fisheries. With respect to salinity, the problem statement is simply absent and should include a discussion of the sources, duration and magnitude of water quality standard exceedance and the historical failure to secure compliance with objectives.

Temperature

While the Technical Report identifies appropriate temperature needs of salmonids and provides a general discussion of temperature as a limiting factor to restoration of fisheries, it fails to specifically describe the spatial and temporal extent of water temperature problems in specific river reaches or address the specific sources of identified temperature impairment. This information needs to be included in any defensible Technical Report.

Upstream Flow Contributions

Omission of instream flow contributions from the upper San Joaquin River (the river upstream of its confluence with the Merced River) goes unexplained and unjustified. This omission augurs a repeat of the upper San Joaquin River's omission and implied exemption from contributing instream flows to the draft D-1630 water rights decision. The Technical Report must incorporate a full analysis of historical and potential instream flow contributions from the upper San Joaquin River. If not, a discussion of why the upper San Joaquin River is excluded from the analysis must be provided.

Range of Alternatives

The flow analysis in the Technical Report fails to offer or consider an adequate range of alternatives. While Figure 3-9 shows simple exceedence plots representing 100%, 60%, 40% and 20% of Vernalis unimpaired flows, only three of these plots represent alternatives that could actually be evaluated in the SED. The Board's report titled *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem*, 3 August 2010, recommended 75% unimpaired flow for the Sacramento River (albeit for a different seasonal period than on the San Joaquin River). While staff initially recommended the same percentage for the San Joaquin River, the draft report, as released, only recommended a 60% criterion for San Joaquin River inflows. There was no discussion or justification for the difference. The Technical Report should address the discrepancy and include and analyze a 75% unimpaired inflow scenario for the San Joaquin River.

Salinity

The salinity analysis of the Technical Report assumes the reader grasps the conversation already under way about South Delta salinity. The salinity analysis needs to provide both a problem statement and a baseline of salinity trends in the South Delta. It needs to discuss the historic salinity condition of South Delta channels before major Delta export pumping and Westside irrigation return flows to the San Joaquin River occurred and describe, in some detail, present conditions. The Central Valley Regional Water Quality Control Board staff published an extensive evaluation of salinity problems in the Central Valley in 2006. We recommend staff consider building on this document to provide a more comprehensive analysis in this Technical Report.

A simple mass balance analysis was used to determine the relative contribution of urban salt loading as a percentage of salt loading entering the head of Old River. We disagree with Technical Report characterization of this percentage as "small." We believe a 5-13% load is significant considering that salinity standards are routinely violated and South Delta channels lack adequate circulation and experience significant null zones. The Technical Report should include a similar mass balance analysis for salt loading from the various upstream sources to provide appropriate context.

In justifying the use of monthly averages in the mass balance analyses to understand the relative importance of contributing factors, the Technical Report claims, "beneficial uses are affected more by longer term salinity averages…" (page 74). This claim requires further elaboration, as excessive salinity levels at critical periods may well have disproportionate impacts.

The centerpiece of the Technical Report's salinity effects evaluation is a 2010 report prepared by Dr. Glenn Hoffman entitled *Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta*. This highly controversial report has not been peer-reviewed. It makes numerous assumptions in concluding that existing salinity levels in South Delta channels are suitable and suggesting that present water quality standards could be relaxed. However, it acknowledges that additional modeling is needed and recommends further studies. While detailing at length Dr. Hoffman's conclusions and recommendations, the Technical Report ignores the considerable controverting evidence and comments presented by South Delta farmers and experts. The Technical Report should explicitly identify the additional needed modeling and studies that will be required before significant weight-of-evidence can be accorded to the Hoffman Report and should propose a formal peer-review of the Report.

Recent information suggests that high levels of salinity in the South Delta may have an effect on fish "homing" on fresh water flows. The Technical Report should discuss and analyze potential impacts of salinity on fish migration.

If the purpose of the salinity analysis in the Technical Report is to provide the technical basis and rationale to enable the Board to propose amendments to the Bay-Delta Plan regarding steps necessary to achieve compliance with existing salinity standards, it is an initial step in the right direction. If, however, it is intended to serve as the technical support and rationale for changing present salinity standards, it is seriously deficient. It should include any comprehensive antidegradation analysis that would be required if salinity standards were proposed to be relaxed.

Water Quality

The Technical Report inexplicably ignores the universe of chemical constituents other than salinity. Water quality and water quantity are flip sides of the same coin; increases or decreases in flow result in changes in constituent concentration and residence time, which in turn impacts beneficial uses.

Consequently, the Technical Report and SED must address the effects and consequences of altered flow regimes on the suite of constituents found in the San Joaquin River, its tributaries and the Delta. These evaluations must extent beyond the 303(d) List of Impaired Waterbodies and encompass increased or decreased additive/synergistic effects and chronic/sublethal impacts. They must include potential impacts caused by increase residence time on bioaccumulative pollutants and oxygen demanding constituents. The Technical Report should include the information necessary to support an antidegradation analysis for any proposed alternative that would increase concentration or residence time and lower water quality.

Water Supply Impact Analysis

We appreciate that the Technical Report seeks to coordinate fishery flows with flows that would help control salinity problems in the South Delta. We also acknowledge and appreciate that the flow analysis continues use by the State Water Resources Control Board of a percent of unimpaired flow approach that mimics the natural hydrograph in all its natural complexity. This approach received substantial scientific support during the Board's Delta flow criteria proceeding. However, this approach does not go far enough.

The Water Supply Impact Analysis states, "[t]his analysis compares flow output from a CALSIM II model run of current conditions in the San Joaquin watershed against estimates of flow needed to satisfy a particular set of SJR flow and southern Delta salinity objective alternatives, and calculates the amount of additional water needed to attain these objectives." Additional needed water will then be "compared against CALSIM II estimates of total diversions from the three eastside tributaries (Stanislaus, Tuolumne, and Merced Rivers) and the portion of the SJR between Vernalis and its confluence with the Merced River." It acknowledges that neither this analysis nor the SED will "address specifically from where the additional water will be provided within the SJR watershed" but serves only to "demonstrate that water is physically available within the watershed.

First, as previously noted, this analysis unacceptably ignores flows from the upper San Joaquin watershed and places an unreasonable burden on water users that depend upon the Stanislaus, Tuolumne and Merced Rivers. Second, this approach, while a necessary initial step, provides little of the information needed to develop a protective flow regime other than to estimate whether 20, 40, 60 or some greater percent of total unimpaired basin runoff is necessary to protect fisheries and water quality. What is critically missing is an evaluation of the specific:

1. requirements necessary to protect fish in each tributary, and
2. impacts to specific water users in specific tributaries from implementation of whatever flow regime is identified to be sufficiently protective.

We believe a more robust and appropriate approach would be to begin to answer these questions now and not wait until some future evidentiary hearing before the Board. While an evidentiary proceeding is the proper place to ultimately "balance" competing needs, resolving the "facts" is an appropriate goal for the Technical Report and SED.

Modeling and CalSim II

Models are complex simulations that, at their best, only represent an idealization of actual field conditions. They must be used with extreme caution to ensure that the underlying model assumptions hold for the site-specific situations being modeled. Subtle changes in coefficients, assumptions or input data can dramatically alter output. It is crucial that models be properly calibrated and verified. Since models only represent an idealization of reality, they're generally better at comparative analyses than absolute analysis: i.e., they're better able to produce a reasonably reliable estimate of relative change in outcome than generate a reliable absolute prediction. Unfortunately, defining where and when a particular constituent will comply with a numerical water quality standard requires reliable prediction.

A critical problem arises when decision makers attribute more precision to modeling results than is warranted and where a model's output is misused to make definitive predictions. As G.E. P. Box noted, "[a]ll models are wrong, but some are useful."

CalSim II is a highly complex simulation model of a complex system that requires significant expertise to run and understand. Consequently, only a few individuals concentrated in DWR, USBR and several consulting firms understand the details and capabilities of CalSim II. State Water Board staff cannot run CalSim II.

The formal peer-review of CalSim II in 2003 (*Strategic Review of CALSIM II and its USE for Water Planning, Management, and Operations in Central California,* 4 December 2003) was highly critical and detailed numerous inadequacies in the model. Among these was the opinion that CalSim II "has not yet been calibrated or validated for making absolute predictions values" (page 9). The 2006 peer-review of the San Joaquin River module (*Review Panel Report San Joaquin River Valley CalSim II Model Review,* 12 January 2006) was even more critical and found that "large uncertainty remains in the new representation due to large unaccounted for flow and salt loads (closure terms) and bias in the salinity model," page 2. The review noted that the San Joaquin module, "retains significant gaps present in the old model, particularly the lack of groundwater representation" (page 9) and it "requires more data for mainstem inflows and diversions of water and salts than is currently available," (ibid). It pointed out that the new model, "systematically underestimates salinity," (ibid). It observed that, "present documentation and testing alone are not sufficient to provide users of the model or model results with a complete reasonable basis for understanding the general accuracy and limitations of CalSim II results. Many assumptions are made without adequate justification and without assessment of their impact on model results," (page 10). While acknowledging that the model is an improvement over its predecessor, the review states, "[m]odel developers also appear to agree that the current representation should be used preferably for comparative purposes and that model output *is not ideal to forecast an absolute condition*" page 48.

We note that Figure 5-2 (page 80) is presented as representing an adequate calibration of CalSim II for purposes of evaluating water supply impacts. Actually there are at least 11 different areas in the figure where CalSim II results vary dramatically in magnitude and occurrence from the observed Vernalis data. These discrepancies appeal to amount as much as 100-200 umho/cm. No explanation is offered in the draft technical report for these numerous and significant variances from actual data. Figure 5-2 is not a winning endorsement for CalSim II's modeling capability. We suspect that a similar calibration comparison focused on the Old River in the South Delta would reveal even greater discrepancy between predicted versus observed values (also applies to DSM2), which is why the Technical Report employees a regression analysis to model salinity impacts.

While a simple regression analysis of Vernalis data versus South Delta data many serve to evaluate water supply impacts, we question whether it is sufficiently accurate to predict compliance with specific water quality standards. We note that the regression analysis comparing salinity at Vernalis versus Old River at Tracy (Figure 4-2) is more scattered than the analysis of Vernalis/Brandt Bridge (Figure 4-4), perhaps because of the null zones in Old River. The Technical Report should discuss the lack of water circulation in the South Delta and the regression analyses should be subject to peer-review.

The CalSim II estimate of flow at Vernalis depicted in Figure 5-1 (page 79) indicates that the model can underestimate winter flow by as much as 150-250 TAF. Perhaps this difference can be attributed to reservoir flood releases or spills but changes in reservoir operation might make this water available during other needed periods. We reiterate that focusing on Vernalis flows can only be an initial step and the Technical Report should extend its analyses to the specific tributaries, including the upper San Joaquin River.

To the extent that results from CalSim II modeling are relied upon by the Technical Report, it is important that the assumptions behind model runs and limitations of model output be made explicitly clear in layman's terms to all parties, especially as staff is unable to run the model. CalSim II should be employed for relative comparative analyses and not relied upon to predict specific results; i.e., whether a potential action will achieve water quality standards or ensure that specific temperature criteria are met. We recommend that all models and the actual modelers be made available for questions and that proposed alternatives to be modeled be discussed and agreed upon by interested parties.

Thank you for considering our comments, suggestions and recommendations. Our organizations look forward to participating actively in the upcoming January 2011 workshop on issues facing the San Joaquin River and South Delta river channels and sloughs.

Sincerely,

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Comments on
The Draft Technical Report On The Scientific Basis For Alternative San Joaquin River Flow And Southern Delta Salinity Objectives

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3 December 2010

On Behalf of the
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The Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives provides well justified summaries of the evidence of the importance of streamflow to the viability of the salmon and steelhead populations in the San Joaquin Basin. However, the recommendation to provide 60% of unimpaired flows in the San Joaquin River at Vernalis from February through June ignores several important flow requirements of Chinook salmon. First, there is very little discussion of the importance of water temperature, as affected by flow management, during the spring when most juvenile salmon undergo smoltification as a highly important determinant affecting juvenile salmon survival and adult salmon production. Second, there are no recommendations to provide fall pulse flows from each tributary to minimize the straying of adult San Joaquin River Basin Chinook salmon to the Sacramento River Basin. Finally, there are no recommendations to minimize losses at the State and Federal pumping facilities considering that there are no plans to install a physical Head of the Old River Barrier (HORB) in the future and the Bio-Acoustic Fish Fence (BAFF) was not very effective at protecting salmon smolts during studies in 2009 and 2010.

Managing Water Temperature for Smoltification

As discussed in the Draft Technical Report, I provided evidence in February and March 2010 that the number of adult Tuolumne River Chinook salmon produced is highly correlated with the number of smolts that migrate from the Tuolumne River in spring (Mesick 2009). Furthermore, the rate that smolts migrate from the Tuolumne River is correlated with water temperatures near the mouth of the river that are less than 59°F, which are suitable for smoltification (Mesick 2009). The EPA has provided ample evidence that water temperatures greater than 59°F impair smoltification and increase the risk of disease (Table 1 in EPA 2003). I provide an additional report with these comments that provides evidence that the number of days that water temperatures were below 59° F from March 20 to June 15 in the lower Merced River is an excellent predictor of the number of adult naturally produced Merced River Chinook salmon that returned to spawn as well as those harvested in the ocean fisheries (Mesick 2010a). My analyses in the Tuolumne (Mesick 2009) and Merced rivers (Mesick 2010a) suggest that if juvenile salmon do not complete the smoltification process during their first spring due temperatures that exceed 59°F, they remain in the tributary where most eventually die, presumably from predation or disease. The likelihood that most juveniles die if they do not complete smoltification during their first spring is based on otolith microchemical analyses that show that very few if any adult fall-run Chinook salmon in the San Joaquin River Basin are produced from yearlings (juveniles that migrate approximately 12 months after they hatch). Microchemical analyses of otoliths taken from about 100 naturally produced adult salmon collected in the Stanislaus River that belonged to the 2000 and 2003 cohorts indicated that none of the adults were produced from yearlings; whereas about 92% of the adults were produced from juveniles that migrated downstream as parr and smolts and 8% as fry in spring 2000 and 2003 (R. Barnett-Johnson, Fisheries Biologist, U.S. Bureau of Reclamation and others, unpublished data).

The Draft Technical Report summarizes the National Marine Fisheries Service analyses (page 52) that suggest that the relationship between adult escapement and flow is more variable at low flows (< 5,000 cfs at Vernalis) than at high flows. My analyses for the Tuolumne (Mesick 2009) and Merced (Mesick 2010a) rivers suggest that this low-flow variability in escapements is primarily due to the influence of water temperature in the lower tributaries. Water temperatures can be suitable for smoltification at low flows during early spring if air temperatures are low.

The issue of managing water temperatures in the lower tributaries versus managing the magnitude of the flow releases as a percentage of unimpaired flows is important for two reasons. First, if the State Water Board requires that at least 60% of the unimpaired flows in the San Joaquin River at Vernalis is to be provided from February through June each year, it is possible that the required flows will not provide water temperatures suitable for smoltification (≤ 59° F) throughout the San Joaquin tributaries to their mouths and thereby not substantially improve smolt survival during the drier water year types. For example, my flow recommendations submitted in February 2010 (Mesick 2010b) would require releases in the Stanislaus and Merced rivers of about 50% to 82% of the total annual unimpaired flows to provide water temperatures at or below 59° F on average only during a brief migration period (March 15 to April 20) during Critical and Dry years. Providing the same volume of water over a much longer period would certainly not be sufficient to manage water temperatures for smoltification. Instead, it would be more beneficial, particularly during Critical and Dry years, to focus the flow requirements on temperature management in March and April, when flow releases can best control water temperatures. Providing suitable water temperatures for smoltification in the lower tributaries during all years (Critical through Wet) for at least the March 15 to April 20 period is critical for maintaining the viability of the salmon populations in the San Joaquin River Basin (Mesick 2009, 2010). In addition, increasing salmon escapements in the San Joaquin River Basin will require increased minimum flows and water temperature management for each of the tributaries, rather than just at Vernalis. Improved flows in the Stanislaus River will not benefit the salmon populations in the Tuolumne and Merced rivers. I recommend that the State Water Board should include my flow recommendations (Mesick 2010b) that were based on meeting the EPA (2001) water temperature criteria for smoltification as an alternative in the Water Supply Impact Analysis. I was the primary author of the Anadromous Fish Restoration Program (USFWS 2005) flow recommendations and I used the same methods to generate my February 2010 flow recommendations to the State Water Board.

The second reason that managing water temperatures in the lower tributaries is important is that the State Water Board should consider that waiting to implement the Vernalis Adaptive Management Plan studies, which include tributary pulse flows and export curtailments, until late April or early May when the smolts are large enough to implant sonic tags is harming the naturally produced fish. The protective measures should be implemented from mid-March to mid-April to protect naturally produced smolts. If the studies must be implemented after April 20th, then additional water and/or export curtailments should be provided for the studies.

Fall Pulse Flows To Minimize Straying

As stated in the July 20, 2010 draft report on the *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem* by the State Water Board, fall pulse flows on the San Joaquin River are needed to provide adequate temperature and dissolved oxygen conditions for adult salmon upstream migration, to reduce straying, improve gamete viability, and improve olfactory homing fidelity for San Joaquin basin salmon. The State Water Board should require increased flows from the Stanislaus, Tuolumne, and Merced rivers as well as Delta export restrictions to reduce stray rates and improve conditions for adult upstream migration (Mesick 2010a). An efficient use of water would be to provide a 10-day pulse flow in late October of 3,600 cfs at Vernalis, when high water temperatures might delay migrating salmon, and then rely on a combination of base flows of 275 cfs and a maximum Delta export rate of 250% of Vernalis flows during October and November throughout the remainder of the migratory period to provide suitable conditions for spawning and egg incubation in the tributaries as well as the necessary flows through the Delta to provide homing cues for adult salmon (Mesick 2010a). Monitoring should be conducted to determine whether these measures would be adequate to minimize adult San Joaquin River Basin salmon stray rates.

Losses At The State And Federal Pumping Facilities

The analyses of adult escapement trends and the VAMP smolt survival studies as summarized in the Draft Technical Report suggest that Delta exports have relatively little effect on the survival of juvenile salmon compared to the effect of spring flows. However, it is likely that losses at the Delta pumping facilities affect the survival of juvenile salmon particularly during Dry and Critical years when spring flow releases from the San Joaquin River tributaries are limited and a physical HORB cannot be installed during the smolt migratory period. The naturally produced adult escapement trends are primarily affected by the unsuitably high water temperatures in the lower tributaries that kill the juvenile salmon before they reach the pumping facilities. However, downstream effects such as losses at the pumping facilities will probably become more important as spring flows are increased. In addition, the VAMP smolt survival studies were conducted during the spring-pulse flows in April and early May and do not represent base flow conditions and a majority of the studies were conducted when the HORB was installed. Finally, loss rates of juvenile salmon are known to be high at the pumping facilities. The total juvenile salmon loss rate, which includes pre-screen mortality, louver efficiency rates, collection-handling-trucking-and release impacts, and post-release survival, is estimated to be 83.4% for the State pumping facilities and 65.0% at the Federal pumping facilities (page 352 in NMFS 2009). These estimated loss rates are probably conservative at the Federal pumping facilities because the pre-screen losses, which are primarily due to predation, have not been studied at the Federal facilities (page 352 in NMFS 2009). There are numerous striped bass near the trash racks and within the fish bypass pipes between the louvers and the salvage holding tanks at the Tracy Fish Facilities and it is likely that the actual pre-screen losses are much higher than the assumed 15% rate currently used to estimate losses. There are also predators that feed on the salvaged fish as they are released in the Delta (see the YouTube Didson camera video named "Feeding Frenzy" at http://il.youtube.com/watch?v=sIoc5SIqpCo&feature=related). During Dry and Critical water year types, approximately 75% of the San Joaquin River flow at Vernalis and 75% of the juvenile salmon enter the Old River (page 58 of the Draft Technical Report) and the pumping facilities. Without protective measures, such as the HORB, more than half of the juvenile salmon die at the Delta pumping facilities. These losses should be minimized to the extent possible, particularly during Dry and Critical water year types.

As described in the Draft Technical Report, the HORB has not been installed during spring since 2007 (page 30) and the BAFF had a low protection efficiency during low flows in 2009 due to high predation rates in the vicinity of the BAFF and it did not keep smolts from entering the Old River during moderate flows in 2010 (page 58). Therefore, it will be necessary to implement other measures to reduce losses of fish that enter the Old River and the State and Federal pumping facilities, particularly during Dry and Critical years when spring flows are minimal. Such measures should include predator reduction, export curtailments, and improved cleaning procedures for trash racks and louvers during the peak smolt migration periods. In the near-term, predator removal efforts should be increased at the Federal and State Facilities, including the canals and forebays leading to the pumps, as well as the release points for salvaged fish. A permanent solution would be to install screens that prevent salmon smolts from being entrained into the canals leading to the pumping facilities. In addition, export rates should be minimized during the smolt migratory period. Trash rack and louver cleaning procedures are in the process of being improved at the Tracy Fish Facilities to help improve louver efficiency. For example, the trash racks are now automatically cleaned at frequent intervals and plans are being implemented to install louvers that can be cleaned in place at the Tracy Fish Facilities. Similar improvements should be made at the State pumping facilities.

Flow Management Priorities

The development of alternatives for the Water Supply Impact Analysis should consider flow management priorities based on the relative importance of winter-spring flows, fall pulse flows, Delta export reductions, and base flows. The studies of adult escapements described in the Draft Technical Report clearly indicate that winter-spring flows, from February through June, are the most important factor affecting the survival of juvenile and adult fall-run Chinook salmon in the San Joaquin River Basin. These flows affect salmon survival by providing floodplain inundation to improve fry survival in the tributaries, suitable water temperatures for smoltification in the tributaries, and suitable water temperatures and water quality in the Delta to minimize stress that affects mortality due to disease and predation. The timing and magnitude of these flows are critical to juvenile salmon survival. Therefore, alternatives for the Water Supply Impact Analysis should vary the duration of spring flows and not reduce the magnitude of flows needed to provide benefits related to floodplain inundation, suitable water temperatures for smoltification, and minimize the risk to disease and predation. The spring flows should also focus on maintaining the magnitude of the flows during the early smolt migratory period, March

15 to April 20, when flow releases can best control water temperatures. Therefore, if flow reductions are necessary for alternatives development, reductions should be made during May and June.

Although other factors, such as fall pulse flows, Delta export rates, and base flows are less important compared to winter-spring flows, maintaining a viable salmon population requires protecting the salmon during all years, including Dry and Critical water years types, to ensure that the population’s genetic diversity is maintained (Mesick 2009, 2010a). Therefore, it is most important to manage fall pulse flows and Delta export rates to protect salmon, particularly when salmon numbers are low. For example, during Dry and Critical years, it is particularly important to minimize Delta exports rates from March 15 until the number of smolts migrating in the Delta declines substantially. In addition, it is particularly important to minimize Delta exports and release pulse flows during October and November during years when San Joaquin Basin escapements are expected to be low to minimize the number of adult salmon that stray to the Sacramento Basin. Base flows should be managed to provide the minimally required habitat for spawning and egg incubation in all years to conserve water for spring flows and fall pulse flows.

Supporting Exhibits

[EPA] U.S. Environmental Protection Agency. 2003. *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards.* EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA.

Mesick, C.F. 2009. The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases. Report prepared for the U.S. Fish and Wildlife Service, Sacramento, CA.

Mesick, C.F. 2010a. The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Merced River due to Insufficient Instream Flow Releases. Report prepared for the California Sportfishing Protection Alliance.

Mesick, C.F. 2010b. Instream flow recommendations for the Stanislaus, Tuolumne, and Merced rivers to maintain the viability of the fall-run Chinook salmon populations. Report produced on behalf of the California Sportfishing Protection Alliance.

[NMFS] National Marine Fisheries Service. 2009. Biological opinion and conference opinion on the long-term operations of the Central Valley Project and State water project.   Endangered Species Act Section 7 Consultation. National Marine Fisheries Service, Southwest Region, June 4, 2009.

[USFWS] U.S. Fish and Wildlife Service. 2005. Recommended Streamflow Schedules to meet the AFRP Doubling Goal in the San Joaquin River Basin. 27 September 2005. Prepared by the Anadromous Fish Restoration Program, USFWS, 4001 N. Wilson Way, Stockton.

The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Merced River due to Insufficient Instream Flow Releases

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ABSTRACT

Fall-run Chinook salmon (*Oncorhynchus tshawytscha)* escapement in the Merced River, which is tributary to the San Joaquin River in the Central Valley of California, has fluctuated from 29,749 adult salmon in 1984 to 82 adult salmon in 1990. The Merced River Chinook salmon population has been augmented with hatchery fish since the Merced River Hatchery (MRH) began operating in summer 1970 and there are large numbers of out-of-basin adult hatchery salmon that stray to the Merced River annually. The Merced River's population of naturally produced fall-run Chinook salmon was judged to be at a high risk of extinction based on criteria by Lindley et al. (2007), because from 1998 to 2007, the population declined at an excessive rate (> 20% annually) and the mean percentage of hatchery fish in the escapement was too high (72.8%).

The decline in escapement is primarily due to inadequate minimum instream flow releases from Crocker-Huffman Dam during the spring when the daily maximum water temperatures in the lower river exceed the EPA (2003) threshold of 59°F for smoltification and to a lesser extent during late October when adult salmon are migrating upstream. The importance of flow and water temperatures in the Merced River and the San Joaquin River near Vernalis during the spring smolt migration period was apparent in analyses with both adult recruitment and smolt CWT survival studies. It is likely that maintaining water temperatures below the EPA (2003) threshold of 59°F, particularly in the lower Merced River, is important for smoltification and is highly correlated with the number of smolts that leave the Merced River. Flow releases from Crocker-Huffman Dam during the spring not only help maintain suitable water temperatures in the Merced River, but also improve smolt survival in the San Joaquin Delta by increasing flows and water temperatures in the Delta. Late October flows are important, because up to 58% of the adult MRH fall-run Chinook salmon with CWTs that were recovered in Central

Valley rivers during the fall-run Chinook salmon escapement surveys from 1979 to 2007 (Mesick et al. 2009a) strayed to the Sacramento River Basin when the 10-day mean flow in the San Joaquin River at Vernalis in late October was less than 3,500 cfs. Other factors that put the population at a high risk of extinction include unusually unfavorable ocean conditions for the survival of juvenile salmon, such as occurred during spring 2005 and 2006 (Lindley et al. 2009).

INTRODUCTION

The escapement of fall-run Chinook salmon (*Oncorhynchus tshawytscha)* population in the Merced River, which is a tributary to the San Joaquin River in the Central Valley of California, was usually less than 500 fish until minimum instream flows were established under the Davis-Grunsky Act in October 1966 and the Merced River Hatchery began operating in summer 1970 (Fig. 1). The total escapement increased to a high of 29,749 in fall 1984 following prolonged flood control releases during the spring of 1982 and 1983. However, total escapement declined to an average of about 500 fish in fall 2007, 2008, and 2009 in spite of high flows in spring 2005 and 2006, presumably as a result of abnormally poor ocean conditions (Lindley et al. 2009).

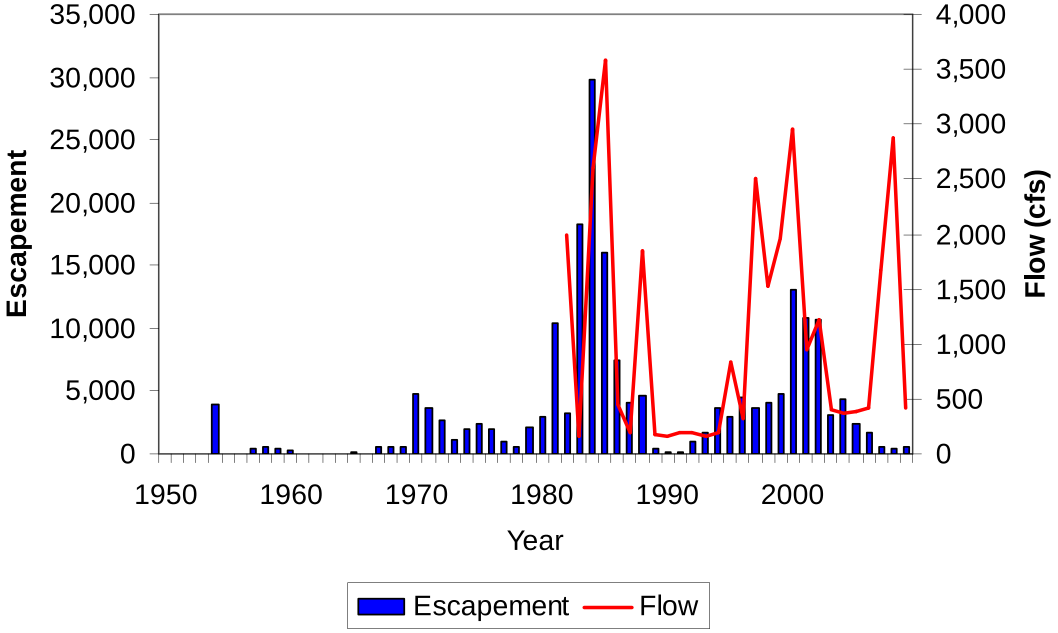

Fig. 1. Total escapement of fall-run Chinook salmon in the Merced River and Merced River Hatchery from 1954 to 2009 and the mean streamflow in the Merced River near Cressy (rivermile 27.75) from 1 February to 15 June two years prior to the escapement estimate. Escapement estimates from 1954 to 2007 were published in the California Department of Fish and Game GrandTab file in March 2010 which is available at www.CalFish.org.

The Merced River Chinook salmon population has been augmented with hatchery fish since the Merced River Hatchery (MRH) began operating in summer 1970. Initially, the hatchery consisted of an artificial spawning channel and off-river ponds for raising juvenile salmon to a yearling size. The artificial spawning channel was 4,372 feet long with 3,830 feet of spawning gravels interspersed with 6 resting pools that were used by naturally spawning fish. During fall 1970, 38 female salmon spawned in the channel and approximately 59,127 juvenile salmon migrated from the channel (Menchen 1971). The spawning channel was used until the fall of 1980, when artificial spawning was first used at the hatchery (Poe 1982). An off-channel rearing pond with a capacity to hold about 100,000 juvenile salmon was used in summer 1971 to rear juveniles to a yearling size for fall releases in the Merced River. Three off-channel rearing ponds were operational by spring 1974, with a total capacity of about 450,000 yearlings (Chase 1978). From 1971 to 1973, the fish reared in the ponds were the progeny of adult salmon that were trapped in the Stanislaus River near the Orange Blossom Bridge (Menchen 1971). Yearlings were reared in the ponds through October 1991; whereas subyearling smolts were released during April through May thereafter. In 1991, the hatchery was modernized to include a permanent hatchery building with the capacity to incubate 3,000,000 eggs, 2 nursery tanks with the capability to start feeding of approximately 100,000 swim-up size salmon each, 10 nursery tanks that hold up to 90,000 fingerlings each, 1,000 linear feet of concrete raceways consisting of ten 100 foot-long ponds, larger water supply lines, and ultraviolet treatment for the water supply (Cozart 2005).

To assess the viability of the Merced River fall-run Chinook salmon population, it is necessary to determine number of hatchery reared fish in the escapement. This has not been previously been done, because many of the MRH fish are not marked for identification and it is likely that unmarked fish from other Central Valley hatcheries, such as the Coleman National Fish Hatchery (CNFH) on Battle Creek, Feather River Hatchery (FRH), Nimbus Fish Hatchery (NFH) on the American River, and the Mokelumne River Fish Installation (MRFI), migrated into the Merced River to spawn. Estimates of the number of naturally produced and hatchery produced salmon in the Merced River escapements from 1980 to 2007 are provided here. The estimates of hatchery reared fish were derived from 28 years of coded-wire-tag (CWT) studies that provide data on the rates that adult hatchery salmon were recovered in the Merced River relative to habitat conditions that affected the survival of the juvenile fish, ocean harvest rates of the adult fish, and habitat conditions that would have affected the homing success of the adults returning to spawn.

The estimates of the number of naturally produced fish in the Merced River escapement are used in this report to show that the population is at a high risk of extinction based on the population level criteria developed by Lindley et al. (2007). Lindley et al. (2007) characterized Chinook salmon populations with a high risk of extinction (greater than 20 percent chance of extinction within 20 years) as those with a total escapement that is less than 250 spawners in three consecutive years (mean of 83 fish per year), a precipitous decline in escapement, a catastrophe defined as an order of magnitude decline within one generation occurring within the last 10 years, and a high hatchery influence. Populations with a low risk of extinction (less than 5 percent chance of extinction in 100 years) have a minimum total escapement of 2,500 spawners in three consecutive years (mean of 833 fish per year), no apparent decline in escapement, no catastrophic declines occurring within the last 10 years, and a low hatchery influence. Populations with a moderate risk of extinction are those at intermediate levels to the low and high risk criteria (e.g., total escapement in three consecutive years between 250 and 2,500 spawners. The overall risk for the population is determined by the criterion indicating the highest risk of extinction. These criteria are slight modifications of those used by Allendorf et al. (1997).

This study further demonstrates that there is a strong relationship between the number of naturally produced adult salmon that return to the Merced River and the magnitude of flow and water temperature during the winter and spring that affect the survival of the juvenile fish. Therefore, the high risk of extinction for the naturally produced population in the Merced River is primarily due to the combined effects of inadequate flow releases in the Merced River and periodically poor ocean conditions, such as occurred in spring 2005 and 2006 (Lindley et al. 2009), that negatively affect the survival of juvenile salmon.

METHODS

The methods used to estimate the number of adult salmon with CWTs recovered in the Merced River are described in Mesick et al. (2009a). Assessing trends in the escapement of naturally produced fish requires estimates of recruitment, which is defined as the number of salmon in the same cohort (same age) that survive to Age 2. The methods used estimate the number of naturally produced adult recruits in the Merced River population are described in Mesick et al. (2009b). Described below are the methods used to estimate the number of untagged hatchery produced Chinook salmon releases that returned to the lower Merced River in the adult escapement.

Untagged Hatchery Salmon Estimates

The estimated numbers of unmarked hatchery fish that returned to the Merced River as adult salmon from 1980 to 2007 are based on the assumption that the unmarked hatchery fish would have returned to the Merced River at the same rates that the marked hatchery fish returned to the Merced River if they were released in the same general location under similar habitat conditions. The number of unmarked fish released was obtained from the CDFG annual reports for the FRH, NFH, MRFI, and MRH and from the Regional Mark Information System for the CNFH. Some of the MRH release data was obtained from planting release records.

If there were a sufficient number of CWT releases of hatchery reared juvenile salmon over a range of habitat conditions, separate logistic models were developed for the CWT recovery rate in the Merced River and important habitat conditions for Age 2, Age 3, and Age 4 salmon. The coefficients for the habitat variables and the model's constant were then used to compute the logit value of the estimated CWT return rate, which corresponded to the number of adults that migrated to the Merced River divided by the number of juveniles released. The logit value was converted into a return rate using the standard formula:

$$\text{Probability of Return} = 1.0 / (1.0 + \text{EXP}(-\text{LOGIT}))$$

Separate models were developed for hatchery releases of juvenile salmon from the MRH, MRFI, and the Sacramento Basin hatcheries because the tendency to migrate to the Merced River differed between them. Based on the CWT recoveries, the MRH releases return to the Merced River at the highest rates because these fish would naturally home to the Merced River (Mesick et al 2009a). The MRFI releases return to the Merced River at moderate rates because the Mokelumne and Merced rivers are both tributaries to the San Joaquin River so the MRFI fish would home to the Mokelumne River with a tendency to stray to other San Joaquin tributaries, particularly the Merced River (Mesick et al. 2009a). The Sacramento Basin hatchery releases return to the Merced River at the lowest rates, because most would home to the Sacramento River (Mesick et al. 2009a).

Separate models were also developed for different release locations because the farther downstream the juvenile fish are trucked from the hatchery, the greater the likelihood that the adults would stray to a non-natal river. Almost all of the recoveries of adult CWT salmon from the Sacramento Basin hatcheries, which include the Coleman National Fish Hatchery (CNFH), Nimbus Fish Hatchery (NFH), and the Feather River Hatchery (FRH), were from juvenile releases in the West Delta. I define the West Delta where the flow from the Sacramento and San Joaquin rivers mix. This includes the release sites near Collinsville on the Sacramento River and Jersey Point on the San Joaquin River and all others in the Bay to the west. The MRFI releases were segregated into Tributary, Mainstem, East Delta, and West Delta regions. Tributary releases were upstream of the confluence with the Delta Cross Channel. The East Delta releases were made in the Mokelumne River between the confluence with the Delta Cross Channel and the mouth of the Mokelumne River, which includes releases at New Hope Landing. The Mainstem releases were made in the Sacramento River near Rio Vista and West Sacramento. The MRH releases were segregated into 3 regions: (1) tributary which includes releases throughout the Merced River; (2) mainstem San Joaquin River releases upstream from Jersey Point; and (3) West Delta releases that included Jersey Point.

The initial steps of the analysis were to make two comparisons: (1) compare various indices of ocean conditions to identify the best one that reflects the survival of juvenile salmon as they entered the ocean at the Gulf of Farallones; and 2) determine whether the month of juvenile release affected adult recovery rates. First, logistic models were used to evaluate different indices of ocean conditions on an index of survival. An index of survival, which was the rate that each CWT release group was recovered in all Central Valley rivers combined as well as the sport and commercial ocean harvest, was used to focus the evaluation on juvenile survival by eliminating the effect of straying and ocean harvest. The survival indices included the CWT data on West Delta releases for the CNFH, FRH, NFH, and MRFI hatcheries that were primarily made at Benicia, Wickland Oil Net Pens, Crockett, and Port Chicago. The logistic models were computed for the survival indices separated by the month of release for April through November. The results indicated that the Coastal Upwelling Index (CUI) that corresponds to the Gulf of Farallones (37.5^{o} N, 123.5^{o} W) for the month of April was most highly correlated with the West Delta survival indices for CWT releases made in April through August (Fig. 2) than were CUI estimates for the months of May through August. The CUI for the month of April was also more highly correlated with the West Delta survival indices than were spring (mean for March, April, and May) estimates of curl and sea surface temperatures (Wells et al. 2007) as well as estimates of production of zooplankton, shortbelly rockfish (*Sebastes jordani)*, and a top Predator, the common murre (*Uria aalge*, Wells et al. 2008). Therefore, the April CUI index was used as the sole index of ocean conditions for the spring and summer releases of hatchery fish. The CUI database is developed and distributed by the Pacific Fisheries Environmental Laboratory, National Marine Fisheries Service's Southwest Fisheries Science Center, Pacific Grove, California.

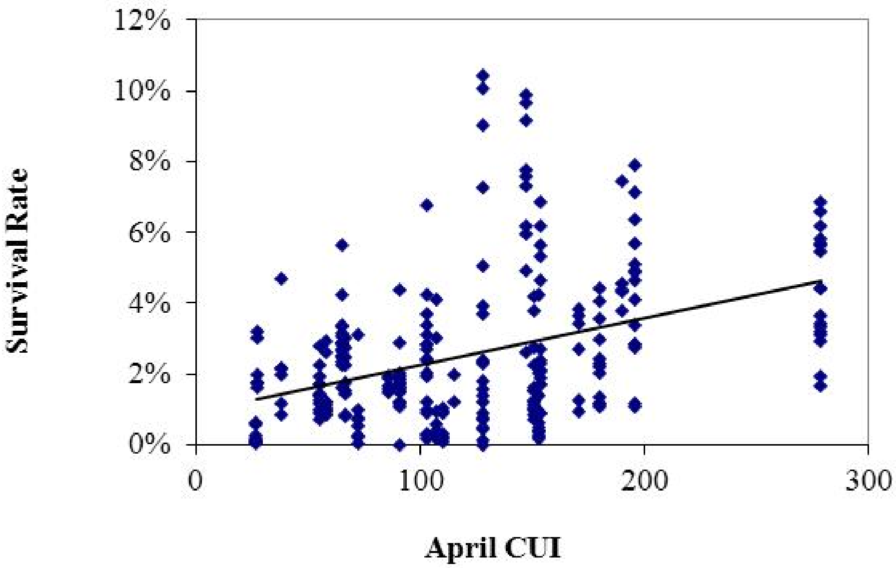

Fig. 2. Survival rates for each coded-wire-tag code of juvenile Central Valley hatchery fall-run Chinook salmon released in the West Delta from April through August from 1980 to 2004 relative to the mean coastal upwelling index for April corresponding to the Gulf of Farallones. Survival rates were computed as the number of adults recovered during inland escapement surveys and in the ocean fisheries divided by the total number of juveniles released. The line represents a linear regression generated by Excel 2010. A linear regression was the best fit to the observed estimates compared to logistic or polynomial regressions.

A similar analysis was conducted for West Delta releases made in September, October, and November. The results indicated that the November CUI was more highly correlated with the West Delta survival indices than were CUI indices for all the months between the April prior to the CWT release and the February following the CWT release. Therefore, the November CUI index was used as the sole index of ocean conditions for the fall releases of hatchery fish.

To determine whether the month when juvenile releases were made affected adult recovery rates (i.e., juvenile survival rates), a conditional variable was added to the West Delta release dataset that identified the month of release and comparisons were made using Analysis of Covariance that included the April CUI index as a covariable. A Tukey HSD all-pairwise comparison test indicated that there were no significant differences in the survival index between releases made in April, May, June, and August. The mean survival indices for May, June, and August ranged between 0.023 and 0.027; whereas, the mean of the survival index for April was 0.017. Although, the survival index for releases made in July was significantly higher ($P \leq 0.05$, mean 0.036) than the other spring and summer months based on the comparison test, most of the July releases were made during a few years when the April CUI was unusually high. Therefore, it was assumed that the effect of different release dates could be accounted for in the logistic model by including a variable of the mean weight of the juvenile salmon for the West Delta releases or a variable on maximum water temperature for the tributary and mainstem releases. The mean weights for the West Delta Sacramento Basin releases were 6.5 g, 9.7 g, and 14.8 g, for the months of April, May-June-Aug, and July, respectively, and it is likely that the high survival rates for July were a function of the large size of the fish released.

Inland Habitat Variables and Smolt Migration Rates

The CWT recovery rate models were developed by using step-wise procedures with a variety of habitat and biological variables including streamflow, maximum daily water temperature, Delta export rates, adult harvest rates in the ocean, rates that MRH adults strayed to the Sacramento River Basin, the April or November CUI index, the mean weight of the juveniles at the time of their release, and the total number of juveniles released in each CWT group (Table 1).

The time periods used to estimate the mean estimates for the habitat variables described in Table 1 were based on the mean number of days for CWT juvenile salmon released in the upper Merced River between the Merced River Hatchery and Shaffer Bridge and recovered at the Hagaman rotary screw trap near the mouth of the Merced River (RM 13), the Mossdale trawl, Chipps Island trawl, and National Marine Fisheries Service trawls in the Bay and ocean. Generally, the average migration rates were slowest in the river and during high flow releases in the Merced River, when water temperatures were low from 1994 to 2006:

Merced River Flows	Hagaman Park	Mossdale	Chipps Island
<2,000 cfs	5.2 days	7.3 days	14.7 days
>2,000 cfs	7.4 days	20.4 days	24.0 days
Miles Traveled	50.6	114.4	170.1

The average migration rate for MRH juveniles released near the mouth of the Merced River, which was typically at Hatfield Park (RM 1.3), was 6.8 days and 5.9 days when Merced River flows were below and above 2,000 cfs, respectively. Trawling by the National Marine Fisheries Service (MacFarlane and Norton 2002) recaptured 3 MRH fish that were released at Hatfield State Park, Dos Reis Park, and Mossdale and then recovered in the trawl between Carquinez Strait and the Gulf of Farallones after an average of 17 days (12 to 28 days) from the date of release in spring 1997. One MRFI CWT juvenile released at Woodbridge Dam in the Mokelumne River was recaptured at the Golden Gate Bridge after 11 days from the date of release in 1997 (MacFarlane and Norton 2002). These results suggest that although the entire group of fish slowly migrated downstream in the Merced River, those that survived were migrating at a faster rate compared to those that died.

To simplify the analysis, it was assumed that the migration rates observed when Merced River flows were less than 2,000 cfs would accurately reflect the habitat conditions that affected the survival of all CWT release groups regardless of flow level. This assumption is reasonable because habitat conditions would be relatively stable during wet year flood control releases and so the precise time period would be less important for computing the mean habitat conditions during high flows. For example, daily water temperatures do not vary as much at high flows as they do at low flows.

The time periods for the habitat variables (Table 1) were intended to track the majority of the release group as they migrated downstream to the ocean. For example, it was assumed that the survival of a group of fish released at the MRH would be primarily affected by the mean habitat conditions (e.g., maximum daily water temperature) near the mouth of the Merced River from day 3 to day 6 after their release. Then it was assumed that they would be affected by the mean conditions in the San Joaquin River near Vernalis, including water temperature, flow, installation of the Head of the Old River Barrier, and export rates, from day 6 to day 15 after their release. Finally, they would be affected by the mean conditions in the Bay west of Chipps Island from day 13 to day 19 after their release.

Age Specific Model Development

It was assumed that the Age 3 CWT recovery models were more accurate than the Age 2 or Age 4 models, particularly for the recovery rates of CWT Sacramento Basin hatchery fish in the Merced River, because Age 3 fish return to spawn in the highest numbers and therefore there is a higher likelihood that rare CWTs would be recovered as Age 3 fish. Furthermore, it was assumed that the factors that affected the juvenile stage would have the same effect on the recovery rates of Age 2, Age 3, and Age 4 fish, because they all belong to the same cohort. Therefore, the Age 3 models were developed first and then the coefficient of the most highly correlated juvenile habitat variable in the Age 3 model was inserted into the Age 2 and Age 4 models. This was done in the *Statistix* program by using an “Offset Variable” that subtracted the coefficient of the most highly correlated juvenile habitat variable from the linear predictor (Analytical software 2008).

RESULTS

The results are presented in two sections. The first presents the logistic models of CWT recovery rates and the estimated number of hatchery salmon in the Merced River escapement. The second pertains to the risk of extinction analysis.

CWT Recovery Rates and Hatchery Salmon in the Merced River Escapement

The coefficients of the logistic regression models used to estimate the CWT recovery rates are presented in Tables 2a-e. The models were moderately predictive of the mean CWT recovery rates for most years when a substantial amount of CWT recovery data were available (Appendix 1). However, the models were not predictive of the observed recovery rates during some years, presumably when the indices used to represent ocean conditions (April and November CUI) did not accurately reflect low rates of survival of juvenile salmon. For example, none of the indices of ocean conditions tested here predicted the unusually low survival rate of 0.08% for the hatchery juveniles released in the West Delta in spring 2005. Survival rates were based on the total CWT recoveries in the ocean fisheries and inland escapements and so only ocean conditions (i.e, not adult harvest or straying) should have affected the survival of West Delta releases.

When the models were used to predict the recoveries of untagged salmon for all years in the preliminary analyses, the total estimated hatchery escapement of tagged and untagged fish exceeded the total observed escapement of naturally produced and hatchery fish in some years. A comparison of the observed to the estimated recovery rates based on the preliminary models indicated that the preliminary models were overestimating the CWT recovery rates during the same years when total estimated hatchery escapements exceeded the total observed escapement estimates. Therefore, the unusually low observed recovery rates (i.e., model outliers) are probably accurate whereas the preliminary models probably did not include all the habitat variables needed to predict the unusually low recovery rates. Some of the missing habitat variables in the model may include factors such as whether the tagged fish were impaired by disease or high predation rates at the site of release. Many factors, such as disease and predation, that are not routinely monitored cannot be empirically modeled.

To develop the final models used to estimate the total number of untagged hatchery fish in the escapement, the unusually low CWT recovery rates were not used in model development. Instead, the models were used for years when the model was fairly predictive compared to the observed data, whereas when CWT recovery rates were unusually low compared to the model prediction, the mean annual CWT recovery rate was used to expand the untagged releases made in the same year (Tables 2a-e). It is assumed that this method overcame the weakness of the final model caused by missing habitat variables, such as disease or predation at the specific release site.

CWT recovery rate models were also not used when there were too few data for some of the release groups. For example, MRH CWT yearling releases during the fall in the San Joaquin River near Mossdale were made only during 5 years (brood years 1980 to 1984) and there was insufficient variation in the habitat variables to construct a meaningful model with those data. So whenever there were too few recovery data to develop a model, the mean annual CWT recovery rate was used to expand the untagged releases made in the same year, and it was assumed that no fish were recovered in the Merced River during years when there were no observed data.

None of the logistic regression models of CWT recovery rates, which were based on individual CWT code releases, were statistically significant. The coefficients for the variables used (Tables 2a-e) had probabilities of at least 0.74 and typically greater than 0.90. A partial explanation is that there was a high level of variability in recovery rates among replicate CWT releases. For example on 26 April 2001, three replicate CWT groups (codes 064419-21) of about 25,000 fish each were released at the Hatfield State Park and the fish in each group were similarly sized (average of 6.9 grams per fish). Although these 3 CWT groups were exact replicates, the recovery rate of the Age 3 adults in the Merced River escapement ranged between 0.0237% and 0.237% (10-fold difference) between the three different CWT groups. A high level of variance among CWT replicate groups primarily reflects the problem that recovering individual CWTs in the escapement is like looking for a needle in a haystack. The total number of CWTs in the escapement is low because very few juvenile fish are tagged and mortality rates to the adult stage are high. In addition, only a portion of the adult carcasses in the escapement are examined for tags and so the potential for sampling error is high. On the other hand, the effect of this sampling error is reduced by the models, which reflect the average of all the observed recovery rates. The plots of the mean observed values versus the predicted values shown in Appendix 1 suggest that the models are moderately predictive.

The estimated numbers of naturally produced, tagged hatchery salmon with CWTs, and untagged hatchery salmon in the Merced River escapement from 1980 to 2007 are summarized in Table 3 and presented by untagged release group in Appendix 2. The estimates of untagged hatchery salmon are probably conservative because no estimates were made for some release groups in years that lacked observed data. For example, MRH yearling releases in the Merced River in fall 1987, 1988, 1989, and 1991 were assumed to produce no returns to the Merced River due to a lack of CWT recovery data.

Risk Of Extinction Analysis

The Merced River fall-run Chinook salmon population would be considered to be at a high risk of extinction based on the criteria by Lindley et al. (2007) because there was a high percentage of hatchery fish in the escapement from 1998 to 2007 and there was a precipitous decline in escapement from 1998 to 2008. The overall risk for the population is determined by the criterion indicating the highest risk of extinction (Lindley, Fishery Biologist, National Marine Fisheries Service, personal communication) and the high percentage of hatchery strays from the MRFI, FRH, and NFH and the precipitous decline in escapement both indicate that the population is at a high risk of extinction.

Based on the other risk of extinction criteria (Lindley et al. 2007), the population would be considered to be at a moderate risk of extinction from 1981 to 2007: (1) the minimum population size was at least 250 adults over a three year period; and (2) there was no catastrophic decline in escapement over a generation. My analyses are based on estimates of the number of naturally produced and hatchery produced adult fall-run Chinook salmon that have returned to the Merced River between 1981 and 2007 (Table 3).

Effective Population Size

The effective population size criteria relates to the loss of genetic diversity (Lindley et al. 2007). The effective population consists of individuals that are reproductively successful, including grilse (Allendorf et al. 1997). In Chinook salmon populations, not all individuals are reproductively successful and the mean ratio of the effective population size to total escapement over a three year period (N_e/N) has been estimated to be 0.20 based on spawner-recruit evaluations of over 100 salmon populations from California to British Columbia (Waples et al. 2004 as cited in Lindley et al. 2007). A few examples of why adult salmon may not reproduce successfully in the Merced River include: (1) redd superimposition that destroys eggs; (2) spawning in habitats with excessive levels of fines; and (3) low survival rates for juveniles that migrate late when high water temperatures in the lower Merced River are unsuitable for survival. Therefore based on effective population size (Ne), the Merced River could be considered to be at high risk if annual escapement (N) drops below a mean of 83 fish for three consecutive years and at low risk if escapement remains above a mean of 833 fish for three consecutive years.

The escapement estimates of naturally produced fish over a three year period dropped to lows of 284 adults from 1989 to 1991, 1,254 adults from 2003 to 2005, and 1,309 adults from 2005 to 2007 (Table 3). Population levels of 284 to 1,309 adults over three years are categorized as a moderate risk of extinction based on the Lindley et al. (2007) criterion. However, the method used to estimate the number of untagged hatchery fish in the escapement was very conservative and it is highly likely that the true numbers of naturally produced fish are lower than those presented in Table 3. Although it is possible to obtain relatively accurate estimates of the number of hatchery reared salmon in the escapement using microchemical analyses of otoliths (Barnett-Johnson et al. 2007), specific analyses have not been done for the Merced River. Therefore, until these studies have been conducted, it would be prudent to consider that the Merced River escapements of naturally produced fish have at least approached the Lindley et al. (2007) definition of a high risk of extinction since 1989.

Population Decline

Another serious threat to the viability of natural salmonid populations identified by Lindley et al. (2007) is a precipitous decline in escapement. Lindley et al. (2007) define a precipitous decline as a decline within the last two generations (6 years) to an annual run size of 500 spawners or fewer or a run size greater than 500 spawners but declining at a rate of at least 10% per year. Lindley et al. (2007) recommend that the population decline rate should be computed as the slope of the natural log of the escapement versus time multiplied by 100 over a ten year period.

The escapement of natural spawners in the Tuolumne River meets both of these criteria. First, the natural escapement declined to fewer than 500 spawners in fall 2003, 2005, and 2007 (Table 3). Second, the population declined at an average rate of 23.7% per year from 1998 to 2007 (Fig. 4).

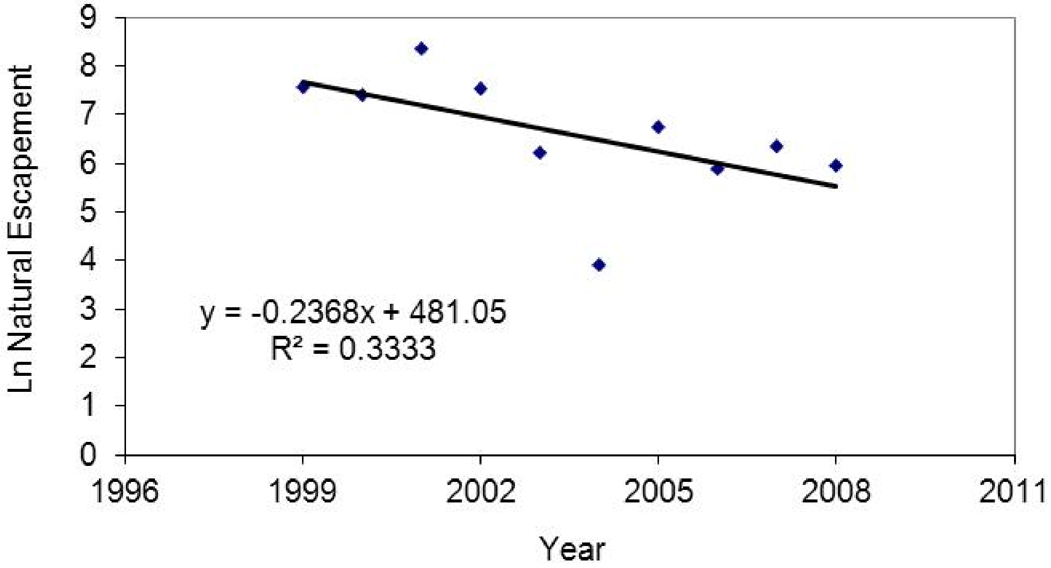

Fig. 4. The natural log (Ln) of the natural escapement of fall-run Chinook salmon in the Merced River from 1999 to 2008. The slope of the regression indicates that the population decline was 23.7% per year.

Catastrophe

Catastrophes are defined by Lindley et al. (2007) as instantaneous declines in population size due to events that occur randomly in time that reflect a sudden shift from a low risk state to a higher one. They view catastrophes as singular events with an identifiable cause and only negative immediate consequences, as opposed to normal environmental variation which can produce very good as well as very bad conditions. Some examples of catastrophes include disease outbreaks, toxic spills, or volcanic eruptions. A high risk situation is created by an order of magnitude (90%) decline in population size over one generation.

The Merced River natural escapement declined by about 82% when the 1999-2001 generation declined from a total of 7,732 fish to a total 1,392 fish for the 2002-2004 generation. The likely cause of this decline is the extended drought conditions and low instream flow releases in the Merced River from 2001 to 2004, which probably resulted in high juvenile mortality rates (see section below titled "*Juvenile Survival in the Merced River*").

Hatchery Influence

The estimated percentages of hatchery fish in the Merced River escapement exceed the Lindley et al. (2007) high risk criterion of less than 10% (3 generations) to 15% (1 to 2 generations) hatchery fish. Since 1998, the mean percentage of hatchery fish in the Merced River escapement is estimated to be 72.8% (range 34.1% to 98.4%, Table 3). It is likely that the mean percentage of hatchery fish in the Merced River escapement is actually higher than 72.8%, because the methods used to estimate the number of untagged hatchery salmon in the escapement were conservative.

Environmental Factors That Affect Salmon Recruitment

The production of Merced River salmon is primarily determined by the instream flow releases from Crocker-Huffman Dam as they affect juvenile survival in the Merced River and provide attraction flows for migrating adult salmon to navigate back to the Merced River. The salmon population is also affected by conditions that affect salmon survival in the San Joaquin Delta and the ocean, although these effects are relatively small or infrequent compared to the importance of instream flow releases. The following describes the factors that affect salmon escapement and/or recruitment relative to adult upstream migration, spawner abundance, spawning habitat and fry production, juvenile survival in the Merced River, Delta, and ocean, and the harvest of adult salmon in the ocean.

Adult Upstream Migration

Up to 58% of the adult MRH fall-run Chinook salmon with CWTs that were recovered in Central Valley rivers during the fall-run Chinook salmon escapement surveys from 1979 to 2007 (Mesick et al. 2009a) strayed to the Sacramento River Basin when San Joaquin River flows were low or Delta exports at the State and Federal pumping facilities were high during the October and November migratory period. From 1996 to 2006, the mean stray rate was 13.9% (range 0% in 2006 to 42.5% in 1999). The relationships between the MRH stray rates and the 10-day mean flow in the San Joaquin River at Vernalis in late October (Fig. 5), the mean October and November Vernalis flows (Fig. 6), and the mean ratio of Delta Exports to Vernalis flows for October and November (Fig. 7) are nearly identical. Adult salmon home to their natal streams in part by following olfactory cues from their natal stream (Quinn 2005) and presumably a minimum flow from each of the three San Joaquin River tributaries, including the Merced River, must pass through the Delta for the salmon to home successfully. Therefore, it should be possible to minimize the percentage of adult San Joaquin Basin salmon that stray to the Sacramento River Basin using a combination of flow and export management. An efficient use of water would be to provide a 10-day pulse flow in late October of 3,600 cfs at Vernalis, when high water temperatures might delay migrating salmon, and then rely on a combination of base flows and Delta export restrictions throughout the remainder of the migratory period to provide suitable conditions for spawning and egg incubation in the tributaries as well as minimum flows through the Delta for homing cues. For example, a 10-day pulse of 1,200 cfs from each of the Stanislaus, Tuolumne, and Merced rivers in late October, October and November base flows of at least 275 cfs for each tributary for spawning and egg incubation, and a maximum Delta export rate of 250% of Vernalis flows during October and November should keep stray rates at or below 6% based on the relationships shown in Figures 5 and 7. If these actions are successful, San Joaquin River Basin stray rates should decrease from the mean of 13.9% for the 1996 to 2006 period to a mean of about 4.8% (maximum of 6% per year).

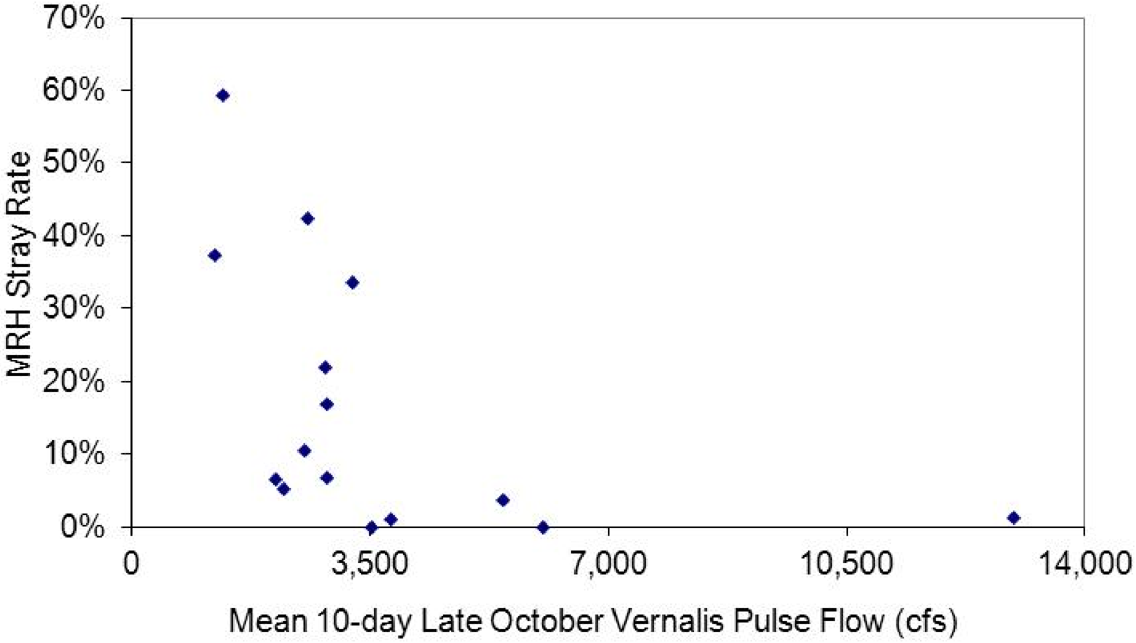

Fig. 5. Adult Merced River Hatchery Chinook salmon stray rates relative to the magnitude of 10-day pulse flows as measured in the San Joaquin River at Vernalis (Dayflow estimates) during late October. Stray rates are computed as the percentage of Merced River Hatchery fall-run Chinook salmon with CWTs (Mesick et al. 2009a) that were released in the San Joaquin River Basin upstream from Jersey Point as juveniles and then recovered as adults in the Sacramento River Basin relative to the adult recoveries in the Central Valley from 1983 to 1988 and from 1995 to 2003. Estimates for 1989 to 1994 were not used because there were less than an estimated total of 1,000 MRH adults with CWTs that returned to all Central Valley rivers during each year and so there was a high degree of uncertainty for these stray rate estimates. The mean Vernalis flows (USGS gauge 11303500) were computed for the 10-day period in mid to late October with the highest flows.

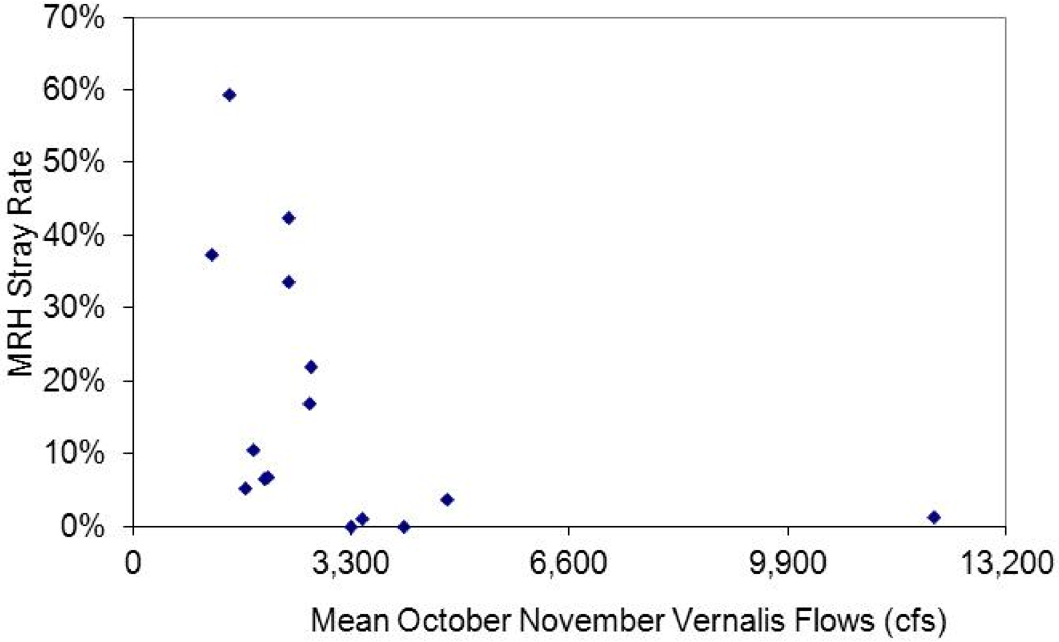

Fig. 6. Adult Merced River Hatchery Chinook salmon stray rates relative to the mean flow in the San Joaquin River at Vernalis (Dayflow estimates) during October and November. Stray rates are computed as the percentage of Merced River Hatchery fall-run Chinook salmon with CWTs (Mesick et al. 2009a) that were released in the San Joaquin River Basin upstream from Jersey Point as juveniles and then recovered as adults in the Sacramento River Basin relative to the adult recoveries in the Central Valley from 1983 to 1988 and from 1995 to 2003. Estimates for 1989 to 1994 were not used because there were less than an estimated total of 1,000 MRH adults with CWTs that returned to all Central Valley rivers during each year and so there was a high degree of uncertainty for these stray rate estimates. The mean Vernalis flows (USGS gauge 11303500) were computed for the 10-day period in mid to late October with the highest flows.

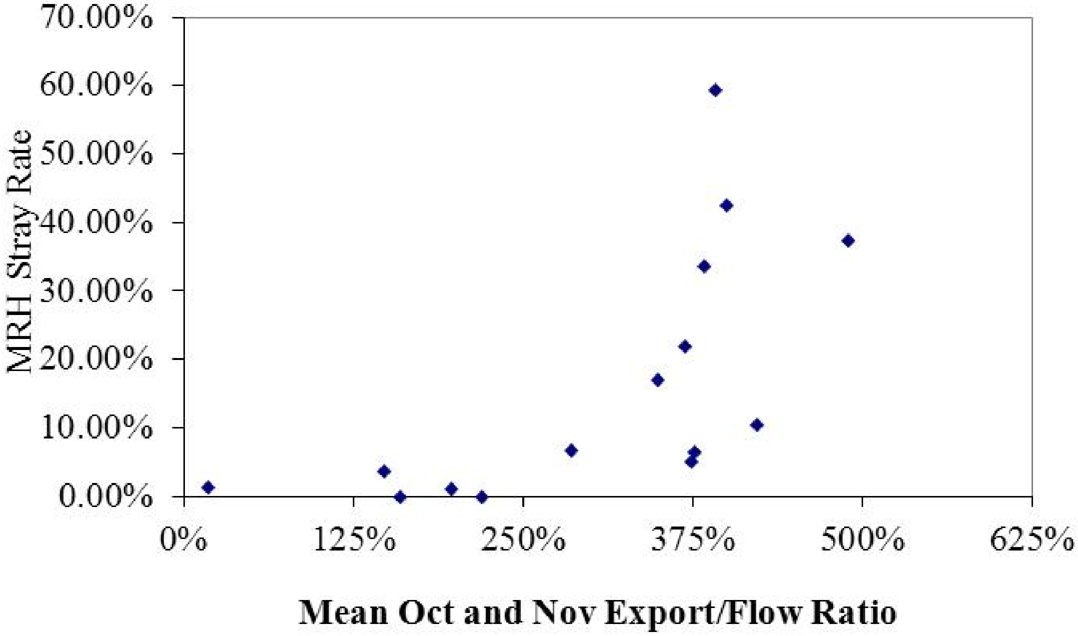

Fig. 7. Adult Merced River Hatchery Chinook salmon stray rates relative to the mean ratio of Delta Exports at the State, Federal, and Contra Costa pumping facilities (Dayflow estimates) to the flow in the San Joaquin River at Vernalis (Dayflow estimates) during October and November. Stray rates are computed as the percentage of Merced River Hatchery fall-run Chinook salmon with CWTs (Mesick et al. 2009a) that were released in the San Joaquin River Basin upstream from Jersey Point as juveniles and then recovered as adults in the Sacramento River Basin relative to the adult recoveries in the Central Valley from 1983 to 1988 and from 1995 to 2003. Estimates for 1989 to 1994 were not used because there were less than an estimated total of 1,000 MRH adults with CWTs that returned to all Central Valley rivers during each year and so there was a high degree of uncertainty for these stray rate estimates. The mean Vernalis flows (USGS gauge 11303500) were computed for the 10-day period in mid to late October with the highest flows.

Spawner Abundance

Spawner abundance can affect juvenile salmon production in two ways. First, too few spawners results in low production of juveniles due to a lack of eggs. On the other hand, the limited availability of spawning habitat in the Merced River could result in high rates of redd superimposition when spawner abundance is high. Redd superimposition could result in egg mortality for early spawners when late spawners dig up the redds of the early spawners.

The Merced River spawner-recruit analysis suggests that recruitment increases as spawner abundance increases; however, the relationship appears to be driven primarily by the data associated with high flows and the relationship with spawner abundance is not statistically significant (Fig. 8). Spawner abundance has no affect on recruitment during dry and normal water year types, which are the majority of observations, as evidenced by a nearly flat relationship from about 500 spawners to 10,500 spawners for the low and medium flow estimates (Fig. 9). This suggests that during dry and normal water year types when only the minimum required flows are released (mean March 20 to April 20 flows < 1,262 cfs), the capacity of the juvenile habitat is so constrained that a small number of spawners can saturate the habitat with juvenile salmon.

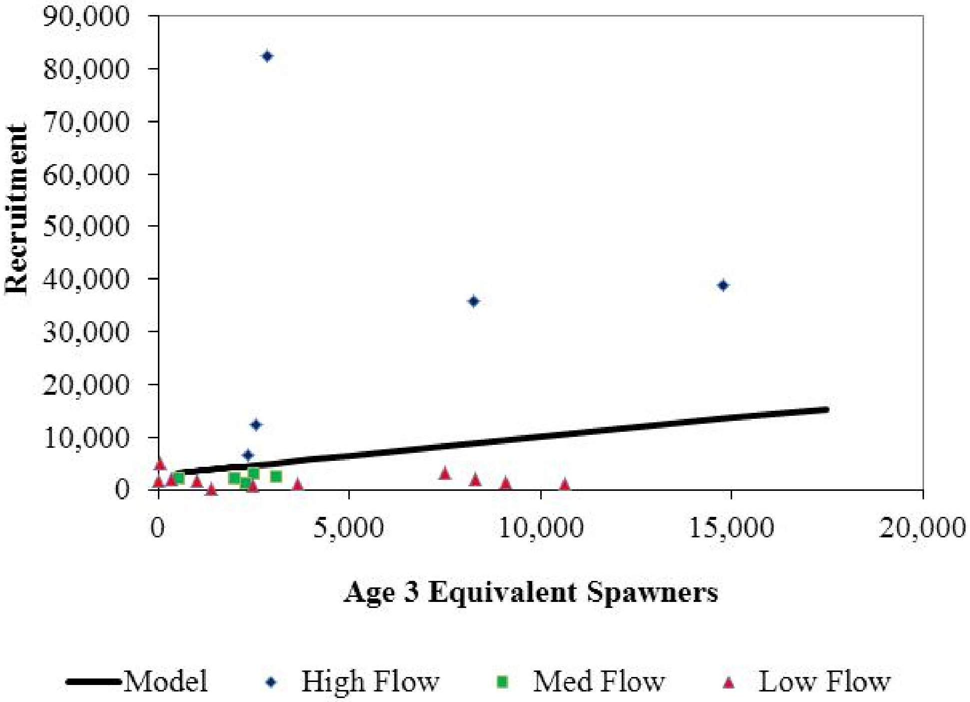

Fig. 8. The observed and modeled relationships between the number of natural recruits and the number of Age 3 equivalent spawners in the Merced River. The model is a 2^{nd} order polynomial regression for adult Merced River recruitment that includes the mean flow at the river's mouth from March 20 to April 20, the number of Age 3 equivalent spawner, which includes both hatchery and natural adults, and a 1^{st} order interaction term for flow and spawner abundance. The plotted model line in the figure represents the stock-recruitment relationship at an average flow of 900 cfs at the mouth of the Merced River. The model was significant (P = 0.00), the adjusted R^2 was 0.74, and the probabilities for the spawner variables were 0.09 and 0.97 for the first and second order terms, respectively. The high flow data occurred when the mean March 20 to April 20 flow was at least 2,500 cfs. The low flow data occurred when the mean March 20 to April 20 flow was less than 275 cfs. The methods used to estimate natural recruitment and Age 3 spawner abundance are described in (Mesick et al. 2009b).

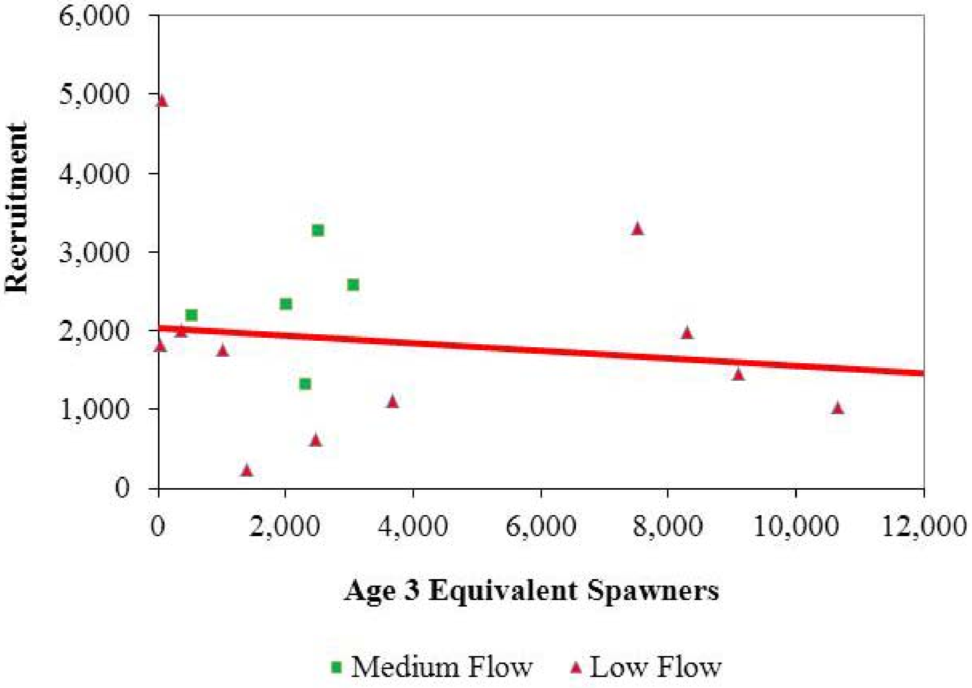

Fig. 9. The number of natural recruits relative to the number of Age 3 equivalent spawners in the Merced River at low and medium flows at the Merced River's mouth from March 20 to April 20. The medium flow data occurred when the mean March 20 to April 20 flow ranged between 618 and 1,272 cfs. The low flow data occurred when the mean March 20 to April 20 flow was less than 325 cfs. The line represents the linear regression for the low flow data. The methods used to estimate natural recruitment and Age 3 spawner abundance are described in (Mesick et al. 2009b).

Juvenile Survival in the Merced River

The survival of juvenile fall-run Chinook salmon that migrate from the Merced River into the San Joaquin River and Delta is thought to be relatively low for fry that must rear for a prolonged period before completing their migration to the ocean compared to the relatively high survival rates for smolt-sized juveniles. The mean recovery rates in the escapement for Coleman National Fish Hatchery (CNFH) fall-run Chinook salmon with CWTs that were released in the Sacramento River range between 0.29% to 0.45% for releases in January through April whereas the mean recovery rate is 1.98% for May releases, when the size of the CNFH juveniles is comparable to the size of the Tuolumne River smolts (methods described in Mesick et al. 2009a). The survival of fry sized juveniles is low during dry and normal water years in the Central Delta, where the Merced River smolts migrate, compared to the North Delta based on ocean recovery rates of CNFH fry with CWTs (Brandes and McLain 2001). The low survival rates of juveniles rearing in the Delta in dry and normal water years may be caused by a combination of factors such as predation, entrainment at numerous small, unscreened diversions, unsuitable water quality, high water temperatures, disease, and direct mortality at the state and federal pumping facilities in the Delta.

The Merced River recruitment of naturally produced adult salmon is strongly correlated with spring flows and water temperatures during the early spring when parr and smolts are migrating from the Merced River. The R^2 values are highest for relationships between recruitment and the mean Vernalis flow during April (Fig. 10), followed by the mean flow at the mouth of the Merced river from March 20 to April 20 (Fig. 11), and the mean daily maximum water temperature from March 20 to April 20 (Fig. 12). The relationship with maximum water temperatures indicates that juvenile survival declines rapidly as water temperatures approach about 59^{o}F. This 59^{o}F threshold corresponds to the upper water temperature threshold for the smoltification process that has been recommended by the EPA (2003). Smoltification is a reversible process such that when conditions are not suitable for smoltification (e.g., water temperatures exceed 59^{o}F), the juveniles can revert to a freshwater or parr stage (Hoar 1988 as summarized in Myrick and Cech 2001). The strong relationship between recruitment and water temperatures during March and April suggest that when maximum daily temperatures exceed 59^{o}F, smoltification ceases and mortality rates are high for the juveniles that do not smolt during the early spring.

The number of Merced River natural recruitments was strongly correlated with the number of days when the maximum water temperatures at the river's mouth were less than 59^{o}F (Fig. 13). An increase in recruitment was not observed until the duration with low temperatures reached at least 23 days (1980); whereas recruitment was highest for the spring 1983 cohort when there were 55 days of maximum temperatures below 59^{o}F (Fig. 13). Exceptions occurred for 1995, when there 54 days of low temperatures (Fig. 14), and 2005, when there were 47 days of low temperatures. In 2005, ocean conditions were unusually poor for juvenile survival (Lindley et al. 2009). The reason for the low recruitment for the spring 1995 cohort is unknown, although it is likely that poor ocean conditions also caused the low recruitment for the 1995 cohort. The April CUI in 1995 was 91, which indicates that conditions were worse for juvenile survival in the ocean than occurred in 2005, when the April CUI was 121. However, the April CUI does not consistently indicate when ocean conditions were poor for the survival of juvenile salmon (Fig. 14).

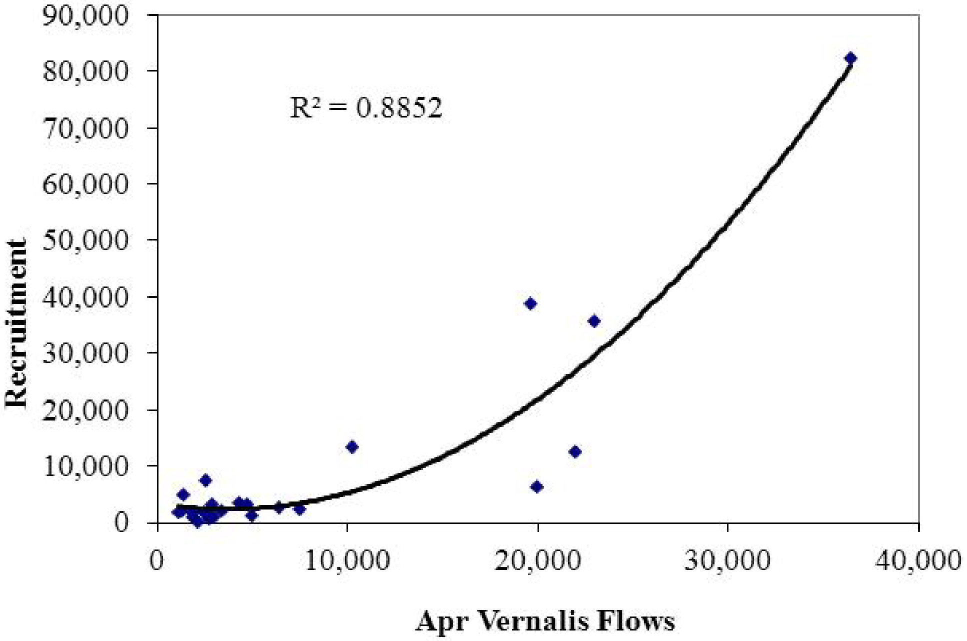

Fig. 10. The number of natural adult recruits relative to the average flow in the San Joaquin River at Vernalis during April from when the cohorts migrated as juveniles toward the ocean from 1980 to 2004. The 2nd order polynomial regression (line) and R^2 value were generated with Excel 2010.

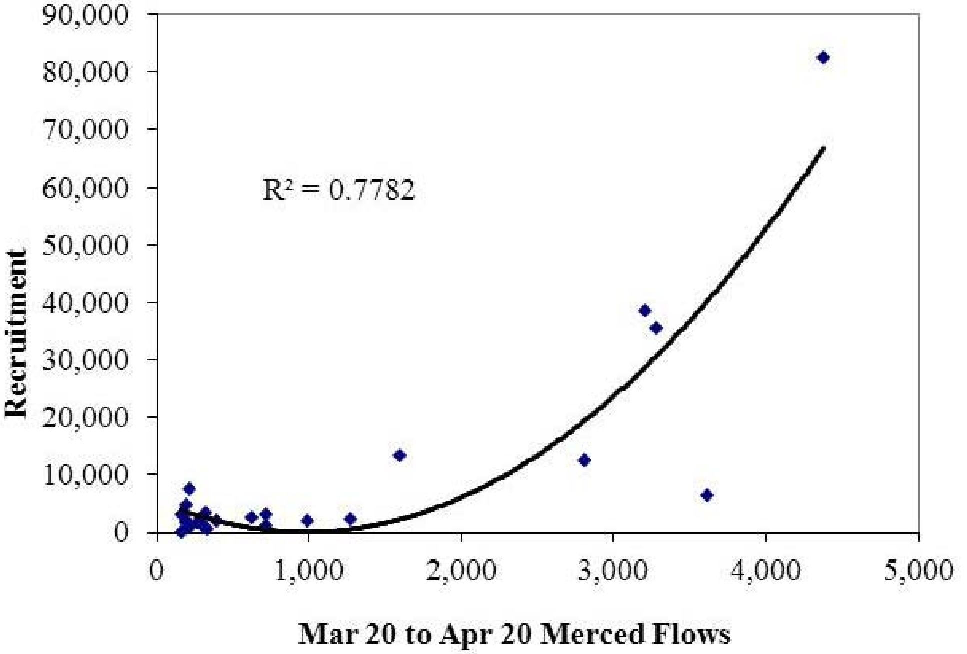

Fig. 11. The number of natural adult recruits relative to the average flow at the Merced River mouth from March 20 to April 20 when the cohorts migrated as juveniles toward the ocean from 1980 to 2004. The 2nd order polynomial regression (line) and R^2 value were generated with Excel 2010.

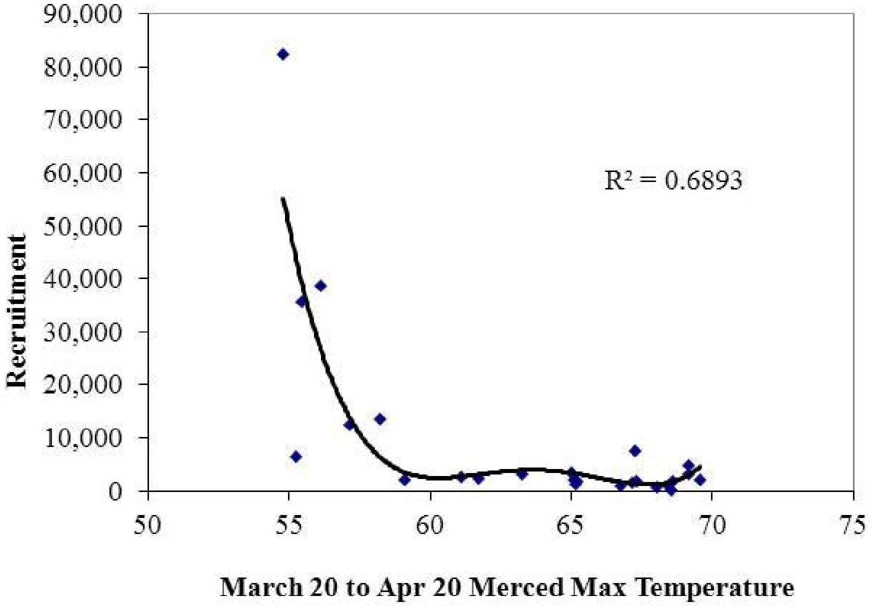

Fig. 12. The number of natural adult recruits relative to the average daily maximum water temperature at the Merced River mouth from March 20 to April 20 when the cohorts migrated as juveniles toward the ocean from 1980 to 2004. The 4^{nd} order polynomial regression (line) and R^2 value were generated with Excel 2010.

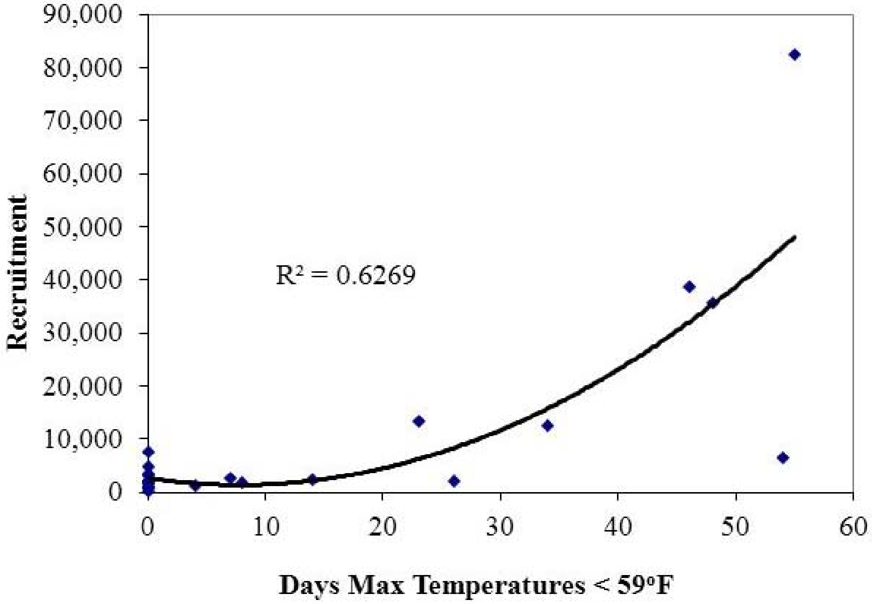

Fig. 13. The number of natural adult recruits relative to the number of days that the maximum water temperature at the Merced River mouth was less than 59^oF from March 20 to June 15 when the cohorts migrated as juveniles toward the ocean from 1980 to 2004. The 2^{nd} order polynomial regression (line) and R^2 value were generated with Excel 2010.

Juvenile Survival In The Delta

CWT smolt survival studies have been conducted in the San Joaquin River to evaluate the effects of flow, Delta export rates, and the installation of a barrier at the head of the Old River which had the objective of minimizing the diversion of flow and juvenile salmon into the Old River, which led to the Federal and State pumping facilities in the Delta, from 1985 to 2004 (SJGRA 2007, Newman 2008). The results indicated that smolt survival was positively correlated with the flow in the San Joaquin River at Dos Reis and the installation of the Old River Barrier (Newman 2008). However, associations between the pumping rates at the State and Federal facilities and smolt survival were weak to negligible (Newman 2008). Therefore, flow releases in the Merced River improve smolt survival in the Delta as well as in the Merced River.

Juvenile Survival In The Ocean

The survival of Central Valley smolts entering the ocean during May and June (MacFarlane and Norton 2002) is probably the most critical phase for salmon in the ocean (Pearcy 1992, Mantua et al. 1997, Quinn 2005). Smolt survival in the ocean is highly correlated with food availability as affected by freshwater outflow from the estuary and coastal upwelling (Casillas 2007). The coastal areas provide abundant food resources for salmon smolts particularly when coastal upwelling provides cold, nutrient rich water and when high freshwater flows create a large interface area between freshwater and saltwater (Casillas 2007). Long-term records indicate that there are 15- to 25-year cycles of warm and cool periods that strongly correlate with marine ecosystem productivity (Mantua et al. 1997; Hollowed et al. 2001). However, more recent cycles have been relatively short with a cool productive cycle from July 1998 to July 2002, a warm unproductive cycle from August 2002 to July 2006, followed by cool productive cycle through at least July 2009 (Ocean Ecosystem Indicators 2008, web site provided by the Northwest Fisheries Science Center, NOAA Fisheries Service). Ocean productivity was particularly poor for the Gulf of the Farallones in 2005 and 2006 as indicated by the abandonment of nests on the Farallon Islands by Cassin’s auklets, which have a similar diet compared to juvenile Chinook salmon, because of poor food availability (Sydeman et al. 2006; Wolf et al. 2009). The Pacific Decadal Oscillation is a basin-scale index of North Pacific sea surface temperatures and provides a good index of sea surface temperatures and has been correlated with Chinook salmon landings in California (Mantua et al. 1997).

An important local process that affects plankton production along the Oregon coast is coastal upwelling (Peterson et al. 2006). Upwelling is caused by northerly winds from April to September that transport offshore surface water southward and away from the coastline. This offshore, southward transport of surface waters is balanced by onshore northward transport of typically cool, high-salinity, nutrient-rich water that drives the marine food-web. The Coastal Upwelling Index (CUI) is based on the wind speed that drives coastal upwelling (Bakun 1973) and the CUI database is developed and distributed by the Pacific Fisheries Environmental Laboratory, National Marine Fisheries Service’s Southwest Fisheries Science Center, Pacific Grove, California. The survival of juvenile coho salmon (*O. kisutch*) is positively correlated with the April and mean April-May CUI values for Oregon coho salmon (Petersen et al. 2006), the mean June to August curl-driven upwelling indices are positively correlated with growth rates of Chinook salmon in a tributary to the Smith River near the California-Oregon border (Wells et al. 2007), and the mean April CUI are positively correlated with the survival to adulthood of Central Valley hatchery salmon released in the San Francisco Bay based on the result presented in the Methods section here. However, strong upwelling is not always correlated with high plankton productivity because the deep source waters for upwelling can be warm and nutrient poor (Peterson et al. 2006).

Merced River fall-run Chinook salmon adult recruitment is poorly correlated with the mean April CUI values for the Gulf of Farallones. For example, the relationship between mean April CUI values and Merced River recruitment (Fig. 14) shows the low recruitment for spring 2005 at low CUI values as expected, but also indicates that recruitment was high in 1986 and 1998 at even lower CUI values. When incorporated into a multiple regression model with the mean La Grange flow from 1 February to 15 June and 2nd order polynomial Age 3 equivalent spawner abundance variables, the CUI had negative coefficients for all periods from April through August, which is contrary to those reported for Oregon coho salmon (Peterson et al. 2006) and the Chinook salmon in the Smith River tributary (Wells et al. 2007). One explanation is that Merced River fall-run Chinook salmon are primarily affected by instream flows in the Merced River when the juveniles are rearing and migrating downstream, whereas ocean conditions would only have an effect during wet years, such as 2005 and 2006, when ocean conditions were unusually unproductive. On the other hand, the survival of hatchery raised salmon that are trucked to the Bay and Chinook salmon migrating in undamed rivers with frequent floodplain inundation such as the Smith River would be expected to be primarily affected by ocean conditions.

Adult Harvest In The Ocean

The decline in the Merced River escapement of naturally produced fall-run Chinook salmon since 1999 (Fig. 4) cannot be explained by the sport and troll harvest rates of adult salmon in the ocean. The Central Valley Index of Ocean Harvest (CVI), which is estimated each year by the Pacific Fishery Management Council (PFMC 2008) by dividing total harvest south of Point Arena by the total hatchery and natural escapement to all Central Valley rivers, averaged 67.2% from 1980 to 1998 and 42.1% from 1999 to 2007 (Fig. 15). CWT based estimates of ocean harvest rates for Central Valley fall-run Chinook salmon were computed by dividing the total number of all Central Valley hatchery CWT salmon harvested in the ocean by the total number of Central Valley hatchery CWT salmon in the ocean harvest and inland escapements for each year (Fig. 15; Mesick et al. 2009a, 2009b). Since the CWT based estimates are not based on the assumption that they are only caught south of Point Arena, they are probably more accurate than the CVI estimates. There is no relationship between the escapement of naturally produced fall-run Chinook salmon in the Merced River from 1999 to 2007 and the CWT based ocean harvest rates (Fig. 16).

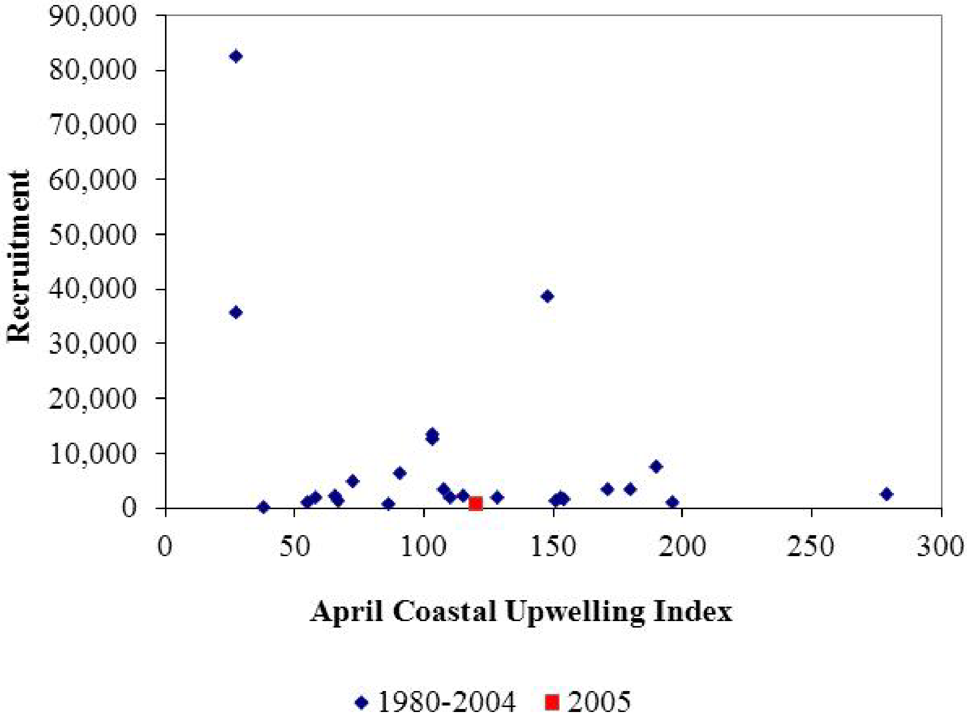

Fig. 14. The relationship between Merced River naturally produced adult fall-run Chinook salmon recruitment and the mean Cumulative Upwelling Index at 37.5°N latitude (Gulf of the Farallones) for May and June from 1980 to 2005.

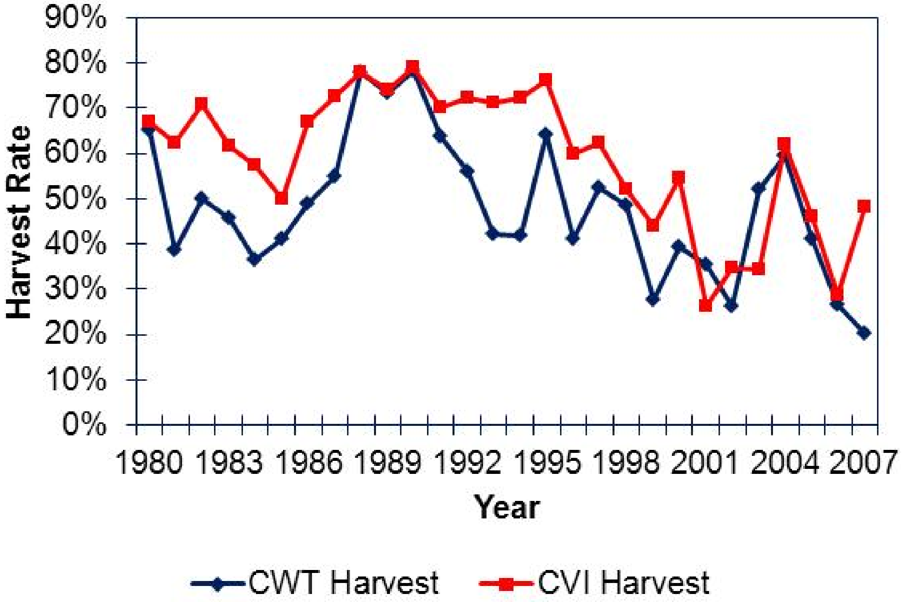

Fig. 15. Estimated ocean harvest rates of Central Valley fall-run Chinook salmon from 1980 to 2007 in the combined commercial (troll) and sport fisheries based on CWT recovery estimates (Mesick et al. 2009a, 2009b) and the Central Valley Index (PFMC 2008).

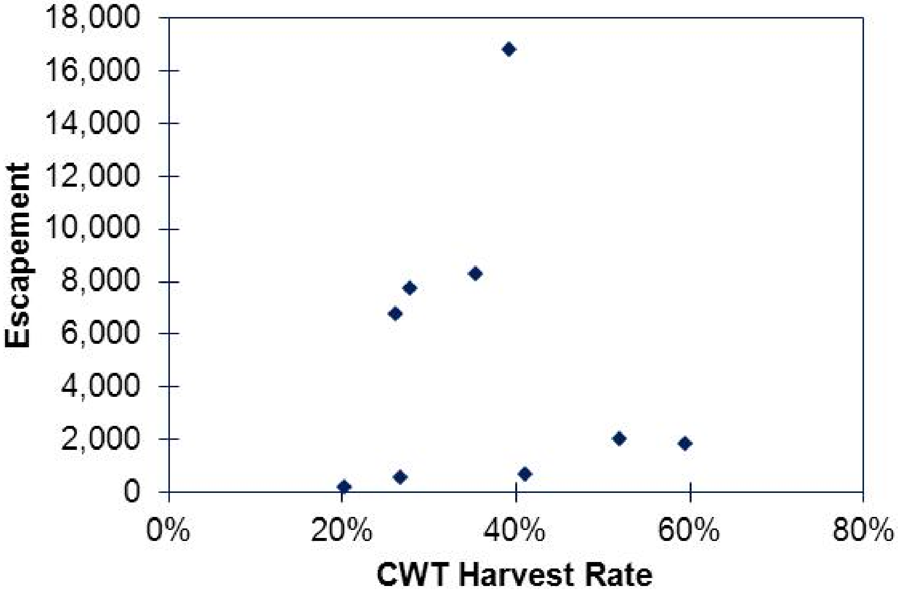

Fig. 16. Escapement of naturally produced Chinook salmon relative to the CWT harvest rate estimates from 1999 to 2007.

DISCUSSION

The Merced River fall-run Chinook salmon population is at a high risk of extinction primarily due to inadequate instream flow releases from Crocker-Huffman Dam, during the spring when the daily maximum water temperatures in the lower river exceed the EPA (2003) threshold of 59^{o}F for smoltification and to a lesser extent during late October when adult salmon are migrating upstream. The importance of flow and water temperatures in the Merced River and the San Joaquin River near Vernalis was apparent in analyses with both adult recruitment and smolt CWT survival studies. It is likely that maintaining water temperatures below the EPA (2003) threshold of 59^{o}F, particularly in the lower Merced River, is important for smoltification and the number of smolts that leave the Merced River; whereas flows and water temperatures in the San Joaquin River are an important determinant of smolt survival in the Delta. The logistic model analysis of CWT return rates of juvenile MRH smolts released in the Merced River indicate that Delta export rates, the presence of a physical barrier at the Head of the Old River, Delta outflow, and ocean conditions (April CUI) have little effect on smolt survival rates compared to the effect of flow and water temperature.

Other factors that put the population at a high risk of extinction include unusually unfavorable ocean conditions for the survival of juvenile salmon and the large numbers of out-of-basin hatchery fish that stray to the Merced River. Unusually unfavorable ocean conditions occurred during spring 2005 and 2006 that caused an extensive failure of the Central Valley fisheries (Lindley et al. 2009). It is likely that these extremely unfavorable ocean conditions were infrequent during the 1980 to 2005 period of study because adult recruitment for the 2005 cohort was unusually low considering that the 2005 April CUI was moderate and high recruitments occurred at much lower April CUI levels (e.g., 1983 and 1998; Fig. 12). The number of out-of-basin hatchery fish in the Merced River is primarily determined by the number of MRFI juvenile salmon that are released in the Delta. Substantially reducing the number of out-of-basin hatchery fish could be accomplished by minimizing the number of juvenile salmon that are trucked to the Delta for release.

To maintain the Merced River fall-run Chinook salmon population at a low risk of extinction, it will be necessary to increase the population in regard to all four of the Lindley et al. (2007) risk of extinction criteria. First, it will be necessary to increase the dry water year flow releases to keep escapement above 833 fish. Second, it will be necessary to increase normal water year flow releases to double the escapements and thereby reduce the rate of decline between wet-year escapements and dry-year escapements to below 10% or less annually. Increasing normal water year flow releases would also help reduce the percentage of hatchery fish. Third, it will be necessary to minimize the number of MRFI juvenile fish that are trucked to the Delta for release.

To keep escapement above 833 fish during Critical and Dry water year types, when the San Joaquin Water Year Index is 2.5 MAF or less, it will be necessary to implement a flow schedule that includes: (1) a 10-day, 1,200 cfs late October pulse flow release to minimize adult straying; and (2) flow management for Crocker-Huffman Dam releases to keep water temperatures throughout the river below a threshold of 59^{o}F from 20 March through at least 20 April to improve smolt survival. The recommended 59-degree Fahrenheit threshold should be maintained from 20 March to 30 April in Below Normal water year types and to at least 15 May in Above Normal and Wet water year types to help reduce the magnitude in population fluctuations and reduce the percentage of hatchery fish.

Another recommendation is to gradually ramp down the flood control releases during early summer to improve the recruitment of riparian tree species and thereby augment the amount of organic matter, shade, and woody debris and thereby improve the habitat quality for juvenile salmon. Research on a variety of cottonwood and willow species suggests that 1 to 1.5 inches/day is the maximum rate of water table decline for seedling survival (McBride et al. 1989; Segelquist et al. 1993; Mahoney and Rood 1993, 1998; Amlin and Rood 2002). Ramping down is necessary so that the root growth of the tree seedlings can keep up with the decline in the groundwater table as flows recede. Ramping rates of 100 to 300 cfs/day in the San Joaquin Basin are thought to prevent seedling desiccation under the assumed 1 inch/day maximum root growth rate.

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Table 1. Habitat and biological variables evaluated in the development of logistic models estimating the recovery rate of adult fall-run Chinook salmon in the Merced River that were released as juvenile salmon reared at the Central Valley hatcheries and marked with coded-wire-tags.

<u>Merced River Hatchery Releases in the Merced River in Spring and Fall</u>

1. Mean flow at the confluence (RM 0) for days 3 to 6 following the release date for releases in the upper river and for the day of the release for releases made near the confluence with the San Joaquin River. The flow estimates were generated from the San Joaquin River basin HEC5Q hydrodynamic and thermodynamic computer model developed by AD Consultants et al. (2009).
2. Mean maximum water temperature at the confluence (RM 0) for days 3 to 6 following the release date for releases in the upper river and for the day of the release for releases made near the confluence with the San Joaquin River. The temperature estimates were generated from the San Joaquin River basin HEC5Q hydrodynamic and thermodynamic computer model developed by AD Consultants et al. (2009).
3. Mean flow in the San Joaquin River at Vernalis for days 6 to 15 following the release date. The flow estimates were obtained from the California Department of Water Resources' (DWR) Dayflow output files, which are available at http://www.water.ca.gov/dayflow/output/
4. Mean maximum water temperature in the San Joaquin River at Vernalis for days 6 to 15 following the release date. The source of the data was USGS gage 11303500.
5. Mean total export rate at the SWP, CVP and CCC for days 6 to 15 following the release date. The export rate estimates were obtained from the DWR Dayflow output files, which are available at http://www.water.ca.gov/dayflow/output/
6. The mean of a conditional variable indicating the presence of the Head of the Old River Barrier (HORB) for days 6 to 15 following the release date. The operation schedule for the HORB is posted at http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbsch.cfm. The variable was assigned a value of 1 when the HORB was completed, a value of 0 when the HORB was not installed, and a fraction of 1 during the construction of the barrier that reflected the degree of construction. For example, if it took 10 days to construct the barrier, a value of 0.9 was given on the ninth day of construction.
7. Mean Delta outflow (cfs) for days 13 to 19 following the release date. The Delta outflow estimates (QOut) were obtained from the California Department of Water Resources' (DWR) Dayflow output files, which are available at http://www.water.ca.gov/dayflow/output/
8. Rate that MRH adult salmon strayed to the Sacramento River Basin. Stray rates were computed as the estimated total adult CWT recoveries in the Sacramento River Basin divided by the total Central Valley inland CWT recoveries. The CWT recovery database is described by (Mesick et al. 2009a).
9. Age-specific rate that adult salmon with CWTs were harvested in the sport and commercial ocean fisheries. Harvest rates were computed as the estimated total

number of adult Central Valley hatchery salmon with CWTs caught in the ocean fisheries divided by the total number of adult salmon recovered in the ocean fisheries and the Central Valley inland escapements. Age-specific rates were used for each model. For example, the model of Age 3 CWT recoveries evaluated the effect of ocean harvest rates of Age 3 salmon. The CWT recovery database is described by (Mesick et al. 2009a).

10. The mean weight of the juvenile fish at the time of their release. The source of the size estimates were obtained from the Regional Mark Information System (RMIS), which is an online database managed by the Regional Mark Processing Center in Portland, Oregon.
11. The Coastal Upwelling Index (CUI) for the month of April for juvenile CWT releases from April through August and the CUI index for the month of November for juvenile releases from September through November. The CUI database is developed and distributed by the Pacific Fisheries Environmental Laboratory, National Marine Fisheries Service's Southwest Fisheries Science Center, Pacific Grove, California.
12. A conditional variable called "Reach" was used to segregate releases in the upper river from those released near the confluence with the San Joaquin River. A value of zero was used for the upper releases, which were usually made near the hatchery; whereas a value of 1.0 was used for the confluence releases typically made at the Hatfield and Hagaman parks.

Merced River Hatchery Releases in the San Joaquin River upstream of Jersey Point in Spring and Fall

1. The 7-day mean flow in the San Joaquin River at Vernalis following the release date.
2. The 7-day mean maximum water temperature in the San Joaquin River at Vernalis following the release date.
3. The 7-day mean total export rate at the SWP, CVP, and CCC following the release date.
4. The 7-day mean for the conditional variable indicating the presence of the Head of the HORB.
5. Mean Delta outflow (cfs) for days 7 to 13 following the release date.
6. The rate that MRH adult salmon strayed to the Sacramento River Basin.
7. Age-specific ocean harvest rates.
8. The mean weight of the juvenile fish at the time of their release.
9. The Coastal Upwelling Index (CUI) for the month of April for juvenile CWT releases from April through August and the CUI index for the month of November for juvenile releases from September through November.

Merced River Hatchery Releases in the West Delta at Jersey Point in Spring

1. The 7-day mean Delta outflow (cfs) following the release date.
2. The rate that MRH adult salmon strayed to the Sacramento River Basin.
3. Age-specific ocean harvest rates.
4. The mean weight of the juvenile fish at the time of their release.
5. The Coastal Upwelling Index (CUI) for the month of April for juvenile CWT releases made in April and May.

Mokelumne River Fish Installation Releases in the Mokelumne River in Spring and Fall

1. The 7-day mean flow at Woodbridge Dam in the Mokelumne River (USGS gage 11325500) following the release date.
2. Mean flow in the Mokelumne River at Woodbridge Dam (USGS gage 11325500) from October 16 to 31 when the adult fish would be migrating upstream in the Delta.
3. The mean flow of water from the Sacramento River to the lower Mokelumne River through Georgiana Slough and the Delta Cross Channel (XGEO) for days 6 to 15 following the release date. The XGEO flow estimates were obtained from the DWR Dayflow output files, which are available at http://www.water.ca.gov/dayflow/output/
4. Mean total export rate at the SWP, CVP and CCC for days 6 to 15 following the release date.
5. Mean Delta outflow (cfs) for days 13 to 19 following the release date.
6. Rate that MRH adult salmon strayed to the Sacramento River Basin.
7. Age-specific rate that adult salmon with CWTs were harvested in the sport and commercial ocean fisheries.
8. The mean weight of the juvenile fish at the time of their release.
9. The Coastal Upwelling Index (CUI) for the month of April for juvenile CWT releases from April through August and the CUI index for the month of November for juvenile releases from September through November.

Mokelumne River Fish Installation Releases in the Sacramento River in Spring and Fall

1. The 7-day mean flow in the Sacramento River following the release date. The flow estimates were obtained from the DWR Dayflow output files, which are available at http://www.water.ca.gov/dayflow/output/
2. Mean Delta outflow (cfs) for days 7 to 13 following the release date.
3. Mean flow in the Mokelumne River at Woodbridge Dam (USGS gage 11325500) from October 16 to 31 when the adult fish would be migrating upstream in the Delta.
4. The rate that MRH adult salmon strayed to the Sacramento River Basin.

5. Age-specific rate that adult salmon with CWTs were harvested in the sport and commercial ocean fisheries.
6. The mean weight of the juvenile fish at the time of their release.
7. The Coastal Upwelling Index (CUI) for the month of April for juvenile CWT releases from April through August and the CUI index for the month of November for juvenile releases from September through November.

<u>Mokelumne River Fish Installation Releases in the East Delta (Mokelumne River between Delta Cross Channel and its mouth) in Spring and Fall</u>

1. The 7-day mean flow of water from the Sacramento River to the lower Mokelumne River through Georgiana Slough and the Delta Cross Channel (XGEO) following the release date.
2. Mean Delta outflow (cfs) for days 3 to 13 following the release date.
3. Mean flow in the Mokelumne River at Woodbridge Dam (USGS gage 11325500) from October 16 to 31 when the adult fish would be migrating upstream in the Delta.
4. The rate that MRH adult salmon strayed to the Sacramento River Basin.
5. Age-specific rate that adult salmon with CWTs were harvested in the sport and commercial ocean fisheries.
6. The mean weight of the juvenile fish at the time of their release.
7. The Coastal Upwelling Index (CUI) for the month of April for juvenile CWT releases from April through August and the CUI index for the month of November for juvenile releases from September through November.

<u>Mokelumne River Fish Installation Releases in the West Delta in Spring and Fall</u>

1. The 7-day Mean Delta outflow (cfs) following the release date.
2. Mean flow in the Mokelumne River at Woodbridge Dam (USGS gage 11325500) from October 16 to 31 when the adult fish would be migrating upstream in the Delta.
3. The rate that MRH adult salmon strayed to the Sacramento River Basin.
4. Age-specific rate that adult salmon with CWTs were harvested in the sport and commercial ocean fisheries.
5. The mean weight of the juvenile fish at the time of their release.
6. The Coastal Upwelling Index (CUI) for the month of April for juvenile CWT releases from April through August and the CUI index for the month of November for juvenile releases from September through November.

Sacramento Basin Hatchery Releases in the West Delta in Spring

1. The 7-day Mean Delta outflow (cfs) following the release date.
2. The mean flow of water from the Sacramento River to the lower Mokelumne River through Georgiana Slough and the Delta Cross Channel (XGEO) from October 10 to 25 when adult fish would be migrating upstream in the Delta.
3. Age-specific rate that adult salmon with CWTs were harvested in the sport and commercial ocean fisheries.
4. The mean weight of the juvenile fish at the time of their release.
5. The total number of juvenile fish released in each CWT group.
6. The Coastal Upwelling Index (CUI) for the month of April for juvenile CWT releases from April through August.

Table 2a. Coefficients of the logistic regression models used to predict CWT recovery rates to the Merced River. Models include CWT releases of Merced River Hatchery (MRH) juvenile salmon into the Merced River (Trib) and San Joaquin River (Mainstem) during the spring and fall. The excluded brood years are those with observed recovery rates near zero that were substantially lower than the predicted estimates or those years without observed recovery rates and the model over predicted the observed escapement. "Pos" indicated that the coefficient was positive, whereas the expected response was negative and so the variable was omitted from the model.

	MRH Trib Spring (Apr-May)			MRH Trib Fall (Sep-Nov)			MRH Mainstem Spring		
Model Deviance	0.12	0.17	0.03	0	0.02	0	0.1	0.06	0.01
Degrees of Freedom	120	135	138	7	7	9	88	79	88
					Coefficients				
Variable	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
Constant	10.4825	11.7777	-2.36988	-7.18501	-7.03883	-10.1657	-7.66714	-4.02061	-9.90351
April Coastal Upwelling Index							0.007061	0.007061	0.007061
Adult Harvest	Pos	-3.80361	Pos	-4.41985	-1.34971	Pos	-1.6662	-7.77867	-1.42525
Adult MRH Stray Rate	-9.14173	-2.98646	Pos	-10.8257	-2.03314	-3.19962	-4.50147	-6.02739	-0.57462
Merced Flow	0.0007511	0.000751	0.000751						
Vernalis Max Temperature	-0.2726	-0.27466	-0.12151		Pos				
Vernalis Flow				0.00005351	0.00003628	0.000112	0.00005825	0.00003896	0.00002716
					Excluded Brood Years				.
	1981	1981		1979	1979	1979	1987	1981	1987
	1986	1986	1986	1985-1992	1985-1992	1985-1992	1989-1994	1987	1989-1994
	1987	1987	1987	1994-2004	1994-2004	1994-2004	2003	1989-1994	2004
	1989	1989	1989				2004	2003	
	1990	1990	1990					2004	
	1991	1991	1991						
	1992	1992	1992						
	1994	2003							
	May-98	2004	2004						
	Apr-02								
	2004								

Table 2b. Mean recovery estimates by brood year for CWT releases of Merced River Hatchery (MRH) juvenile salmon into the San Joaquin River (Mainstem) during the fall, Sacramento Basin hatchery juvenile salmon into the West Delta in spring, and Mokelumne River Fish Installation (MRFI) juvenile salmon into the West Delta in fall. A logistic regression model was developed only for the recovery of Age 3 adults from Sac Basin releases in the West Delta in spring. The coefficients of this logistic model were used to predict CWT recovery rates to the Merced River. The excluded brood years are those with observed recovery rates near zero that were substantially lower than the predicted estimates or those years without observed recovery rates and the model over predicted the observed escapement. "Pos" indicated that the coefficient was positive, whereas the expected response was negative and so the variable was omitted from the model.

		MRH Mainstem Fall			Sac West Delta Spring (Apr-Aug)			MRFI West Delta Fall		
Model Deviance	Brood Year	No Model	No Model	No Model	No Model	0.01	No Model	No Model	No Model	No Model
Degrees of Freedom						145				
Variables		Age 2	Age 3	Age 4	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
						Coefficients				
Constant	1977	no data	no data	no data	0.0000%	-13.5669	0.0000%	no data	no data	no data
April CUI	1978	no data	no data	no data	0.0000%	0.006518	0.0000%	no data	no data	no data
Adult Harvest	1979	no data	no data	no data	0.0000%	Pos	0.0000%	0.0000%	0.0000%	0.0000%
Total Released	1980	0.0397%	0.0212%	0.0000%	0.0000%	8.995E-07	0.0000%	0.0000%	0.0000%	0.0000%
Mean Fish Weight	1981	0.0349%	0.0000%	0.0000%	0.0000%	0.02568	0.0000%	0.0000%	0.0000%	0.0000%
October XGEO	1982	0.0000%	0.1405%	0.0000%	0.0000%	0.0002958	0.0000%	no data	no data	no data
	1983	0.1035%	0.3813%	0.0000%	0.0000%		0.0000%	no data	no data	no data
	1984	0.1132%	0.0000%	0.0000%	0.0000%		0.0000%	no data	no data	no data
	1985	no data	no data	no data	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%
	1986	no data	no data	no data	0.0000%	Excluded Brood Years	0.0000%	no data	no data	no data
	1987	no data	no data	no data	0.0000%	77, 78, 83	0.0000%	no data	no data	no data
	1988	no data	no data	no data	0.0000%	86-89	0.0010%	no data	no data	no data
	1989	no data	no data	no data	0.0000%	2004	0.0000%	no data	no data	no data
	1990	no data	no data	no data	0.0000%		0.0027%	no data	no data	no data
	1991	no data	no data	no data	0.0000%		0.0000%	no data	no data	no data

		MRH Mainstem Fall			Sac West Delta Spring (Apr-Aug)			MRFI West Delta Fall		
Model Deviance	Brood Year	No Model	No Model	No Model	No Model	0.01	No Model	No Model	No Model	No Model
Degrees of Freedom						145				
Variables		Age 2	Age 3	Age 4	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
	1992	no data	no data	no data	0.0000%		0.0000%	no data	no data	no data
	1993	no data	no data	no data	0.0021%		0.0001%	no data	no data	no data
	1994	no data	no data	no data	0.0000%		0.0002%	no data	no data	no data
	1995	no data	no data	no data	0.0000%		0.0000%	no data	no data	no data
	1996	no data	no data	no data	0.0000%		0.0000%	no data	no data	no data
	1997	no data	no data	no data	0.0000%		0.0000%	no data	no data	no data
	1998	no data	no data	no data	0.0030%		0.0000%	no data	no data	no data
	1999	no data	no data	no data	0.0000%		0.0000%	no data	no data	no data
	2000	no data	no data	no data	0.0136%		0.0019%	no data	no data	no data
	2001	no data	no data	no data	0.0024%		0.0007%	0.0291%	0.1054%	0.0127%
	2002	no data	no data	no data	0.0009%		0.0000%	no data	no data	no data
	2003	no data	no data	no data	0.0000%		0.0000%	no data	no data	no data
	2004	no data	no data	no data	0.0000%		0.0000%	no data	no data	no data

Table 2c. Coefficients of the logistic regression models used to predict CWT recovery rates to the Merced River. Models include CWT releases of Merced River Hatchery (MRH) and Mokelumne River Fish Installation (MRFI) juvenile salmon into the West Delta during the spring and MRFI juveniles into the East Delta in spring. Mean recovery estimates by brood year are provided for Age 4 recoveries of MRFI juveniles in the East Delta in spring. The excluded brood years are those with observed recovery rates near zero that were substantially lower than the predicted estimates or those years without observed recovery rates and the model over predicted the observed escapement. “Pos” or “Neg indicated that the sign of the coefficient was opposite of the expected response and so the variable was omitted from the model.

	MRH Delta Spring			MRFI West Delta Spring			MRFI East Delta Spring			
Model Deviance	0.03	0.03	0	0.01	0.01	0	0	0.01	No Model	
Degrees of Freedom	19	18	16	27	31	32	33	55		
	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4	Brood Year
Variables				Coefficients						
Constant	-4.41055	-4.79326	-9.57798	-10.3569	-8.96425	-10.7096	-9.10828	-5.61953	no data	1977
April CUI	Neg	0.002692	0.003779	0.01167	0.01167	0.01167	Neg	Neg	no data	1978
Adult Harvest	-8.59806	-5.64387	-1.37149	-0.33279	-1.41048	Pos	Pos	-7.61826	no data	1979
Adult MRH Stray Rate	-17.7749	-6.5203	-0.09696	-1.36962	-2.74197	-0.18827	-4.60144	-5.42516	no data	1980
Delta Outflow	0.00002981		0.00001025						no data	1981
Total Number Released							3.073E-07	Neg	no data	1982
Mean Fish Weight	0.22094	0.22094	0.22094						no data	1983
Spring XGEO							0.00005944	0.00002392	no data	1984
									no data	1985
				Excluded Brood Years				.	no data	1986
	1979-1994	1979-1994	1979-1994	1982, 1984	1987-1990	1985-1990	1979-1991	1979-1990	no data	1987
	2004	2004	2004	1986-1990	2001, 2004	2001, 2004	1996	2003-2004	no data	1988
				1994, 1996			2001-2004		no data	1989
				2000, 2004					no data	1990
									0.0000%	1991
									0.0005%	1992
									0.0010%	1993
									0.0004%	1994

	MRH Delta Spring			MRFI West Delta Spring			MRFI East Delta Spring			
Model Deviance	0.03	0.03	0	0.01	0.01	0	0	0.01	No Model	
Degrees of Freedom	19	18	16	27	31	32	33	55		
	<u>Age 2</u>	<u>Age 3</u>	<u>Age 4</u>	<u>Age 2</u>	<u>Age 3</u>	<u>Age 4</u>	<u>Age 2</u>	<u>Age 3</u>	Age 4	Brood Year
									0.0000%	1995
									0.0000%	1996
									0.0000%	1997
									0.0000%	1998
									0.0000%	1999
									0.0000%	2000
									0.0000%	2001
									0.0000%	2002
									0.0000%	2003
									0.0000%	2004

Table 2d. Mean recovery estimates by brood year for CWT releases of Mokelumne River Fish Installation (MRFI) juvenile salmon into the East Delta during the fall, the Sacramento River near West Sacramento (mainstem) in spring, and the Sacramento River near Rio Vista (mainstem) in fall.

	MRFI East Delta Fall			MRFI Mainstem Spring (Spring 2001 only)			MRFI Mainstem Fall (Fall 77-81)		
	No Model	No Model	No Model	No Model	No Model	No Model	No Model	No Model	No Model
Brood Year	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1977	No Data	No Data	No Data	No Data	No Data	No Data	0.0000%	0.0000%	0.0000%
1978	No Data	No Data	No Data	No Data	No Data	No Data	0.0000%	0.0648%	0.0000%
1979	No Data	No Data	No Data	No Data	No Data	No Data	0.0000%	0.0432%	0.0000%
1980	No Data	No Data	No Data	No Data	No Data	No Data	0.0000%	0.0000%	0.0000%
1981	No Data	No Data	No Data	No Data	No Data	No Data	0.0000%	0.0000%	0.0000%
1982	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1983	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1984	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1985	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1986	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1987	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1988	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1989	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1990	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1991	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1992	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1993	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1994	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1995	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1996	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1997	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1998	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1999	0.0227%	0.0312%	0.0059%	No Data	No Data	No Data	No Data	No Data	No Data
2000	No Data	No Data	No Data	0.0167%	0.0084%	0.0007%	No Data	No Data	No Data

	MRFI East Delta Fall			MRFI Mainstem Spring (Spring 2001 only)			MRFI Mainstem Fall (Fall 77-81)		
	No Model	No Model	No Model	No Model	No Model	No Model	No Model	No Model	No Model
Brood Year	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
2001	0.0000%	0.0100%	0.0007%	No Data	No Data	No Data	No Data	No Data	No Data
2002	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
2003	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
2004	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data

Table 2e. Mean recovery estimates by brood year for CWT releases of Mokelumne River Fish Installation (MRFI) juvenile salmon into the Mokelumne River (Trib) during the spring and fall.

	MRFI Trib Spring			MRFI Trib Fall		
Brood Year	No Model Age 2	No Model Age 3	No Model Age 4	No Model Age 2	No Model Age 3	No Model Age 4
1977	No Data	No Data	No Data	0.0000%	0.0000%	0.0000%
1978	No Data	No Data	No Data	0.0000%	0.0000%	0.0000%
1979	No Data	No Data	No Data	0.0000%	0.0000%	0.0000%
1980	No Data	No Data	No Data	No Data	No Data	No Data
1981	No Data	No Data	No Data	No Data	No Data	No Data
1982	0.0000%	0.0000%	0.0000%	No Data	No Data	No Data
1983	No Data	No Data	No Data	No Data	No Data	No Data
1984	No Data	No Data	No Data	No Data	No Data	No Data
1985	No Data	No Data	No Data	No Data	No Data	No Data
1986	No Data	No Data	No Data	No Data	No Data	No Data
1987	No Data	No Data	No Data	No Data	No Data	No Data
1988	No Data	No Data	No Data	No Data	No Data	No Data
1989	No Data	No Data	No Data	No Data	No Data	No Data
1990	0.0000%	0.0010%	0.0000%	No Data	No Data	No Data
1991	0.0000%	0.0000%	0.0000%	0.0000%	0.0044%	0.0000%
1992	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
1993	No Data	No Data	No Data	0.0000%	0.0044%	0.0080%
1994	No Data	No Data	No Data	0.0000%	0.0000%	0.0000%
1995	No Data	No Data	No Data	0.0135%	0.0000%	0.0000%
1996	No Data	No Data	No Data	0.0000%	0.0000%	0.0000%
1997	No Data	No Data	No Data	0.0000%	0.0000%	0.0000%
1998	No Data	No Data	No Data	No Data	No Data	No Data
1999	No Data	No Data	No Data	No Data	No Data	No Data
2000	No Data	No Data	No Data	No Data	No Data	No Data

	MRFI Trib Spring			MRFI Trib Fall		
Brood Year	No Model Age 2	No Model Age 3	No Model Age 4	No Model Age 2	No Model Age 3	No Model Age 4
2001	No Data	No Data	No Data	0.0000%	0.0005%	0.0000%
2002	0.0000%	0.0000%	0.0000%	No Data	No Data	No Data
2003	0.0000%	0.0000%	0.0000%	No Data	No Data	No Data
2004	No Data	No Data	No Data	No Data	No Data	No Data

Table 3. Department of Fish and Game estimates of total escapement of fall-run Chinook Salmon in the Merced River and the Merced River Hatchery (GrandTab), estimated total number of marked (coded-wire tag and adipose clipped) hatchery adults that returned to the Merced River and hatchery, estimated number of unmarked hatchery adults from the Coleman National Fish Hatchery, Mokelumne River Fish Installation, Nimbus Fish Hatchery, Feather River Hatchery, and Merced River Hatchery that returned to the Merced River and hatchery, estimated total escapements of naturally produced and hatchery produced adults, and the percent hatchery fish in the total escapement from 1981 to 2008.

			Unmarked Adults							
	Total Escapement	Marked Hatchery Adults	Coleman National Fish Hatchery	Mokelumne Hatchery	Nimbus Hatchery	Feather River Hatchery	Merced River Hatchery	Estimated Natural Escapement	Estimated Hatchery Escapement	Percent Hatchery
1981	10,415	445	0	166	0	0	0	9,805	610	5.9%
1982	3,263	955	0	387	0	1	0	1,920	1,343	41.2%
1983	18,248	5,708	0	6	539	219	0	11,775	6,473	35.5%
1984	29,749	5,355	0	88	38	59	0	24,209	5,540	18.6%
1985	16,052	1,895	0	158	30	86	285	13,599	2,453	15.3%
1986	7,439	2,037	0	297	130	20	1,607	3,348	4,091	55.0%
1987	4,126	700	0	101	71	119	161	2,974	1,152	27.9%
1988	4,592	344	0	0	93	85	142	3,928	664	14.5%
1989	427	157	0	115	0	0	58	97	330	77.3%
1990	82	7	0	0	0	0	4	71	11	13.9%
1991	119	3	0	0	0	0	0	116	3	2.5%
1992	986	252	0	0	33	42	0	658	328	33.3%
1993	1678	493	167	234	93	221	0	638	1,207	71.9%
1994	3589	363	161	692	124	209	15	2,186	1,564	43.6%

			Unmarked Adults							
	Total Escapement	Marked Hatchery Adults	Coleman National Fish Hatchery	Mokelumne Hatchery	Nimbus Hatchery	Feather River Hatchery	Merced River Hatchery	Estimated Natural Escapement	Estimated Hatchery Escapement	Percent Hatchery
1995	2922	1,155	0	1,013	131	338	14	271	2,651	90.7%
1996	4,432	1,551	0	559	97	156	1,298	772	3,660	82.6%
1997	3,660	956	0	290	52	56	1,341	964	2,696	73.7%
1998	4,091	1,392	0	251	31	41	450	1,926	2,165	52.9%
1999	4,766	1,538	0	883	111	140	446	1,648	3,118	65.4%
2000	13,076	4,430	0	1,722	174	207	2,314	4,228	8,848	67.7%
2001	10,844	5,507	0	2,588	147	193	554	1,856	8,988	82.9%
2002	10,706	7,017	0	1,868	32	429	857	503	10,203	95.3%
2003	3,079	1,848	0	1,189	78	197	332	50	3,029	98.4%
2004	4,320	862	0	1,508	104	189	818	839	3,481	80.6%
2005	2532	308	0	867	87	108	797	365	2,167	85.6%
2006	1621	177	0	612	68	118	80	566	1,055	65.1%
2007	574	48	0	113	0	1	35	378	196	34.1%

APPENDIX 1

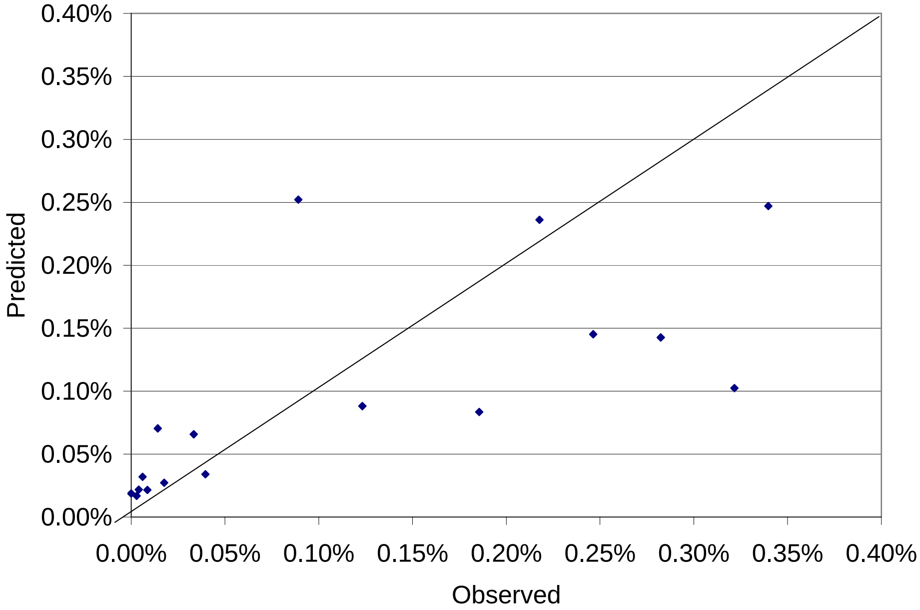

Figure A-1. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 2 Merced River Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the Merced River during spring. Plot does not include low CWT recovery estimates excluded from model development.

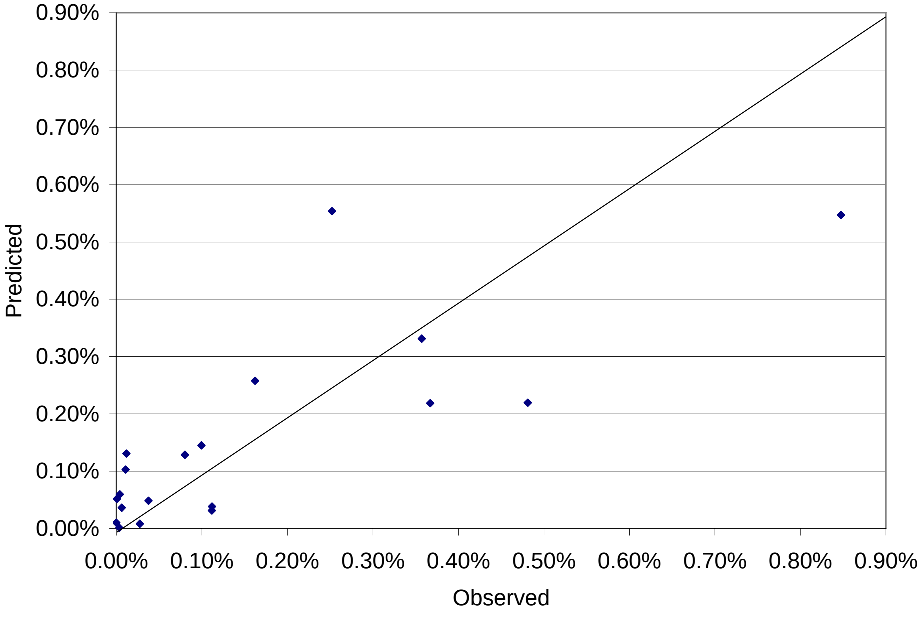

Figure A-2. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 3 Merced River Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the Merced River during spring. Plot does not include low CWT recovery estimates excluded from model development.

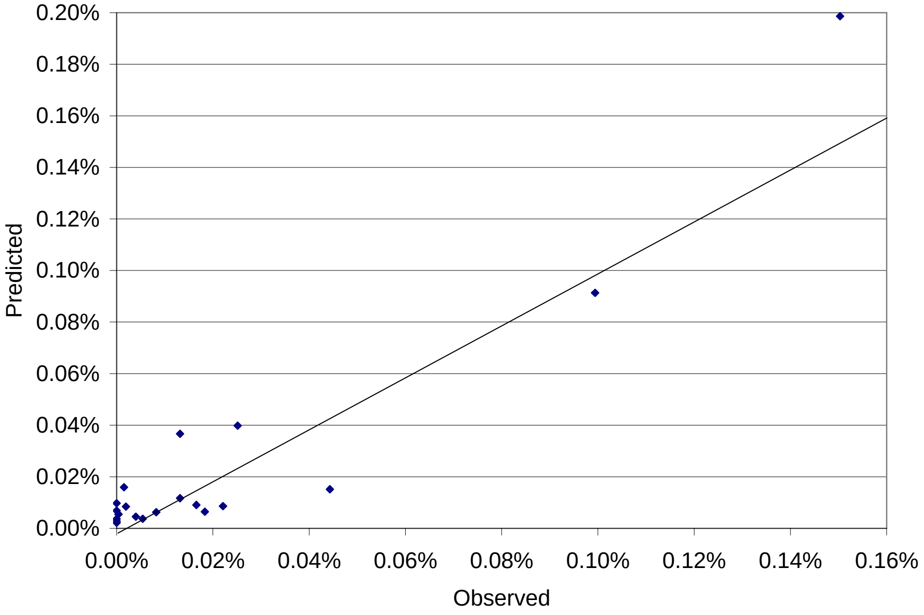

Figure A-3. Predicted recovery rates from the final logistic regression model versus observed recovery rates for each brood year of Age 4 Merced River Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the Merced River during spring. Plot does not include low CWT recovery estimates excluded from model development.

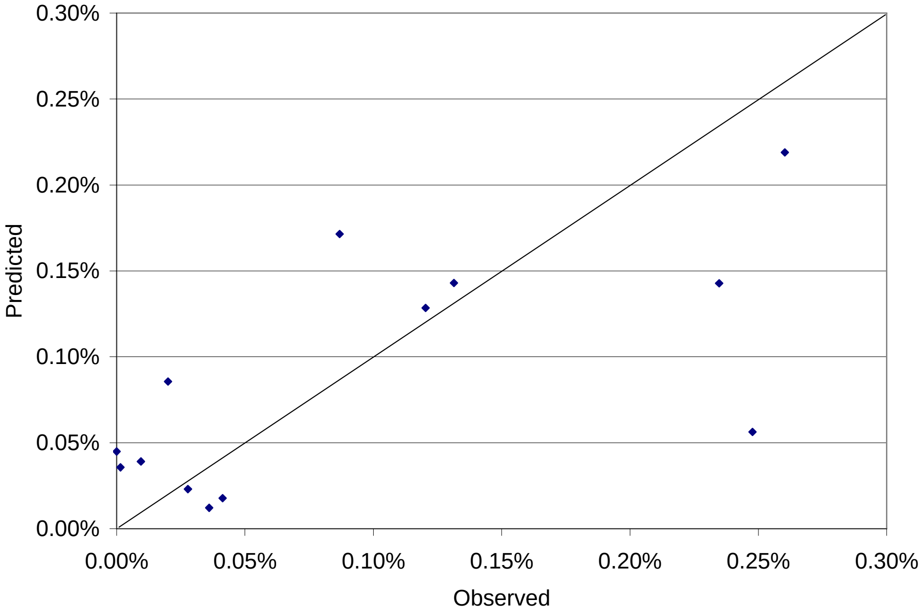

Figure A-4. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 2 Merced River Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the San Joaquin River upstream from Jersey Point during spring. Plot does not include low CWT recovery estimates excluded from model development.

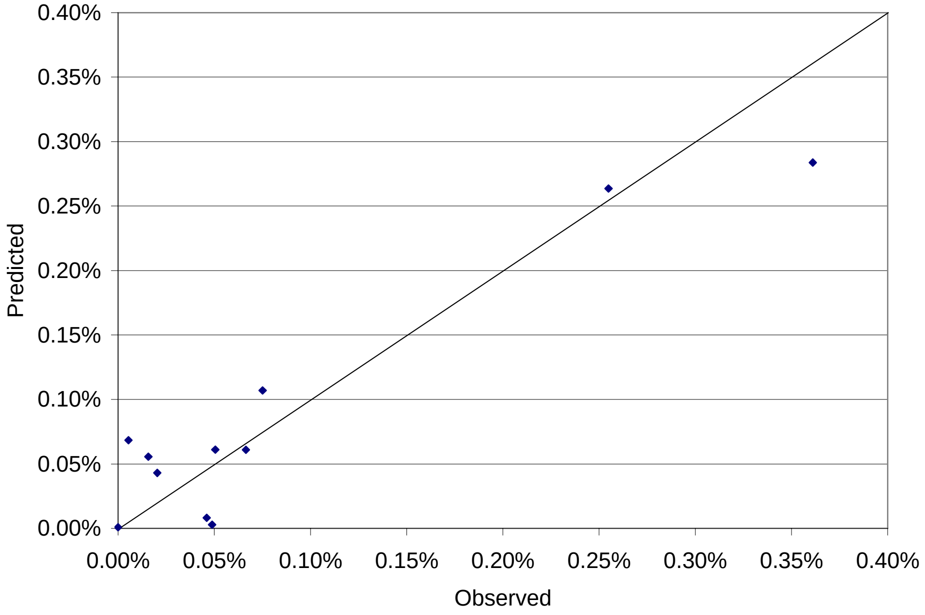

Figure A-5. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 3 Merced River Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the San Joaquin River upstream from Jersey Point during spring. Plot does not include low CWT recovery estimates excluded from model development.

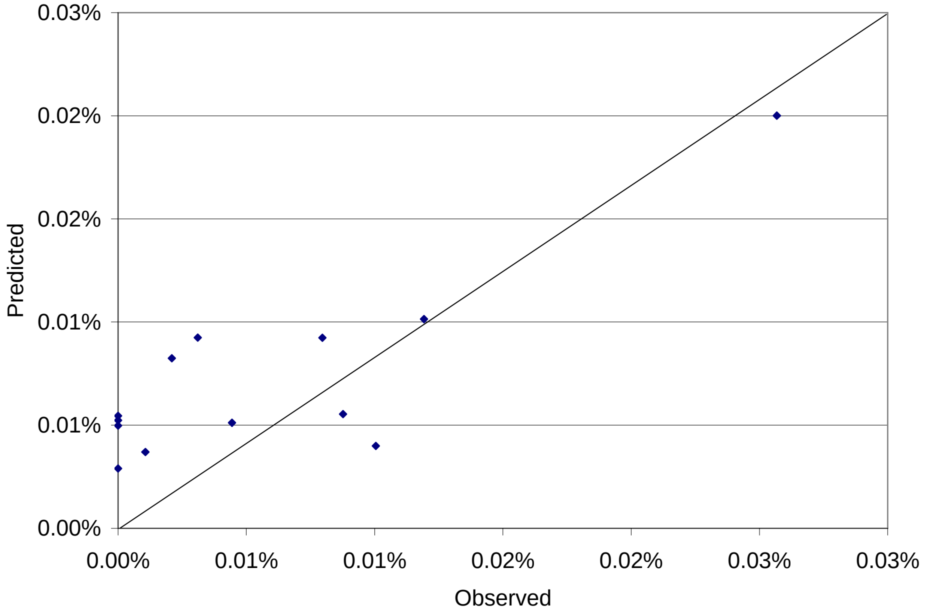

Figure A-6. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 4 Merced River Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the San Joaquin River upstream from Jersey Point during spring. Plot does not include low CWT recovery estimates excluded from model development.

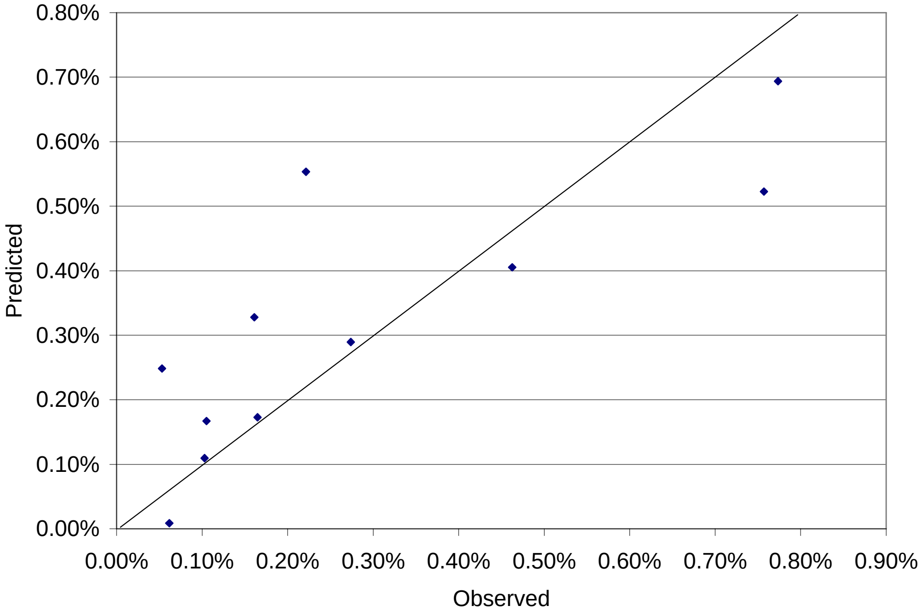

Figure A-7. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 2 Merced River Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the West Delta at Jersey Point during spring. Plot does not include low CWT recovery estimates excluded from model development.

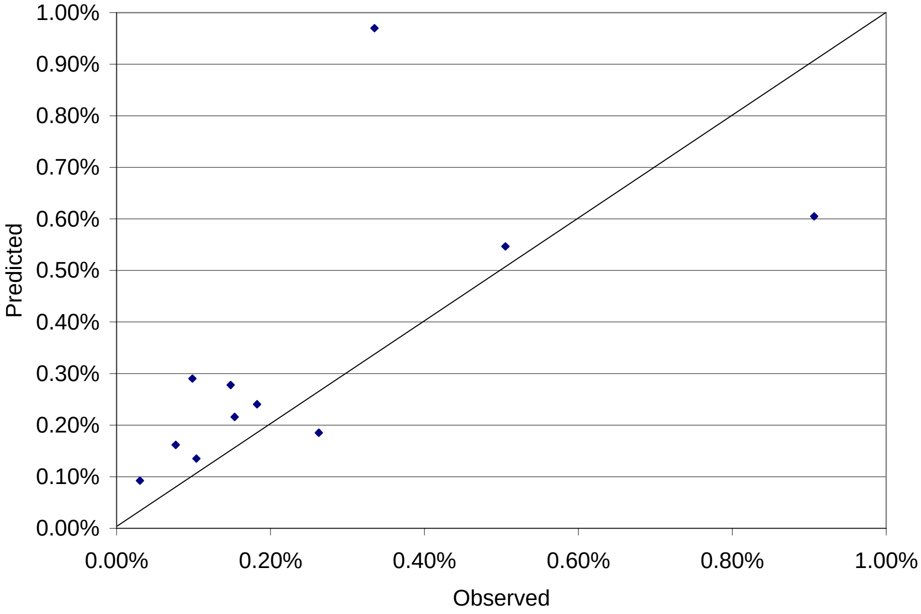

Figure A-8. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 3 Merced River Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the West Delta at Jersey Point during spring. Plot does not include low CWT recovery estimates excluded from model development.

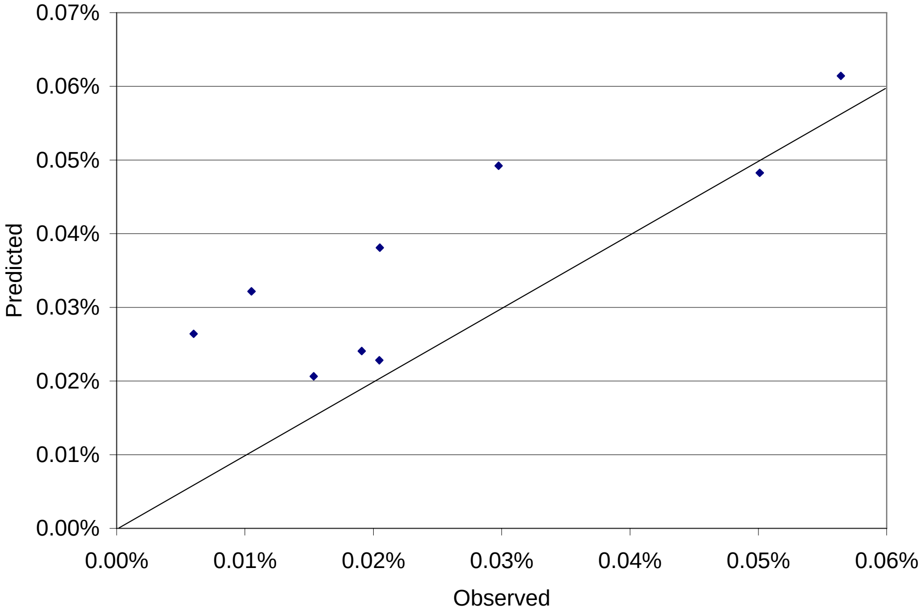

Figure A-9. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 4 Merced River Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the West Delta at Jersey Point during spring. Plot does not include low CWT recovery estimates excluded from model development.

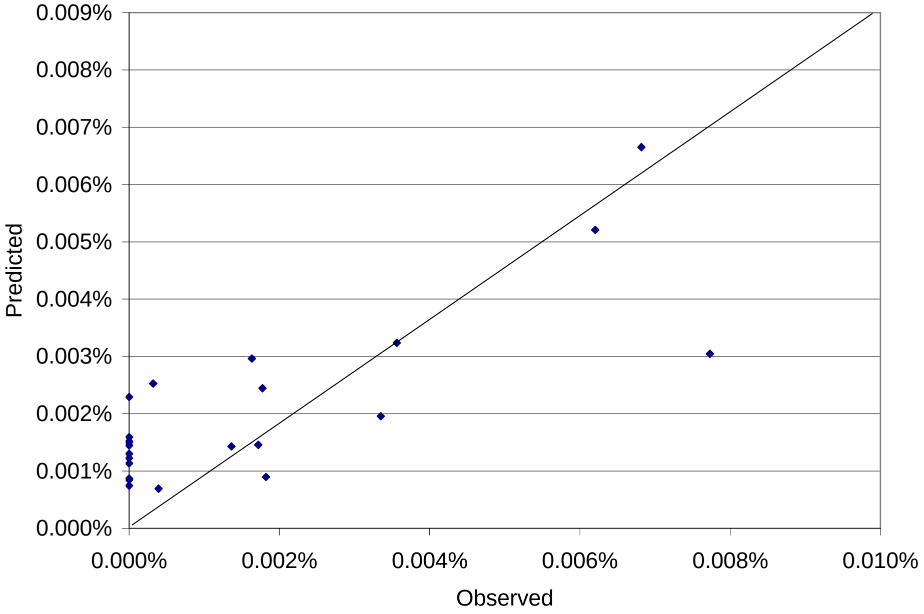

Figure A-10. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 3 Sacramento Basin Hatchery fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the West Delta during spring. Plot does not include low CWT recovery estimates excluded from model development. Models were not developed for Age 2 and Age 4 salmon.

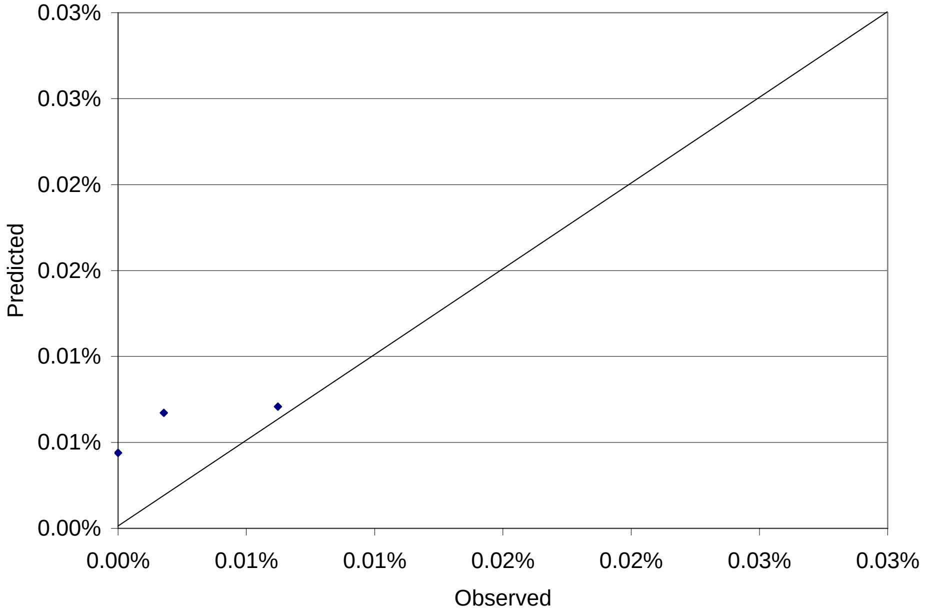

Figure A-11. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 2 Mokelumne River Fish Installation fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the West Delta during spring. Plot does not include low CWT recovery estimates excluded from model development.

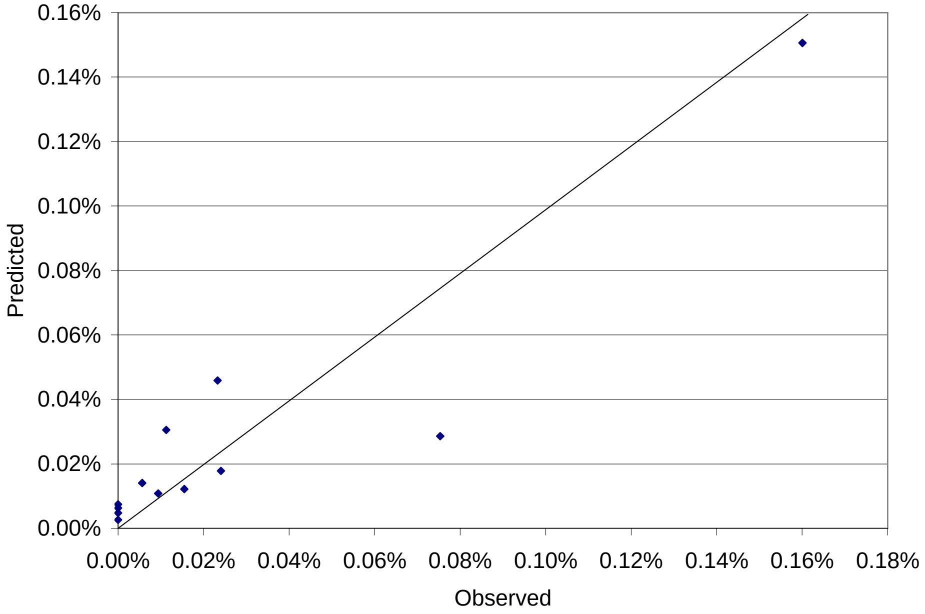

Figure A-12. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 3 Mokelumne River Fish Installation fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the West Delta during spring. Plot does not include low CWT recovery estimates excluded from model development.

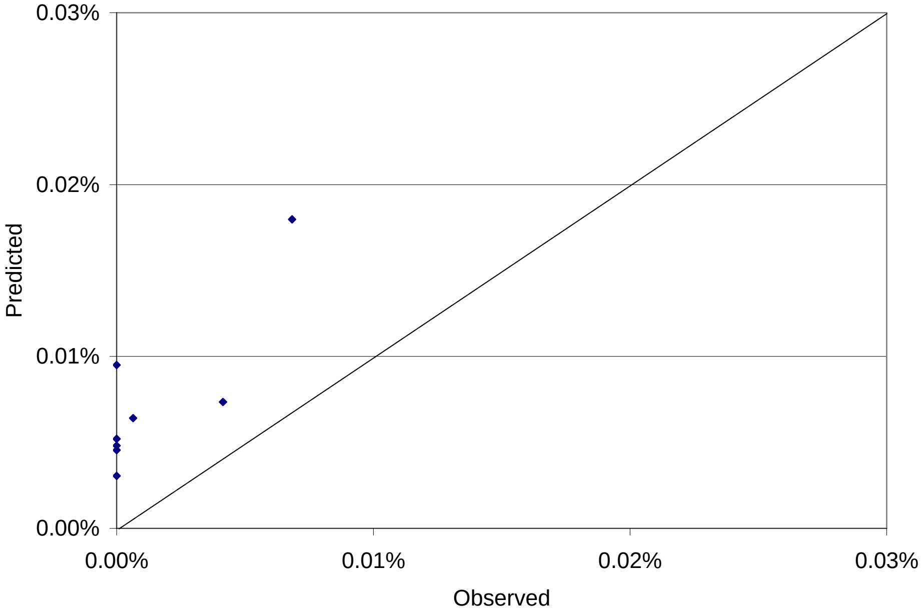

Figure A-13. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 4 Mokelumne River Fish Installation fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the West Delta during spring. Plot does not include low CWT recovery estimates excluded from model development.

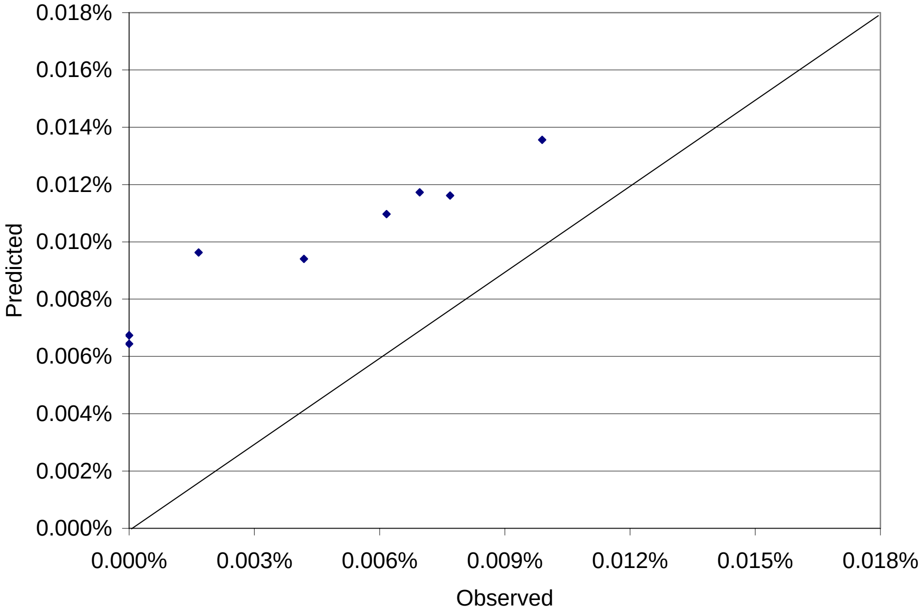

Figure A-14. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 2 Mokelumne River Fish Installation fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the East Delta during spring. Plot does not include low CWT recovery estimates excluded from model development.

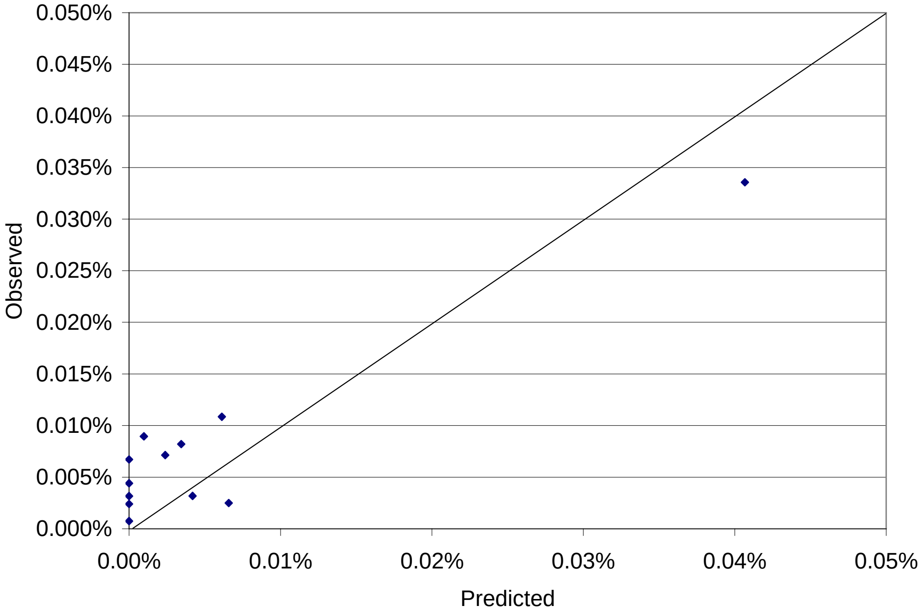

Figure A-15. Predicted recovery rates from the final logistic regression model versus mean observed recovery rates for each brood year of Age 3 Mokelumne River Fish Installation fall-run Chinook salmon in the Merced River that were released as CWT juveniles in the East Delta during spring. Plot does not include low CWT recovery estimates excluded from model development.

APPENDIX 2

Releases of untagged juvenile salmon organized by hatchery, release date, and release location, the estimated rate that each group would be recovered in the Merced River escapement, and the estimated number of untagged adult hatchery salmon in the Merced River escapement from 1980 to 2007. The Release Location Codes 1, 2, 3.1, and 3.2 correspond to tributary, mainstem, East Delta, and West Delta.

Coleman National Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	4-Feb-80	CNFH	92,700	0.0000%	0.0000%	0.0000%	0	0	0
1	20-Apr-79	CNFH	680,975	0.0000%	0.0000%	0.0000%	0	0	0
1	9-May-79	CNFH	42,275	0.0000%	0.0000%	0.0000%	0	0	0
1	19-Oct-79	CNFH	1,013,462	0.0000%	0.0000%	0.0000%	0	0	0
1	3-Dec-79	CNFH	827,504	0.0000%	0.0000%	0.0000%	0	0	0
2	20-Apr-79	Posse Grounds	3,405,975	0.0000%	0.0000%	0.0000%	0	0	0
2	4-Sep-79	RED BLUFF DIVER. DAM	522,575	0.0000%	0.0000%	0.0000%	0	0	0
1	13-Mar-80	BATTLE CREEK	190,000	0.0000%	0.0000%	0.0000%	0	0	0
1	17-Apr-80	BATTLE CREEK	3,515,605	0.0000%	0.0000%	0.0000%	0	0	0
1	7-May-80	BATTLE CREEK	7,101,883	0.0000%	0.0000%	0.0000%	0	0	0
1	22-Sep-80	BATTLE CREEK	613,309	0.0000%	0.0000%	0.0000%	0	0	0
1	2-Jun-82	BATTLE CREEK	250,000	0.0000%	0.0000%	0.0000%	0	0	0
1	17-Jan-83	Tehama Colusa Fish Facilities	538,720	0.0000%	0.0000%	0.0000%	0	0	0
1	18-Jan-83	Antelope Creek	805,420	0.0000%	0.0000%	0.0000%	0	0	0
1	4-Feb-83	BATTLE CREEK	1,136,090	0.0000%	0.0000%	0.0000%	0	0	0
1	28-Apr-83	BATTLE CREEK	3,114,000	0.0000%	0.0000%	0.0000%	0	0	0
1	3-May-83	CLEAR CREEK	200	0.0000%	0.0000%	0.0000%	0	0	0
1	4-May-83	BATTLE CREEK	3,671,312	0.0000%	0.0000%	0.0000%	0	0	0

Coleman National Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	15-Sep-83	BATTLE CREEK	441,178	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Dec-82	Tehama Colusa Fish Facilities	799,200	0.0000%	0.0000%	0.0000%	0	0	0
1	28-Dec-82	Antelope Creek	219,040	0.0000%	0.0000%	0.0000%	0	0	0
2	18-Jan-83	Posse Grounds	2,101,920	0.0000%	0.0000%	0.0000%	0	0	0
2	23-Feb-83	Posse Grounds	545,720	0.0000%	0.0000%	0.0000%	0	0	0
2	24-May-83	RED BLUFF DIVER. DAM	1,173,350	0.0000%	0.0000%	0.0000%	0	0	0
1	23-Apr-84	BATTLE CREEK	1,787,312	0.0000%	0.0000%	0.0000%	0	0	0
1	10-Jul-84	BATTLE CREEK	19,480	0.0000%	0.0000%	0.0000%	0	0	0
2	26-Apr-84	RED BLUFF DIVER. DAM	300,000	0.0000%	0.0000%	0.0000%	0	0	0
2	3-May-84	RED BLUFF DIVER. DAM	564,450	0.0000%	0.0000%	0.0000%	0	0	0
1	25-Jan-85	BATTLE CREEK	169,040	0.0000%	0.0000%	0.0000%	0	0	0
1	8-Mar-85	CLEAR CREEK	199,280	0.0000%	0.0000%	0.0000%	0	0	0
1	11-Mar-85	Antelope Creek	201,770	0.0000%	0.0000%	0.0000%	0	0	0
1	12-Mar-85	Cow Creek	204,660	0.0000%	0.0000%	0.0000%	0	0	0
1	3-Apr-85	BATTLE CREEK	1,458,082	0.0000%	0.0000%	0.0000%	0	0	0
1	13-Jun-85	BATTLE CREEK	5,820	0.0000%	0.0000%	0.0000%	0	0	0
1	23-Nov-85	Tehama Colusa Fish Facilities	729,600	0.0000%	0.0000%	0.0000%	0	0	0
2	24-Jan-85	Posse Grounds	4,141,440	0.0000%	0.0000%	0.0000%	0	0	0
2	25-Jan-85	BALLS FERRY	656,640	0.0000%	0.0000%	0.0000%	0	0	0
2	25-Jan-85	North Street Bridge	2,937,600	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Feb-85	BALLS FERRY	1,211,040	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Feb-85	North Street Bridge	1,546,560	0.0000%	0.0000%	0.0000%	0	0	0
2	4-Feb-85	Posse Grounds	665,280	0.0000%	0.0000%	0.0000%	0	0	0
2	18-Apr-85	RED BLUFF DIVER. DAM	2,007,000	0.0000%	0.0000%	0.0000%	0	0	0
1	4-Apr-86	BATTLE CREEK	2,044,279	0.0000%	0.0000%	0.0000%	0	0	0
1	27-May-86	Tehama Colusa Fish Facilities	603,000	0.0000%	0.0000%	0.0000%	0	0	0
2	14-Apr-86	RED BLUFF DIVER. DAM	608,140	0.0000%	0.0000%	0.0000%	0	0	0

Coleman National Fish Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
1	4-Feb-87	BATTLE CREEK	1,494,700	0.0000%	0.0000%	0.0000%	0	0	0
1	20-Apr-87	BATTLE CREEK	5,312,900	0.0000%	0.0000%	0.0000%	0	0	0
1	5-Jun-87	BATTLE CREEK	11,800	0.0000%	0.0000%	0.0000%	0	0	0
1	5-Apr-88	Tehama Colusa Fish Facilities	1,157,100	0.0000%	0.0000%	0.0000%	0	0	0
1	11-Apr-88	BATTLE CREEK	514,910	0.0000%	0.0000%	0.0000%	0	0	0
1	22-Dec-87	BATTLE CREEK	507,000	0.0000%	0.0000%	0.0000%	0	0	0
2	4-Jan-88	North Street Bridge	4,500,719	0.0000%	0.0000%	0.0000%	0	0	0
2	16-Feb-88	North Street Bridge	959,666	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Apr-88	RED BLUFF DIVER. DAM	725,187	0.0000%	0.0000%	0.0000%	0	0	0
1	16-Feb-89	Stillwater Creek	200,000	0.0000%	0.0000%	0.0000%	0	0	0
1	17-Feb-89	Anderson Creek	100,500	0.0000%	0.0000%	0.0000%	0	0	0
1	28-Mar-89	BATTLE CREEK	53,950	0.0000%	0.0000%	0.0000%	0	0	0
2	3-Feb-89	RED BLUFF DIVER. DAM	5,678,534	0.0000%	0.0000%	0.0000%	0	0	0
2	6-Mar-89	BALLS FERRY	3,824,520	0.0000%	0.0000%	0.0000%	0	0	0
2	23-Mar-89	RED BLUFF DIVER. DAM	684,193	0.0000%	0.0000%	0.0000%	0	0	0
1	30-Mar-90	BATTLE CREEK	769,343	0.0000%	0.0000%	0.0000%	0	0	0
2	5-Mar-90	Sacramento River	3,919,302	0.0000%	0.0000%	0.0000%	0	0	0
3.2	13-May-90	BENICIA	5,608,310	0.0000%	0.0000%	0.0000%	0	0	0
1	26-Feb-91	BATTLE CREEK	200,018	0.0000%	0.0000%	0.0000%	0	0	0
1	28-Feb-91	BATTLE CREEK	680,214	0.0000%	0.0000%	0.0000%	0	0	0
1	30-Oct-90	FEATHER RIVER	719,186	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Nov-90	FEATHER RIVER	540,750	0.0000%	0.0000%	0.0000%	0	0	0
2	28-Feb-91	Anderson River Park	550,045	0.0000%	0.0000%	0.0000%	0	0	0
2	28-Feb-91	BALLS FERRY	672,559	0.0000%	0.0000%	0.0000%	0	0	0
2	28-Feb-91	BEND BRIDGE	307,819	0.0000%	0.0000%	0.0000%	0	0	0
2	28-Feb-91	Posse Grounds	324,679	0.0000%	0.0000%	0.0000%	0	0	0
2	28-Feb-91	Sacramento River, ACID Dam	271,156	0.0000%	0.0000%	0.0000%	0	0	0

Coleman National Fish Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
2	1-Mar-91	Woodson Bridge	666,834	0.0000%	0.0000%	0.0000%	0	0	0
2	22-Apr-91	Sacramento River, Princeton	6,349,775	0.0000%	0.0000%	0.0000%	0	0	0
3.2	29-Apr-91	BENICIA	901,820	0.0000%	0.0027%	0.0027%	0	25	24
3.2	5-May-91	BENICIA	5,049,448	0.0000%	0.0028%	0.0027%	0	142	137
1	23-Mar-92	BATTLE CREEK	10,234	0.0000%	0.0000%	0.0000%	0	0	0
1	23-Mar-93	BATTLE CREEK	3,460,081	0.0000%	0.0000%	0.0000%	0	0	0
2	13-Feb-92	RED BLUFF DIVER. DAM	4,761,200	0.0000%	0.0000%	0.0000%	0	0	0
1	23-Mar-93	BATTLE CREEK	3,460,081	0.0000%	0.0000%	0.0000%	0	0	0
1	10-Mar-94	BATTLE CREEK	419	0.0000%	0.0000%	0.0000%	0	0	0
2	7-Feb-94	RED BLUFF DIVER. DAM	3,336,597	0.0000%	0.0000%	0.0000%	0	0	0
1	23-Mar-95	BATTLE CREEK	474,846	0.0000%	0.0000%	0.0000%	0	0	0
2	13-Feb-95	RED BLUFF DIVER. DAM	1,482,415	0.0000%	0.0000%	0.0000%	0	0	0
2	14-Mar-95	BALLS FERRY	1,317,557	0.0000%	0.0000%	0.0000%	0	0	0
2	29-Jan-96	RED BLUFF DIVER. DAM	1,319,814	0.0000%	0.0000%	0.0000%	0	0	0
2	8-Feb-96	RED BLUFF DIVER. DAM	5,222,300	0.0000%	0.0000%	0.0000%	0	0	0
2	5-Mar-96	RED BLUFF DIVER. DAM	1,001,507	0.0000%	0.0000%	0.0000%	0	0	0
2	20-Feb-97	Bow River Boat Ramp	3,097,705	0.0000%	0.0000%	0.0000%	0	0	0
2	4-Feb-97	Sacramento River -Hunters MHP	1,970,072	0.0000%	0.0000%	0.0000%	0	0	0
2	4-Mar-97	Bow River Boat Ramp	2,915,824	0.0000%	0.0000%	0.0000%	0	0	0
2	4-Feb-98	Below RBDD	8,203,920	0.0000%	0.0000%	0.0000%	0	0	0
1	9-Apr-99	BATTLE CREEK	3,510	0.0000%	0.0000%	0.0000%	0	0	0
1	28-Apr-99	CNFH	478,047	0.0000%	0.0000%	0.0000%	0	0	0
2	29-Jan-99	Bow River Boat Ramp	384,882	0.0000%	0.0000%	0.0000%	0	0	0
2	29-Jan-99	Los Molinos, below river boat ramp	755,073	0.0000%	0.0000%	0.0000%	0	0	0
2	29-Jan-99	Woodson Bridge	370,191	0.0000%	0.0000%	0.0000%	0	0	0
2	26-Feb-99	Los Molinos, below river boat	3,000	0.0000%	0.0000%	0.0000%	0	0	0

Coleman National Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
		ramp							
2	9-Mar-99	Los Molinos, below river boat ramp	3,000	0.0000%	0.0000%	0.0000%	0	0	0
2	26-Mar-99	Los Molinos, below river boat ramp	3,000	0.0000%	0.0000%	0.0000%	0	0	0
2	15-Apr-99	Los Molinos, below river boat ramp	3,000	0.0000%	0.0000%	0.0000%	0	0	0
2	6-May-99	Los Molinos, below river boat ramp	3,100	0.0000%	0.0000%	0.0000%	0	0	0
2	26-Feb-99	Los Molinos, below river boat ramp	3,000	0.0000%	0.0000%	0.0000%	0	0	0
2	9-Mar-99	Los Molinos, below river boat ramp	3,000	0.0000%	0.0000%	0.0000%	0	0	0
2	26-Mar-99	Los Molinos, below river boat ramp	3,000	0.0000%	0.0000%	0.0000%	0	0	0
2	22-Mar-00	ABOVE RED BLUFF DAM	9,932	0.0000%	0.0000%	0.0000%	0	0	0
2	15-Apr-99	Los Molinos, below river boat ramp	3,000	0.0000%	0.0000%	0.0000%	0	0	0
2	4-Apr-00	Los Molinos, below river boat ramp	1,150	0.0000%	0.0000%	0.0000%	0	0	0
1	4-Apr-03	CNFH	1,685,414	0.0000%	0.0000%	0.0000%	0	0	0
1	18-Apr-03	CNFH	5,214,104	0.0000%	0.0000%	0.0000%	0	0	0
1	24-Apr-03	CNFH	3,588,184	0.0000%	0.0000%	0.0000%	0	0	0
1	25-Apr-03	CNFH	3,349,443	0.0000%	0.0000%	0.0000%	0	0	0
1	16-Apr-04	BATTLE CREEK	5,477,399	0.0000%	0.0000%	0.0000%	0	0	0
1	16-Apr-04	CNFH	5,477,399	0.0000%	0.0000%	0.0000%	0	0	0
1	23-Apr-04	BATTLE CREEK	6,614,040	0.0000%	0.0000%	0.0000%	0	0	0
1	23-Apr-04	CNFH	6,614,040	0.0000%	0.0000%	0.0000%	0	0	0
1	15-Apr-05	CNFH	6,097,731	0.0000%	0.0000%	0.0000%	0	0	0
1	29-Apr-05	CNFH	5,609,155	0.0000%	0.0000%	0.0000%	0	0	0

Feather River Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	1-Feb-78	FRH	217,600				0	0	0
1	1-Oct-78	VERONA	57,200				0	0	0
1	1-Nov-78	Tehama Colusa Fish Facilities	76,175				0	0	0
1	1-Nov-78	VERONA	110,000				0	0	0
1	1-Nov-78	YUBA RIVER	104,260				0	0	0
1	1-Dec-78	FRH	27,500				0	0	0
1	1-Dec-78	Tehama Colusa Fish Facilities	401,265				0	0	0
1	1-Dec-78	VERONA	261,045				0	0	0
1	1-Dec-78	YUBA RIVER	300,525				0	0	0
2	1-Apr-78	RIO VISTA	100,480				0	0	0
2	1-May-78	RIO VISTA	744,240				0	0	0
2	1-Jun-78	RIO VISTA	820,540				0	0	0
2	1-Nov-78	RED BLUFF DIVER. DAM	157,500				0	0	0
2	1-Dec-78	RED BLUFF DIVER. DAM	42,100				0	0	0
3.2	1-Jun-78	TIBURON NET PENS	150,500	0.0000%		0.0000%	0	0	0
1	1-Jun-79	VERONA	131,300				0	0	0
1	1-Oct-79	FRH	1,678,903				0	0	0
1	1-Dec-79	FRH	342,412				0	0	0
2	1-May-79	RIO VISTA	339,400				0	0	0
2	1-Jun-79	RIO VISTA	1,226,200				0	0	0
2	1-Jul-79	RIO VISTA	610,650				0	0	0
3.2	1-Aug-79	TIBURON NET PENS	35,950	0.0000%		0.0000%	0	0	0
1	1-Jan-81	FRH	129,370				0	0	0
1	1-Jan-81	VERONA	11,050				0	0	0
1	1-Jun-80	FRH	50,000				0	0	0
1	1-Jun-80	YUBA RIVER	106,610				0	0	0

Feather River Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	1-Jul-80	FRH	62,836				0	0	0
1	1-Jul-80	Nelson Bar	0				0	0	0
1	1-Oct-80	FRH	1,652,592				0	0	0
2	1-Jan-81	RIO VISTA	13,600				0	0	0
2	1-May-80	RIO VISTA	465,325				0	0	0
2	1-Jun-80	RIO VISTA	323,450				0	0	0
2	1-Jul-80	RIO VISTA	373,000				0	0	0
3.2	1-Jul-80	CARQUINEZ STRAIT	42,000	0.0000%	0.0029%	0.0000%	0	1	0
1	1-Feb-81	FRH	0				0	0	0
1	1-Oct-81	FRH	1,330,900				0	0	0
1	1-Nov-81	FRH	124,100				0	0	0
3.2	1-May-81	BENICIA	793,981	0.0000%	0.0066%	0.0000%	0	52	0
3.2	1-Jun-81	BENICIA	1,339,600	0.0000%	0.0064%	0.0000%	0	86	0
3.2	1-Jul-81	BENICIA	814,600	0.0000%	0.0067%	0.0000%	0	55	0
3.2	1-Aug-81	BENICIA	343,850	0.0000%	0.0075%	0.0000%	0	26	0
3.2	1-Sep-81	BENICIA	190,510	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jan-82	Antelope Creek	633,600				0	0	0
1	1-Jan-82	FRH	307,380				0	0	0
1	1-Feb-82	FRH	896,000				0	0	0
1	1-Mar-82	FRH	2,068,640				0	0	0
1	1-Sep-82	FRH	119,884				0	0	0
1	1-Oct-82	FRH	824,985				0	0	0
1	1-Nov-82	FRH	518,200				0	0	0
1	1-Dec-81	FRH	808,640				0	0	0
3.2	1-Apr-82	BENICIA	860,900	0.0000%	0.0010%	0.0000%	0	9	0
3.2	1-May-82	BENICIA	609,150	0.0000%	0.0011%	0.0000%	0	7	0
3.2	1-Jun-82	BENICIA	1,220,200	0.0000%	0.0011%	0.0000%	0	13	0

Feather River Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.2	1-Jul-82	BENICIA	173,600	0.0000%	0.0011%	0.0000%	0	2	0
3.2	1-Aug-82	BENICIA	256,425	0.0000%	0.0014%	0.0000%	0	4	0
3.2	1-Sep-82	BENICIA	34,300	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jan-83	Honcut Creek	100,485				0	0	0
1	1-Jan-83	Stony Creek	185,900				0	0	0
1	1-Feb-83	FEATHER RIVER	2,558,400				0	0	0
1	1-Sep-83	FRH	0				0	0	0
1	1-Oct-83	FRH	1,267,916				0	0	0
2	1-Aug-83	RIO VISTA	36,000				0	0	0
3.2	1-Jun-83	BENICIA	743,200	0.0000%	0.0007%	0.0000%	0	5	0
3.2	1-Jul-83	BENICIA	599,700	0.0000%	0.0007%	0.0000%	0	4	0
3.2	1-Jul-83	TIBURON NET PENS	49,300	0.0000%	0.0007%	0.0000%	0	0	0
3.2	1-Jul-83	Vallejo	48,600	0.0000%	0.0007%	0.0000%	0	0	0
3.2	1-Aug-83	TIBURON NET PENS	48,000	0.0000%	0.0007%	0.0000%	0	0	0
3.2	1-Aug-83	Vallejo	44,800	0.0000%	0.0009%	0.0000%	0	0	0
3.2	1-Sep-83	Vallejo	42,700	0.0286%	0.0864%	0.0231%	12	37	10
3.2	1-Oct-83	TIBURON NET PENS	44,200	0.0286%	0.0864%	0.0231%	13	38	10
1	1-Jan-84	FRH	648,000				0	0	0
1	1-Feb-84	Antelope Creek	0				0	0	0
1	1-Feb-84	BUTTE CREEK	0				0	0	0
1	1-Feb-84	Chico Creek	0				0	0	0
1	1-Feb-84	FRH	0				0	0	0
1	1-Mar-84	FRH	214,200				0	0	0
1	1-Jun-84	FEATHER RIVER	0				0	0	0
2	1-Jun-84	COURTLAND	66,600				0	0	0
2	1-Jun-84	Glen-Colusa	0				0	0	0
2	1-Jun-84	Guisti	62,300				0	0	0

Feather River Fish Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
2	1-Jun-84	RYDE-KOKET	61,600				0	0	0
3.1	1-Jun-84	PALM TRACT	67,600				0	0	0
3.1	1-Jun-84	Whimpy's	59,250				0	0	0
3.2	1-Mar-84	BENICIA	0				0	0	0
3.2	1-May-84	BENICIA	0	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-84	BENICIA	63,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-84	PORT CHICAGO	44,100	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-84	Vallejo	42,750	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-84	BENICIA	634,550	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Aug-84	BENICIA	1,051,175	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Aug-84	Berkeley Marina	230,200	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Sep-84	BENICIA	476,650	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Sep-84	Berkeley Marina	100,200	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jan-85	FEATHER RIVER	182,400				0	0	0
1	1-Feb-85	Bear River	100,800				0	0	0
1	1-May-85	FEATHER RIVER	22,000				0	0	0
1	1-May-85	MOKELUMNE RIVER	106,240				0	0	0
2	1-May-85	COURTLAND	105,400				0	0	0
2	1-May-85	Glen-Colusa	10,034				0	0	0
2	1-May-85	RYDE-KOKET	95,000				0	0	0
3.1	1-May-85	PALM TRACT	105,240				0	0	0
3.1	1-May-85	Whimpy's	104,720				0	0	0
3.2	1-Apr-85	BENICIA	943,050	0.0000%	0.0015%	0.0000%	0	14	0
3.2	1-May-85	BENICIA	479,077	0.0000%	0.0016%	0.0000%	0	8	0
3.2	1-May-85	Berkeley Marina	52,700	0.0000%	0.0015%	0.0000%	0	1	0
3.2	1-May-85	PORT CHICAGO	53,100	0.0000%	0.0015%	0.0000%	0	1	0
3.2	1-Jun-85	BENICIA	465,500	0.0000%	0.0016%	0.0000%	0	7	0

Feather River Fish Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Age 3	Age 4	Escapement Age 2	Age 3	Age 4
3.2	1-Jun-85	TIBURON NET PENS	28,500	0.0000%	0.0019%	0.0000%	0	1	0
3.2	1-Jul-85	BENICIA	2,412,575	0.0000%	0.0018%	0.0000%	0	43	0
3.2	1-Aug-85	BENICIA	2,190,825	0.0000%	0.0020%	0.0000%	0	44	0
3.2	1-Sep-85	BENICIA	1,718,380	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Oct-85	BENICIA	112,800	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Feb-86	AMERICANR-COON CREEK	24,000				0	0	0
1	1-Feb-86	Auburn Ravine Creek	24,000				0	0	0
1	1-Feb-86	Bear River	79,200				0	0	0
1	1-Feb-86	Doty Ravine Creek	24,000				0	0	0
1	1-Feb-86	Dry Creek	84,000				0	0	0
1	1-Feb-86	Secret Ravine Creek	24,000				0	0	0
1	1-Apr-86	FEATHER RIVER	14,400				0	0	0
1	1-May-86	FEATHER RIVER	8,400				0	0	0
1	1-Oct-86	FEATHER RIVER	1,451,450				0	0	0
3.2	1-May-86	BENICIA	573,750	0.0000%	0.0018%	0.0000%	0	10	0
3.2	1-Jun-86	BENICIA	313,200	0.0000%	0.0019%	0.0000%	0	6	0
3.2	1-Jun-86	TIBURON NET PENS	50,000	0.0000%	0.0020%	0.0000%	0	1	0
3.2	1-Jul-86	BENICIA	1,136,800	0.0000%	0.0021%	0.0000%	0	23	0
3.2	1-Aug-86	SF-San Francisco Bay	1,829,275	0.0000%	0.0024%	0.0000%	0	44	0
3.2	1-Sep-86	SF-San Francisco Bay	686,150	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jan-87	AMERICANR-COON CREEK	24,640				0	0	0
1	1-Jan-87	Auburn Ravine Creek	50,400				0	0	0
1	1-Jan-87	Bear River	101,376				0	0	0
1	1-Jan-87	Doty Ravine Creek	49,280				0	0	0
1	1-Jan-87	Dry Creek	75,040				0	0	0
1	1-Jan-87	Secret Ravine Creek	100,000				0	0	0
1	1-Oct-87	GRIDLEY	552,975				0	0	0

Feather River Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.2	1-Apr-87	BENICIA	821,300	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-87	BENICIA	926,500	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-87	BENICIA	2,382,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-87	BENICIA	2,477,075	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Aug-87	BENICIA	1,860,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Sep-87	BENICIA	435,850	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Feb-88	Chico Creek	0				0	0	0
3.2	1-Mar-88	BENICIA	129,200				0	0	0
3.2	1-Apr-88	BENICIA	827,600	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Apr-88	Berkeley Marina	0	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-88	BENICIA	704,850	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-88	BENICIA	1,525,450	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-88	TIBURON NET PENS	50,050	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-88	BENICIA	2,701,750	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Aug-88	BENICIA	1,595,220	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Sep-88	BENICIA	109,000	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jan-89	AMERICANR-COON CREEK	100,678				0	0	0
1	1-Jan-89	Auburn Ravine Creek	100,678				0	0	0
1	1-Jan-89	Bear Creek	100,678				0	0	0
1	1-Jan-89	Chico Creek	0				0	0	0
1	1-Jan-89	Dry Creek	194,072				0	0	0
1	1-Jan-89	FEATHER RIVER	371,800				0	0	0
1	1-Jan-89	Miners Ravine Creek	100,678				0	0	0
1	1-Jan-89	Secret Ravine Creek	100,678				0	0	0
1	1-Feb-89	MOKELUMNE R FISH INS	0				0	0	0
1	1-Apr-89	FEATHER RIVER	0				0	0	0
1	1-Apr-89	GRIDLEY	743,450				0	0	0

Feather River Fish Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
1	1-Dec-88	Chico Creek	0				0	0	0
1	1-Dec-88	FEATHER RIVER	538,400				0	0	0
2	1-Jan-89	Sac River, Colusa Drain	600,320				0	0	0
2	1-Jun-89	Sacramento River	0				0	0	0
3.2	1-Apr-89	BENICIA	685,500	0.0000%	0.0000%	0.0010%	0	0	7
3.2	1-May-89	BENICIA	537,000	0.0000%	0.0000%	0.0010%	0	0	5
3.2	1-Jun-89	BENICIA	972,100	0.0000%	0.0000%	0.0010%	0	0	10
3.2	1-Jun-89	TIBURON NET PENS	43,500	0.0000%	0.0000%	0.0010%	0	0	0
3.2	1-Jul-89	BENICIA	911,400	0.0000%	0.0000%	0.0010%	0	0	9
3.2	1-Aug-89	BENICIA	1,075,900	0.0000%	0.0000%	0.0010%	0	0	11
1	1-Mar-90	GRIDLEY	1,508,250				0	0	0
1	1-Apr-90	GRIDLEY	935,195				0	0	0
2	1-May-90	Hamilton City	10,200				0	0	0
3.2	1-May-90	BENICIA	882,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-90	BENICIA	3,414,050	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-90	TIBURON NET PENS	4,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-90	BENICIA	1,214,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Aug-90	BENICIA	1,449,650	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Sep-90	BENICIA	549,200	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Feb-91	CLEAR CREEK	0				0	0	0
1	1-Mar-91	CLEAR CREEK	0				0	0	0
3.2	1-Apr-91	BENICIA	52,000	0.0000%	0.0032%	0.0027%	0	2	1
3.2	1-May-91	BENICIA	1,401,260	0.0000%	0.0033%	0.0027%	0	47	38
3.2	1-Jun-91	BENICIA	1,229,850	0.0000%	0.0039%	0.0027%	0	48	33
3.2	1-Jun-91	TIBURON NET PENS	55,900	0.0000%	0.0039%	0.0027%	0	2	2
3.2	1-Jul-91	BENICIA	1,245,850	0.0000%	0.0044%	0.0027%	0	55	34
3.2	1-Aug-91	BENICIA	1,235,085	0.0000%	0.0054%	0.0027%	0	67	33

Feather River Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	1-Jan-92	FEATHER RIVER	1,400,000				0	0	0
1	1-Mar-92	FEATHER RIVER	1,655,440				0	0	0
1	1-Apr-92	FEATHER RIVER	768,995				0	0	0
3.2	1-May-92	BENICIA	1,639,350	0.0000%	0.0010%	0.0000%	0	16	0
3.2	1-Jun-92	BENICIA	1,314,900	0.0000%	0.0010%	0.0000%	0	13	0
3.2	1-Jul-92	BENICIA	1,634,100	0.0000%	0.0012%	0.0000%	0	19	0
3.2	1-Aug-92	BENICIA	1,186,400	0.0000%	0.0016%	0.0000%	0	19	0
3.2	1-Sep-92	BENICIA	443,100	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Oct-92	BENICIA	276,160	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jan-93	FEATHER RIVER	1,920,000				0	0	0
1	1-Feb-93	Dry Creek	275,200				0	0	0
1	1-Feb-93	FEATHER RIVER	160,000				0	0	0
1	1-Mar-93	Bear River	200,000				0	0	0
1	1-Mar-93	Honcut Creek	151,000				0	0	0
2	1-Jun-93	Grimes	4,615				0	0	0
3.2	1-May-93	BENICIA	1,836,000	0.0000%	0.0017%	0.0000%	0	32	0
3.2	1-May-93	TIBURON NET PENS	54,000	0.0000%	0.0020%	0.0000%	0	1	0
3.2	1-Jun-93	BENICIA	3,077,270	0.0000%	0.0018%	0.0000%	0	56	0
3.2	1-Jul-93	BENICIA	1,848,518	0.0000%	0.0020%	0.0000%	0	37	0
3.2	1-Aug-93	BENICIA	2,615,660	0.0000%	0.0026%	0.0000%	0	68	0
3.2	1-Sep-93	BENICIA	309,500	0.0000%	0.0027%	0.0000%	0	8	0
1	1-Jan-94	Dry Creek	302,400				0	0	0
1	1-Jan-94	FEATHER RIVER	4,995,200				0	0	0
1	1-Jan-94	Honcut Creek	304,200				0	0	0
1	1-Feb-94	FEATHER RIVER	0				0	0	0
1	1-Mar-94	Bear River	62,400				0	0	0
1	1-Mar-94	FEATHER RIVER	120,000				0	0	0

Feather River Fish Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
1	1-Dec-93	FEATHER RIVER	264,000				0	0	0
2	1-Jul-94	Sacramento River	0				0	0	0
3.2	1-Apr-94	BENICIA	712,642	0.0021%	0.0023%	0.0001%	15	16	1
3.2	1-May-94	BENICIA	2,632,217	0.0021%	0.0024%	0.0001%	56	62	3
3.2	1-Jun-94	BENICIA	1,548,320	0.0021%	0.0025%	0.0001%	33	39	2
3.2	1-Jun-94	TIBURON NET PENS	51,150	0.0021%	0.0028%	0.0001%	1	1	0
3.2	1-Jun-94	WICKLAND OIL NET PEN	0	0.0021%	0.0019%	0.0001%	0	0	0
3.2	1-Jul-94	BENICIA	250,400	0.0021%	0.0026%	0.0001%	5	7	0
3.2	1-Jul-94	San Francisco Bay, San Yerba Buena Naval Yard	627,000	0.0021%	0.0027%	0.0001%	13	17	1
3.2	1-Jul-94	WICKLAND OIL NET PEN	518,300	0.0021%	0.0026%	0.0001%	11	14	1
1	1-Jan-95	FEATHER RIVER	674,786				0	0	0
1	1-Feb-95	FEATHER RIVER	3,142,258				0	0	0
1	1-Feb-95	Honcut Creek	304,290				0	0	0
1	1-Mar-95	Bear River	100,050				0	0	0
1	1-Mar-95	Dry Creek	200,100				0	0	0
1	1-Mar-95	FEATHER RIVER	969,275				0	0	0
1	1-May-95	FEATHER RIVER	0				0	0	0
1	1-May-95	Princeton	25,200				0	0	0
1	1-May-95	Walnut Ave	20,008				0	0	0
1	1-Jun-95	Feather (Tisdale Weir)	26,400				0	0	0
1	1-Jun-95	Feather (Yuba City)	45,500				0	0	0
1	1-Jun-95	Princeton	75,000				0	0	0
2	1-Apr-95	Georgiana Slough	17,160				0	0	0
2	1-May-95	Georgiana Slough	12,000				0	0	0
2	1-May-95	MILLER PARK	5,000				0	0	0
2	1-May-95	Sacramento River	30,000				0	0	0

Feather River Fish Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
2	1-Jun-95	Grimes	125,000				0	0	0
3.2	1-Apr-95	BENICIA	269,152	0.0000%	0.0010%	0.0002%	0	3	0
3.2	1-May-95	BENICIA	396,952	0.0000%	0.0012%	0.0002%	0	5	1
3.2	1-May-95	San Francisco Bay, San Yerba Buena Naval Yard	103,400	0.0000%	0.0012%	0.0002%	0	1	0
3.2	1-May-95	WICKLAND OIL NET PEN	593,080	0.0000%	0.0011%	0.0002%	0	7	1
3.2	1-Jun-95	BENICIA	225,100	0.0000%	0.0012%	0.0002%	0	3	0
3.2	1-Jun-95	S.F. Bay-Oceangraph Ctr.	47,600	0.0000%	0.0013%	0.0002%	0	1	0
3.2	1-Jun-95	San Francisco Bay, San Yerba Buena Naval Yard	89,700	0.0000%	0.0012%	0.0002%	0	1	0
3.2	1-Jun-95	WICKLAND OIL NET PEN	907,432	0.0000%	0.0012%	0.0002%	0	11	2
3.2	1-Jul-94	WICKLAND OIL NET PEN	0	0.0000%	0.0009%	0.0002%	0	0	0
3.2	1-Jul-95	WICKLAND OIL NET PEN	1,544,975	0.0000%	0.0013%	0.0002%	0	19	3
1	1-Jan-96	FEATHER RIVER	156,000				0	0	0
1	1-Jan-96	Honcut Creek	101,401				0	0	0
1	1-Mar-96	Bear Creek	200,830				0	0	0
1	1-Mar-96	Dry Creek	96,600				0	0	0
1	1-Mar-96	FEATHER RIVER	652,000				0	0	0
1	1-May-96	FEATHER RIVER	25,000				0	0	0
2	1-Apr-96	San Joaquin River	5,000				0	0	0
2	1-Apr-96	Turner Cut	49,998				0	0	0
2	1-Apr-96	Vorden Rd	50,004				0	0	0
2	1-May-96	Turner Cut	25,024				0	0	0
2	1-May-96	Vorden Rd	150,011				0	0	0
2	1-Jun-96	Grimes	50,016				0	0	0
3.2	1-Apr-96	BENICIA	556,400	0.0000%	0.0006%	0.0000%	0	3	0
3.2	1-Apr-96	Bennett's Marina	0	0.0000%	0.0005%	0.0000%	0	0	0
3.2	1-Apr-96	WICKLAND OIL NET PEN	388,700	0.0000%	0.0006%	0.0000%	0	2	0

Feather River Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.2	1-May-96	BENICIA	545,100	0.0000%	0.0006%	0.0000%	0	3	0
3.2	1-May-96	Bennett's Marina	0	0.0000%	0.0005%	0.0000%	0	0	0
3.2	1-May-96	Montezuma Slough	74,975	0.0000%	0.0006%	0.0000%	0	0	0
3.2	1-May-96	San Francisco Bay, San Yerba Buena Naval Yard	126,500	0.0000%	0.0006%	0.0000%	0	1	0
3.2	1-May-96	WICKLAND OIL NET PEN	527,850	0.0000%	0.0006%	0.0000%	0	3	0
3.2	1-Jun-96	BENICIA	0	0.0000%	0.0005%	0.0000%	0	0	0
3.2	1-Jun-96	TIBURON NET PENS	49,400	0.0000%	0.0005%	0.0000%	0	0	0
3.2	1-Jun-96	WICKLAND OIL NET PEN	203,200	0.0000%	0.0006%	0.0000%	0	1	0
3.2	1-Jul-96	San Francisco Bay, San Yerba Buena Naval Yard	73,364	0.0000%	0.0006%	0.0000%	0	0	0
3.2	1-Jul-96	WICKLAND OIL NET PEN	2,762,684	0.0000%	0.0006%	0.0000%	0	18	0
1	1-Mar-97	Dry Creek	100,037				0	0	0
3.2	1-May-97	BENICIA	25,200	0.0000%	0.0028%	0.0000%	0	1	0
3.2	1-May-97	TIBURON NET PENS	52,650	0.0000%	0.0030%	0.0000%	0	2	0
3.2	1-May-97	WICKLAND OIL NET PEN	36,830	0.0000%	0.0034%	0.0000%	0	1	0
3.2	1-Jun-97	BENICIA	252,500	0.0000%	0.0030%	0.0000%	0	8	0
3.2	1-Jun-97	Bennett's Marina	155,900	0.0000%	0.0030%	0.0000%	0	5	0
3.2	1-Jun-97	WICKLAND OIL NET PEN	787,300	0.0000%	0.0028%	0.0000%	0	22	0
3.2	1-Jul-97	Bennett's Marina	296,600	0.0000%	0.0028%	0.0000%	0	8	0
3.2	1-Jul-97	WICKLAND OIL NET PEN	3,177,450	0.0000%	0.0030%	0.0000%	0	94	0
1	1-Mar-98	Dry Creek	100,800				0	0	0
1	1-Mar-98	Honcut Creek	200,500				0	0	0
3.2	1-Mar-98	BENICIA	0				0	0	0
3.2	1-Mar-98	WICKLAND OIL NET PEN	0				0	0	0
3.2	1-May-98	WICKLAND OIL NET PEN	2,392,200	0.0000%	0.0009%	0.0000%	0	22	0
3.2	1-Jun-98	WICKLAND OIL NET PEN	1,243,900	0.0000%	0.0009%	0.0000%	0	12	0
1	1-Feb-99	Dry Creek	99,200				0	0	0

Feather River Fish Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
1	1-Feb-99	Honcut Creek	216,000				0	0	0
1	1-Mar-99	Bear River	199,800				0	0	0
3.2	1-May-99	SF-San Francisco Bay	791,670	0.0030%	0.0032%	0.0000%	24	26	0
3.2	1-Jun-99	BENICIA	0	0.0030%	0.0026%	0.0000%	0	0	0
3.2	1-Jun-99	SF-San Francisco Bay	4,933,865	0.0030%	0.0033%	0.0000%	149	164	0
1	1-Jan-00	Dry Creek	100,100	0.0030%	0.0007%	0.0000%	3	1	0
1	1-Jan-00	Honcut Creek	200,201				0	0	0
1	1-Mar-00	Bear River	199,876				0	0	0
3.2	1-Apr-00	BENICIA	0				0	0	0
3.2	1-May-00	BENICIA	0	0.0000%	0.0007%	0.0000%	0	0	0
3.2	1-May-00	SF-San Francisco Bay	3,409,040	0.0000%	0.0009%	0.0000%	0	31	0
3.2	1-Jun-00	BENICIA	486,100	0.0000%	0.0009%	0.0000%	0	4	0
3.2	1-Jun-00	SF-San Francisco Bay	1,541,150	0.0000%	0.0010%	0.0000%	0	15	0
3.2	1-Apr-01	SAN PABLO BAY	568,100	0.0136%	0.0031%	0.0019%	78	18	11
3.2	1-May-01	BENICIA	1,706,850	0.0136%	0.0032%	0.0019%	233	54	32
3.2	1-Jun-01	BENICIA	487,600	0.0136%	0.0032%	0.0019%	67	16	9
2	1-Apr-02	River mile 206 (GCID)	14,402				0	0	0
2	1-May-02	River mile 206 (GCID)	16,293				0	0	0
2	1-Jun-02	River mile 206 (GCID)	13,300				0	0	0
3.2	1-Mar-02	BENICIA	162,800				0	0	0
3.2	1-Apr-02	BENICIA	2,773,538	0.0024%	0.0020%	0.0007%	66	54	20
3.2	1-May-02	BENICIA	1,401,000	0.0024%	0.0021%	0.0007%	33	29	10
3.2	1-Jun-02	BENICIA	422,050	0.0024%	0.0021%	0.0007%	10	9	3
2	1-Mar-03	River mile 206 (GCID)	8,394	0.0024%	0.0012%	0.0007%	0	0	0
2	1-Apr-03	River mile 206 (GCID)	16,720				0	0	0
2	1-May-03	River mile 206 (GCID)	10,450				0	0	0
3.2	1-May-03	BENICIA	2,343,600	0.0009%	0.0015%	0.0000%	21	35	0

Feather River Fish Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.2	1-May-03	Bennett's Marina	904,000	0.0009%	0.0015%	0.0000%	8	13	0
3.2	1-Jun-03	BENICIA	1,703,160	0.0009%	0.0015%	0.0000%	15	25	0
3.2	1-Jun-03	SF-San Francisco Bay	133,400	0.0009%	0.0015%	0.0000%	1	2	0
1	1-Apr-04	Live Oak boat ramp	0				0	0	0
2	1-Apr-04	River mile 206 (GCID)	4,180				0	0	0
2	1-May-04	River mile 206 (GCID)	16,720				0	0	0
2	1-Jun-04	River mile 206 (GCID)	16,720				0	0	0
3.2	1-Apr-04	BENICIA	0				0	0	0
3.2	1-May-04	BENICIA	4,025,988	0.0000%	0.0015%	0.0000%	0	61	0
3.2	1-Jun-04	BENICIA	3,232,600	0.0000%	0.0018%	0.0000%	0	57	0
2	16-May-05	Sacramento River	53,122	0.0000%	0.0014%	0.0000%	0	1	0
3.2	26-Apr-05	SAN PABLO BAY	105,000				0	0	0
3.2	27-Apr-05	SAN PABLO BAY	127,500				0	0	0
3.2	28-Apr-05	SAN PABLO BAY	114,000				0	0	0
3.2	29-Apr-05	SAN PABLO BAY	72,000				0	0	0
3.2	4-May-05	SAN PABLO BAY	69,000				0	0	0
3.2	5-May-05	SAN PABLO BAY	107,300				0	0	0
3.2	6-May-05	SAN PABLO BAY	107,300				0	0	0
3.2	10-May-05	SAN PABLO BAY	295,400				0	0	0
3.2	11-May-05	SAN PABLO BAY	230,000				0	0	0
3.2	12-May-05	SAN PABLO BAY	230,000				0	0	0
3.2	16-May-05	SAN PABLO BAY	115,200				0	0	0
3.2	18-May-05	SAN PABLO BAY	358,800				0	0	0
3.2	19-May-05	SAN PABLO BAY	57,500				0	0	0
3.2	20-May-05	SAN PABLO BAY	112,700				0	0	0
3.2	23-May-05	SAN PABLO BAY	69,000				0	0	0
3.2	25-May-05	SAN PABLO BAY	239,200				0	0	0

Feather River Fish Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Age 3	Age 4	Escapement Age 2	Age 3	Age 4
3.2	26-May-05	SAN PABLO BAY	335,000				0	0	0
3.2	27-May-05	SAN PABLO BAY	250,700				0	0	0
3.2	3-Jun-05	SAN PABLO BAY	181,700				0	0	0
3.2	6-Jun-05	SAN PABLO BAY	345,000				0	0	0
3.2	7-Jun-05	SAN PABLO BAY	179,400				0	0	0
3.2	8-Jun-05	SAN PABLO BAY	278,300				0	0	0
3.2	9-Jun-05	SAN PABLO BAY	272,976				0	0	0
3.2	10-Jun-05	SAN PABLO BAY	289,800				0	0	0
3.2	13-Jun-05	SAN PABLO BAY	193,200				0	0	0
3.2	14-Jun-05	SAN PABLO BAY	193,200				0	0	0
3.2	15-Jun-05	SAN PABLO BAY	184,000				0	0	0
3.2	16-Jun-05	SAN PABLO BAY	151,800				0	0	0
3.2	17-Jun-05	SAN PABLO BAY	213,900				0	0	0
3.2	20-Jun-05	SAN PABLO BAY	142,600				0	0	0
3.2	21-Jun-05	SAN PABLO BAY	248,400				0	0	0
3.2	22-Jun-05	SAN PABLO BAY	231,992				0	0	0
3.2	23-Jun-05	SAN PABLO BAY	326,600				0	0	0
3.2	24-Jun-05	SAN PABLO BAY	213,900				0	0	0
3.2	27-Jun-05	SAN PABLO BAY	142,600				0	0	0
3.2	28-Jun-05	SAN PABLO BAY	173,600				0	0	0
3.2	29-Jun-05	SAN PABLO BAY	142,600				0	0	0
3.2	10-Apr-06	SAN PABLO BAY	1,909,000				0	0	0
3.2	3-May-06	SAN PABLO BAY	2,852,414				0	0	0
3.2	18-May-06	YERBA BUENA ISLAND	59,000				0	0	0
3.2	1-Jun-06	SAN PABLO BAY	3,871,900				0	0	0
3.2	8-Jun-06	YERBA BUENA ISLAND	57,000				0	0	0

Mokelumne River Fish Installation

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Age 3	Age 4	Escapement Age 2	Age 3	Age 4
1	1-Jan-79	MOKELUMNE RIVER	15,225	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Oct-78	MOKELUMNE RIVER	32,908	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Nov-78	MOKELUMNE RIVER	20,134	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Dec-78	MOKELUMNE RIVER	10,000	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Jan-79	RED BLUFF DIVER. DAM	51,700	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Jan-79	RIO VISTA	75,000	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Nov-78	RED BLUFF DIVER. DAM	47,304	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Nov-78	RIO VISTA	102,076	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Dec-78	RED BLUFF DIVER. DAM	191,800	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Jan-79	NEW HOPE LANDING	108,000	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jul-79	MOKELUMNE R FISH INS	65,406	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Oct-79	RIO VISTA	174,200	0.0000%	0.0648%	0.0000%	0	113	0
2	1-Nov-79	RIO VISTA	19,167	0.0000%	0.0648%	0.0000%	0	12	0
3.1	1-Aug-79	NEW HOPE LANDING	106,568	0.0130%	0.0055%	0.0000%	14	6	0
3.1	1-Sep-79	NEW HOPE LANDING	103,008	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Oct-79	NEW HOPE LANDING	26,315	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Nov-79	NEW HOPE LANDING	245,210	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Nov-80	MOKELUMNE RIVER	50,000	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Oct-80	RIO VISTA	672,750	0.0000%	0.0432%	0.0000%	0	291	0
2	1-Nov-80	RIO VISTA	88,500	0.0000%	0.0432%	0.0000%	0	38	0
2	1-Dec-80	RIO VISTA	40,700	0.0000%	0.0432%	0.0000%	0	18	0
3.1	1-Jun-80	NEW HOPE LANDING	105,050	0.0141%	0.0068%	0.0000%	15	7	0
3.1	1-Jul-80	NEW HOPE LANDING	25,800	0.0171%	0.0074%	0.0000%	4	2	0
3.1	1-Aug-80	NEW HOPE LANDING	90,000	0.0167%	0.0073%	0.0000%	15	7	0
3.1	1-Oct-80	NEW HOPE LANDING	20,000	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Oct-81	RIO VISTA	264,743	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Nov-81	RIO VISTA	586,905	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Dec-81	RIO VISTA	56,200	0.0000%	0.0000%	0.0000%	0	0	0

Mokelumne River Fish Installation

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.1	1-Jun-81	NEW HOPE LANDING	167,034	0.0149%	0.0038%	0.0000%	25	6	0
3.1	1-Nov-81	NEW HOPE LANDING	72,000	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Dec-81	NEW HOPE LANDING	30,030	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Dec-82	MOKELUMNE RIVER	17,600	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Nov-82	RIO VISTA	516,145	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Dec-82	RIO VISTA	40,000	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Nov-82	NEW HOPE LANDING	89,998	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Oct-83	RIO VISTA	705,000	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Nov-83	RIO VISTA	52,640	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-May-83	NEW HOPE LANDING	454,134	0.0195%	0.0038%	0.0000%	88	17	0
3.1	1-Oct-83	NEW HOPE LANDING	10,010	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Jun-84	THORNTON-Moke	15,250	0.0115%	0.0046%	0.0000%	2	1	0
3.1	22-Aug-84	NEW HOPE LANDING	82,350	0.0124%	0.0047%	0.0000%	10	4	0
3.2	13-Aug-84	BENICIA	98,350	0.0189%	0.0430%	0.0149%	19	42	15
3.2	14-Aug-84	BENICIA	105,250	0.0189%	0.0430%	0.0149%	20	45	16
3.2	15-Aug-84	BENICIA	112,400	0.0189%	0.0430%	0.0149%	21	48	17
3.2	16-Aug-84	BENICIA	120,830	0.0189%	0.0430%	0.0149%	23	52	18
3.2	17-Aug-84	BENICIA	122,235	0.0189%	0.0430%	0.0149%	23	53	18
3.2	20-Aug-84	BENICIA	76,250	0.0189%	0.0430%	0.0149%	14	33	11
3.2	21-Aug-84	BENICIA	45,750	0.0189%	0.0430%	0.0149%	9	20	7
1	18-Oct-85	MOKELUMNE R FISH INS	24,200	0.0000%	0.0000%	0.0000%	0	0	0
1	21-Oct-85	MOKELUMNE R FISH INS	48,000	0.0000%	0.0000%	0.0000%	0	0	0
1	23-Oct-85	MOKELUMNE R FISH INS	122,400	0.0000%	0.0000%	0.0000%	0	0	0
2	9-Oct-85	RIO VISTA	27,300	0.0000%	0.0000%	0.0000%	0	0	0
3.2	11-Sep-85	BENICIA	24,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	12-Sep-85	BENICIA	24,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	16-Sep-85	BENICIA	26,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	17-Sep-85	BENICIA	23,100	0.0000%	0.0000%	0.0000%	0	0	0
3.2	18-Sep-85	BENICIA	23,100	0.0000%	0.0000%	0.0000%	0	0	0

Mokelumne River Fish Installation

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.2	19-Sep-85	BENICIA	27,300	0.0000%	0.0000%	0.0000%	0	0	0
3.2	20-Sep-85	BENICIA	13,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	24-Sep-85	BENICIA	13,300	0.0000%	0.0000%	0.0000%	0	0	0
3.2	25-Sep-85	BENICIA	27,930	0.0000%	0.0000%	0.0000%	0	0	0
3.2	26-Sep-85	BENICIA	48,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	27-Sep-85	BENICIA	46,200	0.0000%	0.0000%	0.0000%	0	0	0
3.2	30-Sep-85	BENICIA	33,600	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Oct-85	BENICIA	51,200	0.0000%	0.0000%	0.0000%	0	0	0
3.2	2-Oct-85	BENICIA	100,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	3-Oct-85	BENICIA	103,700	0.0000%	0.0000%	0.0000%	0	0	0
3.2	4-Oct-85	BENICIA	159,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	7-Oct-85	BENICIA	92,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	8-Oct-85	BENICIA	93,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	9-Oct-85	BENICIA	59,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	10-Oct-85	BENICIA	74,100	0.0000%	0.0000%	0.0000%	0	0	0
3.2	11-Oct-85	BENICIA	28,600	0.0000%	0.0000%	0.0000%	0	0	0
3.2	17-Oct-85	BENICIA	24,200	0.0000%	0.0000%	0.0000%	0	0	0
3.2	18-Oct-85	BENICIA	35,200	0.0000%	0.0000%	0.0000%	0	0	0
3.2	21-Oct-85	BENICIA	44,200	0.0000%	0.0000%	0.0000%	0	0	0
3.2	22-Oct-85	BENICIA	42,000	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Aug-86	MOKELUMNE R FISH INS	27,000	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Sep-86	MOKELUMNE R FISH INS	35,200	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Oct-86	MOKELUMNE R FISH INS	36,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	25-Jun-86	BENICIA	50,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	26-Jun-86	BENICIA	56,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	27-Jun-86	BENICIA	66,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-86	BENICIA	1,000,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Aug-86	BENICIA	39,600	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Aug-86	Bennett's Marina	39,600	0.0000%	0.0000%	0.0000%	0	0	0

Mokelumne River Fish Installation

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.2	1-Aug-86	Berkeley Marina	170,100	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Sep-86	BENICIA	191,500	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Sep-86	Bennett's Marina	50,600	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Apr-87	BENICIA	601,665	0.0000%	0.0052%	0.0000%	0	31	0
3.2	1-May-87	BENICIA	398,700	0.0000%	0.0052%	0.0000%	0	21	0
3.2	1-Jun-87	BENICIA	467,950	0.0000%	0.0052%	0.0000%	0	24	0
3.2	1-Jun-87	Bennett's Marina	391,100	0.0000%	0.0052%	0.0000%	0	20	0
3.2	1-Jul-87	BENICIA	135,050	0.0000%	0.0052%	0.0000%	0	7	0
3.2	1-Jul-87	Mare Island	162,956	0.0000%	0.0052%	0.0000%	0	8	0
3.2	1-Aug-87	BENICIA	77,366	0.0000%	0.0052%	0.0000%	0	4	0
3.2	1-Apr-88	Berkeley Marina	524,500	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-88	BENICIA	316,300	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-88	Bennett's Marina	690,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-88	Berkeley Marina	638,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-88	BENICIA	133,300	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Sep-89	MOKELUMNE RIVER	50,400	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-89	NEW HOPE LANDING	418,700	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-89	BENICIA	92,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-89	Bennett's Marina	896,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-89	Bennett's Marina	1,066,900	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-89	Bennett's Marina	476,700	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-89	Berkeley Marina	48,700	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Aug-89	Bennett's Marina	761,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Sep-89	Bennett's Marina	37,200	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Apr-90	MOKELUMNE R FISH INS	20,800	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jun-90	Lodi Lake	4,000	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Mar-90	NEW HOPE LANDING	350,600	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-90	BENICIA	649,825	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-90	Bennett's Marina	517,500	0.0000%	0.0000%	0.0000%	0	0	0

Mokelumne River Fish Installation

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates			Escapement		
				Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.2	1-Jul-90	BENICIA	459,700	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-90	Bennett's Marina	650,500	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Aug-90	Bennett's Marina	488,900	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Mar-92	MOKELUMNE RIVER	6,000	0.0000%	0.0000%	0.0000%	0	0	0
1	1-May-91	Lodi Lake	25,200	0.0000%	0.0010%	0.0000%	0	0	0
1	1-Jun-91	Lodi Lake	13,000	0.0000%	0.0010%	0.0000%	0	0	0
1	1-Oct-91	MOKELUMNE R FISH INS	28,350	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-91	NEW HOPE LANDING	103,950	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-May-91	NEW HOPE LANDING	103,850	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-91	Bennett's Marina	821,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-91	Bennett's Marina	771,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-91	BENICIA	390,600	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Oct-92	MOKELUMNE R FISH INS	131,552	0.0000%	0.0044%	0.0000%	0	6	0
2	1-Apr-92	RIO VISTA	472,840	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-92	Byron	36,050	0.0000%	0.0045%	0.0000%	0	2	0
3.1	1-Apr-92	NEW HOPE LANDING	0	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-May-92	NEW HOPE LANDING	0	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Apr-92	BENICIA	39,000	0.0067%	0.0116%	0.0052%	3	5	2
3.2	1-May-92	BENICIA	967,537	0.0067%	0.0116%	0.0052%	65	113	50
3.2	1-Jun-92	BENICIA	1,091,873	0.0067%	0.0116%	0.0052%	73	127	57
3.2	1-Jul-92	BENICIA	1,164,100	0.0067%	0.0116%	0.0052%	78	135	61
3.2	1-Aug-92	BENICIA	213,800	0.0067%	0.0116%	0.0052%	14	25	11
1	1-Mar-93	MOKELUMNE RIVER	1,200	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Apr-93	MOKELUMNE RIVER	5,440	0.0000%	0.0000%	0.0000%	0	0	0
1	1-May-93	MOKELUMNE RIVER	0	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jun-93	Woodbridge Dam	10,010	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-93	Byron	15,000	0.0123%	0.0028%	0.0005%	2	0	0
3.1	1-Oct-93	NEW HOPE LANDING	313,720	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-93	BENICIA	437,500	0.0092%	0.0204%	0.0083%	40	89	36

Mokelumne River Fish Installation

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
3.2	1-Jun-93	BENICIA	1,547,500	0.0092%	0.0204%	0.0083%	143	315	128
3.2	1-Jul-93	BENICIA	1,026,600	0.0092%	0.0204%	0.0083%	95	209	85
2	1-Jun-94	Sacramento River	514,350	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-May-94	NEW HOPE LANDING	149,820	0.0124%	0.0025%	0.0010%	19	4	1
3.1	1-Jun-94	NEW HOPE LANDING	5,167	0.0142%	0.0026%	0.0010%	1	0	0
3.2	1-May-94	BENICIA	136,800	0.0160%	0.0246%	0.0129%	22	34	18
3.2	1-Jun-94	BENICIA	1,107,570	0.0160%	0.0246%	0.0129%	177	272	143
1	1-Sep-95	MOKELUMNE RIVER	275,110	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Oct-95	MOKELUMNE RIVER	152,005	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Feb-96	MOKELUMNE RIVER	3,165	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Mar-96	MOKELUMNE RIVER	3,394	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Apr-96	MOKELUMNE RIVER	590,956	0.0000%	0.0000%	0.0000%	0	0	0
1	1-May-96	MOKELUMNE RIVER	1,014	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Oct-96	Woodbridge Dam	177,060	0.0135%	0.0000%	0.0000%	24	0	0
3.1	1-Jun-96	NEW HOPE LANDING	774,046	0.0049%	0.0069%	0.0000%	38	53	0
3.2	1-May-96	BENICIA	770,800	0.0044%	0.0131%	0.0046%	34	101	35
3.2	1-Jun-96	BENICIA	744,865	0.0044%	0.0131%	0.0046%	33	97	34
1	1-Feb-97	Woodbridge Dam	8,956	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Mar-97	Woodbridge Dam	2,280	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Sep-97	Woodbridge Dam	39,240	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Oct-97	Woodbridge Dam	295,936	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-97	NEW HOPE LANDING	104,258	0.0000%	0.0066%	0.0000%	0	7	0
3.1	1-May-97	NEW HOPE LANDING	80,000	0.0000%	0.0065%	0.0000%	0	5	0
3.1	1-Jun-97	NEW HOPE LANDING	943,878	0.0000%	0.0071%	0.0000%	0	67	0
3.2	1-Apr-97	San Pablo	98,883	0.0000%	0.0328%	0.0180%	0	32	18
3.2	1-May-97	BENICIA	636,000	0.0000%	0.0328%	0.0180%	0	209	114
3.2	1-Jun-97	BENICIA	807,765	0.0000%	0.0328%	0.0180%	0	265	145
3.2	1-Jul-97	Bennett's Marina	140,000	0.0000%	0.0328%	0.0180%	0	46	25
3.2	1-Jul-97	WICKLAND OIL NET PEN	58,800	0.0000%	0.0328%	0.0180%	0	19	11

Mokelumne River Fish Installation

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	1-Feb-98	Woodbridge Dam	6,938	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Mar-98	Woodbridge Dam	5,525	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Apr-98	Woodbridge Dam	2,146	0.0000%	0.0000%	0.0000%	0	0	0
1	1-May-98	Woodbridge Dam	1,724,300	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jun-98	Woodbridge Dam	3,846	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jul-98	Woodbridge Dam	1,878	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Oct-98	Woodbridge Dam	71,000	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Nov-98	Woodbridge Dam	233,100	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-98	NEW HOPE LANDING	108,000	0.0058%	0.0088%	0.0000%	6	10	0
3.1	1-May-98	NEW HOPE LANDING	1,039	0.0048%	0.0082%	0.0000%	0	0	0
3.2	1-Jun-98	WICKLAND OIL NET PEN	1,271,400	0.0071%	0.0192%	0.0074%	90	243	94
3.2	1-Jul-98	WICKLAND OIL NET PEN	596,900	0.0071%	0.0192%	0.0074%	42	114	44
3.2	1-Aug-98	WICKLAND OIL NET PEN	144,900	0.0071%	0.0192%	0.0074%	10	28	11
3.2	1-Apr-98	JERSEY PT,SAN JOAQ.R	105,450	0.0138%	0.0190%	0.0070%	15	20	7
1	1-Jan-99	Woodbridge Dam	2,671	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Feb-99	Woodbridge Dam	2,172	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Mar-99	Woodbridge Dam	1,635	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Apr-99	Woodbridge Dam	1,635	0.0000%	0.0000%	0.0000%	0	0	0
1	1-May-99	Woodbridge Dam	4,024	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jun-99	Woodbridge Dam	840	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jul-99	Woodbridge Dam	1,755	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-May-99	NEW HOPE LANDING	1,208,802	0.0099%	0.0091%	0.0000%	119	110	0
3.2	1-Jun-99	WICKLAND OIL NET PEN	738,407	0.0671%	0.1615%	0.0575%	495	1,193	425
3.2	1-Jul-99	WICKLAND OIL NET PEN	440,200	0.0671%	0.1615%	0.0575%	295	711	253
3.2	1-Sep-99	Antioch Boat Ramp	9,600	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Oct-99	Antioch Boat Ramp	206,620	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Oct-99	WICKLAND OIL NET PEN	297,600	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-99	JERSEY PT,SAN JOAQ.R	100,966	0.0835%	0.1505%	0.0505%	84	152	51
1	1-Jan-00	Woodbridge Dam	2,808	0.0000%	0.0000%	0.0000%	0	0	0

Mokelumne River Fish Installation

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
1	1-Mar-00	Woodbridge Dam	7,106	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Apr-00	Woodbridge Dam	992	0.0000%	0.0000%	0.0000%	0	0	0
1	1-May-00	Woodbridge Dam	828	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jun-00	Woodbridge Dam	2,400	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jul-00	Woodbridge Dam	1,958	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-00	LIGHTHOUSE MARINA	0	0.0111%	0.0332%	0.0000%	0	0	0
3.1	1-Apr-00	NEW HOPE LANDING	501,668	0.0111%	0.0332%	0.0000%	56	167	0
3.1	1-May-00	NEW HOPE LANDING	522,700	0.0113%	0.0334%	0.0000%	59	175	0
3.1	1-Jul-00	NEW HOPE LANDING	447,892	0.0141%	0.0366%	0.0000%	63	164	0
3.1	1-Sep-00	NEW HOPE LANDING	391,779	0.0227%	0.0312%	0.0059%	89	122	23
3.2	1-Apr-00	BENICIA	181,800		0.0178%	0.0048%	0	32	9
3.2	1-Apr-00	Bennett's Marina	185,300		0.0178%	0.0048%	0	33	9
3.2	1-Apr-00	WICKLAND OIL NET PEN	463,700		0.0178%	0.0048%	0	83	22
3.2	1-May-00	WICKLAND OIL NET PEN	698,450		0.0178%	0.0048%	0	124	34
3.2	1-Jun-00	WICKLAND OIL NET PEN	642,925		0.0178%	0.0048%	0	115	31
3.2	1-May-00	JERSEY PT,SAN JOAQ.R	0		0.0178%	0.0047%	0	0	0
1	1-Jan-01	Woodbridge Dam	818	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Feb-01	Jahant Road	368,246	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Mar-01	Jahant Road	307,020	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Mar-01	Woodbridge Dam	2,062	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Apr-01	MOKELUMNE RIVER	0	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Apr-01	Woodbridge Dam	2,940	0.0000%	0.0000%	0.0000%	0	0	0
1	1-May-01	Jahant Road	238,100	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Apr-01	Yolo Co Park	0	0.0167%	0.0084%	0.0007%	0	0	0
2	1-May-01	Yolo Co Park	0	0.0167%	0.0084%	0.0007%	0	0	0
3.1	1-Jan-01	NEW HOPE LANDING	1,822,530	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Feb-01	NEW HOPE LANDING	1,002,333	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Mar-01	NEW HOPE LANDING	370,974	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-01	NEW HOPE LANDING	602,075	0.0110%	0.0032%	0.0000%	66	19	0

Mokelumne River Fish Installation

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.1	1-May-01	NEW HOPE LANDING	551,000	0.0106%	0.0032%	0.0000%	58	17	0
3.2	1-Apr-01	BENICIA	0	0.0000%	0.0250%	0.0218%	0	0	0
3.2	1-Apr-01	SAN PABLO BAY	1,464,200	0.0000%	0.0250%	0.0218%	0	366	320
3.2	1-May-01	SAN PABLO BAY	1,398,452	0.0000%	0.0250%	0.0218%	0	349	305
3.2	1-Apr-01	JERSEY PT,SAN JOAQ.R	0	0.0000%	0.0250%	0.0218%	0	0	0
1	1-Feb-02	Woodbridge Dam	1,828,878	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jun-02	Woodbridge Dam	2,290	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Oct-02	BEAN FARM	0	0.0000%	0.0005%	0.0000%	0	0	0
3.1	1-Feb-02	M&T NF	47,000	0.0000%	0.0000%	0.0000%	0	0	0
3.1	4-Apr-00	NF MR	0	0.0000%	0.0753%	0.0000%	0	0	0
3.1	18-Apr-02	NEW HOPE LANDING	276,132	0.0000%	0.0753%	0.0000%	0	208	0
3.1	1-May-02	NEW HOPE LANDING	39,561	0.0000%	0.0753%	0.0000%	0	30	0
3.1	1-Jul-02	NEW HOPE LANDING	49,590	0.0000%	0.0753%	0.0000%	0	37	0
3.1	1-Oct-02	North Mokelumne	0	0.0000%	0.0100%	0.0007%	0	0	0
3.1	1-Oct-02	South Mokelumne	0	0.0000%	0.0100%	0.0007%	0	0	0
3.2	1-Feb-02	SAN PABLO BAY	1,160,079	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-02	SAN PABLO BAY	1,980,300	0.0156%	0.0307%	0.0000%	310	608	0
3.2	9-Apr-02	JERSEY PT,SAN JOAQ.R	0	0.0344%	0.0312%	0.0000%	0	0	0
3.2	1-Oct-02	JERSEY PT,SAN JOAQ.R	0	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jan-03	Woodbridge Dam	10,799	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Apr-03	MOKELUMNE R FISH INS	0	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jun-03	Lodi Lake	850	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jul-03	Woodbridge Dam	795	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-03	NEW HOPE LANDING	4,646,988	0.0000%	0.0098%	0.0000%	0	456	0
3.2	1-Apr-03	Conoco Phillips	2,175,025	0.0000%	0.0120%	0.0044%	0	261	96
3.2	1-May-03	Antioch Boat Ramp	575	0.0000%	0.0120%	0.0044%	0	0	0
3.2	1-May-03	TIBURON NET PENS	50,600	0.0000%	0.0120%	0.0044%	0	6	2
1	1-Apr-04	Woodbridge Dam	3,175	0.0000%	0.0000%	0.0000%	0	0	0
1	1-May-04	MOKELUMNE R FISH INS	0	0.0000%	0.0000%	0.0000%	0	0	0

Mokelumne River Fish Installation

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	1-Jun-04	Lodi Lake	989	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Apr-04	THORNTON-Moke	1,013,700	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-May-04	THORNTON-Moke	2,389,877	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-Jun-04	THORNTON-Moke	210,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-04	BENICIA	1,792,400	0.0070%	0.0249%	0.0055%	125	447	98
3.2	1-May-04	TIBURON NET PENS	51,700	0.0070%	0.0249%	0.0055%	4	13	3
3.2	1-Jun-04	BENICIA	216,800	0.0070%	0.0249%	0.0055%	15	54	12
1	1-Feb-05	Woodbridge Dam	1,457	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Mar-05	Woodbridge Dam	1,016	0.0000%	0.0000%	0.0000%	0	0	0
1	5-Apr-05	Woodbridge Dam	1,057	0.0000%	0.0000%	0.0000%	0	0	0
1	1-May-05	MERCED R FISH FACIL.	0	0.0000%	0.0000%	0.0000%	0	0	0
3.1	5-Apr-05	THORNTON-Moke	242,350	0.0000%	0.0000%	0.0000%	0	0	0
3.1	1-May-05	THORNTON-Moke	2,009,715	0.0000%	0.0000%	0.0000%	0	0	0
3.1	27-Jun-05	THORNTON-Moke	1,642,960	0.0000%	0.0000%	0.0000%	0	0	0
3.2	5-Apr-05	SAN PABLO BAY	296,400	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-05	SAN PABLO BAY	1,275,680	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-May-05	TIBURON NET PENS	51,300	0.0000%	0.0000%	0.0000%	0	0	0
3.2	27-Jun-05	SAN PABLO BAY	432,000	0.0000%	0.0000%	0.0000%	0	0	0
1	24-Jan-06	MOKELUMNE RIVER	2,116				0	0	0
1	10-Feb-06	MOKELUMNE RIVER	2,010				0	0	0
1	4-Apr-06	MOKELUMNE RIVER	2,040				0	0	0
1	14-Apr-06	MOKELUMNE RIVER	4,095				0	0	0
1	18-Apr-06	MOKELUMNE RIVER	302,400				0	0	0
1	20-Apr-06	MOKELUMNE RIVER	106,200				0	0	0
1	21-Apr-06	MOKELUMNE RIVER	417,600				0	0	0
1	1-May-06	MOKELUMNE RIVER	108,884				0	0	0
1	5-May-06	MOKELUMNE RIVER	102,872				0	0	0
1	10-May-06	MOKELUMNE RIVER	636,600				0	0	0
1	11-May-06	MOKELUMNE RIVER	344,200				0	0	0

Mokelumne River Fish Installation

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	12-May-06	MOKELUMNE RIVER	528,000				0	0	0
1	23-May-06	MOKELUMNE RIVER	230,100				0	0	0
1	24-May-06	MOKELUMNE RIVER	312,700				0	0	0
1	30-May-06	MOKELUMNE RIVER	354,000				0	0	0
1	5-Jun-06	MOKELUMNE RIVER	62,045				0	0	0
1	6-Jun-06	MOKELUMNE RIVER	291,600				0	0	0
1	7-Jun-06	MOKELUMNE RIVER	216,000				0	0	0
1	12-Jun-06	MOKELUMNE RIVER	102,200				0	0	0
3.2	24-Apr-06	SAN PABLO BAY	125,400				0	0	0
3.2	25-Apr-06	SAN PABLO BAY	128,625				0	0	0
3.2	2-May-06	SAN PABLO BAY	222,250				0	0	0
3.2	3-May-06	SAN PABLO BAY	236,250				0	0	0
3.2	4-May-06	SAN PABLO BAY	98,000				0	0	0
3.2	5-May-06	SAN PABLO BAY	227,500				0	0	0
3.2	8-May-06	SAN PABLO BAY	174,000				0	0	0
3.2	9-May-06	SAN PABLO BAY	239,750				0	0	0
3.2	18-May-06	San Francisco Bay	49,500				0	0	0
3.2	1-Jun-06	SAN PABLO BAY	282,300				0	0	0
3.2	2-Jun-06	SAN PABLO BAY	269,500				0	0	0
3.2	8-Jun-06	San Francisco Bay	42,000				0	0	0
3.2	10-Jun-06	San Francisco Bay	51,450				0	0	0

Merced River Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	21-Jun-78	MERCED R FISH FACIL.	100,000	0.0000%	0.0050%	0.0022%	0	5	2
1	29-Sep-78	MERCED R FISH FACIL.	195,000	0.0000%	0.5399%	0.0571%	0	1,053	111
1	17-Oct-84	MERCED R FISH FACIL.	73,600	0.3878%	1.8231%	0.0439%	285	1,342	32
1	14-Oct-85	MERCED R FISH FACIL.	63,000	0.4204%	0.1867%	0.0316%	265	118	20
1	8-Mar-86	MERCED R FISH FACIL.	15,876	0.0000%	0.0000%	0.0000%	0	0	0
1	14-Mar-86	MERCED R FISH FACIL.	20,448	0.0000%	0.0000%	0.0000%	0	0	0
1	18-Mar-86	MERCED R FISH FACIL.	88,830	0.0000%	0.0000%	0.0000%	0	0	0
1	20-Mar-86	MERCED R FISH FACIL.	38,762	0.0000%	0.0000%	0.0000%	0	0	0
1	26-Mar-86	MERCED R FISH FACIL.	14,544	0.0000%	0.0000%	0.0000%	0	0	0
1	3-Apr-86	MERCED R FISH FACIL.	49,298	0.0075%	0.0811%	0.0385%	4	40	19
1	8-Apr-86	MERCED R FISH FACIL.	12,760	0.0084%	0.0908%	0.0431%	1	12	5
1	30-May-86	MERCED R FISH FACIL.	351,250	0.0018%	0.0193%	0.0092%	6	68	32
1	18-Jun-86	MERCED R FISH FACIL.	24,960	0.0010%	0.0103%	0.0049%	0	3	1
1	19-Oct-87	MERCED R FISH FACIL.	254,842	0.0000%	0.0000%	0.0000%	0	0	0
2	29-Apr-87	SJR at Mile 82	1,632	0.0000%	0.0000%	0.0000%	0	0	0
2	30-Apr-87	SJR at Mile 82	1,860	0.0000%	0.0000%	0.0000%	0	0	0
2	1-May-87	SAN JOAQ.R,BELOW OLD	3,130	0.0000%	0.0000%	0.0000%	0	0	0
2	14-May-87	SAN JOAQ.R,ABOVE OLD	4,548	0.0000%	0.0000%	0.0000%	0	0	0
1	17-Mar-88	Stanislaus River, American Trails Cmp.	206,370	0.0000%	0.0000%	0.0000%	0	0	0
1	18-Apr-88	MERCED FISH FACIL.	3,200	0.0000%	0.0000%	0.0000%	0	0	0
1	17-Oct-88	Fisherman Bend Merced R.	39,510	0.0000%	0.0000%	0.0000%	0	0	0
1	18-Oct-88	Fisherman Bend Merced R.	42,105	0.0000%	0.0000%	0.0000%	0	0	0
1	19-Oct-88	Fisherman Bend Merced R.	40,450	0.0000%	0.0000%	0.0000%	0	0	0
1	20-Oct-88	Fisherman Bend Merced R.	20,445	0.0000%	0.0000%	0.0000%	0	0	0
1	24-Oct-88	MERCED R FISH FACIL.	1,000	0.0000%	0.0000%	0.0000%	0	0	0
2	10-Mar-88	USFWS Los Banos	1,082	0.0000%	0.0000%	0.0000%	0	0	0
2	23-Mar-88	USFWS Los Banos	800	0.0000%	0.0000%	0.0000%	0	0	0

Merced River Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates			Escapement		
				Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	6-Oct-89	MERCED R FISH FACIL.	96,334	0.0000%	0.0000%	0.0000%	0	0	0
1	7-Oct-89	MERCED R FISH FACIL.	82,848	0.0000%	0.0000%	0.0000%	0	0	0
2	20-Apr-89	Dos Rios Ranch	9,996	0.0306%	0.0009%	0.0029%	3	0	0
2	2-May-89	MOSSDALE	1,300	0.0310%	0.0009%	0.0029%	0	0	0
2	4-May-89	MOSSDALE	2,550	0.0307%	0.0009%	0.0029%	1	0	0
3.2	5-Jun-89	Berkeley Marina	183,600	0.0000%	0.0000%	0.0000%	0	0	0
3.2	6-Jun-89	Berkeley Marina	240,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	7-Jun-89	Berkeley Marina	245,700	0.0000%	0.0000%	0.0000%	0	0	0
3.2	8-Jun-89	Berkeley Marina	198,400	0.0000%	0.0000%	0.0000%	0	0	0
2	11-May-90	MOSSDALE	1,104	0.0000%	0.0000%	0.0000%	0	0	0
2	18-May-90	MOSSDALE	1,056	0.0000%	0.0000%	0.0000%	0	0	0
1	21-Oct-91	Merced River	104,822	0.0000%	0.0000%	0.0000%	0	0	0
1	4-Mar-92	Fisherman Bend	34,648	0.0000%	0.0000%	0.0000%	0	0	0
2	13-May-92	MOSSDALE	1,188	0.0000%	0.0000%	0.0000%	0	0	0
2	14-May-92	MOSSDALE	2,282	0.0000%	0.0000%	0.0000%	0	0	0
2	22-Apr-93	MOSSDALE	1,120	0.0416%	0.0249%	0.0052%	0	0	0
2	29-Apr-93	MOSSDALE	2,120	0.0447%	0.0261%	0.0053%	1	1	0
2	6-May-93	MOSSDALE	2,120	0.0442%	0.0259%	0.0053%	1	1	0
2	13-May-93	MOSSDALE	4,120	0.0415%	0.0248%	0.0052%	2	1	0
2	13-May-93	San Joaquin River	23,200	0.0415%	0.0248%	0.0052%	10	6	1
2	20-May-93	San Joaquin River	4,150	0.0402%	0.0243%	0.0051%	2	1	0
2	27-Apr-94	MOSSDALE	2,005	0.0658%	0.0321%	0.0054%	1	1	0
2	4-May-94	MOSSDALE	2,013	0.0633%	0.0313%	0.0053%	1	1	0
2	10-May-94	MOSSDALE	2,023	0.0633%	0.0313%	0.0053%	1	1	0
2	17-May-94	MOSSDALE	2,042	0.0629%	0.0312%	0.0053%	1	1	0
1	14-Apr-95	Shaffer Bridge	2,430	0.1602%	0.1675%	0.0457%	4	4	1
1	21-Apr-95	Hwy 120	1,008	0.1308%	0.1367%	0.0373%	1	1	0
1	28-Apr-95	MOKELUMNE RIVER	0	0.2302%	0.2407%	0.0658%	0	0	0
1	1-May-95	Orange Blossom Bridge	1,001	0.3007%	0.3146%	0.0860%	3	3	1

Merced River Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	2-May-95	MERCED R FISH FACIL.	138,000	0.3027%	0.3166%	0.0865%	418	437	119
1	3-May-95	Hagaman Park	1,000	0.2986%	0.3124%	0.0854%	3	3	1
1	3-May-95	MERCED R FISH FACIL.	74,800	0.2986%	0.3124%	0.0854%	223	234	64
1	5-May-95	MOKELUMNE RIVER	0	0.2799%	0.2928%	0.0800%	0	0	0
1	10-May-95	MERCED R FISH FACIL.	276,450	0.2186%	0.2286%	0.0624%	604	632	173
1	12-May-95	Hwy 120	199	0.2156%	0.2255%	0.0616%	0	0	0
1	12-May-95	Orange Blossom Bridge	1,003	0.2156%	0.2255%	0.0616%	2	2	1
1	15-May-95	MOKELUMNE RIVER	0	0.2122%	0.2219%	0.0606%	0	0	0
1	19-May-95	Hwy 120	210	0.2009%	0.2101%	0.0574%	0	0	0
1	19-May-95	Orange Blossom Bridge	1,018	0.2009%	0.2101%	0.0574%	2	2	1
1	26-May-95	Orange Blossom Bridge	1,015	0.2023%	0.2116%	0.0578%	2	2	1
1	14-Jun-95	Hwy 120	210	0.2269%	0.2373%	0.0648%	0	0	0
1	14-Jun-95	Orange Blossom Bridge	4,046	0.2269%	0.2373%	0.0648%	9	10	3
2	11-May-95	MOSSDALE	2,052	0.1515%	0.0109%	0.0084%	3	0	0
2	18-May-95	MOSSDALE	2,014	0.1555%	0.0111%	0.0085%	3	0	0
2	25-May-95	MOSSDALE	2,024	0.1533%	0.0110%	0.0084%	3	0	0
2	31-May-95	MOSSDALE	2,037	0.1366%	0.0102%	0.0080%	3	0	0
2	29-Jun-95	DOS REIS ROAD	8,400	0.0590%	0.0058%	0.0054%	5	0	0
2	30-Jun-95	DOS REIS ROAD	4,589	0.0601%	0.0059%	0.0054%	3	0	0
1	10-Jun-96	Knights Ferry	20,162	0.0135%	0.0581%	0.0048%	3	12	1
2	19-Apr-96	MOSSDALE	4,984	0.0220%	0.0570%	0.0051%	1	3	0
2	3-May-96	MOSSDALE	2,603	0.0212%	0.0555%	0.0050%	1	1	0
2	8-May-96	MOSSDALE	2,597	0.0214%	0.0559%	0.0050%	1	1	0
2	15-May-96	MOSSDALE	2,549	0.0251%	0.0622%	0.0054%	1	2	0
2	23-May-96	MOSSDALE	2,553	0.0277%	0.0664%	0.0056%	1	2	0
2	29-May-96	MOSSDALE	2,553	0.0217%	0.0563%	0.0050%	1	1	0
2	5-Jun-96	MOSSDALE	2,428	0.0186%	0.0508%	0.0047%	0	1	0
2	24-Apr-97	MOSSDALE	2,594	0.1292%	0.1108%	0.0104%	3	3	0
2	1-May-97	MOSSDALE	2,564	0.1267%	0.1094%	0.0103%	3	3	0

Merced River Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates			Escapement		
				Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
2	10-May-97	MOSSDALE	3,503	0.1259%	0.1089%	0.0103%	4	4	0
2	16-May-97	MOSSDALE	3,237	0.1143%	0.1021%	0.0098%	4	3	0
2	22-May-97	MOSSDALE	4,080	0.1111%	0.1002%	0.0097%	5	4	0
2	29-May-97	MOSSDALE	4,043	0.1093%	0.0991%	0.0096%	4	4	0
2	4-Jun-97	MOSSDALE	4,065	0.1079%	0.0982%	0.0096%	4	4	0
2	24-Jun-97	DOS REIS ROAD	32,000	0.1028%	0.0951%	0.0093%	33	30	3
1	1-Apr-98	Hagaman Park	1,500	0.0775%	0.4633%	0.0362%	1	7	1
1	6-Apr-98	Hagaman Park	2,010	0.0812%	0.4853%	0.0379%	2	10	1
1	13-Apr-98	Hagaman Park	2,000	0.0822%	0.4912%	0.0384%	2	10	1
1	20-Apr-98	Hagaman Park	2,000	0.0747%	0.4462%	0.0348%	1	9	1
1	27-Apr-98	Hagaman Park	2,008	0.0657%	0.3928%	0.0307%	1	8	1
1	4-May-98	Hagaman Park	2,000	0.0626%	0.3743%	0.0292%	1	7	1
1	12-May-98	Hagaman Park	2,001	0.0812%	0.4848%	0.0379%	2	10	1
1	13-May-98	MERCED R FISH FACIL.	113,500	0.0828%	0.4943%	0.0386%	94	561	44
1	18-May-98	MERCED R FISH FACIL.	113,450	0.0752%	0.4493%	0.0351%	85	510	40
1	19-May-98	Hagaman Park	3,007	0.0714%	0.4270%	0.0333%	2	13	1
1	27-May-98	Hagaman Park	3,000	0.0577%	0.3453%	0.0269%	2	10	1
1	27-May-98	MERCED R FISH FACIL.	60,546	0.0577%	0.3453%	0.0269%	35	209	16
1	29-May-98	MERCED R FISH FACIL.	107,900	0.0566%	0.3386%	0.0264%	61	365	28
1	31-May-98	MERCED R FISH FACIL.	84,945	0.0549%	0.3285%	0.0256%	47	279	22
1	3-Jun-98	Hagaman Park	3,004	0.0540%	0.3227%	0.0252%	2	10	1
1	8-Jun-98	Hagaman Park	2,000	0.0555%	0.3320%	0.0259%	1	7	1
1	17-Jun-98	Hagaman Park	3,037	0.0644%	0.3848%	0.0300%	2	12	1
1	24-Jun-98	MERCED R FISH FACIL.	24,480	0.0464%	0.2776%	0.0216%	11	68	5
1	25-Jun-98	Hagaman Park	0	0.0428%	0.2560%	0.0199%	0	0	0
2	9-Apr-98	MOSSDALE	500	0.0968%	0.1554%	0.0098%	0	1	0
2	9-Apr-98	Mossdale	3,000	0.0968%	0.1554%	0.0098%	3	5	0
2	21-Apr-98	MOSSDALE	500	0.0821%	0.1391%	0.0091%	0	1	0
2	23-Apr-98	MOSSDALE	6,582	0.0776%	0.1340%	0.0089%	5	9	1

Merced River Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates			Escapement		
				Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
2	30-Apr-98	MOSSDALE	6,030	0.0687%	0.1235%	0.0084%	4	7	1
2	5-May-98	MOSSDALE	1,537	0.0648%	0.1188%	0.0081%	1	2	0
2	7-May-98	MOSSDALE	6,515	0.0655%	0.1196%	0.0082%	4	8	1
2	14-May-98	MOSSDALE	5,010	0.0724%	0.1280%	0.0086%	4	6	0
2	21-May-98	MOSSDALE	5,011	0.0758%	0.1320%	0.0088%	4	7	0
2	29-May-98	MOSSDALE	5,923	0.0719%	0.1273%	0.0086%	4	8	1
2	3-Jun-98	MOSSDALE	300	0.0668%	0.1213%	0.0083%	0	0	0
2	10-Jun-98	MOSSDALE	5,300	0.0644%	0.1183%	0.0081%	3	6	0
2	11-Jun-98	MOSSDALE	4,816	0.0652%	0.1193%	0.0082%	3	6	0
1	4-Mar-99	Hagaman Park	1,005	0.0000%	0.0000%	0.0000%	0	0	0
1	17-Mar-99	Hagaman Park	1,501	0.0000%	0.0000%	0.0000%	0	0	0
1	30-Mar-99	Hagaman Park	2,000	0.0000%	0.0000%	0.0000%	0	0	0
1	6-Apr-99	Hagaman Park	2,002	0.0715%	0.0790%	0.0056%	1	2	0
1	13-Apr-99	Hagaman Park	2,007	0.1543%	0.1706%	0.0121%	3	3	0
1	21-Apr-99	Gallo	863	0.2875%	0.3178%	0.0225%	2	3	0
1	21-Apr-99	Hagaman Park	2,000	0.2875%	0.3178%	0.0225%	6	6	0
1	28-Apr-99	Gallo	500	0.1268%	0.1402%	0.0099%	1	1	0
1	6-May-99	Hagaman Park	2,008	0.1576%	0.1742%	0.0123%	3	3	0
1	11-May-99	MERCED R FISH FACIL.	44,500	0.0976%	0.1079%	0.0076%	43	48	3
1	12-May-99	Gallo	300	0.0863%	0.0954%	0.0068%	0	0	0
1	12-May-99	Hagaman Park	2,000	0.0863%	0.0954%	0.0068%	2	2	0
1	17-May-99	Robinson Ranch	5,000	0.0668%	0.0739%	0.0052%	3	4	0
1	18-May-99	Gallo	1,001	0.0662%	0.0733%	0.0052%	1	1	0
1		Hagaman Park	2,012	0.0662%	0.0733%	0.0052%	1	1	0
1	19-May-99	Gallo	531	0.0659%	0.0729%	0.0052%	0	0	0
1	21-May-99	Gallo	20,880	0.0657%	0.0726%	0.0051%	14	15	1
1	23-May-99	Gallo	539	0.0655%	0.0724%	0.0051%	0	0	0
1	25-May-99	Gallo	544	0.0651%	0.0719%	0.0051%	0	0	0
1	25-May-99	Hagaman Park	3,041	0.0651%	0.0719%	0.0051%	2	2	0

Merced River Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates			Escapement		
				Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	27-May-99	Hagaman Park	2,025	0.0647%	0.0715%	0.0051%	1	1	0
1	No Date	Robinson Ranch	10,026	0.0000%	0.0000%	0.0000%	0	0	0
1		Robinson Ranch	10,026	0.0000%	0.0000%	0.0000%	0	0	0
2	27-Apr-99	MOSSDALE	5,000	0.2166%	0.3450%	0.0277%	11	17	1
2	6-May-99	MOSSDALE	3,300	0.2170%	0.3453%	0.0277%	7	11	1
2	13-May-99	MOSSDALE	3,016	0.2065%	0.3341%	0.0271%	6	10	1
2	19-May-99	MOSSDALE	300	0.1798%	0.3046%	0.0254%	1	1	0
2	24-May-99	MOSSDALE	4,000	0.1768%	0.3012%	0.0252%	7	12	1
2	27-May-99	MOSSDALE	911	0.1745%	0.2986%	0.0250%	2	3	0
2	28-May-99	MOSSDALE	4,020	0.1739%	0.2979%	0.0250%	7	12	1
2	3-Jun-99	MOSSDALE	4,307	0.1732%	0.2970%	0.0249%	7	13	1
2	4-Jun-99	MOSSDALE	4,013	0.1732%	0.2971%	0.0249%	7	12	1
1	8-Mar-00	Merced River	2,038	0.0000%	0.0000%	0.0000%	0	0	0
1	13-Mar-00	Merced River	1,152	0.0000%	0.0000%	0.0000%	0	0	0
1	14-Mar-00	Merced River	706	0.0000%	0.0000%	0.0000%	0	0	0
1	15-Mar-00	Hagaman Park	2,002	0.0000%	0.0000%	0.0000%	0	0	0
1	21-Mar-00	Hagaman Park	2,000	0.0000%	0.0000%	0.0000%	0	0	0
1	28-Mar-00	Hagaman Park	2,117	0.0000%	0.0000%	0.0000%	0	0	0
1	3-Apr-00	Gallo	500	0.0881%	0.1460%	0.0054%	0	1	0
1	4-Apr-00	Hagaman Park	2,028	0.0873%	0.1448%	0.0053%	2	3	0
1	5-Apr-00	Robinson Ranch	2,001	0.0866%	0.1436%	0.0053%	2	3	0
1	12-Apr-00	Gallo	2,038	0.0864%	0.1433%	0.0053%	2	3	0
1	13-Apr-00	Hagaman Park	2,008	0.0873%	0.1448%	0.0053%	2	3	0
1	24-Apr-00	Gallo	2,004	0.2384%	0.3948%	0.0146%	5	8	0
1	25-Apr-00	Hwy 59	3,008	0.2331%	0.3860%	0.0143%	7	12	0
1	25-Apr-00	SNELLING	5,000	0.2331%	0.3860%	0.0143%	12	19	1
1	26-Apr-00	Hagaman Park	2,000	0.2242%	0.3713%	0.0137%	4	7	0
1	29-Apr-00	Gallo	1,070	0.1568%	0.2598%	0.0096%	2	3	0
1	12-May-00	Gallo	896	0.0956%	0.1585%	0.0058%	1	1	0

Merced River Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	14-May-00	MERCED R FISH FACIL.	152,438	0.0919%	0.1524%	0.0056%	140	232	9
1	15-May-00	Gallo	3,003	0.0919%	0.1523%	0.0056%	3	5	0
1	15-May-00	Hwy 59	2,021	0.0919%	0.1523%	0.0056%	2	3	0
1	15-May-00	SNELLING	5,002	0.0919%	0.1523%	0.0056%	5	8	0
1	16-May-00	Hagaman Park	2,026	0.0920%	0.1525%	0.0056%	2	3	0
2	3-May-00	Old River Barrier	10,133	0.0522%	0.2785%	0.0039%	5	28	0
2	10-May-00	Old River Barrier	10,059	0.0517%	0.2768%	0.0039%	5	28	0
3.2	28-Mar-00	Berkeley Marina	0	0.0000%	0.0000%	0.0000%	0	0	0
1	18-Jan-01	Hagaman Park	2,000	0.0000%	0.0000%	0.0000%	0	0	0
1	26-Jan-01	Hagaman Park	1,010	0.0000%	0.0000%	0.0000%	0	0	0
1	31-Jan-01	Gallo	1,140	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Feb-01	Hagaman Park	2,029	0.0000%	0.0000%	0.0000%	0	0	0
1	6-Feb-01	Hagaman Park	1,070	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Mar-01	Gallo	810	0.0000%	0.0000%	0.0000%	0	0	0
1	7-Mar-01	Hagaman Park	2,014	0.0000%	0.0000%	0.0000%	0	0	0
1	19-Mar-01	Gallo	1,397	0.0000%	0.0000%	0.0000%	0	0	0
1	22-Mar-01	Hagaman Park	2,016	0.0000%	0.0000%	0.0000%	0	0	0
1	29-Mar-01	Hagaman Park	2,014	0.0000%	0.0000%	0.0000%	0	0	0
1	2-Apr-01	Gallo	1,300	0.0957%	0.0431%	0.0051%	1	1	0
1	3-Apr-01	Hagaman Park	0	0.0960%	0.0432%	0.0051%	0	0	0
1	6-Apr-01	Hagaman Park	2,016	0.0965%	0.0434%	0.0051%	2	1	0
1	16-Apr-01	Gallo	2,097	0.1460%	0.0658%	0.0077%	3	1	0
1	16-Apr-01	Henderson Park	5,028	0.1460%	0.0658%	0.0077%	7	3	0
1	16-Apr-01	Robinson Ranch	3,043	0.1460%	0.0658%	0.0077%	4	2	0
1	18-Apr-01	Hagaman Park	2,008	0.1788%	0.0805%	0.0095%	4	2	0
1	22-Apr-01	Gallo	2,204	0.1800%	0.0811%	0.0095%	4	2	0
1	22-Apr-01	Henderson Park	5,031	0.1800%	0.0811%	0.0095%	0	0	0
1	22-Apr-01	Robinson Ranch	3,150	0.1800%	0.0811%	0.0095%	6	3	0
1	25-Apr-01	Gallo	789	0.1354%	0.0609%	0.0072%	1	0	0

Merced River Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
1	26-Apr-01	Hagaman Park	2,053	0.1226%	0.0552%	0.0065%	3	1	0
1	27-Apr-01	Gallo	375	0.1150%	0.0518%	0.0061%	0	0	0
1	2-May-01	Hagaman Park	2,055	0.1168%	0.0526%	0.0062%	2	1	0
1	4-May-01	Gallo	847	0.1383%	0.0623%	0.0073%	1	1	0
1	9-May-01	Gallo	1,449	0.1881%	0.0847%	0.0100%	3	1	0
1	9-May-01	Henderson Park	5,015	0.1881%	0.0847%	0.0100%	9	4	0
1	9-May-01	Robinson Ranch	3,021	0.1881%	0.0847%	0.0100%	6	3	0
1	10-May-01	Hagaman Park	2,017	0.1882%	0.0848%	0.0100%	4	2	0
1	11-May-01	MERCED R FISH FACIL.	162,000	0.1855%	0.0835%	0.0098%	300	135	16
1	14-May-01	MERCED R FISH FACIL.	40,964	0.1442%	0.0649%	0.0076%	59	27	3
1	16-May-01	Hagaman Park	2,050	0.1133%	0.0510%	0.0060%	2	1	0
1	21-May-01	Gallo	2,415	0.0986%	0.0444%	0.0052%	2	1	0
1	21-May-01	Henderson Park	5,024	0.0986%	0.0444%	0.0052%	5	2	0
1	21-May-01	Robinson Ranch	3,249	0.0986%	0.0444%	0.0052%	3	1	0
1	24-May-01	Hagaman Park	2,020	0.0958%	0.0431%	0.0051%	2	1	0
1	26-May-01	Gallo	600	0.0952%	0.0429%	0.0050%	1	0	0
1	31-May-01	Hagaman Park	1,618	0.0914%	0.0411%	0.0048%	1	1	0
2	12-Apr-01	MOSSDALE	3,053	0.1264%	0.0569%	0.0088%	4	2	0
2	26-Apr-01	MOSSDALE	3,035	0.1402%	0.0610%	0.0092%	4	2	0
2	26-Apr-01	Old River Barrier	7,012	0.1402%	0.0610%	0.0092%	10	4	1
2	1-May-01	MOSSDALE	1,523	0.1401%	0.0610%	0.0092%	2	1	0
2	9-May-01	Old River Barrier	7,268	0.1410%	0.0612%	0.0093%	10	4	1
2	10-May-01	MOSSDALE	1,527	0.1415%	0.0614%	0.0093%	2	1	0
2	22-May-01	MOSSDALE	3,044	0.1251%	0.0565%	0.0088%	4	2	0
2	31-May-01	DOS REIS ROAD	110	0.1224%	0.0557%	0.0087%	0	0	0
1	7-Feb-02	Hagaman Park	0	0.0000%	0.0000%	0.0000%	0	0	0
1	13-Feb-02	Hagaman Park	1,859	0.0000%	0.0000%	0.0000%	0	0	0
1	20-Feb-02	Gallo	687	0.0000%	0.0000%	0.0000%	0	0	0
1	23-Feb-02	Gallo	1,268	0.0000%	0.0000%	0.0000%	0	0	0

Merced River Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	27-Feb-02	Hagaman Park	2,224	0.0000%	0.0000%	0.0000%	0	0	0
1	6-Mar-02	Gallo	764	0.0000%	0.0000%	0.0000%	0	0	0
1	6-Mar-02	Hagaman Park	2,015	0.0000%	0.0000%	0.0000%	0	0	0
1	13-Mar-02	Hagaman Park	2,075	0.0000%	0.0000%	0.0000%	0	0	0
1	19-Mar-02	Gallo	1,881	0.0000%	0.0000%	0.0000%	0	0	0
1	20-Mar-02	Hagaman Park	2,018	0.0000%	0.0000%	0.0000%	0	0	0
1	27-Mar-02	Hagaman Park	2,068	0.0000%	0.0000%	0.0000%	0	0	0
1	30-Mar-02	Hagaman Park	2,023	0.0000%	0.0000%	0.0000%	0	0	0
1	2-Apr-02	MERCED R FISH FACIL.	5,928	0.0102%	0.0429%	0.0050%	1	3	0
1	3-Apr-02	Hagaman Park	2,042	0.0102%	0.0431%	0.0051%	0	1	0
1	3-Apr-02	Henderson Park	5,053	0.0102%	0.0431%	0.0051%	1	2	0
1	4-Apr-02	Gallo	2,067	0.0103%	0.0433%	0.0051%	0	1	0
1	4-Apr-02	Robinson Ranch	3,050	0.0103%	0.0433%	0.0051%	0	1	0
1	10-Apr-02	Hagaman Park	2,024	0.0110%	0.0465%	0.0055%	0	1	0
1	12-Apr-02	Gallo	2,596	0.0115%	0.0484%	0.0057%	0	1	0
1	16-Apr-02	MERCED R FISH FACIL.	7,100	0.0119%	0.0504%	0.0059%	1	4	0
1	17-Apr-02	Hagaman Park	2,022	0.0120%	0.0508%	0.0060%	0	1	0
1	17-Apr-02	Henderson Park	5,092	0.0120%	0.0508%	0.0060%	1	3	0
1	18-Apr-02	Gallo	2,044	0.0121%	0.0511%	0.0060%	0	1	0
1	18-Apr-02	Robinson Ranch	3,006	0.0121%	0.0511%	0.0060%	0	2	0
1	21-Apr-02	Gallo	2,500	0.0121%	0.0513%	0.0060%	0	1	0
1	1-May-02	MERCED R FISH FACIL.	368,160	0.0242%	0.1021%	0.0120%	89	376	44
1	2-May-02	Hagaman Park	2,025	0.0239%	0.1012%	0.0119%	0	2	0
1	2-May-02	Henderson Park	5,036	0.0239%	0.1012%	0.0119%	1	5	1
1	3-May-02	Gallo	3,114	0.0230%	0.0971%	0.0114%	1	3	0
1	3-May-02	Robinson Ranch	3,088	0.0230%	0.0971%	0.0114%	1	3	0
1	4-May-02	Gallo	1,246	0.0215%	0.0910%	0.0107%	0	1	0
1	8-May-02	Hagaman Park	2,116	0.0170%	0.0719%	0.0085%	0	2	0
1	14-May-02	Hagaman Park	2,014	0.0103%	0.0436%	0.0051%	0	1	0

Merced River Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates			Escapement		
				Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	15-May-02	MERCED R FISH FACIL.	7,149	0.0102%	0.0431%	0.0051%	1	3	0
1	16-May-02	Henderson Park	5,027	0.0102%	0.0430%	0.0050%	1	2	0
1	17-May-02	Gallo	2,008	0.0102%	0.0430%	0.0051%	0	1	0
1	17-May-02	Robinson Ranch	3,025	0.0102%	0.0430%	0.0051%	0	1	0
1	20-May-02	Gallo	2,400	0.0102%	0.0430%	0.0050%	0	1	0
1	22-May-02	Hagaman Park	2,077	0.0101%	0.0427%	0.0050%	0	1	0
1	29-May-02	Hagaman Park	2,048	0.0099%	0.0418%	0.0049%	0	1	0
2	5-Apr-02	Mossdale	2,017	0.0113%	0.0404%	0.0079%	0	1	0
2	11-Apr-02	MOSSDALE	5,091	0.0117%	0.0413%	0.0080%	1	2	0
2	17-Apr-02	MOSSDALE	2,043	0.0123%	0.0428%	0.0082%	0	1	0
2	19-Apr-02	Old River Barrier	12,334	0.0124%	0.0429%	0.0082%	2	5	1
2	24-Apr-02	Old River Barrier	12,126	0.0125%	0.0431%	0.0083%	2	5	1
2	26-Apr-02	MOSSDALE	5,064	0.0125%	0.0432%	0.0083%	1	2	0
2	3-May-02	MOSSDALE	2,005	0.0124%	0.0431%	0.0083%	0	1	0
2	9-May-02	MOSSDALE	5,010	0.0123%	0.0428%	0.0082%	1	2	0
2	14-May-02	MOSSDALE	2,014	0.0119%	0.0418%	0.0081%	0	1	0
2	23-May-02	MOSSDALE	5,057	0.0115%	0.0409%	0.0080%	1	2	0
1	22-Feb-03	Gallo	800	0.0000%	0.0000%	0.0000%	0	0	0
1	12-Mar-03	Gallo	1,652	0.0000%	0.0000%	0.0000%	0	0	0
1	22-Mar-03	MERCED R FISH FACIL.	17,400	0.0000%	0.0000%	0.0000%	0	0	0
1	26-Mar-03	Gallo	20,500	0.0000%	0.0000%	0.0000%	0	0	0
1	2-Apr-03	Hagaman Park	0	0.0935%	0.0752%	0.0012%	0	0	0
1	2-Apr-03	Henderson Park	5,000	0.0935%	0.0752%	0.0012%	5	4	0
1	3-Apr-03	Gallo	2,000	0.0935%	0.0752%	0.0012%	2	2	0
1	3-Apr-03	MERCED R FISH FACIL.	20,800	0.0935%	0.0752%	0.0012%	19	16	0
1	3-Apr-03	Ratzlaff	3,035	0.0935%	0.0752%	0.0012%	3	2	0
1	3-Apr-03	Robinson Ranch	3,000	0.0935%	0.0752%	0.0012%	3	2	0
1	4-Apr-03	MERCED R FISH FACIL.	19,800	0.0938%	0.0755%	0.0012%	19	15	0
1	5-Apr-03	MERCED R FISH FACIL.	47,400	0.0951%	0.0765%	0.0012%	45	36	1

Merced River Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
1	5-Apr-03	Shaffer Bridge	21,375	0.0951%	0.0765%	0.0012%	20	16	0
1	6-Apr-03	Shaffer Bridge	26,250	0.0981%	0.0789%	0.0012%	26	21	0
1	8-Apr-03	Hagaman Park	2,101	0.1112%	0.0894%	0.0014%	2	2	0
1	13-Apr-03	MERCED R FISH FACIL.	11,625	0.1327%	0.1068%	0.0016%	15	12	0
1	14-Apr-03	MERCED R FISH FACIL.	10,000	0.1320%	0.1062%	0.0016%	13	11	0
1	15-Apr-03	Hagaman Park	2,000	0.1313%	0.1056%	0.0016%	3	2	0
1	15-Apr-03	Henderson Park	5,000	0.1313%	0.1056%	0.0016%	7	5	0
1	16-Apr-03	Gallo	2,000	0.1302%	0.1048%	0.0016%	3	2	0
1	16-Apr-03	Ratzlaff	3,010	0.1302%	0.1048%	0.0016%	4	3	0
1	16-Apr-03	Robinson Ranch	3,000	0.1302%	0.1048%	0.0016%	4	3	0
1	22-Apr-03	Hagaman Park	2,040	0.1155%	0.0929%	0.0014%	2	2	0
1	23-Apr-03	MERCED R FISH FACIL.	10,209	0.1151%	0.0926%	0.0014%	12	9	0
1	24-Apr-03	Henderson Park	5,000	0.1152%	0.0926%	0.0014%	6	5	0
1	25-Apr-03	Gallo	2,000	0.1160%	0.0933%	0.0014%	2	2	0
1	25-Apr-03	Ratzlaff	3,000	0.1160%	0.0933%	0.0014%	3	3	0
1	25-Apr-03	Robinson Ranch	3,000	0.1160%	0.0933%	0.0014%	3	3	0
1	29-Apr-03	Hagaman Park	2,016	0.1524%	0.1226%	0.0019%	3	2	0
1	30-Apr-03	MERCED R FISH FACIL.	1,807	0.1736%	0.1397%	0.0021%	3	3	0
1	2-May-03	Hagaman Park	2,021	0.2109%	0.1697%	0.0026%	4	3	0
1	5-May-03	MERCED R FISH FACIL.	9,979	0.2218%	0.1785%	0.0027%	22	18	0
1	6-May-03	Hagaman Park	2,015	0.2148%	0.1728%	0.0027%	4	3	0
1	6-May-03	Henderson Park	5,017	0.2148%	0.1728%	0.0027%	11	9	0
1	7-May-03	Gallo	2,185	0.1991%	0.1602%	0.0025%	4	4	0
1	7-May-03	Ratzlaff	3,000	0.1991%	0.1602%	0.0025%	6	5	0
1	7-May-03	Robinson Ranch	3,000	0.1991%	0.1602%	0.0025%	6	5	0
1	12-May-03	MERCED R FISH FACIL.	43,100	0.1005%	0.0808%	0.0012%	43	35	1
1	13-May-03	Hagaman Park	2,009	0.0954%	0.0768%	0.0012%	2	2	0
2	4-Apr-03	MOSSDALE	2,000	0.0326%	0.0653%	0.0053%	1	1	0
2	10-Apr-03	MOSSDALE	5,044	0.0333%	0.0662%	0.0053%	2	3	0

Merced River Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
2	18-Apr-03	MOSSDALE	2,000	0.0351%	0.0686%	0.0055%	1	1	0
2	22-Apr-03	Old River Barrier	6,015	0.0350%	0.0685%	0.0055%	2	4	0
2	24-Apr-03	MOSSDALE	5,000	0.0350%	0.0685%	0.0055%	2	3	0
2	29-Apr-03	Old River Barrier	12,043	0.0353%	0.0689%	0.0055%	4	8	1
2	2-May-03	MOSSDALE	2,000	0.0352%	0.0688%	0.0055%	1	1	0
2	9-May-03	MOSSDALE	5,060	0.0348%	0.0683%	0.0054%	2	3	0
2	16-May-03	MOSSDALE	2,000	0.0330%	0.0658%	0.0053%	1	1	0
2	23-May-03	MOSSDALE	5,000	0.0324%	0.0651%	0.0053%	2	3	0
1	5-Apr-04	MERCED R FISH FACIL.	10,200	0.0663%	0.0109%	0.0050%	7	1	1
1	6-Apr-04	Henderson Park	5,000	0.0672%	0.0111%	0.0051%	3	1	0
1	7-Apr-04	Gallo	2,000	0.0692%	0.0114%	0.0052%	1	0	0
1	7-Apr-04	Ratzlaff	3,128	0.0692%	0.0114%	0.0052%	2	0	0
1	7-Apr-04	Robinson Ranch	3,000	0.0692%	0.0114%	0.0052%	2	0	0
1	19-Apr-04	MERCED R FISH FACIL.	10,200	0.0916%	0.0151%	0.0069%	9	2	1
1	20-Apr-04	Henderson Park	5,016	0.0967%	0.0159%	0.0073%	5	1	0
1	21-Apr-04	Gallo	2,032	0.1026%	0.0169%	0.0077%	2	0	0
1	21-Apr-04	Ratzlaff	3,057	0.1026%	0.0169%	0.0077%	3	1	0
1	21-Apr-04	Robinson Ranch	3,003	0.1026%	0.0169%	0.0077%	3	1	0
1	3-May-04	MERCED R FISH FACIL.	10,200	0.1793%	0.0295%	0.0135%	18	3	1
1	4-May-04	Henderson Park	5,010	0.1781%	0.0293%	0.0134%	9	1	1
1	5-May-04	Gallo	2,010	0.1748%	0.0287%	0.0132%	4	1	0
1	5-May-04	MERCED R FISH FACIL.	165,430	0.1748%	0.0287%	0.0132%	289	48	22
1	5-May-04	Ratzlaff	3,032	0.1748%	0.0287%	0.0132%	5	1	0
1	5-May-04	Robinson Ranch	3,027	0.1748%	0.0287%	0.0132%	5	1	0
1	17-May-04	MERCED R FISH FACIL.	10,200	0.0660%	0.0109%	0.0050%	7	1	1
1	18-May-04	Henderson Park	5,017	0.0656%	0.0108%	0.0049%	3	1	0
1	19-May-04	Gallo	2,000	0.0654%	0.0108%	0.0049%	1	0	0
1	19-May-04	MERCED R FISH FACIL.	94,980	0.0654%	0.0108%	0.0049%	62	10	5
1	19-May-04	Ratzlaff	3,003	0.0654%	0.0108%	0.0049%	2	0	0

Merced River Hatchery

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	19-May-04	Robinson Ranch	3,017	0.0654%	0.0108%	0.0049%	2	0	0
2	9-Apr-04	MOSSDALE	2,010	0.0000%	0.0000%	0.0050%	0	0	0
2	16-Apr-04	MOSSDALE	5,016	0.0000%	0.0000%	0.0051%	0	0	0
2	21-Apr-04	MOSSDALE	2,007	0.0000%	0.0000%	0.0051%	0	0	0
2	29-Apr-04	MOSSDALE	5,009	0.0000%	0.0000%	0.0051%	0	0	0
2	7-May-04	MOSSDALE	2,039	0.0000%	0.0000%	0.0051%	0	0	0
2	13-May-04	MOSSDALE	5,008	0.0000%	0.0000%	0.0051%	0	0	0
2	20-May-04	MOSSDALE	2,029	0.0000%	0.0000%	0.0049%	0	0	0
2	28-May-04	MOSSDALE	2,000	0.0000%	0.0000%	0.0049%	0	0	0
1	5-Apr-05	MERCED R FISH FACIL.	7,565	0.0000%	0.0000%	0.0000%	0	0	0
1	18-Apr-05	MERCED R FISH FACIL.	983	0.0000%	0.0000%	0.0000%	0	0	0
1	10-May-05	MERCED R FISH FACIL.	10,600	0.0000%	0.0000%	0.0000%	0	0	0
1	Apr-Jun 2005	Gallo	10,144	0.0000%	0.0000%	0.0000%	0	0	0
1	Apr-May 2005	Henderson Park	20,019	0.0000%	0.0000%	0.0000%	0	0	0
1	Apr-May 2005	Robinson Ranch	12,016	0.0000%	0.0000%	0.0000%	0	0	0
1	18-Apr-06	Merced River	427				0	0	0
1	24-Apr-06	Merced River	311				0	0	0
1	25-May-06	Merced River	73,000				0	0	0
1	1-Jun-06	Merced River	57,000				0	0	0
1	2-Jun-06	Merced River	61,097				0	0	0
1	8-Jun-06	Merced River	18,500				0	0	0
1	19-Jun-06	Merced River	8,215				0	0	0
2	6-Apr-06	San Joaquin River	2,062				0	0	0
2	20-Apr-06	San Joaquin River	5,000				0	0	0
2	27-Apr-06	San Joaquin River	5,041				0	0	0
2	3-May-06	San Joaquin River	5,000				0	0	0
2	4-May-06	San Joaquin River	2,000				0	0	0
2	11-May-06	San Joaquin River	7,000				0	0	0

Merced River Hatchery

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates			Escapement		
				Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
2	18-May-06	San Joaquin River	7,000				0	0	0
2	25-May-06	San Joaquin River	5,000				0	0	0
2	1-Jun-06	San Joaquin River	5,000				0	0	0
2	8-Jun-06	San Joaquin River	5,000				0	0	0

Nimbus Fish Hatchery, American River

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Age 3	Age 4	Escapement Age 2	Age 3	Age 4
1	1-Jan-78	NFH	191,520				0	0	0
1	1-Apr-78	NFH	138,600				0	0	0
2	1-Apr-78	RIO VISTA	1,810,750				0	0	0
2	1-May-78	RIO VISTA	325,070				0	0	0
2	1-Jun-78	RIO VISTA	2,552,025				0	0	0
2	1-Oct-78	RIO VISTA	107,380				0	0	0
2	1-Nov-78	RIO VISTA	121,660				0	0	0
1	1-Jan-79	NFH	352,500				0	0	0
1	1-Apr-79	NFH	510,724				0	0	0
1	1-Jun-79	NFH	18,375				0	0	0
2	1-Apr-79	RIO VISTA	864,735				0	0	0
2	1-May-79	RIO VISTA	2,860,120				0	0	0
2	1-Jun-79	RIO VISTA	2,330,700				0	0	0
2	1-Sep-79	RIO VISTA	150,960				0	0	0
2	1-Oct-79	RIO VISTA	116,500				0	0	0
1	1-Feb-80	NFH	2,131,767				0	0	0
1	1-Mar-80	NFH	326,388				0	0	0
1	1-Apr-80	NFH	301,003				0	0	0
2	1-Jun-80	RIO VISTA	3,544,795				0	0	0
3.2	1-Sep-80	BENICIA	270,281	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jan-81	NFH	4,360,140				0	0	0
1	1-Feb-81	NFH	6,485,377				0	0	0
1	1-Mar-81	Bear River	100,050				0	0	0
1	1-Dec-80	NFH	1,510,292				0	0	0
3.2	1-Apr-81	BENICIA	335,699	0.0000%	0.0057%	0.0000%	0	19	0
3.2	1-Apr-81	Pittsburg	1,536,048	0.0000%	0.0055%	0.0000%	0	85	0

Nimbus Fish Hatchery, American River

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
3.2	1-May-81	BENICIA	877,820	0.0000%	0.0066%	0.0000%	0	58	0
3.2	1-Jun-81	BENICIA	1,337,250	0.0000%	0.0063%	0.0000%	0	84	0
3.2	1-Jul-81	BENICIA	1,739,360	0.0000%	0.0168%	0.0000%	0	293	0
1	1-Jan-82	NFH	2,557,676				0	0	0
1	1-Feb-82	Bear River	135,000				0	0	0
1	1-Feb-82	Cosumnes River	100,000				0	0	0
1	1-Feb-82	Doty Ravine Creek, Auburn & Coon Creek	94,800				0	0	0
1	1-Feb-82	NFH	2,077,112				0	0	0
1	1-Dec-81	NFH	3,100,896				0	0	0
2	1-May-82	RIO VISTA	727,925				0	0	0
2	1-Jun-82	RIO VISTA	1,149,000				0	0	0
3.2	1-Jul-82	BENICIA	1,458,625	0.0000%	0.0012%	0.0000%	0	18	0
3.2	1-Aug-82	BENICIA	1,457,905	0.0000%	0.0014%	0.0000%	0	20	0
1	1-Jan-83	American River	1,141,693				0	0	0
1	1-Feb-83	American River	475,492				0	0	0
1	1-Mar-83	American River	364,048				0	0	0
1	1-Apr-83	American River	971,612				0	0	0
1	1-Dec-82	Auburn Ravine Creek	86,432				0	0	0
1	1-Dec-82	Bear River	331,726				0	0	0
1	1-Dec-82	Cache Creek	167,020				0	0	0
1	1-Dec-82	Calaveras River	190,880				0	0	0
1	1-Dec-82	COON CREEK	100,640				0	0	0
1	1-Dec-82	Cosumnes River	599,040				0	0	0
1	1-Dec-82	Doty Ravine Creek	50,912				0	0	0
1	1-Dec-82	Dry Creek	223,449				0	0	0
1	1-Dec-82	MOKELUMNE RIVER	548,780				0	0	0
1	1-Dec-82	Putah Creek	158,788				0	0	0

Nimbus Fish Hatchery, American River

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
1	1-Dec-82	Rancheria Creek	32,211				0	0	0
1	1-Dec-82	Secret Ravine Creek	61,568				0	0	0
1	1-Dec-82	Sutter Creek	31,018				0	0	0
3.2	1-Apr-83	BENICIA	615,000	0.0000%	0.0006%	0.0000%	0	4	0
3.2	1-Apr-83	Vallejo	1,012,500	0.0000%	0.0006%	0.0000%	0	6	0
3.2	1-May-83	BENICIA	391,400	0.0000%	0.0006%	0.0000%	0	2	0
3.2	1-Jun-83	BENICIA	603,300	0.0000%	0.0007%	0.0000%	0	4	0
3.2	1-Jul-83	BENICIA	1,915,200	0.0000%	0.0007%	0.0000%	0	13	0
3.2	1-Aug-83	BENICIA	0	0.0000%	0.0006%	0.0000%	0	0	0
3.2	1-Aug-83	Berkeley Marina	0	0.0000%	0.0006%	0.0000%	0	0	0
3.2	1-Aug-83	PORT CHICAGO	0	0.0000%	0.0006%	0.0000%	0	0	0
1	1-Mar-84	NFH	441,000				0	0	0
1	1-Apr-84	NFH	900,335				0	0	0
1	1-Jun-84	NFH	381,250				0	0	0
3.2	1-May-84	BENICIA	180,000	0.0000%	0.0032%	0.0000%	0	6	0
3.2	1-Jun-84	BENICIA	862,650	0.0000%	0.0032%	0.0000%	0	28	0
3.2	1-Jul-84	BENICIA	2,826,300	0.0000%	0.0034%	0.0000%	0	96	0
3.2	1-Jul-84	Berkeley Marina	0				0	0	0
3.2	1-Jul-84	FORT BAKER MINOR PT	0				0	0	0
3.2	1-Jul-84	PORT CHICAGO	0				0	0	0
1	1-Jan-85	NFH	5,350,800				0	0	0
1	1-Feb-85	NFH	3,407,900				0	0	0
1	1-Mar-85	NFH	531,680				0	0	0
2	1-Apr-85	Garcia Bend	424,800				0	0	0
2	1-May-85	Garcia Bend	285,600				0	0	0
3.2	1-May-85	BENICIA	692,400	0.0000%	0.0016%	0.0000%	0	11	0
3.2	1-Jun-85	BENICIA	2,987,700	0.0000%	0.0016%	0.0000%	0	47	0

Nimbus Fish Hatchery, American River

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
3.2	1-Jul-85	BENICIA	820,300	0.0000%	0.0016%	0.0000%	0	13	0
	1-Jul-85	Berkeley Marina	0	0.0000%	0.0013%	0.0000%	0	0	0
2	1-Jan-86	DISCOVERY PARK	452,915				0	0	0
2	1-Jan-86	Garcia Bend	386,700				0	0	0
2	1-Feb-86	DISCOVERY PARK	3,668,925				0	0	0
2	1-Mar-86	Garcia Bend	523,180				0	0	0
3.2	1-May-86	BENICIA	497,790	0.0000%	0.0018%	0.0000%	0	9	0
3.2	1-Jun-86	BENICIA	2,850,750	0.0000%	0.0019%	0.0000%	0	53	0
3.2	1-Jul-86	BENICIA	1,538,950	0.0000%	0.0020%	0.0000%	0	31	0
1	1-Jan-87	Cosumnes River	216,000				0	0	0
1	1-Jan-87	NFH	1,038,000				0	0	0
1	1-Feb-87	NFH	647,480				0	0	0
2	1-Apr-87	DISCOVERY PARK	401,600				0	0	0
3.2	1-May-87	BENICIA	1,310,975	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-87	BENICIA	2,594,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-87	BENICIA	271,050	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Mar-88	DISCOVERY PARK	410,710				0	0	0
2	1-Mar-88	Garcia Bend	345,260				0	0	0
2	1-Apr-88	DISCOVERY PARK	96,600				0	0	0
2	1-Apr-88	Garcia Bend	116,600				0	0	0
2	1-Apr-88	MILLER PARK	285,000				0	0	0
2	1-Jun-88	DISCOVERY PARK	145,000				0	0	0
3.2	1-May-88	BENICIA	264,000	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-88	BENICIA	1,183,593	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-88	Mare Island	1,364,200	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-88	BENICIA	580,700	0.0000%	0.0000%	0.0000%	0	0	0
2	1-Feb-89	DISCOVERY PARK	170,752				0	0	0

Nimbus Fish Hatchery, American River

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
2	1-Feb-89	Garcia Bend	1,083,740				0	0	0
2	1-Feb-89	MILLER PARK	529,250				0	0	0
2	1-Mar-89	DISCOVERY PARK	682,020				0	0	0
2	1-Mar-89	MILLER PARK	1,662,387				0	0	0
2	1-Jun-89	Garcia Bend	99,400				0	0	0
3.2	1-Jan-89	Suisun	815,200	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-89	BENICIA	657,314	0.0000%	0.0000%	0.0010%	0	0	7
3.2	1-Jul-89	BENICIA	2,629,870	0.0000%	0.0000%	0.0010%	0	0	26
1	1-Jan-90	American River	3,123,500				0	0	0
1	1-Jan-90	AMERICANR-COON CREEK	124,500				0	0	0
1	1-Jan-90	Auburn Ravine Creek	124,500				0	0	0
1	1-Jan-90	Bear River	273,800				0	0	0
1	1-Jan-90	Cosumnes River	522,800				0	0	0
1	1-Jan-90	Dry Creek	124,500				0	0	0
1	1-Feb-90	American River	759,516				0	0	0
1	1-Mar-90	American River	575,230				0	0	0
1	1-Apr-90	American River	846,265				0	0	0
1	1-May-90	American River	624,500				0	0	0
3.2	1-May-90	BENICIA	338,800	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-90	BENICIA	195,718	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jun-90	Maritime Acad.	376,200	0.0000%	0.0000%	0.0000%	0	0	0
3.2	1-Jul-90	BENICIA	1,001,650	0.0000%	0.0000%	0.0000%	0	0	0
1	1-Jan-91	Secret Ravine Creek	26,640				0	0	0
1	1-Feb-91	Auburn Ravine Creek	17,200				0	0	0
1	1-Mar-91	AMERICANR-COON CREEK	99,008				0	0	0
1	1-Mar-91	Cosumnes River	97,920				0	0	0
1	1-Mar-91	Dry Creek	197,352				0	0	0

Nimbus Fish Hatchery, American River

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
2	1-Mar-91	Garcia Bend	96,000				0	0	0
2	1-Mar-91	MILLER PARK	1,174,500				0	0	0
2	1-Apr-91	Garcia Bend	848,835				0	0	0
2	1-Apr-91	MILLER PARK	148,750				0	0	0
2	1-May-91	RIO VISTA	1,543,000				0	0	0
3.2	1-May-91	BENICIA	1,029,300	0.0000%	0.0029%	0.0027%	0	30	28
3.2	1-Jun-91	BENICIA	1,592,700	0.0000%	0.0031%	0.0027%	0	49	43
3.2	1-Jul-91	BENICIA	443,100	0.0000%	0.0032%	0.0027%	0	14	12
1	1-Feb-92	AMERICANR-COON CREEK	114,600				0	0	0
1	1-Feb-92	Auburn Ravine Creek	101,612				0	0	0
1	1-Mar-92	Bear River	118,400				0	0	0
1	1-Mar-92	Cosumnes River	514,000				0	0	0
1	1-Mar-92	Dry Creek	118,400				0	0	0
2	1-Jan-92	MILLER PARK	414,000				0	0	0
2	1-Feb-92	MILLER PARK	229,200				0	0	0
2	1-Mar-92	Garcia Bend	3,098,500				0	0	0
2	1-Apr-92	Garcia Bend	1,844,990				0	0	0
3.2	1-May-92	BENICIA	2,664,950	0.0000%	0.0009%	0.0000%	0	24	0
3.2	1-Jun-92	BENICIA	1,557,000	0.0000%	0.0010%	0.0000%	0	15	0
3.2	1-Jul-92	BENICIA	177,200	0.0000%	0.0011%	0.0000%	0	2	0
1	1-Feb-93	AMERICANR-COON CREEK	100,190				0	0	0
1	1-Feb-93	Auburn Ravine Creek	101,190				0	0	0
1	1-Feb-93	Cosumnes River	200,380				0	0	0
1	1-Feb-93	Dry Creek	100,190				0	0	0
1	1-Feb-93	Miners Ravine Creek	50,095				0	0	0
1	1-Mar-93	Secret Ravine Creek	51,660				0	0	0
2	1-Feb-93	MILLER PARK	774,860				0	0	0

Nimbus Fish Hatchery, American River

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
2	1-Mar-93	MILLER PARK	2,534,800				0	0	0
2	1-Apr-93	MILLER PARK	1,312,550				0	0	0
2	1-Jun-93	RIO VISTA	449,275				0	0	0
2	1-Jun-93	Sacramento River	2,262,200				0	0	0
3.2	1-Jul-93	BENICIA	490,600	0.0000%	0.0018%	0.0000%	0	9	0
3.2	1-Jul-93	San Francisco Bay, San Yerba Buena Naval Yard	110,000	0.0000%	0.0019%	0.0000%	0	2	0
3.2	1-Jul-93	WICKLAND OIL NET PEN	639,800	0.0000%	0.0018%	0.0000%	0	12	0
3.2	1-Aug-93	BENICIA	362,000	0.0000%	0.0019%	0.0000%	0	7	0
3.2	1-Aug-93	WICKLAND OIL NET PEN	604,200	0.0000%	0.0019%	0.0000%	0	11	0
1	1-Jan-94	Cosumnes River	206,800				0	0	0
1	1-Feb-94	AMERICANR-COON CREEK	107,800				0	0	0
1	1-Feb-94	Auburn Ravine Creek	107,800				0	0	0
1	1-Feb-94	Dry Creek	107,800				0	0	0
1	1-Feb-94	Miners Ravine Creek	53,900				0	0	0
1	1-Feb-94	Secret Ravine Creek	53,900				0	0	0
2	1-Jan-94	MILLER PARK	1,998,700				0	0	0
2	1-Feb-94	MILLER PARK	1,105,500				0	0	0
2	1-Apr-94	MILLER PARK	713,500				0	0	0
2	1-May-94	MILLER PARK	478,600				0	0	0
3.2	1-Jun-94	BENICIA	1,565,900	0.0021%	0.0023%	0.0001%	34	36	2
3.2	1-Jun-94	San Francisco Bay, San Yerba Buena Naval Yard	78,000	0.0021%	0.0024%	0.0001%	2	2	0
3.2	1-Jun-94	WICKLAND OIL NET PEN	2,509,100	0.0021%	0.0023%	0.0001%	54	58	3
3.2	1-Jul-94	BENICIA	36,600	0.0021%	0.0023%	0.0001%	1	1	0
1	1-Feb-95	AMERICANR-COON CREEK	99,840				0	0	0
1	1-Feb-95	Auburn Ravine Creek	99,840				0	0	0
1	1-Feb-95	Cosumnes River	200,720				0	0	0

Nimbus Fish Hatchery, American River

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
1	1-Feb-95	Dry Creek	100,880				0	0	0
1	1-Feb-95	Miners Ravine Creek	49,920				0	0	0
1	1-Feb-95	Secret Ravine Creek	49,920				0	0	0
2	1-Jan-95	MILLER PARK	1,603,640				0	0	0
2	1-Feb-95	Garcia Bend	3,903,475				0	0	0
2	1-Mar-95	MILLER PARK	591,008				0	0	0
3.2	1-Jun-95	BENICIA	874,450	0.0000%	0.0011%	0.0002%	0	10	2
3.2	1-Jun-95	San Francisco Bay, San Yerba Buena Naval Yard	484,000	0.0000%	0.0011%	0.0002%	0	5	1
3.2	1-Jun-95	WICKLAND OIL NET PEN	973,650	0.0000%	0.0011%	0.0002%	0	11	2
3.2	1-Jul-95	BENICIA	187,000	0.0000%	0.0012%	0.0002%	0	2	0
3.2	1-Jul-95	San Francisco Bay, San Yerba Buena Naval Yard	204,000	0.0000%	0.0011%	0.0002%	0	2	0
3.2	1-Jul-95	WICKLAND OIL NET PEN	1,500,600	0.0000%	0.0011%	0.0002%	0	17	3
1	1-Jan-96	AMERICANR-COON CREEK	102,000				0	0	0
1	1-Jan-96	Auburn Ravine Creek	104,400				0	0	0
1	1-Jan-96	Cosumnes River	228,000				0	0	0
1	1-Jan-96	Dry Creek	102,000				0	0	0
1	1-Jan-96	Miners Ravine Creek	51,600				0	0	0
1	1-Jan-96	Secret Ravine Creek	51,600				0	0	0
2	1-Jan-96	MILLER PARK	1,934,400				0	0	0
2	1-Feb-96	MILLER PARK	2,149,301				0	0	0
3.2	1-May-96	BENICIA	538,600	0.0000%	0.0006%	0.0000%	0	3	0
3.2	1-May-96	San Francisco Bay, San Yerba Buena Naval Yard	253,000	0.0000%	0.0006%	0.0000%	0	1	0
3.2	1-May-96	WICKLAND OIL NET PEN	1,078,600	0.0000%	0.0006%	0.0000%	0	6	0
3.2	1-Jun-96	BENICIA	1,008,450	0.0000%	0.0006%	0.0000%	0	6	0
3.2	1-Jun-96	San Francisco Bay, San Yerba Buena Naval	67,200	0.0000%	0.0006%	0.0000%	0	0	0

Nimbus Fish Hatchery, American River

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
		Yard							
3.2	1-Jun-96	WICKLAND OIL NET PEN	1,084,600	0.0000%	0.0006%	0.0000%	0	6	0
1	1-Feb-97	AMERICANR-COON CREEK	102,096				0	0	0
1	1-Feb-97	Auburn Ravine Creek	102,600				0	0	0
1	1-Feb-97	Dry Creek	110,040				0	0	0
1	1-Feb-97	Miners Ravine Creek	55,836				0	0	0
1	1-Feb-97	Secret Ravine Creek	50,268				0	0	0
2	1-Jan-97	MILLER PARK	2,011,880				0	0	0
2	1-Feb-97	Garcia Bend	1,066,540				0	0	0
2	1-Feb-97	MILLER PARK	797,980				0	0	0
2	1-Mar-97	Garcia Bend	1,249,036				0	0	0
3.2	1-May-97	BENICIA	367,600	0.0000%	0.0028%	0.0000%	0	10	0
3.2	1-May-97	WICKLAND OIL NET PEN	1,003,800	0.0000%	0.0028%	0.0000%	0	28	0
3.2	1-Jun-97	WICKLAND OIL NET PEN	2,683,400	0.0000%	0.0027%	0.0000%	0	73	0
1	1-Mar-98	AMERICANR-COON CREEK	120,450				0	0	0
1	1-Mar-98	Auburn Ravine Creek	126,900				0	0	0
1	1-Mar-98	Dry Creek	366,700				0	0	0
2	1-Mar-98	Garcia Bend	1,253,570				0	0	0
3.2	1-May-98	BENICIA	570,400	0.0000%	0.0009%	0.0000%	0	5	0
3.2	1-May-98	WICKLAND OIL NET PEN	372,000	0.0000%	0.0009%	0.0000%	0	3	0
3.2	1-Jun-98	Bennett's Marina	132,000	0.0000%	0.0009%	0.0000%	0	1	0
3.2	1-Jun-98	SF-San Francisco Bay	132,000	0.0000%	0.0009%	0.0000%	0	1	0
3.2	1-Jun-98	TIBURON NET PENS	52,000	0.0000%	0.0010%	0.0000%	0	1	0
3.2	1-Jun-98	WICKLAND OIL NET PEN	2,693,254	0.0000%	0.0010%	0.0000%	0	26	0
1	1-Apr-99	AMERICANR-COON CREEK	118,400				0	0	0
1	1-Apr-99	Auburn Ravine Creek	100,750				0	0	0
1	1-Apr-99	Dry Creek	321,720				0	0	0

Nimbus Fish Hatchery, American River

				Merced Recovery Rates			Escapement		
Release Location Code	Date Released	Release Location	Total Number Released	Age 2	Age 3	Age 4	Age 2	Age 3	Age 4
3.2	1-May-99	BENICIA	120,000	0.0030%	0.0033%	0.0000%	4	4	0
3.2	1-May-99	WICKLAND OIL NET PEN	896,900	0.0030%	0.0032%	0.0000%	27	29	0
3.2	1-Jun-99	BENICIA	509,208	0.0030%	0.0032%	0.0000%	15	16	0
3.2	1-Jun-99	SF-San Francisco Bay	217,500	0.0030%	0.0034%	0.0000%	7	7	0
3.2	1-Jun-99	TIBURON NET PENS	52,008	0.0030%	0.0037%	0.0000%	2	2	0
3.2	1-Jun-99	WICKLAND OIL NET PEN	2,741,792	0.0030%	0.0032%	0.0000%	83	89	0
3.2	1-May-00	BENICIA	356,200	0.0000%	0.0008%	0.0000%	0	3	0
3.2	1-May-00	WICKLAND OIL NET PEN	1,735,500	0.0000%	0.0008%	0.0000%	0	15	0
3.2	1-Jun-00	WICKLAND OIL NET PEN	1,760,000	0.0000%	0.0008%	0.0000%	0	15	0
3.2	1-Jun-02	TIBURON NET PENS	50,400	0.0024%	0.0020%	0.0007%	1	1	0
3.2	1-Jun-02	WICKLAND OIL NET PEN	1,493,073	0.0024%	0.0020%	0.0007%	36	30	11
3.2	1-Jul-02	WICKLAND OIL NET PEN	1,736,850	0.0024%	0.0020%	0.0007%	42	35	12
3.2	1-May-03	WICKLAND OIL NET PEN	480,000	0.0009%	0.0015%	0.0000%	4	7	0
3.2	1-Jun-03	Treasure Island USCG Station	502,300	0.0009%	0.0015%	0.0000%	4	7	0
3.2	1-Jun-03	WICKLAND OIL NET PEN	3,379,000	0.0009%	0.0015%	0.0000%	30	49	0
3.2	1-Jun-04	SAN PABLO BAY	4,693,466	0.0000%	0.0014%	0.0000%	0	68	0
3.2	25-May-05	WICKLAND OIL TERMINAL	1,854,000				0	0	0
3.2	26-May-05	WICKLAND OIL TERMINAL	152,500				0	0	0
3.2	2-Jun-05	WICKLAND OIL TERMINAL	290,400				0	0	0
3.2	3-Jun-05	WICKLAND OIL TERMINAL	154,100				0	0	0
3.2	6-Jun-05	WICKLAND OIL TERMINAL	142,600				0	0	0
3.2	7-Jun-05	VALLEJO PUBLIC BOAT RAMP	138,000				0	0	0
3.2	8-Jun-05	WICKLAND OIL TERMINAL	400,200				0	0	0
3.2	9-Jun-05	WICKLAND OIL TERMINAL	253,700				0	0	0
3.2	10-Jun-05	WICKLAND OIL TERMINAL	143,000				0	0	0
3.2	13-Jun-05	WICKLAND OIL TERMINAL	289,800				0	0	0
3.2	20-Jun-05	WICKLAND OIL TERMINAL	524,400				0	0	0

Nimbus Fish Hatchery, American River

Release Location Code	Date Released	Release Location	Total Number Released	Merced Recovery Rates Age 2	Merced Recovery Rates Age 3	Merced Recovery Rates Age 4	Escapement Age 2	Escapement Age 3	Escapement Age 4
3.2	22-Jun-05	WICKLAND OIL TERMINAL	91,300				0	0	0
3.2	2-Jun-06	WICKLAND OIL TERMINAL	136,000				0	0	0
3.2	5-Jun-06	San Francisco Bay	271,400				0	0	0
3.2	6-Jun-06	San Francisco Bay	239,200				0	0	0
3.2	7-Jun-06	San Francisco Bay	239,200				0	0	0
3.2	8-Jun-06	San Francisco Bay	253,000				0	0	0
3.2	9-Jun-06	San Francisco Bay	279,400				0	0	0
3.2	12-Jun-06	San Francisco Bay	276,000				0	0	0
3.2	13-Jun-06	San Francisco Bay	303,900				0	0	0
3.2	14-Jun-06	San Francisco Bay	294,400				0	0	0
3.2	15-Jun-06	San Francisco Bay	299,600				0	0	0
3.2	16-Jun-06	San Francisco Bay	321,500				0	0	0
3.2	19-Jun-06	San Francisco Bay	225,000				0	0	0

The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases

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ABSTRACT

Fall-run Chinook salmon (*Oncorhynchus tshawytscha)* escapement in the Tuolumne River, Central Valley of California, has declined from 130,000 salmon during the 1940s to less than 500 salmon during the early 1990s and in 2007. The Tuolumne River's naturally produced fall-run Chinook salmon population was judged to be at a high risk of extinction since 1990 because escapement has repeatedly declined to low levels, the population has declined rapidly, and the mean percentage of hatchery fish in the escapement has been high. A potential consequence of the population declining to 157 salmon from 1990 to 1992 and the resulting loss of genetic viability is that the population's productivity declined by about 50% from 1996 to 2005.

The decline in escapement is primarily due to inadequate minimum instream flow releases from La Grange Dam in late winter and spring during the non-flood years. In most years, except spring 2005, the number of smolts migrating from the Tuolumne River has been a good predictor of adult recruitment. The estimated number of smolt-sized outmigrants passing rotary screw traps near the mouth of the Tuolumne River approximately doubled in response to 2- to 3-day, 3,000 cfs pulse flows in late winter that inundated about 500 acres of floodplain habitat. Adult recruitment more than doubled when prolonged late winter pulse flows of at least 3,000 cfs occurred and the water temperatures near the river's mouth were kept below 15^{o}C through at least early May. Another problem is that up to 58% of Merced River Hatchery Chinook salmon strayed to the Sacramento River Basin whenever flows in the San Joaquin River were less than 3,500 cfs for 10 days in late October. Other analyses show that spawner abundance, spawning habitat degradation, and the harvest of adult salmon in the ocean have not caused the decline in escapement.

INTRODUCTION

The escapement of fall-run Chinook salmon (*Oncorhynchus tshawytscha)* population in the Tuolumne River, which is a tributary to the San Joaquin River in the Central Valley of California, has gradually declined from 130,000 salmon during the 1940s to less than 500 salmon during the early 1990s and in 2007 (Fig. 1). Since the 1940s, escapement has been correlated with the mean flow at Modesto (U.S. Geological Survey gauge 1129000) from 1 February through 15 June two years before escapement when the Age 3 salmon were rearing and migrating as juveniles toward the ocean. This correlation suggests that escapement has been primarily determined by the rate of juvenile survival, which is primarily determined by the magnitude and duration of late winter and spring flows since the 1940s.

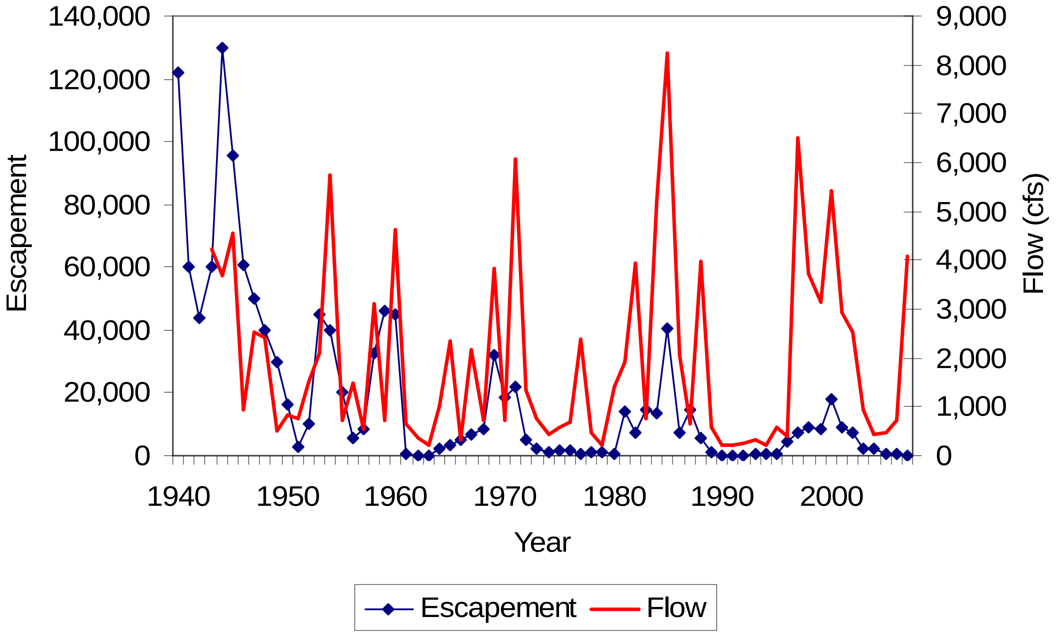

Fig. 1. Tuolumne River fall-run Chinook salmon escapement and mean streamflow in the Tuolumne River at Modesto (DWR gauge data for MOD) from 1 February to 15 March two years prior to the escapement estimate from 1940 to 2007. Escapement estimates from 1952 to 2007 are published in the California Department of Fish and Game GrandTab file available at www.CalFish.org and those from 1940 to 1951 are cited in Fry (1961).

I present evidence below that the decline in escapement is primarily due to the inadequate minimum instream flow releases from La Grange Dam (river kilometer 84.0) during the non flood years. Since the 1940s, escapements have declined to low levels during extended droughts whereas extended flood control releases of at least 3,000 cfs occur during the winter and spring period approximately 30% of the years (Figure 1). The enlargement of Don Pedro Reservoir in 1971 from 290,000 acre-feet to 2,030,000 acre-feet (TIM and MID 2005) reduced the frequency of prolonged late winter and spring flood control releases by a small degree from 28% of the years prior to 1971 to 24% of the years since 1971, because the reservoir is kept full to maximize the certainty of the water supply. The minimum flow requirements under the original Federal Energy Regulatory Commission (FERC) License (Article 37) ranged between 40,123 acre-feet per year in the driest years to 123,210 AF per water year in wet years from 1971 to 1995 (TID and MID 2005), which is about 14% of the unimpaired flows in the Tuolumne River. In 1996, Article 37 was amended and the minimum flow requirements increased to a range of 94,000 acre-feet in the driest years to 300,923 acre-feet during the wet years (TID and MID 2005), which is about 33% of the unimpaired flows. Additional flows were released during the relatively dry years since 1996 during April and May on a temporary basis to study the effects of flow and Delta exports on the survival of tagged juvenile fall-run Chinook salmon released in the lower San Joaquin River near Stockton (SJRGA 2007). I provide evidence below that the Tuolumne River salmon population of naturally produced fish is at a high risk of extinction since 1996 due to the inadequate instream flow releases during the relatively dry water years as required under Article 37.

My risk of extinction analyses are based on the criteria developed by Lindley et al. (2007), who characterized the risk of extinction for Chinook salmon populations in the Sacramento-San Joaquin Basin relative to population size, rates of population decline, catastrophes, and hatchery influence. To estimate the number of naturally produced fall-run Chinook salmon in the lower Tuolumne River from 1981 to 2007, I rely on two analyses. The first analysis, which is described in Mesick et al. (2009a), estimates the rates that hatchery produced Chinook salmon with coded-wire-tags (CWTs) and those that were untagged but released in association with the CWT releases were recovered in the lower Tuolumne River from 1981 to 2007. This period was selected because of the availability of CWT recovery data needed to estimate the number of hatchery fish in the escapement (Mesick et al. 2009a). The second analysis, which is described here, assumes that the untagged Central Valley hatchery produced Chinook salmon that were released during the same month and in the same general location (e.g., tributary, mainstem Sacramento or San Joaquin rivers, or Bay-Delta releases) would return to the Tuolumne River at the same rate as the CWT salmon released during the same month and general location. Finally, I show the relationships between the smolt-sized (>70 mm Fork Length) Chinook salmon that outmigrated from the Tuolumne River, the number of naturally produced adult recruits that survive to Age 2, and the instream flow releases into the lower Tuolumne River from LaGrange Dam to provide evidence that the Chinook salmon population is at risk of extinction due to inadequate instream flow releases.

Lindley et al. (2007) characterized Chinook salmon populations with a high risk of extinction (greater than 20 percent chance of extinction within 20 years) as those with a total escapement that is less than 250 spawners in three consecutive years (mean of 83 fish per year), a precipitous decline in escapement, a catastrophe defined as an order of magnitude decline within one generation occurring within the last 10 years, and a high hatchery influence. Populations with a low risk of extinction (less than 5 percent chance of extinction in 100 years) have a minimum total escapement of 2,500 spawners in three consecutive years (mean of 833 fish per year), no apparent decline in escapement, no catastrophic declines occurring within the last 10 years, and a low hatchery influence. Populations with a moderate risk of extinction are those at intermediate levels to the low and high risk criteria (e.g., total escapement in three consecutive years between 250 and 2,500 spawners. The overall risk for the population is determined by the criterion indicating the highest risk of extinction. These criteria are slight modifications of those used by Allendorf et al. (1997).

METHODS

The methods used to estimate the number of naturally produced adult recruits that survived to Age 2 are described in Mesick et al. (2009b). Described below are the methods used to (1) estimate the number of untagged hatchery produced Chinook salmon releases that returned to the lower Tuolumne River in the adult escapement; (2) estimate the number of smolt-sized Chinook salmon that outmigrated from the Tuolumne River based on rotary screw trap studies, and (3) adjust the estimated number of naturally produced adult recruits to account for fish that strayed to the Sacramento River Basin.

Untagged Hatchery Salmon Estimates

The estimated numbers of unmarked hatchery fish that returned to the Tuolumne River as adult salmon are based on the assumption that the unmarked hatchery fish would have returned to the Tuolumne River at the same rates that the marked hatchery fish returned to the Tuolumne River if they were released during the same month and in the same general location. The number of unmarked fish released from each hatchery was obtained from the CDFG annual reports for the Feather River, Nimbus, Mokelumne River, and Merced River hatcheries. Some of the Merced hatchery release data was obtained from planting release records.

Most of the CWTs recovered as adults in the Tuolumne River (Table 1) were released as juvenile salmon that were produced at the Merced River Hatchery (MRH), Mokelumne River Fish Installation (MRFI), Nimbus Fish Hatchery (NFH), and the Feather River Hatchery (FRH) as described in Mesick et al. (2009). Relative to the number of juveniles released, the highest adult recovery rates in the Tuolumne River escapement occurred for juveniles released in the Delta and Bay and moderate recovery rates occurred for juveniles released in the Sacramento and San Joaquin rivers (Table 1). I define the Delta and Bay region of the Central Valley as the areas where the flow from the Sacramento and San Joaquin rivers mix: downstream from Collinsville on the Sacramento River, New Hope Landing on the Mokelumne River, and Jersey Point on the San Joaquin River. Straying rates of hatchery fish, and thereby recovery of hatchery fish in the Tuolumne River, tend to increase the further that the juvenile salmon are trucked and released downstream toward the Delta and Bay where their natal waters are mixed with flows from other rivers (Mesick et al 2009a).

There were few adults recovered in the Tuolumne River from juvenile releases in the other Central Valley tributaries with the exception of MRH releases in the Merced River (Table 1). Therefore, I assumed that none of the untagged salmon from the FRH, NFH, and MRFI that were released in the other Central Valley tributaries were recovered in the Tuolumne River.

Another factor affecting the recovery rates of hatchery adults in the Tuolumne River was the timing of the juvenile releases. The highest recovery rates occurred from yearling releases in October and November and smolt releases in April and May, and low rates occurred during the other months (Mesick et al. 2009a). The highest recovery rates occurred from yearling releases in October and November for a few comparisons that could be made within the same year, whereas they were many more smolt releases over a variety of water year types and the mean recovery rates occurred for the smolt releases based on the entire dataset (Table 1).

For about half the releases of untagged hatchery juveniles there were releases of CWT juveniles during the same year, month, and general location that I used to estimate the number of untagged recoveries in the Tuolumne River. In these cases, I used the mean monthly-, age-specific CWT recovery rates to estimate the number of untagged salmon in the Tuolumne River escapement when the tagged and untagged fish were released during the same year, month, and general location (tributary, mainstem river, or Bay-Delta). For example, if 0.0033% of the FRH fish with CWTs released in the Bay-Delta in June 1985 returned to spawn in the Tuolumne River as Age 3 salmon in fall 1987, then I assumed that 0.0033% of the untagged FRH salmon released in the Bay-Delta in June 1985 returned to spawn in the Tuolumne River as Age 3 salmon in fall 1987.

There were many instances when no paired releases of tagged and untagged fish were made in the same month and a few cases when there were no CWT releases in the same year. I believe that there are two main factors that affected the number of unmarked hatchery strays that returned to the Tuolumne River: (1) the survival of the planted juveniles, which primarily was affected by the month and location of planting, and (2) the relative amount of flow from the Tuolumne River relative to the San Joaquin River when the adults were returning. Another obvious pattern in the annual variation was that few if any out-of-basin CWTs were recovered in the Tuolumne River from juvenile releases made during the 1987 to 1992 drought when instream flow releases were low (Table 1) and during spring 2005 and 2006, when ocean conditions were unfavorable (Lindley et al. 2009).

I employed a simple empirical approach to estimate recovery rates for the untagged hatchery releases when there were no paired CWT release data. For those cases when there were recovery estimates for at least one month in a year, but not all months when untagged releases were made from the same hatchery and at the same location, I computed the recovery rate for the months without specific CWT data by multiplying the known CWT recovery rate by the ratio of the mean of all years for Age 3 salmon during the month without CWT data divided by the mean for all years for Age 3 salmon during the month with the CWT data. For example in April 1995, CWT FRH juveniles were released in the Delta, but there no CWT Delta releases in May. The recovery rate for Age 2 fish in the Tuolumne from this cohort released in April is 0.00858%. The mean recovery rate of Age 3 fish for April and May releases is 0.0013% and 0.0005%, respectively for the FRH releases in the Delta. The computed recovery rate for Age 2 fish for the May FRH releases is 0.00330% (0.00858% * 5/13).

For the few cases when there were no corresponding CWT releases in the same year, I used three sets of CWT recovery estimates. For the 1987 to 1992 drought years, I used the mean age-specific CWT recovery rates for the drought years (Table 1). For spring 2005 and 2006, I used the mean age-specific CWT recovery rates during spring 2005 and 2006, which were zero, to estimate the recoveries of all unmarked fish released during 2005 and 2006. For all the other years, I used the mean age-specific recovery rates for all years (Table 1).

One particular problem was that there were very few releases of NFH CWT fish that could be used to estimate the recoveries of unmarked NFH fish in the Tuolumne River. Therefore, I assumed that the NFH fish that were planted in the Bay-Delta and Sacramento River would stray to the Tuolumne River at the same rate as the FRH fish as both hatcheries are in the Sacramento River Basin and therefore their fish should have similar homing tendencies. This seems reasonable based on the few available comparisons between the two sets of recovery estimates. For example, the mean recovery rate of Age 3 fish from the FRH releases in the Bay-Delta in May was 0.0005% whereas it was 0.0007% for NFH releases in the Bay-Delta in May (Table 1).

Few CWTs from the Coleman National Fish Hatchery were recovered in the Tuolumne River regardless of where they were planted in the Bay-Delta, Sacramento River, or Battle Creek or when they were planted (Mesick et al. 2009). However, the lack of CNFH recoveries in the Tuolumne River may be an artifact that few CNFH CWTs were released in April and May in the Bay-Delta and Sacramento River during non-drought years when Tuolumne River recoveries would have been expected. A total of 334,359 CNFH CWTs were released in April and May in the Bay-Delta CWTs (1982 to 1986 only) and a total of 610,313 CNFH CWTs were released in the Sacramento River (1981 to 1984 only) during non-drought years (Mesick et al 2009a) and these numbers are quite low compared to the other hatcheries (Table 1). Most CNFH CWT releases in the Bay-Delta and Sacramento River were made in February and March, when survival rates were generally low for pre-smolt juveniles. Nevertheless, in keeping with an empirical approach, it was assumed that no untagged CNFH salmon returned to the Tuolumne River.

There are several sources of potential error associated with my estimates of untagged hatchery fish in the escapement and my estimates should be considered as an index that reflects trends over time. The estimates of hatchery fish with CWTs are relatively accurate for the Tuolumne River, particularly since 1983 when the recovery data were accurately recorded and many carcasses were examined for CWTs (Mesick et al 2009a). Most of the uncertainty associated with the CWT estimates is that some of the juveniles releases were so small that no adults were recovered during the Tuolumne River escapement surveys. It is impossible to determine the true recovery rates in those cases and it is difficult to know the minimum number of juveniles that needed to be released each year to provide accurate results. I believe that my estimates of untagged hatchery fish based on paired releases with CWT fish in the same general location, month, and year are reasonably accurate but there they have a much higher degree of uncertainty because small differences in timing (e.g., early May versus late May juvenile releases) and location (Central Delta versus North Delta releases) can affect the return rates to the Tuolumne River. There are other estimates for which I use CWT rates from different months, years, and/or hatcheries that have high levels of uncertainty. It is highly likely that a complex statistical analysis would show that 95% confidence intervals would be very large compared to the mean values. Nevertheless as I discuss in the Results section, using my estimates of untagged hatchery fish do not change any of my conclusions because my estimates of untagged hatchery fish are near zero when escapements are low (i.e., no effect to minimum population size) and they are rarely a substantial percentage of the high escapements (i.e., little effect on population trends and percentages of hatchery fish).

Smolt-Sized Outmigrant Estimates

One EG Solutions, Inc. rotary screw trap (2.4 m diameter) was fished at Shiloh (river kilometer 5.5) in 1998 whereas two traps were fished side by side at the Grayson site (river kilometer 8.4) from 1999 to 2008 during the majority of the smolt outmigration period from April 1 to at least until May 29 (Palmer and Sonke 2008). In spring 2008, a weir was constructed about 15 meters upstream of the trap to divert more flow and juvenile salmon into the trap (Palmer and Sonke 2008). The California Department of Fish and Game provided the catch data for all years sampled.

Trap capture efficiency tests were conducted in most years by typically marking about 2,000 hatchery juveniles (500 to 3,000) with dye and releasing them at about dusk about 0.4 kilometers upstream of the traps from 1999 to 2004 (Fuller 2005) and about 1.6 kilometers upstream of the trap in 2006 and 2008 (Palmer and Sonke 2008). The tests were repeated over a range of flows and the percentage of the marked fish that were captured in the traps was computed for each release group. The number of efficiency tests with smolt-sized fish conducted each year was 8 tests at Shiloh in 1998 and ranged between 0 to 12 (mean 5.4) tests at the Grayson site from 1999 to 2008 (Palmer and Sonke 2008). The calibration tests conducted in a given year did not always represent the entire flow range that occurred in a given year and there were few if any replicate tests at the same flow. Almost all of the Grayson trap tests had been conducted at flows ≤ 1,500 cfs; whereas there were 3 tests at about 2,000 cfs, 3 tests at about 3,000 cfs, and five tests in 2006 at flows ranging between 4,764 and 7,942 cfs. These flow data were measured at the U.S. Geological Survey gauge 1129000 at Modesto. Another problem is that there was an inadequate number of recaptures from the eight tests in 1998 (mean 2.4 recaptures per test) and five tests in 2006 (mean 2.6 recaptures per test). The CVPIA Comprehensive Assessment and Monitoring Protocol for rotary screw trap studies recommends that a minimum of 20 fish should be recaptured during each test (Anonymous 1997).

I developed efficiency models that I used to estimate the abundance of smolt-sized fish ($\geq$ 70 mm fork length) for the Shiloh trap with the 1998 data (Fig. 2) and for the Grayson traps with the combined 1998 to 2001, 2003, 2004, and 2006 data (Fig. 3) using multiple linear regressions. The results of the trap efficiency tests for spring 2002 were not used to generate the model of smolt-sized fish for the Grayson trap, because the efficiencies were abnormally low compared to all the other years, which suggests a temporary abnormality in the test procedure. I did not use the spring 2008 efficiency data because the weir used to improve capture efficiencies in 2008 was not used in previous years. The percentage of marked fish recaptured was regressed against the natural log (Ln) of flow at Modesto and the mean fork length (FL) of the release group. I conducted a second regression model to generate adjusted-R^2 and probably values by transforming the efficiency percentages into their natural logs. However, these values do not fully reflect the high level of uncertainty for smolt abundance estimates at flows greater than about 3,000 cfs (spring 1998, 2005, and 2006 estimates) due to the relatively low number of tests, the low number of recaptures per test, and the low efficiencies. For example, although the recovery rates at the 2006 high flows were relatively consistent ranging between 0 and 0.42% (mean 0.21%), a potential error of 0.1% could result in a 50% change in the estimated smolt abundance. The calibration models are as follows:

Shiloh Trap Efficiency Model, 1998

% Juveniles Captured = -0.00106*LN (Modesto Flow cfs))-(0.00008773*FL) + 0.01733; low efficiency values were truncated at 0.0005. The adj-R^2 for this model for natural log transformed efficiency estimates is 0.33 and $P = 0.1602$.

Grayson Trap Efficiency Model For Smolts, 1999-2007

% Juveniles $\geq$ 70 mm FL Captured = -0.02190*LN (Modesto Flow cfs)) - (0.0004120*FL) + 0.22453; low efficiency values were truncated at 0.002. The adj-R^2 for this model for natural log transformed efficiency estimates is 0.35 and $P = 0.0000$.

Adjustments For Sampling Periods

Three adjustments were made to the juvenile abundance estimates. The 1998 estimates were multiplied by 7/5 because weekends were not sampled. The traps were operated 7 days a week during all the other years. Two other adjustments were necessary because rotary screw trapping did not span the entire smolt outmigration period, which typically is March 20 to June 15 based on years when the Grayson and Shiloh rotary screw trap studies encompassed the entire period. Sampling did not begin until early April during 2003 to 2005 whereas sampling ceased in late May or early June in most other years. I standardized the periods for all studies to March 20 to June 15 by assuming that the abundance estimates per day for the unsampled days would have been the same as the estimated mean abundance per day at the beginning or the end of the sampling period. For 2003 to 2005, when sampling began on April 1 or 2, I multiplied the mean abundance estimate per day for each day sampled through April 10 times the number of unsampled

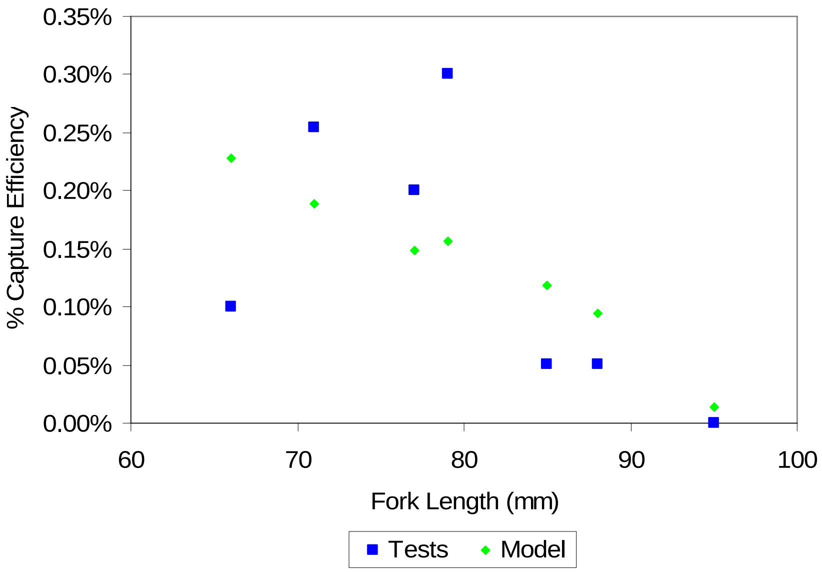

Fig. 2. Trap capture efficiency estimates (Tests) based on the percentage of marked releases of smolt-sized fish that were captured in the single rotary screw trap at Shiloh in the Tuolumne River (rkm 5.5) in spring 1998 relative to their mean fork length of all fish released and efficiency model predictions (Model) based on a multiple regression model of the capture efficiencies relative to the natural log of Modesto flows and the mean fork length of the juvenile salmon at release.

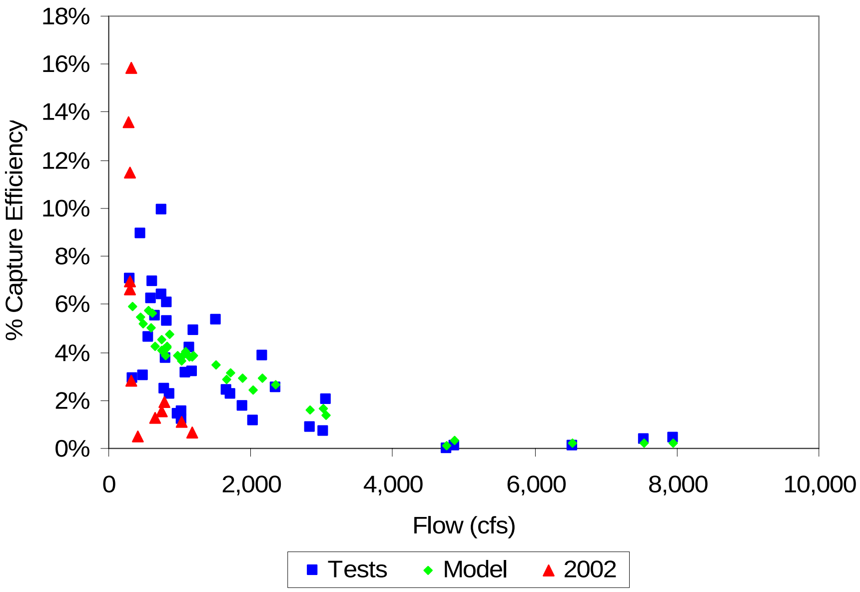

Fig. 3. Trap capture efficiency estimates (Tests) based on the percentage of marked releases of smolt-sized fish (> 65 mm fork length) that were captured in the paired rotary screw traps at Grayson in the Tuolumne River (rkm 8.4) during 1999-2001 and 2003-2005 relative to the mean streamflow at Modesto and efficiency model predictions (Model) based on a multiple regression model of the capture efficiencies relative to the natural log of Modesto flows and the mean fork length of the juvenile salmon at release. The 2002 estimates were omitted from the model because they were abnormally low compared to all other years.

days from March 20. For the other years when sampling ceased before June 15, I multiplied the mean abundance estimates per day for each day sampled for the last few days when catch rates were relatively consistent times the number of unsampled days. Table 2 presents the data used to compute these adjustments.

Recruitment Estimates Adjusted For Straying

I estimate the percentage of the adult MRH fall-run Chinook salmon with CWTs that were recovered in the Sacramento River Basin relative to the total number recovered in all Central Valley river during the fall-run Chinook salmon escapement surveys from 1979 to 2007 (Mesick et al. 2009a). The estimated stray rates are presented in Table 3.

The analyses of risk assessment are based on the number of spawners in the escapement. However, assessments of the effects of instream flow and other environmental factors on the Tuolumne River escapement are best made with estimates of either juvenile production or adult recruitment that are not affected by ocean harvest, which varies substantially over time (see Results). To focus my assessments on the effects of late winter and spring flows on juvenile survival and not include the effects of fall pulse flows on adult straying, I adjusted my recruitment estimates to compensate for the number that strayed to the Sacramento River Basin when fall pulse flows were inadequate. This adjustment had substantial effects on the recruitment estimates in some years as the estimated straying rates varied from near zero to up to 58% (see Results).

I adjusted the recruitment estimates to reflect normal stray rates that are no higher than 6% annually should adequate fall pulse flow releases occur every year. I made these adjustments by computing the difference between the observed CWT stray rate (Table 3) and a 6% stray rate and then multiplying the difference plus 1 times the escapement to compute a low-stray adjusted escapement estimate (Table 3). I computed a low-stray adjusted recruitment estimate (Table 3) using the low-stray adjusted escapement estimates according to the methods described in Mesick et al. (2009b).

RESULTS

The results are presented in two sections. The first pertains to the risk of extinction analysis. The second pertains to an analysis of the environmental factors that control salmon recruitment for the Tuolumne River.

Risk Of Extinction Analysis

The Tuolumne River fall-run Chinook salmon population is at a high risk of extinction based on the criteria by Lindley et al. (2007) because the total escapement of naturally produced fish was estimated to be 1,232 spawners from 2006 to 2008 (i.e., moderate risk), there was a precipitous decline in escapement (i.e., high risk), there was a catastrophic decline in escapement over a generation between 2000 and 2006 (i.e., high risk), and the mean percentage of hatchery fish in the escapement was 19.2% since 1998 (i.e., high risk). The overall risk for the population is determined by the criterion indicating the highest risk of extinction (Lindley, Fishery Biologist, National Marine Fisheries Service, personal communication). My analyses are based on estimates of the number of naturally produced and hatchery produced adult fall-run Chinook salmon that have returned to the Tuolumne River between 1981 and 2007 (Table 4).

Effective Population Size

The effective population size criteria relates to the loss of genetic diversity (Lindley et al. 2007). The effective population consists of individuals that are reproductively successful, including grilse (Allendorf et al. 1997). In Chinook salmon populations, not all individuals are reproductively successful and the mean ratio of the effective population size to total escapement over a three year period (N_e/N) has been estimated to be 0.20 based on spawner-recruit evaluations of over 100 salmon populations from California to British Columbia (Waples et al. 2004 as cited in Lindley et al. 2007). A few examples of why adult salmon may not reproduce successfully in the Tuolumne River include: (1) redd superimposition that destroys eggs; (2) spawning in habitats with excessive levels of fines; and (3) low survival rates for juveniles that migrate late when high water temperatures in the lower Tuolumne River are unsuitable for survival. Therefore based on effective population size (Ne), the Tuolumne River could be considered to be at high risk if annual escapement (N) drops below a mean of 83 fish for three consecutive years and at low risk if escapement remains above a mean of 833 fish for three consecutive years.

Since the Federal Energy Regulatory Commission license for the Don Pedro Project was amended in 1996 to improve minimum instream flows in the lower Tuolumne River and the minimum flow allocation was 94,000 acre-feet per water year, the number of naturally produced Chinook salmon in the escapement declined to a low of 1,409 between 2005 and 2007 (Table 4). A total of 1,409 salmon is within the range of 250 to 2,500 for the moderate risk of extinction criterion of Lindley et al. (2007). If one assumes that there were no untagged hatchery salmon in the 2008 escapement, then the total declines to 1,232 for the 2006 to 2008 period (Table 4). This total would be lower than 1,232 if there were untagged hatchery salmon in the 2008 escapement. Furthermore, it is highly likely that the number of naturally produced adults that return in the Tuolumne River escapement will continue to decline in fall 2009, because the estimate of smolt-sized Chinook salmon that outmigrated from the Tuolumne River was unusually low in spring 2007 and 2008, 937 and 2,351 respectively (Palmer and Sonke 2008), which is a small fraction of the 351,943 and 97,424 smolt outmigrants in 2005 and 2006, respectively, that produced the 2007 and 2008 escapements.

Prior to the 1996 improvement in minimum instream flow requirements, when the minimum flow allocation was 40,123 acre-feet per water year, the natural escapement dropped to a low of 157 adult salmon between 1990 and 1992 (Table 4). Allendorf et al. (1977) concluded that the Tuolumne River fall-run Chinook salmon population was at a high risk of extinction prior to 1996 based on the effective population size and population decline criteria described by Lindley et al. (1997). However, the 1996 minimum instream flow requirements increased the minimum Tuolumne River fall-run Chinook salmon escapements from a level indicating high risk to a level indicating a moderate risk of extinction based on Lindley et al.'s (2007) population size criterion alone.

Population Decline

Another serious threat to the viability of natural salmonid populations identified by Lindley et al. (2007) is a precipitous decline in escapement, which has occurred on the Tuolumne River. Lindley et al. (2007) define a precipitous decline as a decline within the last two generations (6 years) to an annual run size of 500 spawners or fewer or a run size greater than 500 spawners but declining at a rate of at least 10% per year. Lindley et al. (2007) recommend that the population decline rate should be computed as the slope of the log of the escapement versus time multiplied by 100 over a ten year period.

The escapement of natural spawners in the Tuolumne River meets both of these criteria. First, the natural escapement declined to fewer than 500 spawners in fall 2007 and 2008 (Table 4). Second, the population declined at an average rate of 19.2% per year from 1999 to 2008 (Fig. 4).

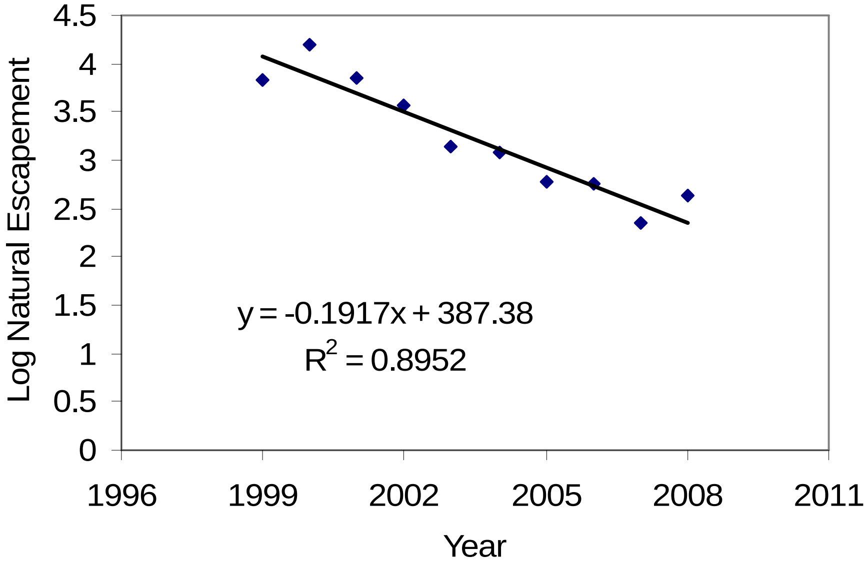

Fig. 4. The log of the natural escapement of fall-run Chinook salmon in the Tuolumne River from 1999 to 2008. The slope of the regression indicates that the population decline was 19.2% per year.

Catastrophe

Catastrophes are defined by Lindley et al. (2007) as instantaneous declines in population size due to events that occur randomly in time that reflect a sudden shift from a low risk state to a higher one. They view catastrophes as singular events with an identifiable cause and only negative immediate consequences, as opposed to normal environmental variation which can produce very good as well as very bad conditions. Some examples of catastrophes include disease outbreaks, toxic spills, or volcanic eruptions. A high risk situation is created by an order of magnitude (90%) decline in population size over one generation. The Tuolumne River natural escapement declined by about 87% when the 2000-2002 generation declined from a total of 26,626 fish to a total 3,214 fish for the 2003-2005 generation. The likely cause of this decline is the extended drought conditions and low instream flow releases in the Tuolumne River from 2001 to 2004, which probably resulted in high juvenile mortality rates (see Smolt Outmigrant Production section below).

Hatchery Influence

Since 1996 when the increased Tuolumne River minimum instream flows began, the mean percentage of hatchery fish in the Tuolumne River escapement is estimated to be 21.3% (range 1.3% to 48.3%, Table 4). Although most of the hatchery fish in the Tuolumne River escapement were produced at the Merced River Hatchery, which is within the same diversity group as the Tuolumne River, and the Merced River Hatchery primarily provides small numbers of study fish and so generally follows "best management practices", the percentages of estimated hatchery fish in the Tuolumne River escapement exceed the Lindley et al. (2007) high risk criterion of less than 10% (3 generations) to 15% (1 to 2 generations) hatchery fish.

Potential Consequence of Reduced Genetic Diversity

A potential consequence of the Tuolumne River effective population declining to 157 salmon from 1990 to 1992 and the resulting loss of genetic viability is that the population's productivity declined by about 50% from 1996 to 2005 (Fig. 5) even though higher minimum instream flows were instituted, a barrier was installed at the head of the Old River in 1997 and 2000 to 2004 to improve smolt survival in the San Joaquin River Delta (SJRGA 2007), export rates at the Federal and State pumping facilities were reduced during the primary smolt migration period (SJRGA 2007), and habitat restoration, including spawning gravel augmentation, floodplain restoration, and predator pond isolation projects had been completed in the Tuolumne River (TID and MID 2005).

The methods used to estimate recruitment, which is the number of adult salmon that survived to Age 2, are described in Mesick et al. (2009b) using the natural escapement estimates in Table 4. The statistical tests of significance included Robust Inference and a Permutation Test conducted by Dr. Alan Hubbard[i]. He used these tests because they avoid the potential problem of autocorrelation in population trend analyses that would violate an assumption of correlation analyses. Dr. Hubbard's analysis indicates that the slopes of the regressions between the two data sets shown in Fig. 5 are marginally significantly different ($P = 0.01$ for the Robust Inference test and $P = 0.08$ for the Permutation Test). There were no significant differences in the intercepts for the two regressions. It is likely that the statistical significance of the difference between the slopes for the two time periods would increase ($P < 0.05$ for both tests), if the statistical models could include the effects of spawner abundance and poor ocean conditions in 2005. However, there were too few estimates to include these variables in the tests.

Although there are no data to show that the population's productivity rate was directly affected by a loss of genetic viability, the likelihood that the Tuolumne River population was heavily repopulated with hatchery fish (Table 4) strongly suggests a causal link between genetic viability and population productivity. In 1993, of the total escapement of 471 salmon, 44% were naturally produced, 15% were San Joaquin River Basin Hatchery fish, and 41% were Sacramento River Basin hatchery fish (methods described in Mesick et al 2009a).

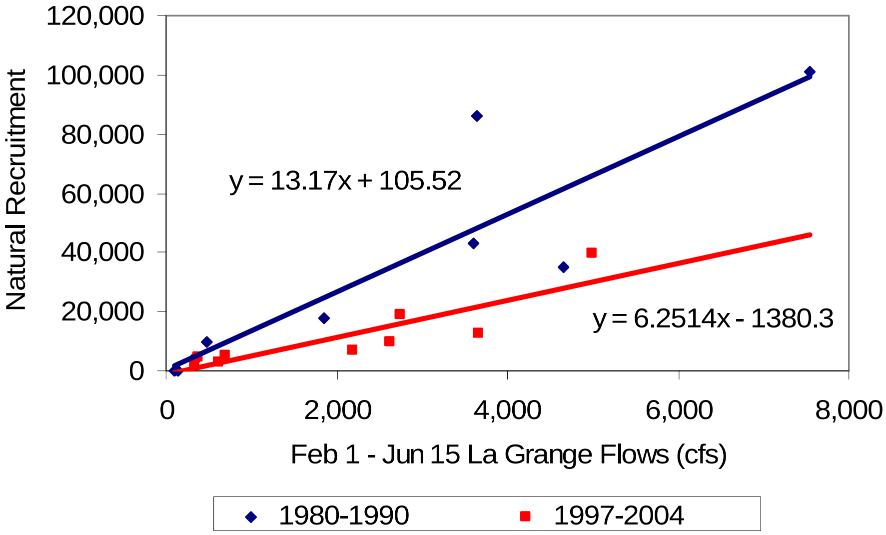

Fig. 5. Tuolumne River natural fall-run Chinook salmon recruitment plotted with mean flow in the Tuolumne River from the La Grange Dam (rkm 84) during February 1 through June 15 during two periods: 1980 to 1990 (pre-FSA) and from 1997 to 2004 (post-FSA). Recruitment is the number of adults in the escapement and ocean harvest (including shaker mortality) that belong to individual cohorts of same-aged fish (Mesick et al. 2009b). Estimates were excluded for which spawner abundance was less than 650 Age 3 equivalent fish to minimize the effect of spawner abundance on the relationship between flow and recruitment.

Environmental Factors That Affect Salmon Recruitment

I provide evidence that the production of Tuolumne River salmon is primarily determined by the instream flow releases from La Grange Dam as they affect juvenile survival in the Tuolumne River and provide attraction flows for migrating adult salmon to navigate back to the Tuolumne River. The salmon population is also affected by conditions that affect salmon survival in the San Joaquin Delta and the ocean, although these effects are relatively small or infrequent compared to the importance of instream flow releases. The following describes the factors that affect salmon escapement and/or recruitment relative to adult upstream migration, spawner abundance, spawning habitat and fry production, juvenile survival in the Tuolumne River, Delta, and ocean, and the harvest of adult salmon in the ocean.

Adult Upstream Migration

Up to 58% of the adult MRH fall-run Chinook salmon with CWTs that were recovered in Central Valley rivers during the fall-run Chinook salmon escapement surveys from 1979 to 2007 (Mesick et al. 2009a) strayed to the Sacramento River Basin when the 10-day mean flow in the San Joaquin River at Vernalis in late October was less than 3,500 cfs; whereas stray rates were less than 6% when flows were at least 3,500 cfs (Fig. 6). From 1996 to 2006, the mean stray rate was 14.6% (range 0% in 2006 to 43.5% in 1999). Adult salmon home to their natal streams in part by following olfactory cues from their natal stream (Quinn 2005) and presumably 1,200 cfs from each of the three San Joaquin River tributaries, including the Tuolumne River, is needed for at least a 10-day period in mid to late October for the salmon to home successfully. If these flows are provided, the stray rates should decrease from the existing mean of 14.6% to a mean of about 5%, and thereby increase Tuolumne River escapement by an average of 10%.

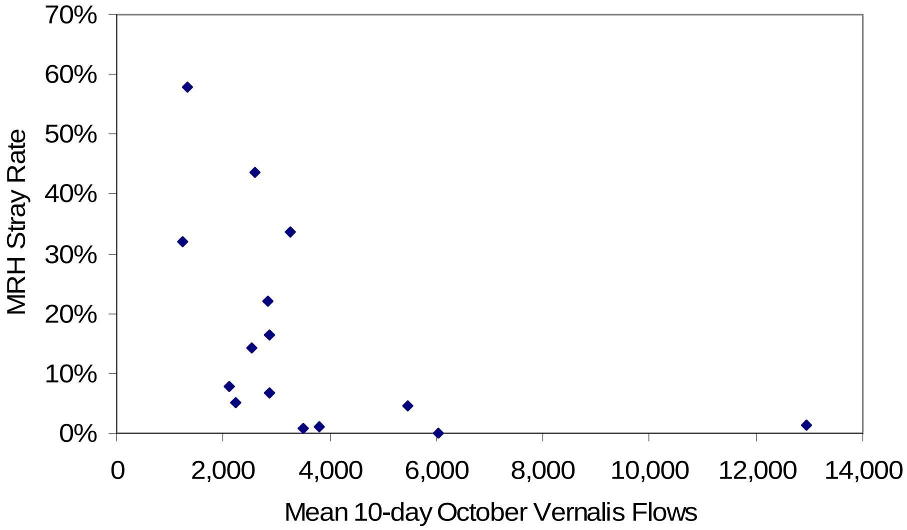

Fig. 6. The percentage of Merced River Hatchery fall-run Chinook salmon with CWTs (Mesick et al. 2009a) that were released in the San Joaquin River Basin upstream from Jersey Point as juveniles and then recovered as adults in the Sacramento River Basin relative to the adult recoveries in the Central Valley from 1983 to 1988 and from 1995 to 2003. Estimates for 1989 to 1994 were not used because there were fewer than a total of 1,000 CWTs in all Central Valley rivers during these years and so there was a high degree of uncertainty in the stray rate estimates. The mean Vernalis flows (USGS gauge 11303500) were computed for the 10-day period in mid to late October with the highest flows.

Spawner Abundance

Spawner abundance can affect juvenile salmon production in two ways. First, too few spawners results in low production of juveniles due to a lack of eggs. On the other hand, the limited availability of spawning habitat in the Tuolumne River could result in high rates of redd superimposition rates at high spawner abundances that could result in the mortality of the eggs of early spawners when late spawners dig up their redds. Most spawning in the Tuolumne River occurs in the upper 8 kilometers below La Grange Dam and extensive redd superimposition occurs in this area (TID and MID 2005).

My results suggest that adult recruitment is affected to only a slight degree by spawner abundance ranging between 434 and 39,347 Age 3 equivalent spawners based on a model that holds the effects of flow constant (Fig. 7). The relationship is primarily driven by the data associated with low flow (non flood control) releases that probably constrain the amount of habitat for juvenile salmon. Therefore, I conclude that during managed flow releases, the rearing habitat in the Tuolumne River can support the progeny of no more than about 434 adults and that redd superimposition has had no detectable effect on recruitment.

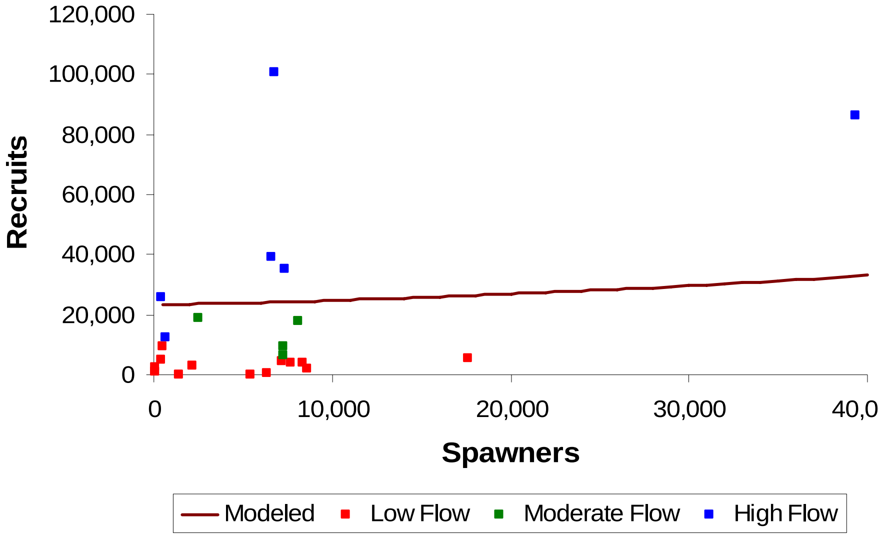

Fig. 7. The relationship between the number of natural recruits to the number of Age 3 equivalent spawners in the Tuolumne River from 1981 to 2004 segregated by low flows (<1,000 cfs) at La Grange Dam from 1 February to 15 June, moderate flows (1,000 to 2,999 cfs), and high flows (3,000 cfs to 7,540 cfs). The modeled relationship, which holds flow constant at 3,000 cfs, is based on multiple linear regression analysis between recruitment, the mean flow at La Grange Dam and quadratic terms for the number of Age 3 equivalent spawners including both hatchery and natural adults. The methods used to estimate natural recruitment and Age 3 spawner abundance are described in (Mesick et al. 2009b).

Spawning Habitat And Fry Production

Although the spawning habitat in the Tuolumne River has been extensively degraded, the production of fry is sufficient to saturate the rearing habitat in the lower Tuolumne River. The spawning habitat has been degraded by extensive in-river gold dredging and gravel mining during the first half of the 1900s, blocked gravel recruitment by the upstream dams, and 60,000 cfs flood control releases in January 1997 that washed away several key spawning beds and deposited tons of fine sediment in the remaining spawning beds (TID and MID 2005).

In spite of the degraded spawning habitat conditions, rotary screw trap studies conducted about 22 kilometers downstream from La Grange Dam in 1999 and 2000 indicated that the juvenile production was estimated to be at least 7,297,177 and 3,481,884 fish, respectively. Relative to the number of Age 3 equivalent spawners, the number of fry produced per spawner was 1,007 and 480 in 1999 and 2000, respectively, which indicates that 17% and 8% of the total number of eggs likely deposited in redds survived to a juvenile stage (fry, parr, and smolts) that began migrating into the lower river during 1999 and 2000, respectively. These estimates are relatively accurate for the period sampled because an adequate number (12-15) of trap efficiency tests were conducted that include tests with both fry and smolts at flows between 320 cfs and about 5,000 cfs (Vick et al. 2000, Hume et al. 2001). However, the actual number of juveniles produced would probably have been higher if sampling had begun in late December when fry begin migrating rather than on 19 January and 10 January for the 1999 and 2000 studies, respectively. It is likely that these numbers of juvenile produced far exceeded the capacity of the rearing habitat, because only 0.4% of these fish in 1999 and 1.4% of these fish in 2000 survived to a smolt-size at the downstream Tuolumne River trap at Grayson. The mean flows in 1999 and 2000 from 1 Mar to 15 June were slightly greater than 2,000 cfs, which is well above the minimum release requirements, and so juvenile survival rates would be expected to be even lower during minimum instream flow releases. These low juvenile survival rates provide strong evidence that the poor quality of the rearing habitat and the infrequent floodplain inundation is a substantial limiting factor for the Tuolumne River salmon population.

From 1999 to 2003, approximately 19,250 cubic yards of gravel was used to reconstruct spawning beds in the area near the La Grange Dam (TID and MID 2005). Although the reconstructed sites have not been highly used by Chinook salmon spawners compared to the pre-1997 conditions, it is unlikely that spawning conditions would have degraded further since 1997.

Juvenile Survival in the Tuolumne River

The survival of juvenile fall-run Chinook salmon that migrate from the Tuolumne River into the San Joaquin River and Delta is thought to be relatively low for fry and parr that must rear for a prolonged period before completing their migration to the ocean compared to the relatively high survival rates for smolt-sized juveniles. The mean recovery rates in the escapement for Coleman National Fish Hatchery (CNFH) fall-run Chinook salmon with CWTs that were released in the Sacramento River range between 0.29% to 0.45% for releases in January through April whereas the mean recovery rate is 1.98% for May releases, when the size of the CNFH juveniles is comparable to the size of the Tuolumne River smolts (methods described in Mesick et al. 2009a). The survival of fry and parr sized juveniles is low during dry and normal water years in the Central Delta, where the Tuolumne River smolts migrate, compared to the North Delta based on ocean recovery rates of CNFH fry with CWTs (Brandes and McLain 2001). The low survival rates of juveniles rearing in the Delta in dry and normal water years may be caused by a combination of factors such as predation, entrainment at numerous small, unscreened diversions, unsuitable water quality, high water temperatures, disease, and direct mortality at the state and federal pumping facilities in the Delta.

The number of smolt-sized outmigrants passing the Grayson rotary screw traps near the mouth of the Tuolumne River is highly correlated (adj-$R^2 = 0.93$, $P = 0.001$) with flow releases at the La Grange Dam from February 1 to June 15 from 1998 to 2005 (Fig. 8). This suggests that prolonged late winter and spring flows in the Tuolumne River are an important factor determining the survival rate of fry to the smolt-size of at least 70 mm fork length and that flows in excess of 3,000 cfs during fry rearing are important to their survival.

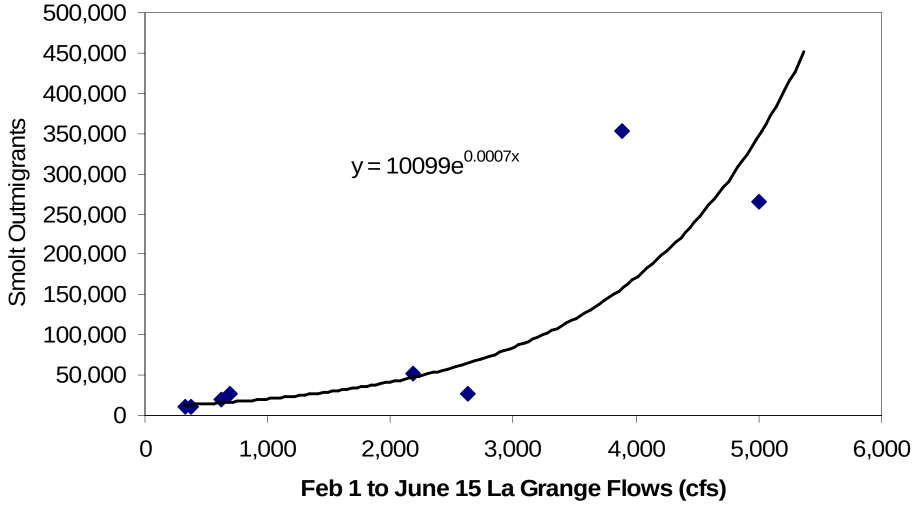

Fig. 8. The Number of smolt-sized Chinook salmon outmigrants (FL > 70 mm) passing the Grayson rotary screw trap site (rkm 8.4) plotted with flows at La Grange between March 1 and June 15 in the Tuolumne River from 1998 to 2005. The abundance of Age 3 equivalent spawners ranged from 1,645 in fall 2004 to 17,646 in fall 2000. The regression model has an R^2 of 0.93 and a probability level of 0.001. The spring 2006 estimates were omitted because the number of Age 3 equivalent spawners in fall 2005 was only 447 adults, which limited smolt production unlike the other years when flows were the primary determinant.

In most years, the number of smolt outmigrants from the Tuolumne River has been a good predictor of adult recruitment. The relationship between Tuolumne River adult recruitment and spring flows from 1996 to 2005 (Fig. 9) is nearly identical to the relationship between smolt outmigrants and flows, except that there was a high mortality rate for the smolts in the ocean during spring 2005 that resulted in low adult recruitment.

It is likely that the survival of fry to a smolt-size in the Tuolumne River is dependent on prolonged flood control releases greater than 3,000 cfs because these releases result in the inundation of a substantial amount of floodplain habitat. Floodplain inundation between the La Grange Dam (rkm 84) and the Santa Fe Bridge (rkm 34) begins at a flow somewhere between 1,100 cfs and 3,100 cfs, when approximately 513 acres of overbank area become inundated (USFWS 2008). Floodplain inundation increases from 513 acres at 3,100 cfs to 823 acres at 5,300 cfs (USFWS 2008).

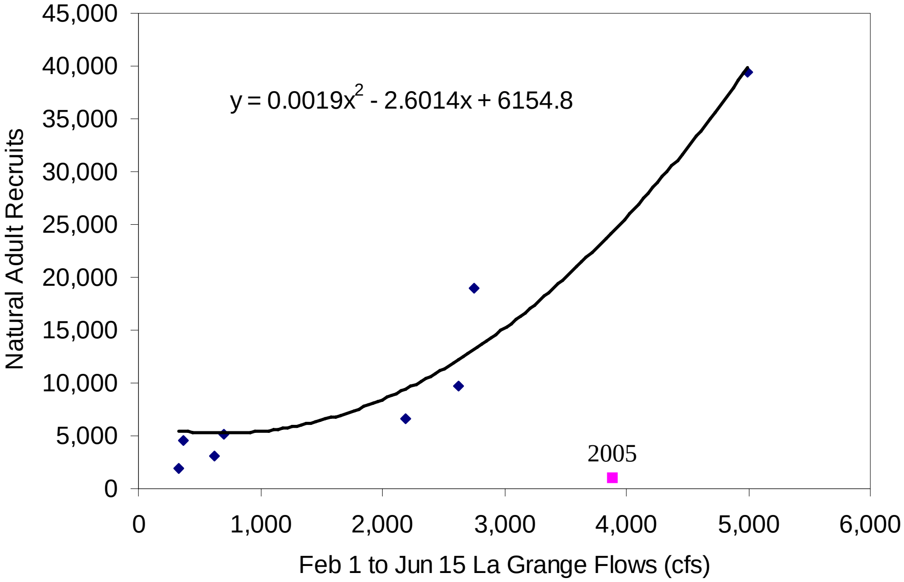

Fig. 9. The number of natural adult recruits relative to the average flow release from La Grange Dam from February 1 through June 15 when the cohorts migrated as juveniles toward the ocean from 1997 to 2005, when Age 3 equivalent spawner abundance was at least 1,007 fish. The quadratic equation computed by Excel is presented for the relationship for the estimates from 1997 to 2004.

Several recent studies document the importance of floodplain habitat to juvenile Chinook salmon in the Central Valley. Survival and growth rates of juvenile salmon were higher in inundated floodplain habitats in the Sacramento River's Yolo Bypass (Sommer et al. 2001) and Cosumnes River (Moyle 2000) than in the main channel. There is also extensive use of the seasonally inundated wetlands in the Sutter Bypass in lower Butte Creek by spring-run Chinook salmon fry that grow rapidly and outmigrate as smolts earlier than the juveniles that rear in the main creek channel (Ward and McReynolds 2001, Ward et al. 2002).

It is likely that the Tuolumne River floodplains improve juvenile survival when inundated by a combination of factors such as improved food availability, refuge from predators, and increased water temperatures in February and March that increase juvenile salmon growth rates. Floodplain inundation, particularly the ascending and descending limbs of the hydrograph, often provides most of the organic matter that drives aquatic food webs in rivers (Allan 1995) and aquatic productivity is related to area inundated in some rivers (Large and Petts 1996). Water temperatures were higher in the inundated floodplain habitats in the Yolo Bypass than in the main channel and the higher temperatures and the abundant food resources resulted in rapid growth rates (Sommer et al. 2001). It is also likely that inundated floodplains provide refuge for juvenile salmon from the abundant predatory fish in the Tuolumne River, which include largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), Sacramento pikeminnow (*Ptychocheilus grandis*), and striped bass (*Morone saxatilis*), although this has not been verified by studies.

Timing of Late Winter Floodplain Inundation – Since 1996, the management of instream flow releases from La Grange Dam has focused on pulse flows that began in mid to late April of at least 1,100 cfs for about 10 days to improve smolt survival. However, it is likely that late winter base flows usually less than 350 cfs during dry years resulted in high rates of juvenile mortality before the pulse flows were initiated, and therefore, there has been no substantial increase in the production of smolt outmigrants or adult recruitment since 1996.

Floodplain inundation must occur in February and/or March to improve the survival of fry to a smolt-size and to increase their growth rates so that they begin smoltification and their migration toward the ocean in early spring when water temperatures are most suitable for their survival. The smolting process is metabolically demanding and juveniles release hormones, including cortisol that inhibits their immune system, making smolts more vulnerable to disease and other stress (Quinn 2005). The upper water temperature threshold for the smoltification process that has been recommended by the EPA (2003) is 15^{o}C.

When flood control releases averaged almost 5,000 cfs from 1 February to 15 June in the Tuolumne River in 1998, the smolts migrated from the river from mid March through at least mid June (Fig. 10). However, the required instream flow releases are inadequate to maintain water temperatures below the 15-degree threshold when smolts are migrating, except in mid March or when pulse flows of 1,200 to 1,400 cfs are made in mid to late April (Fig. 11). The mean daily water temperatures at Modesto (river kilometer 23.5) typically exceed the 15-degree threshold for smolts in early April and May during base flow releases (< 350 cfs) but usually decline to less than 15 degrees when pulse flows of at least 1,000 cfs are made in mid to late April (Fig. 11). However from mid May to mid June, flows may need to be increased to 5,000 cfs to maintain the 15-degree threshold near the mouth of the Tuolumne River based on the HEC5Q Water Temperature Model developed for the CalFed Ecosystem Restoration Program.

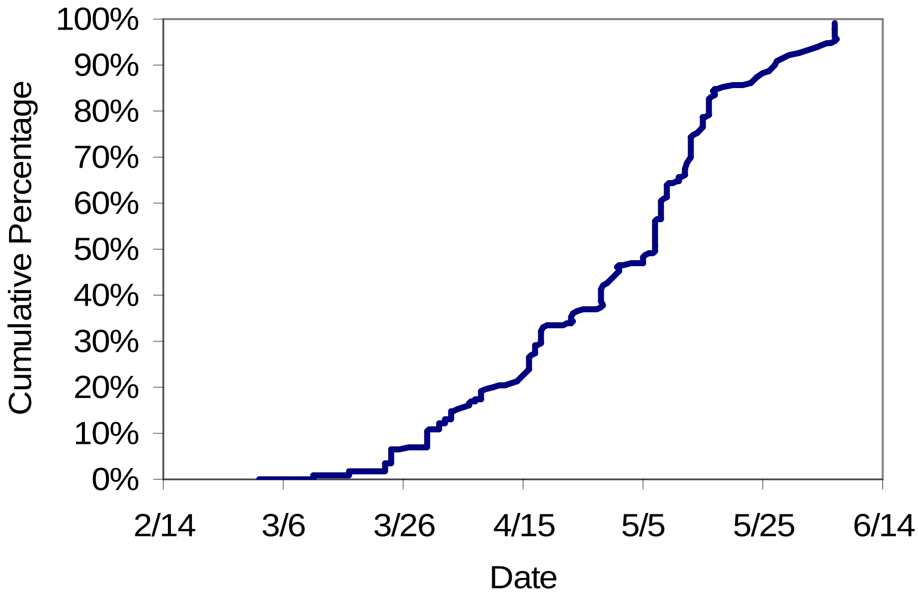

Fig. 10. Cumulative percentage of the number of smolt-sized (> 70 mm fork length) outmigrants passing the Grayson rotary screw trap in 1998, when trapping ceased on 6 June at a smolt passage rate of 2,800 (1.5%) per day.

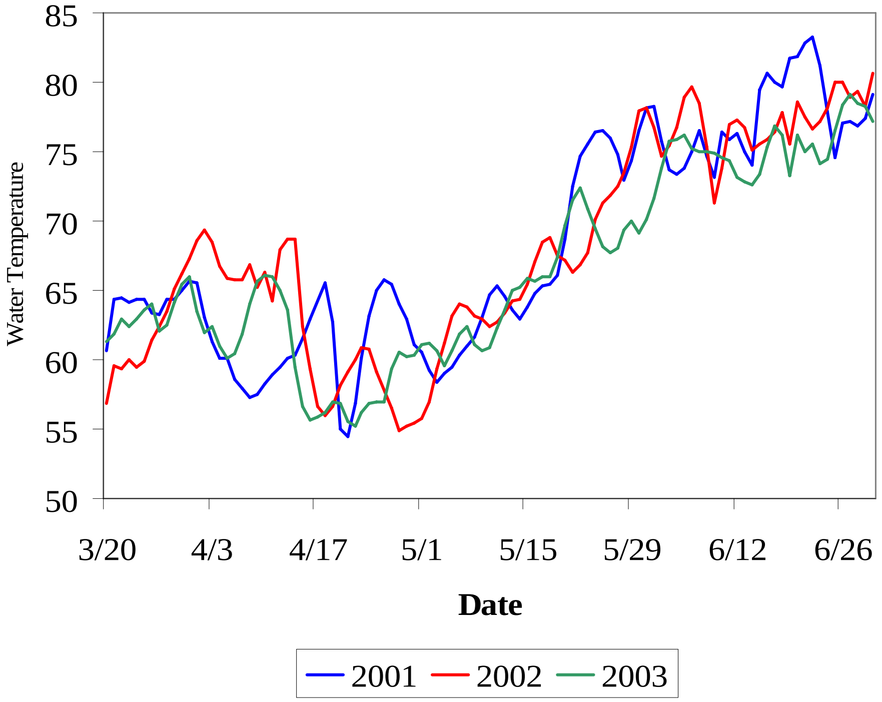

Fig. 11. The mean daily water temperature in the Tuolumne River near Modesto (river kilometer 23.5) during 2001 to 2003. Temperature estimates are provided by the California Department of Water Resources at the online Data Exchange Center. Pulse flows of at least 1,000 cfs were made from 24 April to 8 May 2001, 24 April to 1 May 2002, and 14 to 22 April 2003. The Modesto temperature gage did not function in spring 2004.

Empirical evidence that pulse flows of at least 3,000 cfs that inundate the floodplain habitats during February and March increase fry survival is based on rotary screw trap studies conducted near the mouth of the Tuolumne River from 1999 to 2004. Even brief pulse flows doubled fry survival based on a comparison of the estimated abundance of smolt-sized juvenile salmon leaving the river in 2001 to 2004. During 2002 and 2003, when there were no late winter pulse flows (Fig. 12), the estimated number of smolt-sized juveniles that migrated from the Tuolumne River was 10,095 and 10,305, respectively. During 2001 and 2004, when there were 2- to 3-day winter pulse flows of about 3,000 cfs (Fig. 12), the estimated number of smolts migrating from the river increased to 26,370 in 2001 and 20,330 in 2004 During all four years, there were 8- to 10-day flows of 1,200 to 1,400 cfs in late April or early May (Fig. 12).

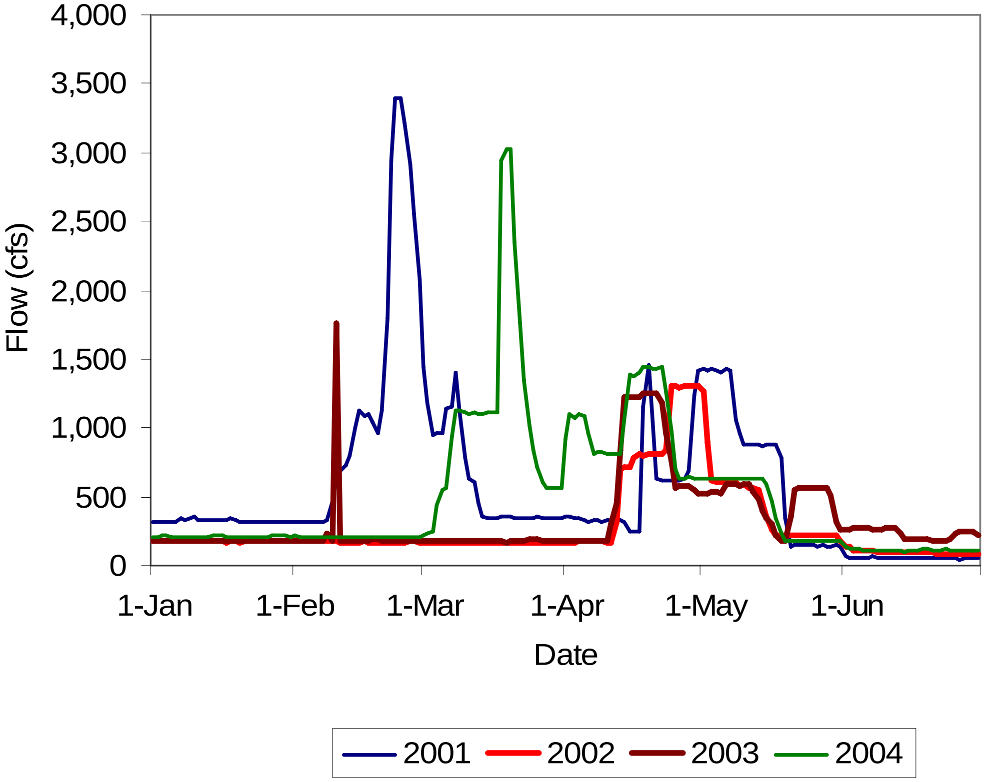

Fig. 12. Flows measured in the Tuolumne River at La Grange from 1 January to 30 June in 2001 to 2004. Two- to 3-day pulse flows occurred in late winter only in 2001 and 2004 whereas there were 8- to 10 day, 1,200 to 1,400 cfs pulse flows in mid to late April during all 4 years.

The other important benefit of the brief pulse flow releases is that the smolts migrated earlier in 2001 and 2004 when the pulse flows were made than in 2002 and 2003 when there were no pulse flows. The mean number of smolts passing the Grayson rotary screw traps in early April is 495 smolts per day (498 to 491) in 2001 and 2004, when the brief late winter pulse flows occurred, and 26 smolts per day (22 to 29) in 2002 and 2003, where there were no late winter pulses (Table 2). The cumulative percentage of smolts caught at the Grayson trap site by 15 April was also higher during 2001 when the late winter pulses were made compared to 2002: 41.2% in 2001 and 8.4% in 2002; the rotary screw trap studies were started too late to provide accurate estimates for 2003 and 2004. This suggests that brief late winter pulse flows improve growth rates and thereby accelerate the smoltification process, which should lead to increased smolt survival rates through the lower Tuolumne River and Delta.

The evidence for the benefits of high late winter flows that inundate floodplain habitats is clearer for the Stanislaus River, where there are additional rotary screw trap estimates of the number of salmon juveniles produced in the spawning reach upstream of Oakdale (river kilometer 64.7) as well as rotary screw trap estimates of the number that survived to a smolt size and migrated from the river at Caswell state park (river kilometer 13.8) for a variety of flow releases. The Stanislaus River studies are appropriate to discuss here because the salmon are also strongly affected by late winter and spring pulse flows, the river is less than 16 kilometers to the north of the Tuolumne River, and both rivers have been extensively degraded by in-river gravel and gold mining and agricultural use of floodplain habitats. The estimates for spring 2000 indicate that when the flows at Ripon exceeded 3,000 cfs in late February and early March, 74% of the juvenile salmon that migrated past the upper trap survived their migration to the lower trap and that in April and most of May, there were substantially more juveniles leaving the river than passed the upper trap (Fig. 13). This suggests that many juveniles were able to grow to a smolt size in the lower river downstream from Oakdale in April and May even though the flows had declined to 1,000 cfs to 1,500 cfs.

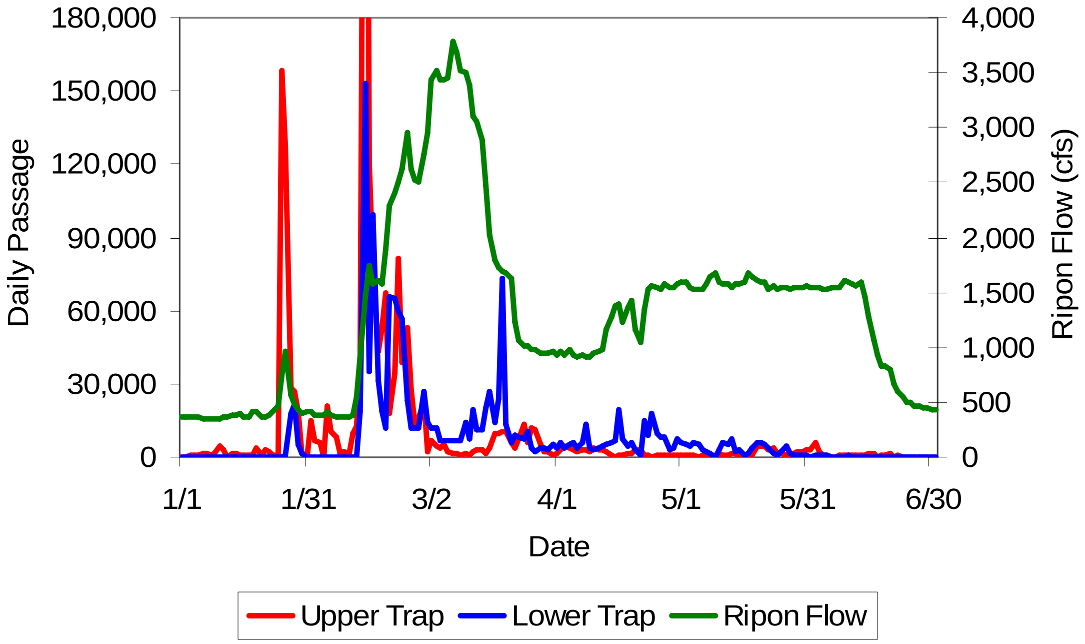

Fig. 13. Estimated daily passage of Chinook salmon fry and smolt-sized outmigrants at Oakdale (upper trap) and Caswell Park (lower trap) rotary screw traps plotted with mean daily flow at Ripon in Stanislaus River in 2000.

In contrast, juvenile survival in the Stanislaus River in spring 2001 was much lower when there were no high flow releases in late winter (Fig. 14). In 2001, only 11% of the juveniles survived their migration between the upper and lower traps and there were fewer juveniles passing the lower trap in April and May compared to the number that passed the upper trap even during the 1,500 cfs pulse flow (Fig. 14). These results suggest that without late winter pulse flows, the smolts were in relatively poor health and few survived their downstream migration in spite of the 1,500 cfs pulse flows in late April and early May.

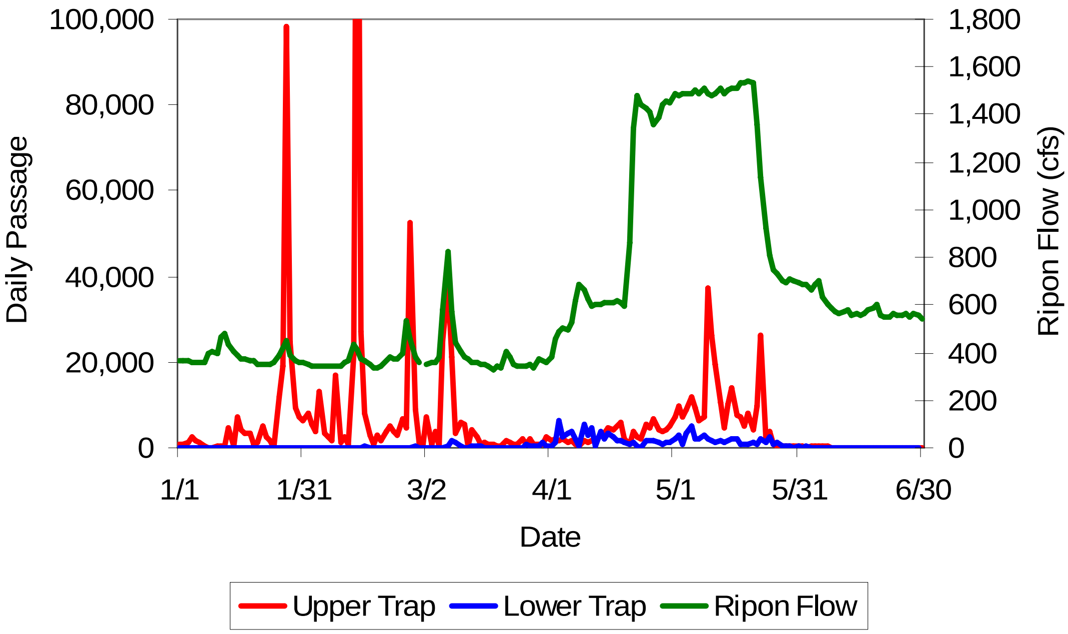

Fig. 14. Estimated daily passage of Chinook salmon fry and smolt-sized outmigrants at Oakdale (upper trap) and Caswell Park (lower trap) rotary screw traps plotted with mean daily flow at Ripon in Stanislaus River in 2001.

Importance of spring water temperatures - Although the rotary screw trap studies suggest that the brief late winter pulse flows in Tuolumne River in 2001 and 2004 approximately doubled the number of smolt-sized juvenile salmon that migrated from the river and caused a greater percentage of the smolts to migrate early in the season, there was only a 13% increase in adult recruitment in 2001 and 2004 compared to 2002 and 2003. The mean recruitment estimates for 2002 and 2003 is 4,129 adults (range 2,626 to 5,632) when there were no late winter pulse flows and 4,679 adults (range 3,274 to 6,084) for 2001 and 2004 when there were 2 to 5 day late winter pulse flows.

One possible explanation for the lower than expected increases in recruitment from the brief late winter pulse flows is that the water temperatures in the lower river exceeded the 15-degree threshold for smolts during early April and in May, when base flow releases were made (Fig. 11) and it is possible that high temperatures allowed disease(s) to progress and cause delayed mortality as the smolts migrated through the Delta. The USFWS conducted a survey of the health and physiological condition of juvenile fall-run Chinook salmon in the San Joaquin River and its primary tributaries, the Stanislaus, Tuolumne, and Merced rivers, during spring 2000 and 2001 (Nichols and Foott 2002). *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease (BKD), was detected in naturally produced juveniles caught in rotary screw traps from the Stanislaus and Tuolumne rivers and juveniles caught with a Kodiak trawl at Mossdale in the San Joaquin River. No gross clinical signs of BKD were seen in any of the fish examined. Other diseases, such as Proliferative Kidney Disease was detected in the Merced River (Nichols and Foott 2002) and Columnaris disease was detected in the Stanislaus River in 2007 by the USFWS, but not in the Tuolumne River, possibly due to the limited amount of testing conducted for disease. These diseases rapidly progress as water temperatures exceed a mean daily temperature of 15°C (Nichols and Foott 2002, Jones et al. 2007). Survival rates of Chinook salmon at 42 days postchallenge was 5% at 14°C in the laboratory (Jones et al. 2007) and so high mortality rates of outmigrating smolts could occur in the Delta or ocean.

The extent that the water temperatures exceeded the 15-degree threshold for smolts in early April is well correlated with the adult recruitment observed from 2001 to 2003, when water temperature data are available. Adult recruitment was the lowest at 2,626 adult recruits in spring 2002, when the pulse flows did not begin until 24 April. Prior to the pulse flow releases in 2002, the mean water temperatures at Modesto from 29 March to 14 April was 19.4 degrees, which substantially exceeded the 15 degree threshold (Fig. 11). In contrast, adult recruitment was higher, 6,084 and 5,632 adult recruits for spring 2001 and 2003, when the mean daily water temperatures were 16.1 degrees and 17.2 degrees in early April, respectively (Figure 11).

Recruitment and the abundance of smolt outmigrants were substantially higher in 1999 and 2000 when late winter flows exceeded 3,000 cfs from at least mid February to mid March and high flows releases kept water temperatures below or near the 15-degree threshold for smolts through mid May. In 1999, modeled water temperatures near the river's mouth were below the 15-degree threshold through 14 April and close to the threshold (mean 15.6^{o}C, maximum 17.8^{o}6) from 15 April 18 May (San Joaquin River Basin HEC5Q Water Temperature Model Developed for the CalFed Ecosystem Restoration Program). In 2000, modeled water temperatures near the river's mouth were below the 15-degree threshold through 1 April and close to the threshold (mean 16.1^{o}C, maximum 18.3^{o}C) from 2 April to 17 May (San Joaquin River Basin HEC5Q Water Temperature Model Developed for the CalFed Ecosystem Restoration Program cited in direct testimony of Gordus). The number of smolt-sized juveniles that migrated from the river in 1999 and 2000 was 26,832 and 52,132, respectively. This computes to an average increase of 387% compared to 2002 and 2003 when there were no late winter pulses. Adult recruitment was 9,293 and 12,103 in 1999 and 2000, respectively, which is 259% higher than the mean recruitment for 2002 and 2003, when there were no late winter pulses and water temperatures exceeded the 59-degree threshold in early April. It is likely that recruitment increased substantially by a mean of 259% in 1999 and 2000 primarily because the 59-degree threshold for smolts was not exceeded in late March and early April, compared to the 113% increase in 2001 and 2004 when the 59-degree threshold was exceeded. However, it is also likely that the high recruitment estimates for 1999 and 2000 would not have been possible without the late winter flows of at least 3,000 cfs that augmented the food supply, increased growth rates, and accelerated smoltification and migration of the smolts so that a large percentage migrated by late April when water temperatures were below the 59-degree threshold.

Juvenile Survival In The Delta

CWT smolt survival studies have been conducted in the San Joaquin River to evaluate the effects of flow, Delta export rates, and the installation of a barrier at the head of the Old River which had the objective of minimizing the diversion of flow and juvenile salmon into the Old River, which led to the Federal and State pumping facilities in the Delta, from 1985 to 2004 (SJGRA 2007, Newman 2008). The results indicated that smolt survival was positively correlated with the flow in the San Joaquin River at Dos Reis and the installation of the Old River Barrier (Newman 2008). However, associations between the pumping rates at the State and Federal facilities and smolt survival were weak to negligible (Newman 2008). Therefore, flow releases in the Tuolumne River improve smolt survival in the Delta as well as in the Tuolumne River.

Juvenile Survival In The Ocean

The survival of Central Valley smolts entering the ocean during May and June (MacFarlane and Norton 2002) is probably the most critical phase for salmon in the ocean (Pearcy 1992, Mantua et al. 1997, Quinn 2005). Smolt survival in the ocean is highly correlated with food availability as affected by freshwater outflow from the estuary and coastal upwelling (Casillas 2007). The coastal areas provide abundant food resources for salmon smolts particularly when coastal upwelling provides cold, nutrient rich water and when high freshwater flows create a large interface area between freshwater and saltwater (Casillas 2007). Long-term records indicate that there are 15- to 25-year cycles of warm and cool periods that strongly correlate with marine ecosystem productivity (Mantua et al. 1997; Hollowed et al. 2001). However, more recent cycles have been relatively short with a cool productive cycle from July 1998 to July 2002, a warm unproductive cycle from August 2002 to July 2006, followed by cool productive cycle through at least July 2009 (Ocean Ecosystem Indicators 2008, web site provided by the Northwest Fisheries Science Center, NOAA Fisheries Service). Ocean productivity was particularly poor for the Gulf of the Farallones in 2005 and 2006 as indicated by the abandonment of nests on the Farallon Islands by Cassin’s auklets, which have a similar diet compared to juvenile Chinook salmon, because of poor food availability (Sydeman et al. 2006; Wolf et al. 2009). The Pacific Decadal Oscillation is a basin-scale index of North Pacific sea surface temperatures and provides a good index of sea surface temperatures and has been correlated with Chinook salmon landings in California (Mantua et al. 1997).

An important local process that affects plankton production along the Oregon coast is coastal upwelling (Peterson et al. 2006). Upwelling is caused by northerly winds from April to September that transport offshore surface water southward and away from the coastline. This offshore, southward transport of surface waters is balanced by onshore northward transport of typically cool, high-salinity, nutrient-rich water that drives the marine food-web. The Coastal Upwelling Index (CUI) is based on the wind speed that drives coastal upwelling (Bakun 1973) and the CUI database is developed and distributed by the Pacific Fisheries Environmental Laboratory, National Marine Fisheries Service's Southwest Fisheries Science Center, Pacific Grove, California. The survival of juvenile coho salmon (*O. kisutch*) is positively correlated with the April and mean April-May CUI values for Oregon coho salmon (Petersen et al. 2006) and the mean June to August curl-driven upwelling indices are positively correlated with growth rates of Chinook salmon in a tributary to the Smith River near the California-Oregon border (Wells et al. 2007). However, strong upwelling is not always correlated with high plankton productivity because the deep source waters for upwelling can be warm and nutrient poor (Peterson et al. 2006).

Tuolumne River fall-run Chinook salmon adult recruitment is poorly correlated with the mean CUI values from April through August for the Gulf of Farallones. For example, the relationship between mean CUI values for the May-June period, when most Central Valley smolts enter the ocean (MacFarlane and Norton 2002), with Tuolumne River recruitment (Fig. 15) shows the low recruitment for spring 2005 at low CUI values as expected, but also indicates that recruitment was high in 1986 and 1998 at similarly low CUI values. When incorporated into a multiple regression model with the mean La Grange flow from 1 February to 15 June and quadratic Age 3 equivalent spawner abundance variables, the CUI had negative coefficients for all periods from April through August, which is contrary to those reported for Oregon coho salmon (Peterson et al. 2006) and the Chinook salmon in the Smith River tributary (Wells et al. 2007). One explanation is that Tuolumne River fall-run Chinook salmon are primarily affected by instream flows in the Tuolumne River when the juveniles are rearing and migrating downstream, whereas ocean conditions would only have an effect during wet years, such as 2005 and 2006, when ocean conditions were unusually unproductive. On the other hand, the survival of hatchery raised salmon that are trucked to the Bay and Chinook salmon migrating in undamed rivers with frequent floodplain inundation such as the Smith River would be expected to be primarily affected by ocean conditions.

The mean May-June CUI is relatively high (240), indicating a high level of plankton productivity, during the 1996 to 2006 period compared to the 1981 to 1995 period (mean CUI = 213), and so changes in ocean productivity in the Gulf of Farallones do not explain the reduced recruitment productivity that occurred from 1996 to 2005 in the Tuolumne River.

Adult Harvest In The Ocean

Adult ocean harvest rates have declined since 1996 (Fig. 16) and so the decline in Tuolumne River escapement since 1996 cannot have been caused by the harvest of adult salmon in the ocean. My estimates of ocean harvest rates for all CWT Chinook salmon recovered during the fall-run Chinook salmon escapement surveys in the Central Valley from 1980 to 2007 (Mesick et al. 2009a, 2009b) indicate that the mean ocean harvest rate was 56% from 1980 to 1995 and 42% from 1996 to 2007. The Central Valley Index of Ocean Harvest (CVI), which is estimated each year by the Pacific Fishery Management Council (PFMC 2008) by dividing total harvest south of Point Arena by the total hatchery and natural escapement to all Central Valley rivers, averaged 69% from 1980 to 1995 and 46% from 1996 to 2007.

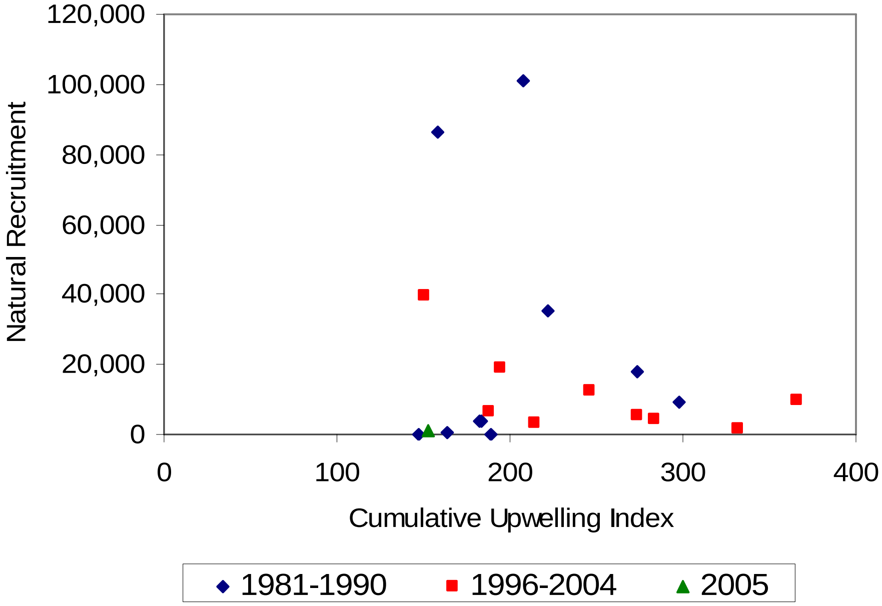

Fig. 15. The relationship between Tuolumne River naturally produced adult fall-run Chinook salmon recruitment and the mean Cumulative Upwelling Index at 37.5°N latitude (Gulf of the Farallones) for May and June from 1981 to 2005.

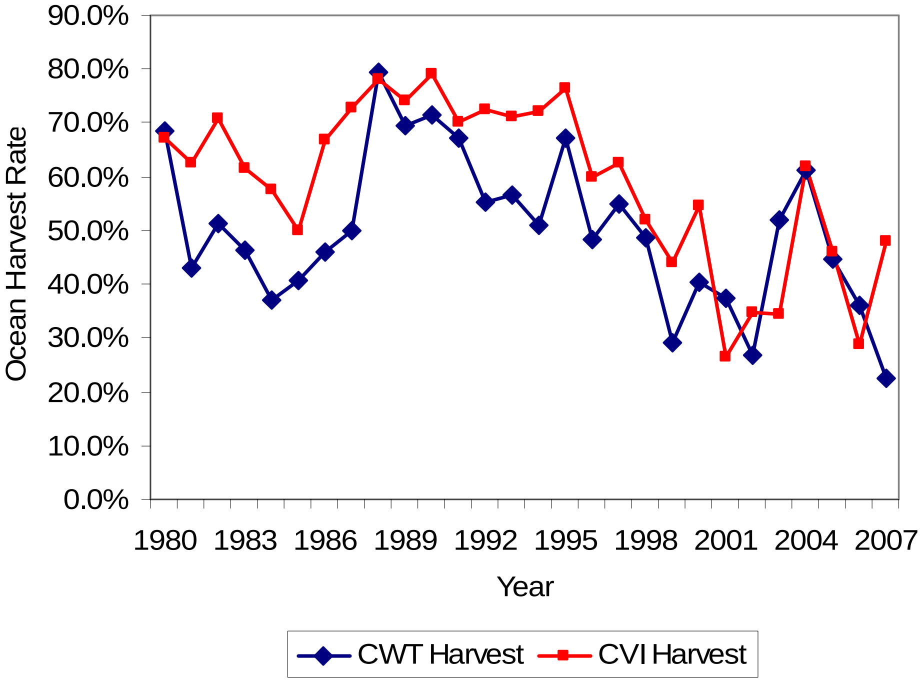

Fig. 16. Estimated rates of ocean harvest of Central Valley fall-run Chinook salmon from 1980 to 2007 in the combined commercial and sport fisheries based on CWT

recovery estimates (Mesick et al. 2009a, 2009b) and the Central Valley Index (PFMC 2008).

DISCUSSION

The above analyses indicate that the Tuolumne River fall-run Chinook salmon population is at a high risk of extinction since 1996 due to inadequate instream flow releases from La Grange Dam, primarily when juvenile salmon are rearing and outmigrating in late winter and spring and to a lesser extent during late October when adult salmon are migrating upstream. It is likely that the low escapements observed since 2005 have resulted in a decline in the population's genetic diversity, which puts the population at risk of extinction (Allendorf 1997, Lindley et al. 2007). The results also suggest that the extreme decline in escapement during the 1987 to 1992 drought and resulting decline in genetic diversity caused a 50% reduction in the population's productivity.

To maintain the Tuolumne River fall-run Chinook salmon population at a low risk of extinction, it will be necessary to increase the population in regard to all four of the Lindley et al. (2007) risk of extinction criteria. First, it will be necessary to increase the dry water year flow releases to keep escapement above 833 fish. Second, it will be necessary to increase normal water year flow releases to double the escapements and thereby reduce the rate of decline between wet-year escapements and dry-year escapements from 19.2% annually to 10% or less annually and reduce the percentage of hatchery fish in the escapement from 21.3% to about 10%.

To keep escapement above 833 fish during Critical and Dry water year types, when the San Joaquin Water Year Index is 2.5 MAF or less, it will be necessary to implement a flow schedule that includes: (1) a 10-day, 1,200 cfs late October pulse flow release to minimize adult straying; (2) a 2-day, 3,000 cfs pulse flow release in late February to increase fry survival and to accelerate both the smoltification process and smolt migration timing; and (3) flow management for La Grange Dam releases to keep water temperatures throughout the river below a threshold of 59°F from 20 March through at least 20 April to improve smolt survival. Releasing the 1,200 cfs fall pulse flows each year to minimize the percentage that stray to the Sacramento River Basin to no more than 6% would be expected to increase the mean recruitment for the 1996 to 2005 period from the observed 10,254 recruits under existing conditions to 12,054 adult recruits with the improved fall pulse flows, which computes to a possible 17.5% increase in recruitment (i.e., escapement). However, reducing stray rates alone would still not elevate the Tuolumne River population to a low risk of extinction, because escapement would still have declined to 1,241 adults from 2006 to 2008, the population would decline at an average annual rate of 19.9% from 1999 to 2008, and the percentage of hatchery fish would be 17.3%. There is uncertainty regarding the effectiveness of a brief late winter pulse flow and managing spring water temperatures to a threshold of 15°C primarily because they have not be used in concert before. However theoretically, implementing all three pulse flows should be effective at keeping escapement above 833 adult salmon when ocean food resources for juvenile salmon are not exceptionally poor, as they were in 2005 and 2006.

To minimize the magnitude in population fluctuations and reduce the percentage of hatchery fish in the population to less than 10%, it will be necessary to implement flow schedules that extend the duration for late winter pulse flows to 14 days in Below Normal and Above Normal water year types and to 21 days in Wet water year types. The recommended 59-degree Fahrenheit threshold should be maintained from 20 March to 30 April in Below Normal water year types and to at least 15 May in Above Normal and Wet water year types.

Another recommendation is to gradually ramp down the flood control releases during early summer to improve the recruitment of riparian tree species and thereby augment the amount of organic matter, shade, and woody debris and thereby improve the habitat quality for juvenile salmon. Research on a variety of cottonwood and willow species suggests that 1 to 1.5 inches/day is the maximum rate of water table decline for seedling survival (McBride et al. 1989; Segelquist et al. 1993; Mahoney and Rood 1993, 1998; Amlin and Rood 2002). Ramping down is necessary so that the root growth of the tree seedlings can keep up with the decline in the groundwater table as flows recede. Ramping rates of 100 to 300 cfs/day in the San Joaquin Basin are thought to prevent seedling desiccation under the assumed 1 inch/day maximum root growth rate.

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Table 1. The mean percentage of Chinook salmon with CWTs recovered in the Tuolumne River relative to the number released in the Bay-Delta, mainstem Sacramento and San Joaquin rivers, and tributaries from the Feather River Hatchery, Mokelumne River Fish Facility, Merced River Hatchery, and the Nimbus Fish Hatchery by month of release and age of adult salmon recovered in the escapement from 1981 to 2007 and for the 1987 to 1992 drought years (Age-D). The number of CWT lots (CWTs), years with CWT releases (Years), number of tagged and associated untagged juveniles released (# CWTs), and the number of unassociated untagged juvenile salmon released are also presented by month.

Bay-Delta Releases

Feather River Hatchery

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2		0.00000%	0.00110%	0.00147%	0.00060%	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	0.00557%	
Age 3		0.00000%	0.00023%	0.00127%	0.00053%	0.00331%	0.00000%	0.00000%	0.00000%	0.00000%	0.02686%	
Age 4		0.00000%	0.00000%	0.00035%	0.00005%	0.00000%	0.00000%	0.00917%	0.00000%	0.00000%	0.00000%	
Age 2-D				0.00000%	0.00000%	0.00000%						
Age 3-D				0.00000%	0.00000%	0.00000%						
Age 4-D				0.00000%	0.00000%	0.00000%						
CWTs	0	23	43	95	201	202	81	49	2	4	13	0
Years	0	5	6	14	18	16	6	6	1	2	4	
# CWTs	0	606,636	1,520,758	13,728,108	23,315,464	14,413,217	4,650,592	2,200,750	85,408	215,875	638,056	0
Non-CWTs			292,000	11,786,382	39,620,644	46,308,815	27,195,991	17,048,815	5,095,540	433,160		

Mokelumne River Fish Installation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2				0.00074%	0.00011%	0.00000%	0.00000%		0.00000%	0.00000%	0.00000%	
Age 3				0.00209%	0.00353%	0.00321%	0.00000%		0.00470%	0.00782%	0.00000%	
Age 4				0.00025%	0.00131%	0.00000%	0.00000%		0.00000%	0.00000%	0.00000%	
Age 2-D				0.00000%	0.00000%	0.00000%						
Age 3-D				0.00000%	0.00000%	0.00000%						
Age 4-D				0.00000%	0.00000%	0.00000%						
CWTs				168	136	47	15		18	33	6	
Years				9	10	7	2		2	2	2	
# CWTs				12,197,656	32,857,855	25,409,233	534,777		2,066,760	1,027,431	208,020	
Non-CWTs	1,930,530	2,209,412	721,574	14,458,819	22,961,208	17,280,915	7,274,488	2,896,049	1,113,617	1,784,065	407,208	30,030

Merced River Hatchery

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2				0.03498%	0.02393%					0.00000%		
Age 3				0.07362%	0.04933%					0.05690%		
Age 4				0.00672%	0.00670%					0.00000%		
Age 2-D				0.01155%	0.00530%	BY 1988						
Age 3-D				0.02059%	0.00629%	BY 1988						
Age 4-D				0.00000%	0.00000%	BY 1988						
CWTs				41	39					9		
Years				6	7					3		
# CWTs				1,057,024	1,250,090					277,245		
Non-CWTs			100			867,700						

Nimbus Fish Hatchery

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2		0.00000%	0.00000%		0.00081%	0.00046%	0.00000%	0.00000%				
Age 3		0.00000%	0.00000%		0.00071%	0.00014%	0.00000%	0.00000%				
Age 4		0.00000%	0.00000%		0.00068%	0.00016%	0.00054%	0.00000%				
CWTs		1	1		24	44	32	4				
Years		1	1		1	4	4	1				
# CWTs		50,970	49,395		16,503,100	13,010,547	1,785,576	200,066				
Non-CWTs	815,200			3,499,247	18,026,535	53,465,226	20,307,755	2,424,105	270,281			

Mainstem River Releases

Feather River Hatchery

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2		0.00000%	0.00000%	0.00000%	0.00018%	0.00000%	0.00000%	0.00000%				
Age 3		0.00000%	0.00000%	0.00072%	0.00005%	0.00000%	0.00000%	0.00000%				
Age 4		0.00000%	0.00000%	0.00000%	0.00029%	0.00000%	0.00000%	0.00000%				
CWTs		166	67	292	237	69	3	2				
Years		7	8	17	20	4	1	1				
# CWTs		3,867,364	2,156,924	11,848,267	11,897,739	3,518,521	83,025	72,008				
Non-CWTs	613,920		8,394	257,944	2,133,427	2,845,341	983,650	36,000			157,500	42,100

Mokelumne River Fish Installation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2				0.00469%	0.00000%					0.00000%	0.00000%	
Age 3				0.00000%	0.00000%					0.00000%	0.02708%	
Age 4				0.00000%	0.00000%					0.00000%	0.00000%	
CWTs	1			13	7					5	12	
Years	1			1	1					1	2	
# CWTs	14,290			335,314	180,666					214,043	469,078	
Non-CWTs	126,700			472,840	0	514,350				1,843,993	1,412,737	328,700

Merced River Hatchery

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2				0.05664%	0.01039%					0.03841%	0.00000%	
Age 3				0.08079%	0.02469%					0.07954%	0.00000%	
Age 4				0.03080%	0.00399%					0.00000%	0.00000%	
CWTs				181	84					32	7	
Years				11	7					4	1	
# CWTs				5,207,336	3,446,630					935,259	326,430	
Non-CWTs				157,945	233,664	80,218						

Nimbus Fish Hatchery

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CWTs/Years	1		1									
# CWTs	48000		48,720									
Non-CWTs	8,349,320	11,639,846	12,528,241	8,370,510	6,220,315	12,387,395			150,960	223,880	121,660	

Tributary Releases

Feather River Hatchery

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%				0.00000%	0.00000%	
Age 3	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	0.00215%				0.01679%	0.00000%	
Age 4	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%				0.00000%	0.00000%	
CWTs	4	30	42	72	69	34				8	12	
Years	3	3	7	8	8	4				3	3	
# CWTs	792,330	1,099,592	2,773,111	3,738,407	4,146,314	3,566,645				5,479,069	2,723,738	
Non-CWTs	13,822,471	8,228,948	8,999,798	2,462,040	161,640	359,810	62,836		119,884	8,816,921	932,735	2,943,787

Mokelumne River Fish Installation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2				0.00000%	0.00000%	0.00000%			0.00000%	0.00000%	0.00000%	
Age 3				0.00527%	0.00000%	0.00000%			0.00000%	0.00000%	0.00000%	
Age 4				0.00000%	0.00000%	0.00000%			0.00000%	0.00000%	0.00000%	
CWTs				43	41	6			10	48	3	
Years				3	5	2			2	6	1	
# CWTs				668,364	1,195,358	177,882			3,858,022	5,404,300	144,900	
Non-CWTs	34,437	2,221,822	337,238	1,461,476	4,610,822	710,070	71,792	27,000	399,950	1,119,411	303,234	27600

Merced River Hatchery

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Age 2		0.02204%	0.00000%	0.00137%	0.00569%					0.00305%	0.00177%	
Age 3		0.20898%	0.00000%	0.00549%	0.02717%					0.00000%	0.00582%	
Age 4		0.01582%	0.01369%	0.00130%	0.00444%					0.00000%	0.00105%	
CWTs		3	7	236	121					15	25	
Years		1	2	13	9					4	3	
# CWTs		50,388	196,214	6,587,958	3,264,254					1,082,249	729,108	
Non-CWTs	4150	9,957	300,427	462,685	2,717,349	316,618				195,000	818,956	

Nimbus Fish Hatchery

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
# CWTs	0	0	0	0	0	0	0	0	0	0	0	0
Non-CWTs	16,562,691	21,157,730	4,302,638	2,889,732		544,625						7,193,652

Table 2. The dates when rotary screw trapping started and stopped at the Shiloh site in 1998 and at the Grayson site from 1999 to 2006, the mean expanded abundance estimate of juvenile salmon passing the traps per day (Fish/Day) during the beginning and/or final period of sampling, and the number of days during the beginning and/or final period of sampling used to compute the mean estimates of the number of fish passing the trap per day.

	Sampling Start Period				Sampling End Period			
Year	Date Sampling Began	Mean Fish/Day 3/20 to 3/29	Mean Fish/Day 4/2 to 4/10	Number of Unsampled Days	Date Sampling Ended	Mean Fish/Day	Number of Unsampled Days	Percentage Adjustment in Abundance Estimate
1998	15-Feb	1,695	2,039	--	6-Jun	5,600	2	23.5%
1999	12-Jan	91	127	--	6-Jun	24	4	0.8%
2000	9-Jan	107	70	--	27-May	44	5	1.6%
2001	3-Jan	93	498	--	22-May	61	4	5.9%
2002	15-Jan	42	22	--	31-May	36	6	5.6%
2003	1-Apr	--	29	12	19-May	63	4	24.8%
2004	1-Apr	--	491	15	26-May	102	8	56.9%
2005	2-Apr	--	389	14	17-Jun	324	8	1.5%
2006	25-Jan	398	1,781	--	21-Jun	397	8	0.0%

Table 3. Estimates of the observed natural escapements (Exhibit 2), stray rates of CWT Merced River Hatchery fish (Exhibit 2), improved stray rates if adequate pulse flows had been released each year to keep stray rates at or below 6%, the estimated changes in stray rates, and the estimates of "no-stray" escapements and natural recruitment from 1980 to 2008.

Year	Observed Escapement	Observed Stray Rate	Improved Stray Rate	Stray Rate Change	Escapement Increase	No Stray Escapement	Stray Adjusted Natural Escapement	Stray Adjusted Natural Recruitment
1980	--	--	--	--	--	--	--	45,079
1981	14,253	0.7%	0.7%	0.0%	0	14,253	14,160	9,889
1982	7,126	17.4%	6.0%	11.4%	812	7,938	6,696	35,697
1983	14,836	9.2%	6.0%	3.2%	475	15,311	13,943	100,906
1984	13,689	0.8%	0.8%	0.0%	0	13,689	13,579	17,890
1985	40,322	0.9%	0.9%	0.0%	0	40,322	39,946	4,074
1986	7,404	3.4%	3.4%	0.0%	0	7,404	7,149	89,192
1987	14,751	12.3%	6.0%	6.3%	929	15,680	13,869	4,241
1988	5,779	6.6%	6.0%	0.6%	35	5,814	5,430	817
1989	1,275	21.3%	6.0%	15.3%	195	1,470	1,198	350
1990	96	95.5%	6.0%	89.5%	86	182	90	341
1991	77	38.4%	6.0%	32.4%	25	102	72	1,485
1992	132	19.9%	6.0%	13.9%	18	150	124	1,365
1993	471	56.4%	6.0%	50.4%	237	708	443	3,647
1994	506	25.4%	6.0%	19.4%	98	604	476	6,024
1995	827	21.4%	6.0%	15.4%	127	954	778	35,547
1996	4,362	31.5%	6.0%	25.5%	1,112	5,474	4,101	11,984
1997	7,146	28.7%	6.0%	22.7%	1,622	8,768	6,719	27,898
1998	8,910	18.1%	6.0%	12.1%	1,078	9,988	8,375	35,790
1999	8,232	16.2%	6.0%	10.2%	840	9,072	7,736	9,868
2000	17,873	10.9%	6.0%	4.9%	876	18,749	16,800	14,233
2001	8,782	20.3%	6.0%	14.3%	1,256	10,038	8,251	7,149
2002	7,173	48.3%	6.0%	42.3%	3,034	10,207	6,742	3,004
2003	2,163	35.8%	6.0%	29.8%	645	2,808	2,033	6,315
2004	1,984	38.7%	6.0%	32.7%	649	2,633	1,864	3,313
2005	719	15.0%	6.0%	9.0%	65	784	676	987
2006	625	7.6%	6.0%	1.6%	10	635	587	--
2007	224	1.3%	1.3%	0.0%	0	224	221	--
2008	455	4.6%	4.6%	0.0%	0	455	434	--

Table 4. The Department of Fish and Game estimated escapement of fall-run Chinook Salmon in the Tuolumne River (GrandTab), the estimated total number of marked (coded-wire tag and adipose clipped) hatchery adults that returned to the Tuolumne River, the estimated number of unmarked hatchery adults from the Mokelumne, Nimbus, Feather, and Merced river hatcheries that returned to the Tuolumne River, the escapement of naturally produced and hatchery produced adults, and the percent hatchery fish in the escapement from 1981 to 2008. The 2008 marked hatchery adult estimates are presented in Ford and Kirihara (2009), which do not include the unmarked assocated releases of juvenile fish, which are included for all other estimates.

			Unmarked Hatchery Adults						
	Total Escapement	Marked Hatchery Adults	Mokelumne Hatchery	Nimbus Hatchery	Feather River Hatchery	Merced River Hatchery	Estimated Natural Escapement	Estimated Hatchery Escapement	Percent Hatchery
1981	14,253	50	31	9	3	0	14,160	93	0.7%
1982	7,126	753	439	41	10	0	5,883	1,243	17.4%
1983	14,836	339	5	515	508	0	13,468	1,368	9.2%
1984	13,689	31	1	33	46	0	13,579	110	0.8%
1985	40,322	272	31	46	28	0	39,946	376	0.9%
1986	7,404	156	6	22	71	0	7,149	255	3.4%
1987	14,751	1,672	87	3	28	21	12,940	1,811	12.3%
1988	5,779	279	6	0	0	99	5,395	384	6.6%
1989	1,275	179	9	37	4	43	1,003	272	21.3%
1990	96	70	8	12	0	2	4	92	95.5%
1991	77	20	6	0	0	3	47	30	38.4%
1992	132	23	0	3	0	0	106	26	19.9%
1993	471	114	0	46	105	0	205	266	56.4%
1994	506	106	2	18	0	2	378	128	25.4%
1995	827	142	5	10	15	5	650	177	21.4%
1996	4,362	1,057	54	5	87	170	2,988	1,374	31.5%
1997	7,146	1,328	11	1	0	709	5,097	2,049	28.7%

			Unmarked Hatchery Adults						
	Total Escapement	Marked Hatchery Adults	Mokelumne Hatchery	Nimbus Hatchery	Feather River Hatchery	Merced River Hatchery	Estimated Natural Escapement	Estimated Hatchery Escapement	Percent Hatchery
1998	8,910	1,422	56	69	21	45	7,297	1,613	18.1%
1999	8,232	1,061	32	86	77	80	6,896	1,336	16.2%
2000	17,873	1,321	256	6	0	366	15,924	1,949	10.9%
2001	8,782	1,591	54	4	0	138	6,995	1,787	20.3%
2002	7,173	2,742	553	0	64	106	3,707	3,466	48.3%
2003	2,163	565	127	0	38	45	1,388	775	35.8%
2004	1,984	472	229	0	32	35	1,215	769	38.7%
2005	719	87	0	0	0	21	611	108	15.0%
2006	625	8	0	0	0	40	577	48	7.6%
2007	224	0	0	0	0	3	221	3	1.3%
2008	455	≥ 21	?	?	?	?	≤ 434	≥ 21	≥ 4.6%

List of End Notes

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Instream Flow Recommendations For The Stanislaus, Tuolumne, And Merced Rivers To Maintain The Viability Of The Fall-Run Chinook Salmon Populations

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INTRODUCTION

Maintaining viable Chinook salmon populations requires that escapements do not decline below about 833 adult salmon (a total of 2,500 salmon in 3 years), fluctuations in escapement between wet and dry years are reduced by increasing dry year escapements, and the percentages of hatchery fish are reduced to no more than 10% (Lindley and others 2007, pages 29 and 30 in Mesick 2009). Currently, the Tuolumne River population is at a high risk of extinction (Mesick 2009); final analyses have not been conducted for the Stanislaus and Merced rivers, but it is likely that both populations would be considered to be at a high risk of extinction due to high percentages of hatchery fish. Restoring these populations to viable levels will require implementing the recommended flows in Table 1. The Dry year recommendations are needed to keep escapements above the minimum level of 833 adults per year. The Normal and Wet year recommendations are needed to reduce the percentage of hatchery fish in the population to about 10%.

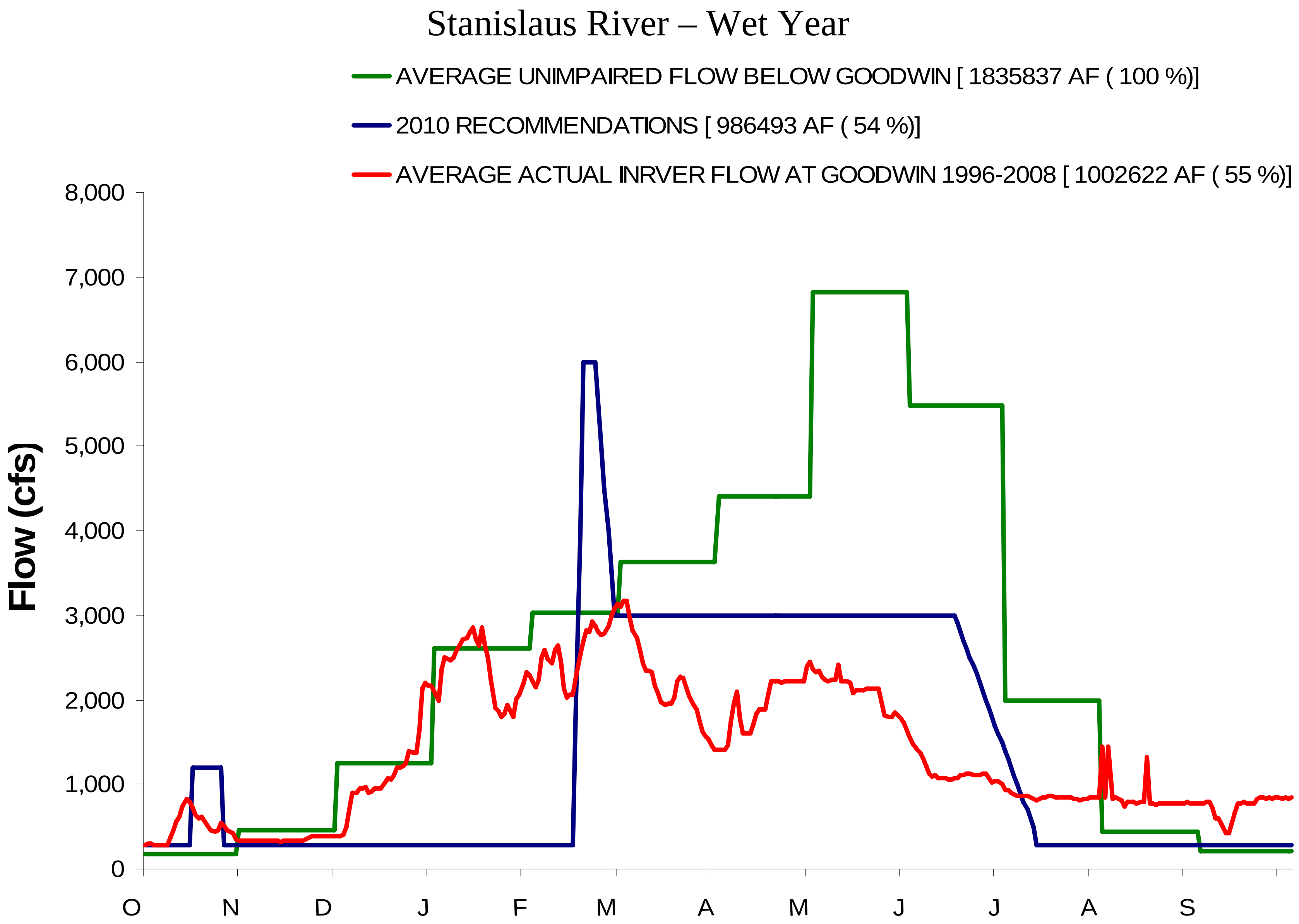
The recommended flow schedules in Table 1 include: (1) pulse flows in late October to provide the cue required for upstream migration of adult salmon to their natal river; (2) pulse flows to inundate tributary floodplain habitat in winter to augment food resources for salmon fry; (3) adequate flow releases to maintain water temperatures near 59^{o}F (15^{o}C) to the mouth of each tributary during the spring to accelerate smolt outmigration and maximize smolt health; (4) base flows of 275 cfs to provide spawning and rearing habitat for Central Valley steelhead and fall-run Chinook salmon; and (5) up-ramping rates of no more than 2,000 cfs per day and down-ramping rates of no more than 500 cfs during winter and spring, except at the cessation of spring pulse flows during Above Normal and Wet years, when down-ramping rates should be 100 cfs per day to promote riparian tree seedling survival (USFWS 2005).

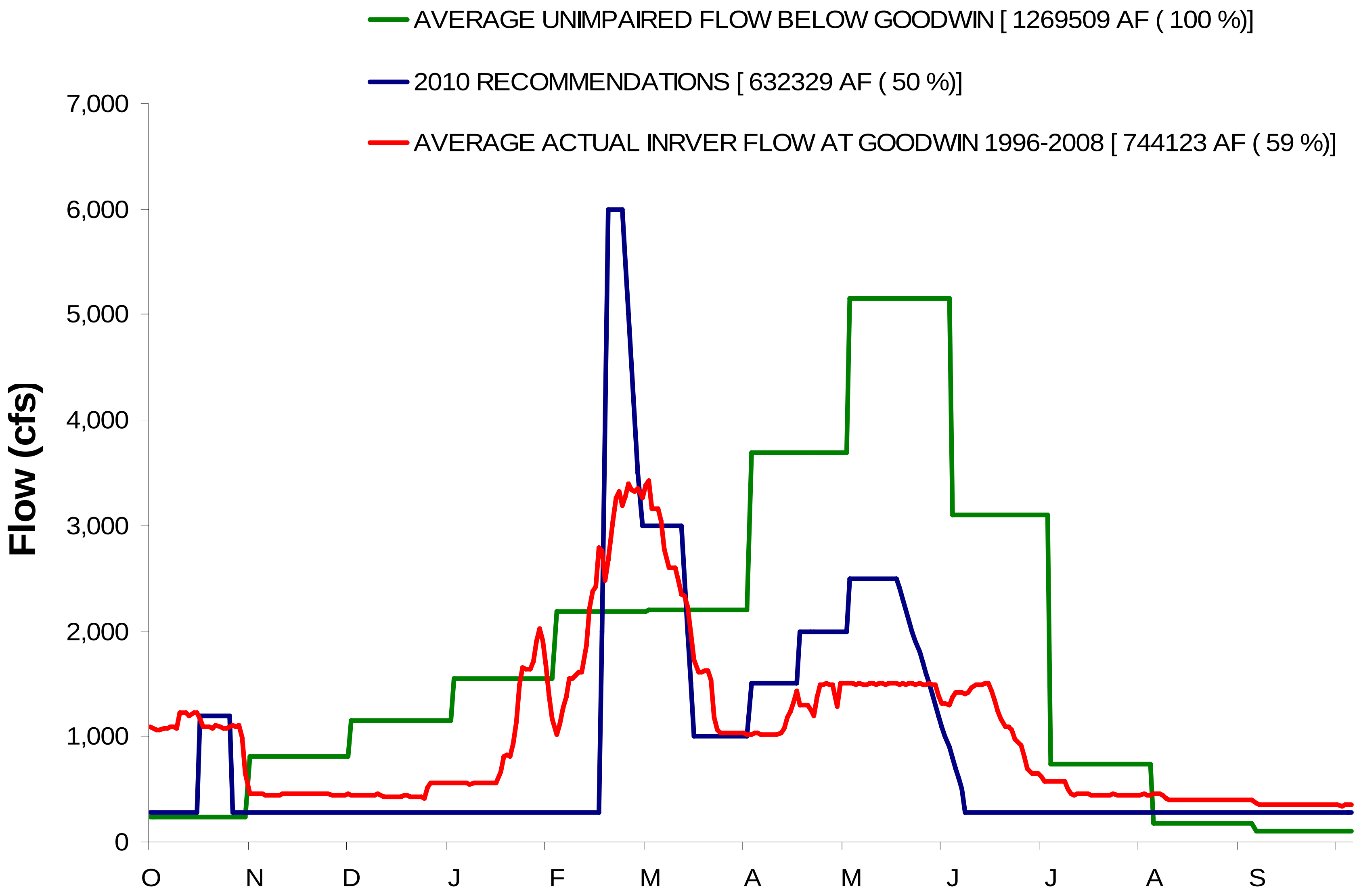
METHODS

The following graphics compare the daily recommended flows schedules in Table 1 with the mean monthly unimpaired flows, and the mean daily flow releases made from 1996 to 2008 for Critical, Dry, Below Normal, Above Normal, and Wet year types. The flow volumes (acre-feet) and percentages of the unimpaired flows are presented on each graph and at the end of Table 1.

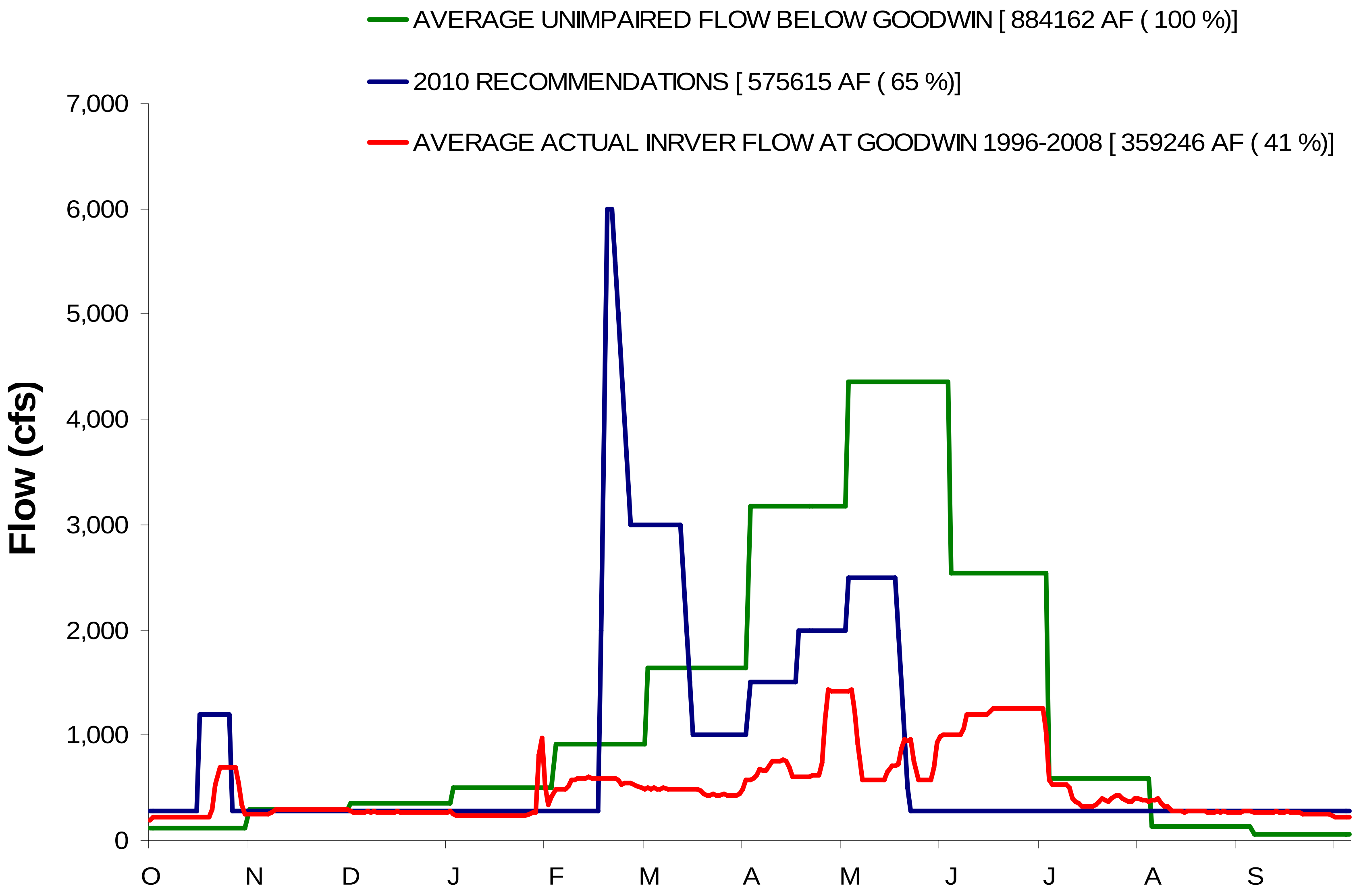
RESULTS

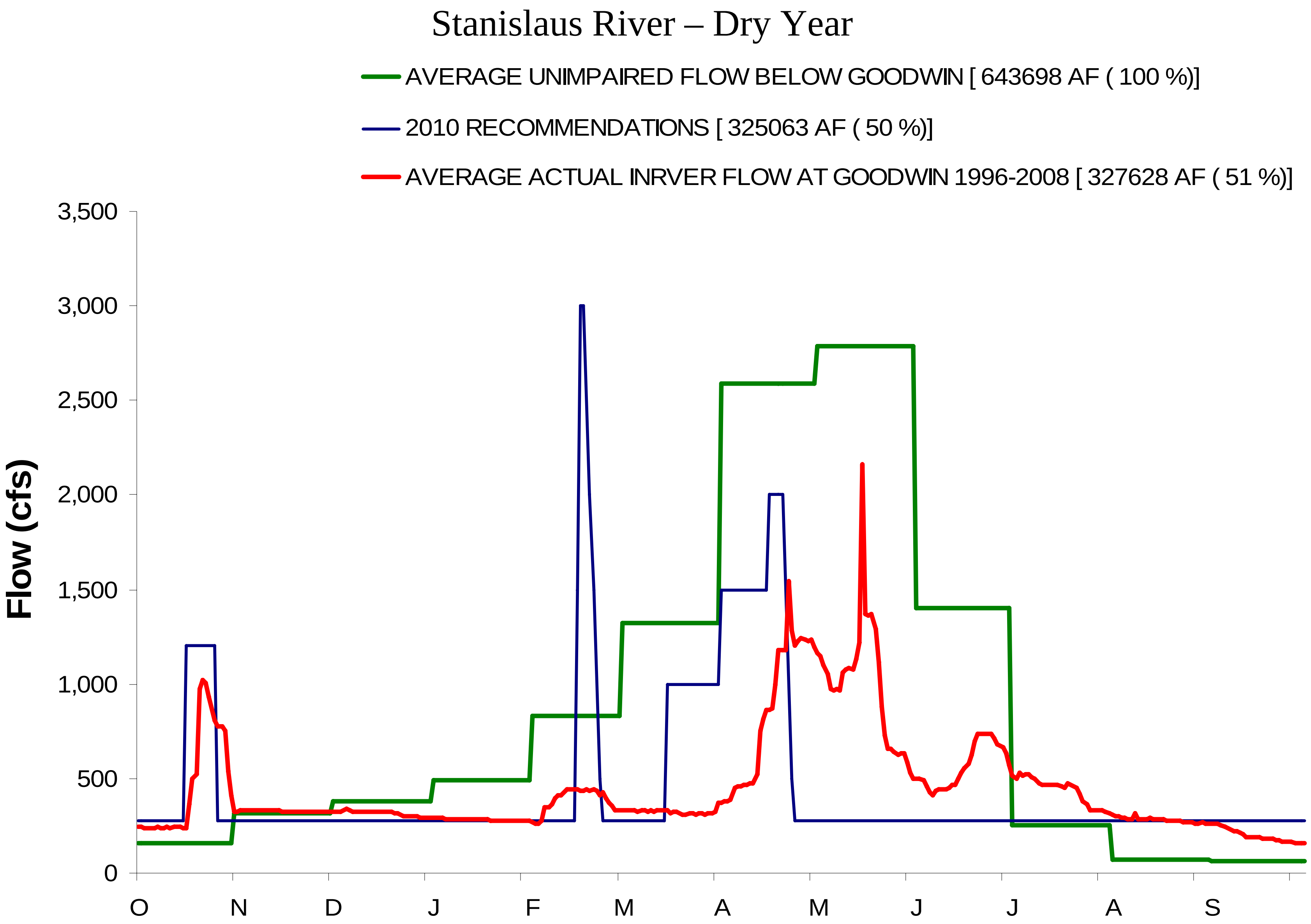
To implement the recommended flow schedules in Table 1, it will be necessary to augment fishery flow volumes during Above Normal water years for the Stanislaus River and reschedule flow releases during the other water year types. For the Tuolumne River, it will be necessary to augment fishery flow volumes during Critical, Dry, and Below Normal water years and reschedule flow releases during Above Normal and Wet years to the extent possible. For the Merced River, it will be necessary to augment fishery flow volumes during all but Wet water years.


Stanislaus River – Wet Year
AVERAGE UNIMPAIRED FLOW BELOW GOODWIN [1835837 AF (100 %)]
2010 RECOMMENDATIONS [986493 AF (54 %)]
AVERAGE ACTUAL INRVER FLOW AT GOODWIN 1996-2008 [1002622 AF (55 %)]
Flow (cfs)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
O
N
D
J
F
M
A
M
J
J
A
S

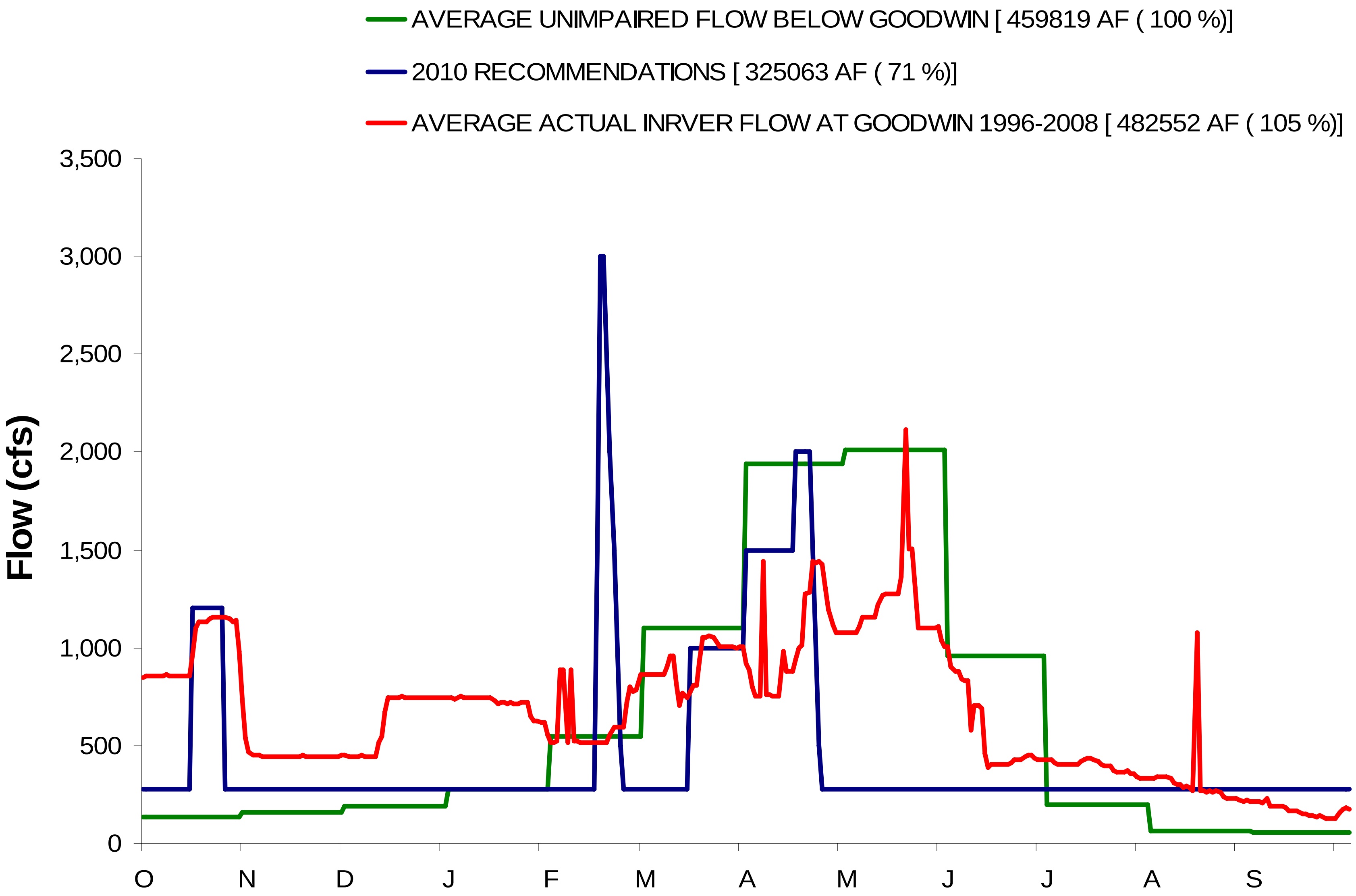

Stanislaus River – Above Normal Year

Stanislaus River – Below Normal Year

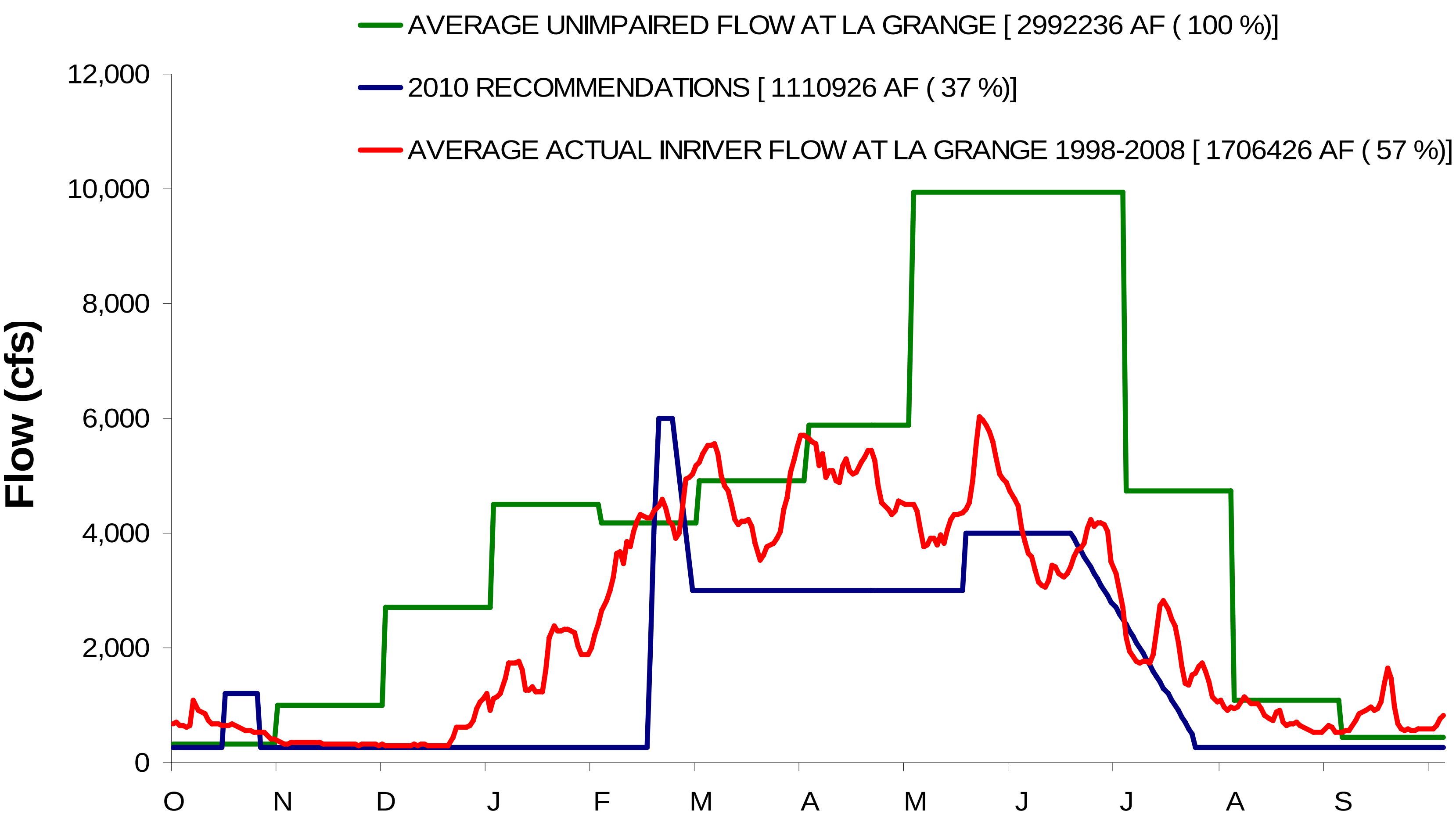



Stanislaus River – Dry Year
AVERAGE UNIMPAIRED FLOW BELOW GOODWIN [643698 AF (100 %)]
2010 RECOMMENDATIONS [325063 AF (50 %)]
AVERAGE ACTUAL INRVER FLOW AT GOODWIN 1996-2008 [327628 AF (51 %)]
Flow (cfs)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
O
N
D
J
F
M
A
M
J
J
A
S

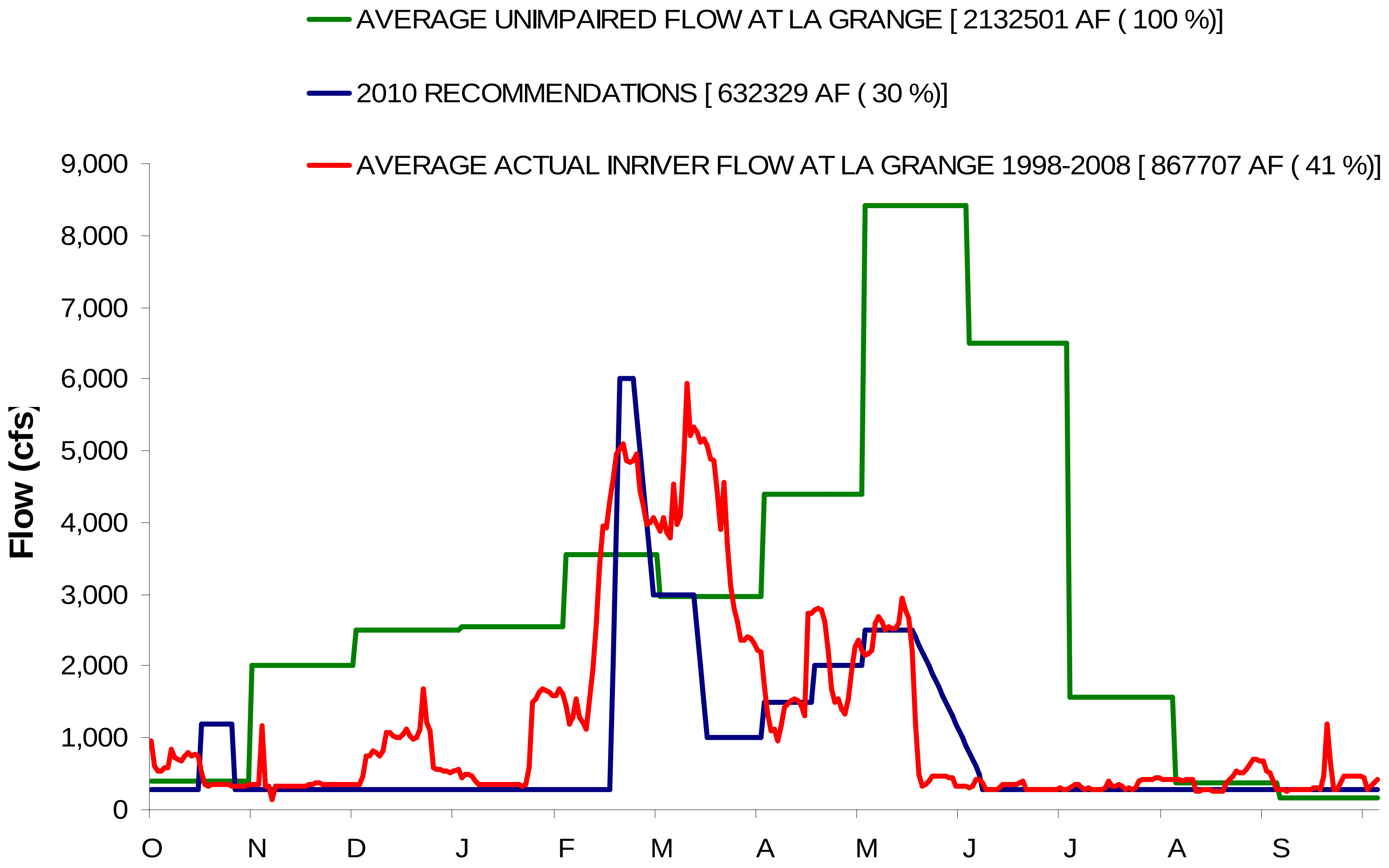
Stanislaus River – Critical Year



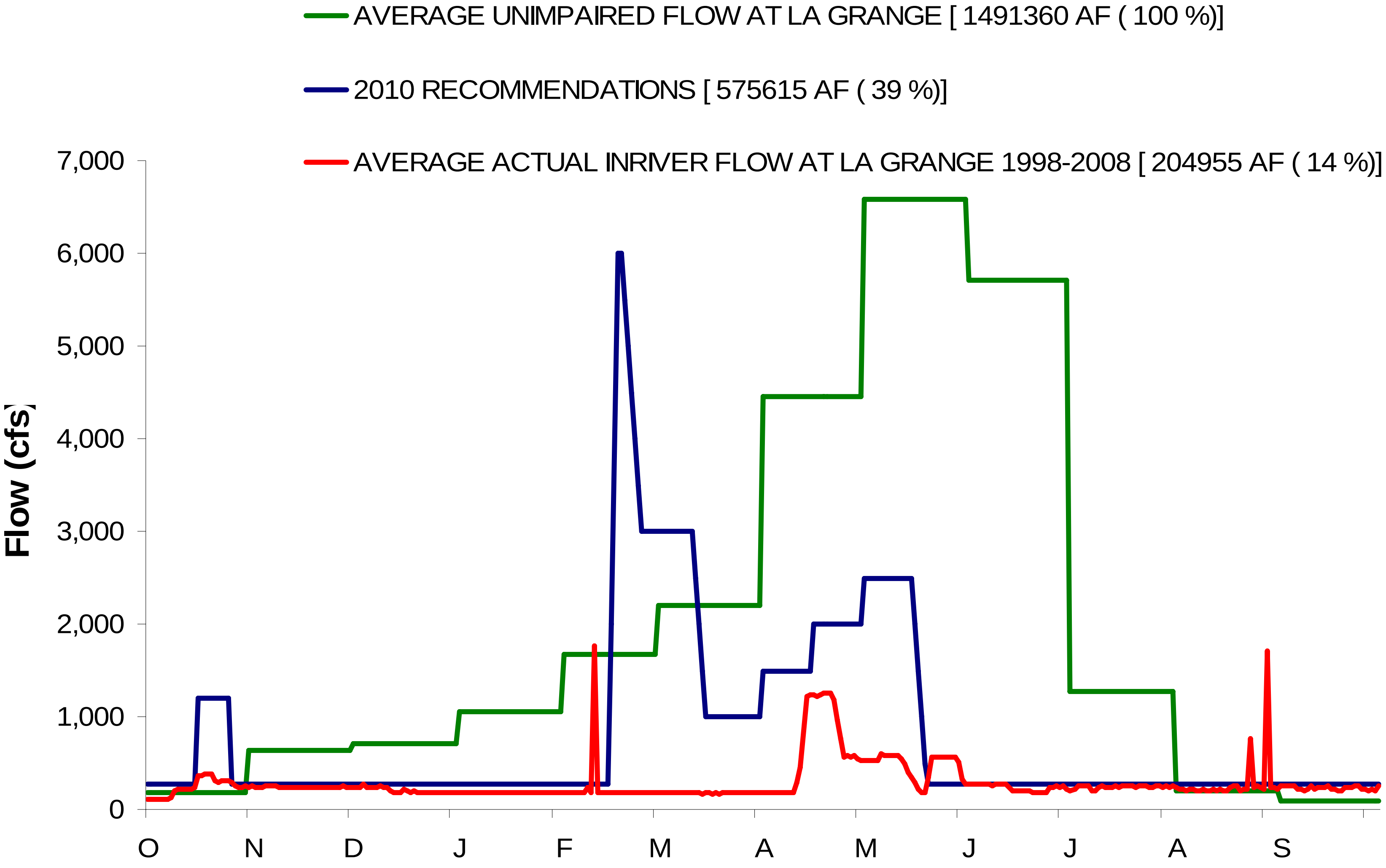
Tuolumne River – Wet Year



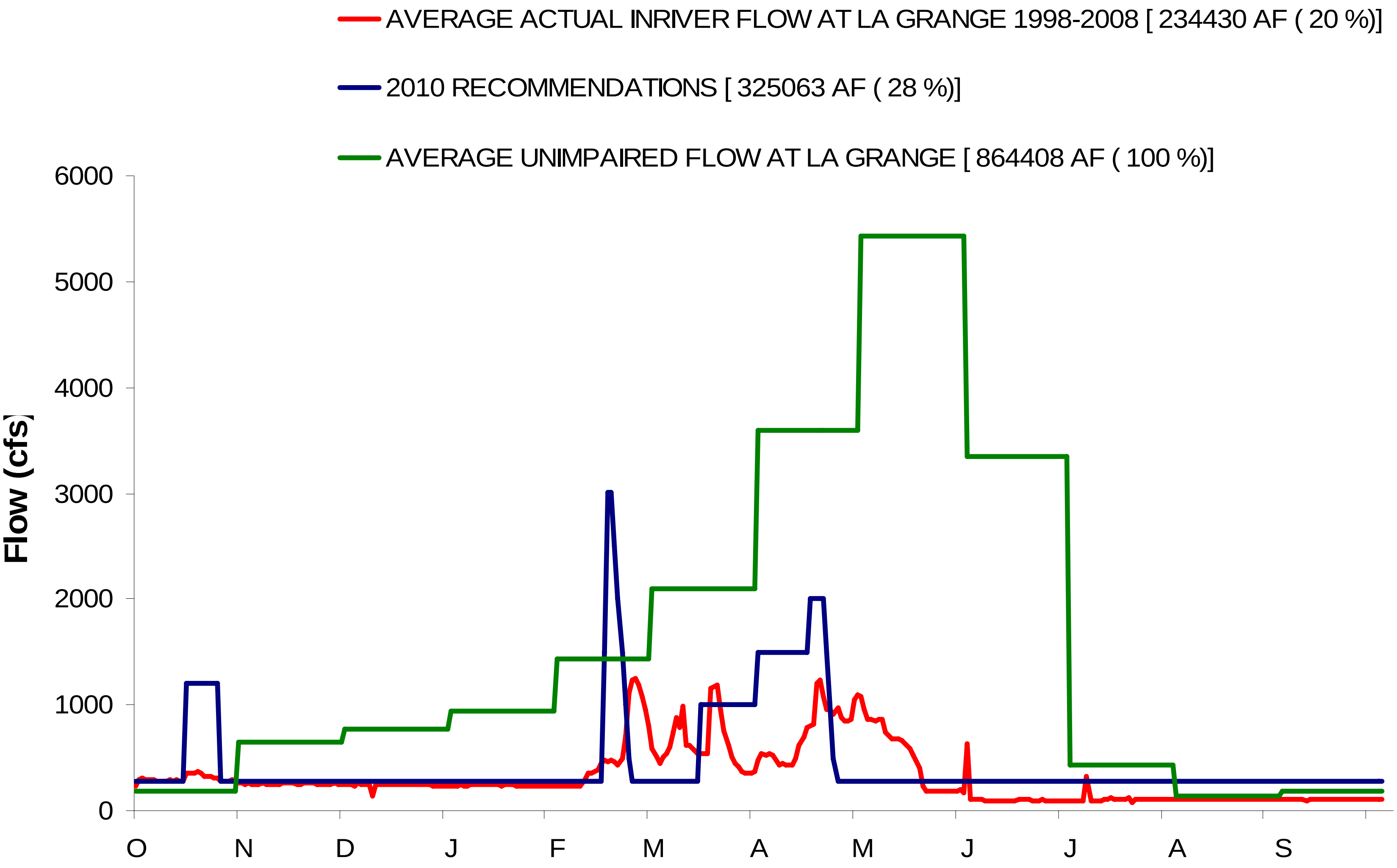
Tuolumne River – Above Normal Year

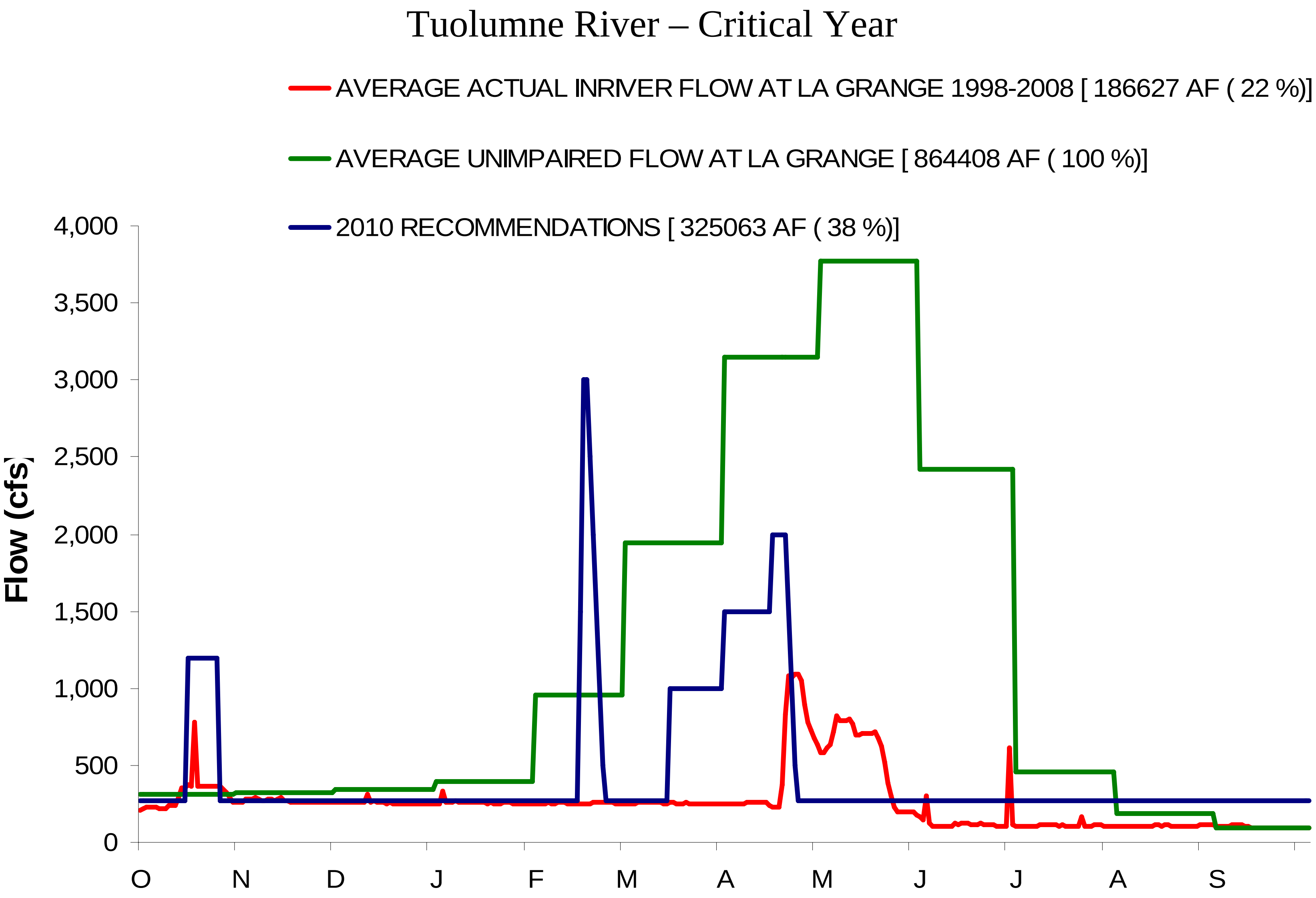


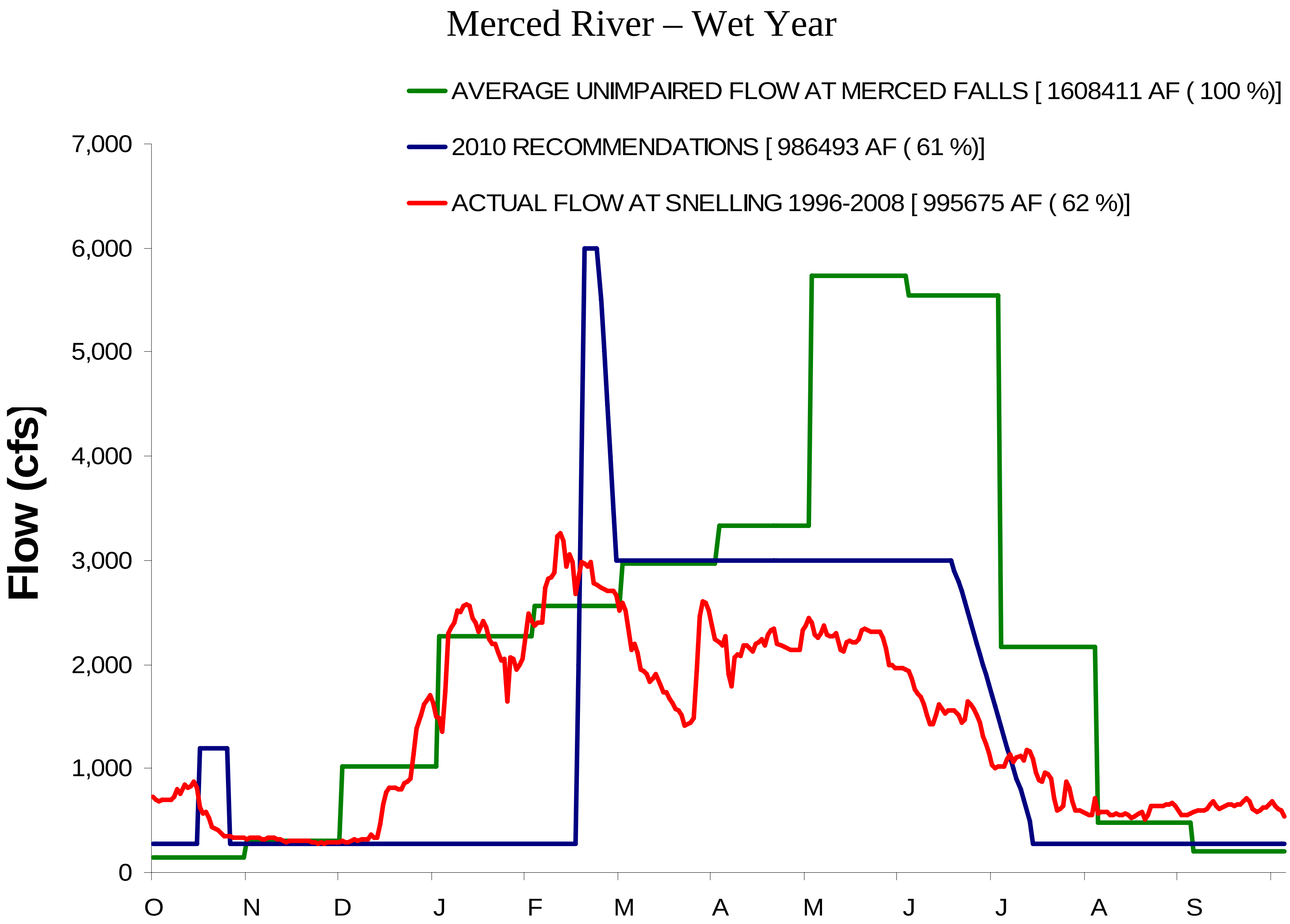
Tuolumne River – Below Normal Year



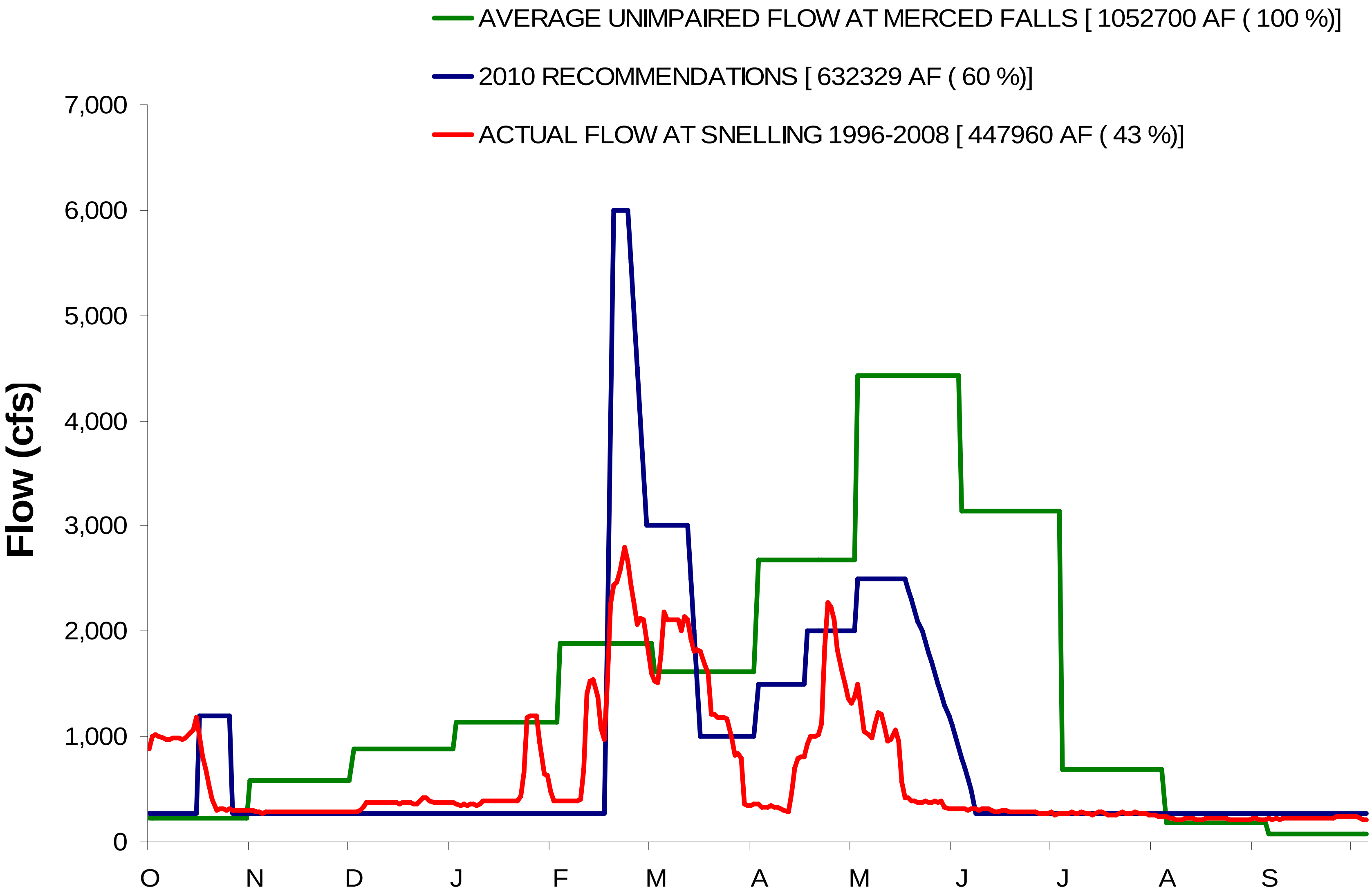
Tuolumne River – Dry Year



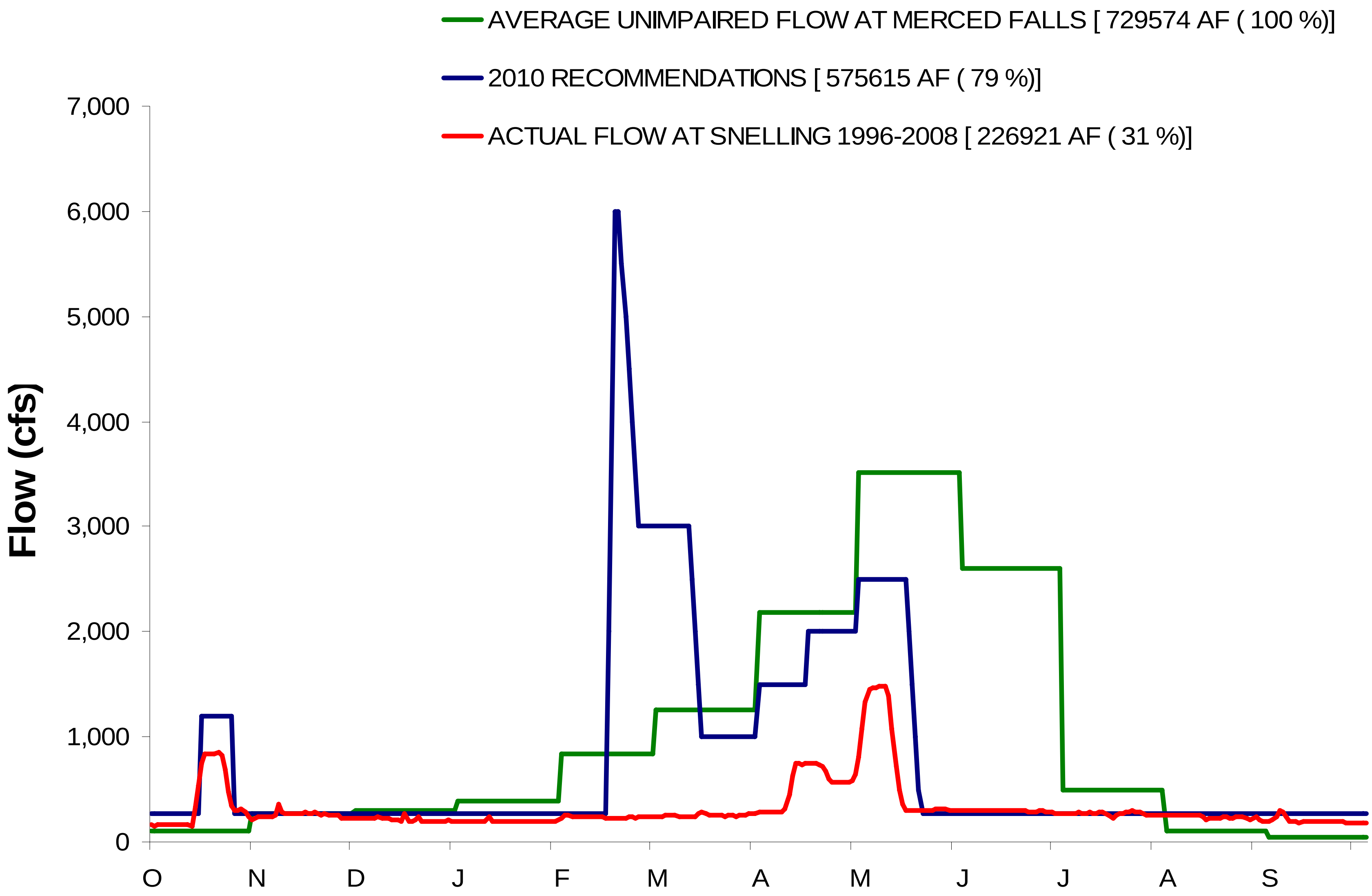

Tuolumne River – Critical Year
AVERAGE ACTUAL INRIVER FLOW AT LA GRANGE 1998-2008 [186627 AF (22 %)]
AVERAGE UNIMPAIRED FLOW AT LA GRANGE [864408 AF (100 %)]
2010 RECOMMENDATIONS [325063 AF (38 %)]
Flow (cfs)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
O
N
D
J
F
M
A
M
J
J
A
S


Merced River – Wet Year
AVERAGE UNIMPAIRED FLOW AT MERCED FALLS [1608411 AF (100 %)]
2010 RECOMMENDATIONS [986493 AF (61 %)]
ACTUAL FLOW AT SNELLING 1996-2008 [995675 AF (62 %)]
Flow (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
O
N
D
J
F
M
A
M
J
J
A
S

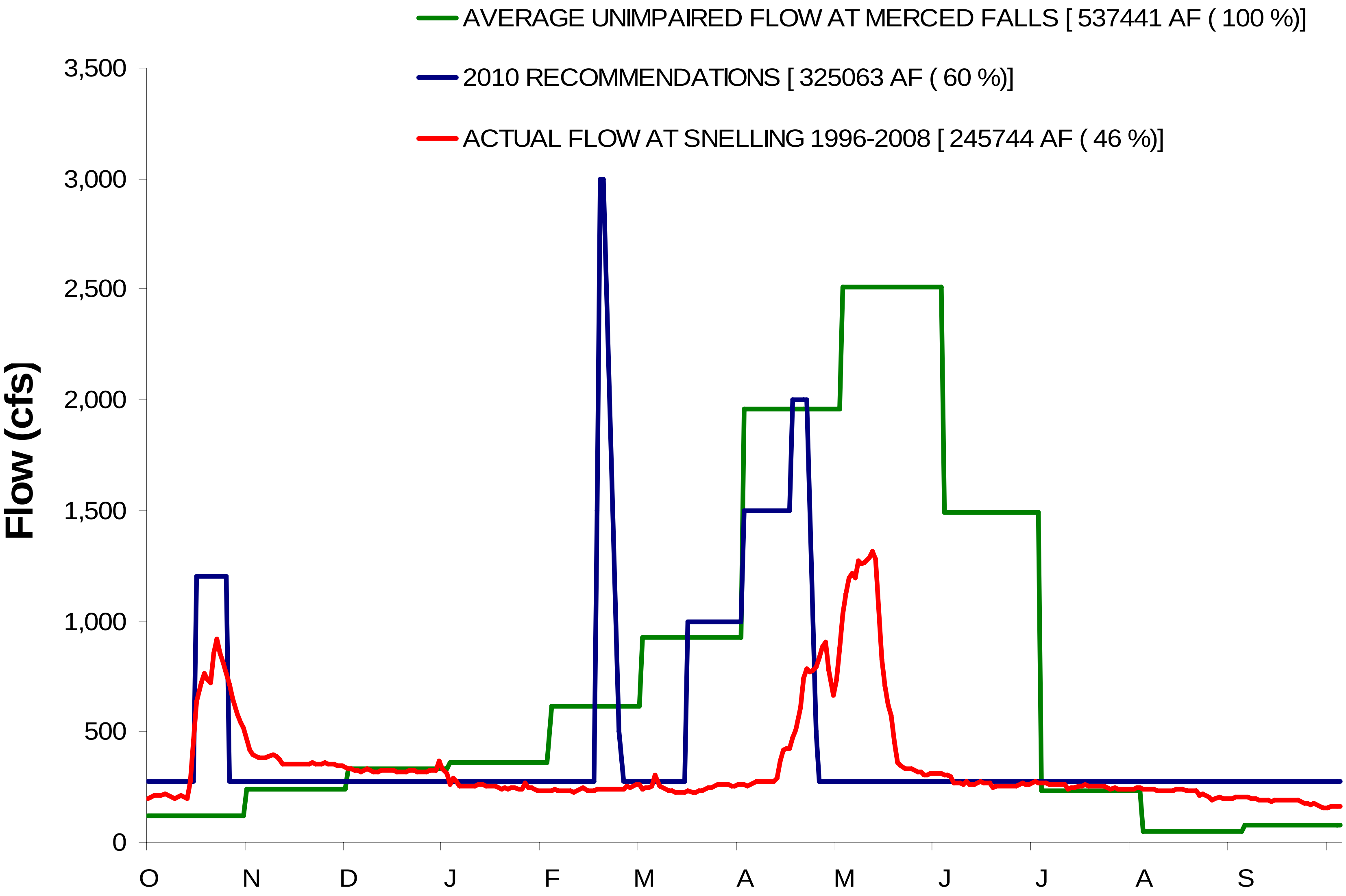
Merced River – Above Normal Year



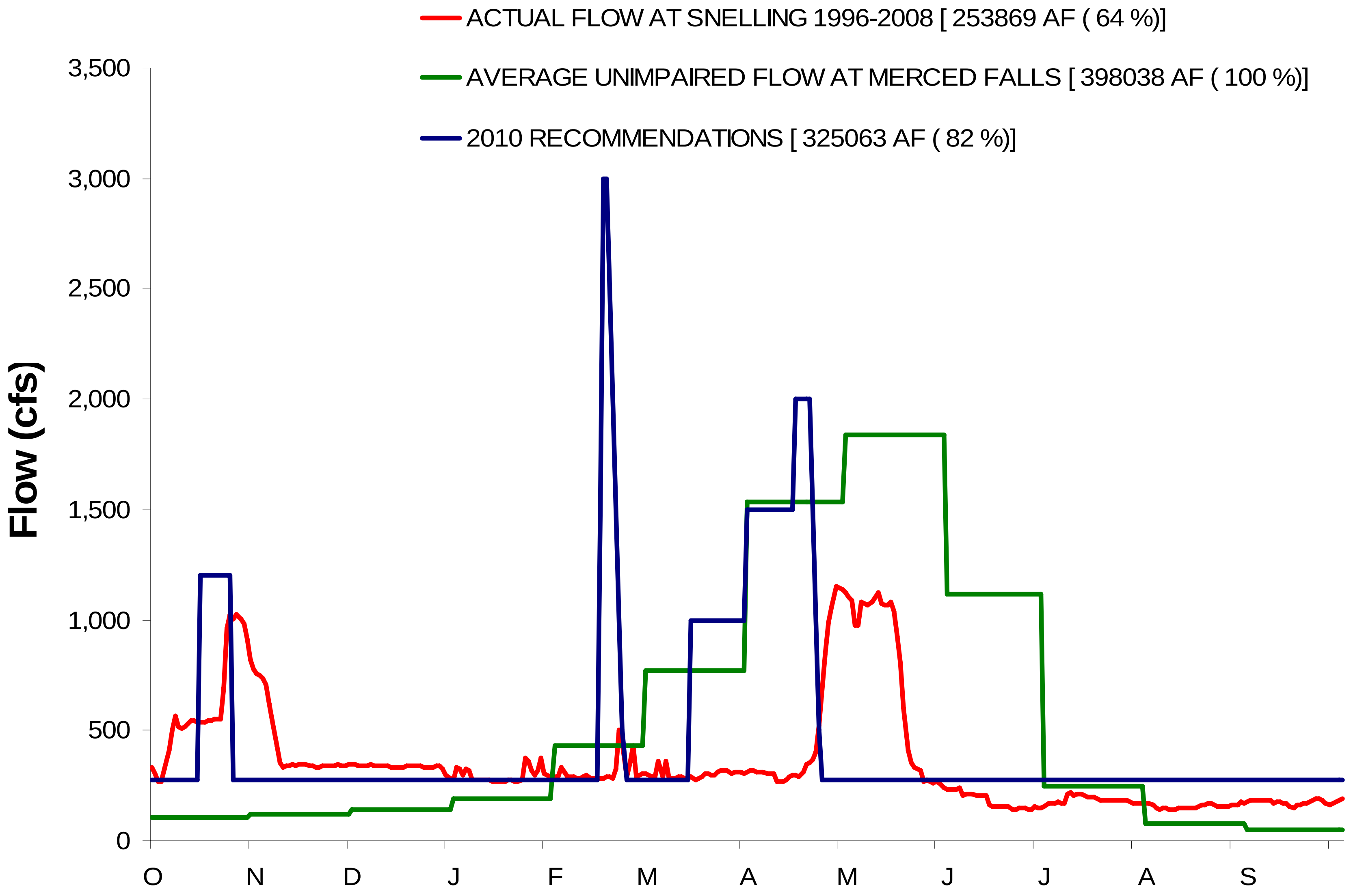
Merced River – Below Normal Year



Merced River – Dry Year



Merced River – Critical Year



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[USFWS] U.S. Fish and Wildlife Service. 2005. Recommended Streamflow Schedules to meet the AFRP Doubling Goal in the San Joaquin River Basin. 27 September 2005. Copies can be obtained at USFWS, 4001 N. Wilson Way, Stockton CA 95205.

Table 1. Recommended daily streamflow releases (cubic feet per second) for the Stanislaus, Tuolumne, and Merced rivers during Critical, Dry, Below Normal, Above Normal, and Wet water years to maintain the viability of the fall-run Chinook salmon populations and help recover Central Valley steelhead populations.

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
1-Oct	275	275	275	275	275	275
2-Oct	275	275	275	275	275	275
3-Oct	275	275	275	275	275	275
4-Oct	275	275	275	275	275	275
5-Oct	275	275	275	275	275	275
6-Oct	275	275	275	275	275	275
7-Oct	275	275	275	275	275	275
8-Oct	275	275	275	275	275	275
9-Oct	275	275	275	275	275	275
10-Oct	275	275	275	275	275	275
11-Oct	275	275	275	275	275	275
12-Oct	275	275	275	275	275	275
13-Oct	275	275	275	275	275	275
14-Oct	275	275	275	275	275	275
15-Oct	275	275	275	275	275	275
16-Oct	1200	1200	1200	1200	1200	1200
17-Oct	1200	1200	1200	1200	1200	1200
18-Oct	1200	1200	1200	1200	1200	1200
19-Oct	1200	1200	1200	1200	1200	1200
20-Oct	1200	1200	1200	1200	1200	1200
21-Oct	1200	1200	1200	1200	1200	1200
22-Oct	1200	1200	1200	1200	1200	1200
23-Oct	1200	1200	1200	1200	1200	1200
24-Oct	1200	1200	1200	1200	1200	1200
25-Oct	1200	1200	1200	1200	1200	1200
26-Oct	275	275	275	275	275	275
27-Oct	275	275	275	275	275	275
28-Oct	275	275	275	275	275	275
29-Oct	275	275	275	275	275	275
30-Oct	275	275	275	275	275	275
31-Oct	275	275	275	275	275	275
1-Nov	275	275	275	275	275	275
2-Nov	275	275	275	275	275	275

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
3-Nov	275	275	275	275	275	275
4-Nov	275	275	275	275	275	275
5-Nov	275	275	275	275	275	275
6-Nov	275	275	275	275	275	275
7-Nov	275	275	275	275	275	275
8-Nov	275	275	275	275	275	275
9-Nov	275	275	275	275	275	275
10-Nov	275	275	275	275	275	275
11-Nov	275	275	275	275	275	275
12-Nov	275	275	275	275	275	275
13-Nov	275	275	275	275	275	275
14-Nov	275	275	275	275	275	275
15-Nov	275	275	275	275	275	275
16-Nov	275	275	275	275	275	275
17-Nov	275	275	275	275	275	275
18-Nov	275	275	275	275	275	275
19-Nov	275	275	275	275	275	275
20-Nov	275	275	275	275	275	275
21-Nov	275	275	275	275	275	275
22-Nov	275	275	275	275	275	275
23-Nov	275	275	275	275	275	275
24-Nov	275	275	275	275	275	275
25-Nov	275	275	275	275	275	275
26-Nov	275	275	275	275	275	275
27-Nov	275	275	275	275	275	275
28-Nov	275	275	275	275	275	275
29-Nov	275	275	275	275	275	275
30-Nov	275	275	275	275	275	275
1-Dec	275	275	275	275	275	275
2-Dec	275	275	275	275	275	275
3-Dec	275	275	275	275	275	275
4-Dec	275	275	275	275	275	275
5-Dec	275	275	275	275	275	275
6-Dec	275	275	275	275	275	275
7-Dec	275	275	275	275	275	275
8-Dec	275	275	275	275	275	275
9-Dec	275	275	275	275	275	275

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
10-Dec	275	275	275	275	275	275
11-Dec	275	275	275	275	275	275
12-Dec	275	275	275	275	275	275
13-Dec	275	275	275	275	275	275
14-Dec	275	275	275	275	275	275
15-Dec	275	275	275	275	275	275
16-Dec	275	275	275	275	275	275
17-Dec	275	275	275	275	275	275
18-Dec	275	275	275	275	275	275
19-Dec	275	275	275	275	275	275
20-Dec	275	275	275	275	275	275
21-Dec	275	275	275	275	275	275
22-Dec	275	275	275	275	275	275
23-Dec	275	275	275	275	275	275
24-Dec	275	275	275	275	275	275
25-Dec	275	275	275	275	275	275
26-Dec	275	275	275	275	275	275
27-Dec	275	275	275	275	275	275
28-Dec	275	275	275	275	275	275
29-Dec	275	275	275	275	275	275
30-Dec	275	275	275	275	275	275
31-Dec	275	275	275	275	275	275
1-Jan	275	275	275	275	275	275
2-Jan	275	275	275	275	275	275
3-Jan	275	275	275	275	275	275
4-Jan	275	275	275	275	275	275
5-Jan	275	275	275	275	275	275
6-Jan	275	275	275	275	275	275
7-Jan	275	275	275	275	275	275
8-Jan	275	275	275	275	275	275
9-Jan	275	275	275	275	275	275
10-Jan	275	275	275	275	275	275
11-Jan	275	275	275	275	275	275
12-Jan	275	275	275	275	275	275
13-Jan	275	275	275	275	275	275
14-Jan	275	275	275	275	275	275
15-Jan	275	275	275	275	275	275

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
16-Jan	275	275	275	275	275	275
17-Jan	275	275	275	275	275	275
18-Jan	275	275	275	275	275	275
19-Jan	275	275	275	275	275	275
20-Jan	275	275	275	275	275	275
21-Jan	275	275	275	275	275	275
22-Jan	275	275	275	275	275	275
23-Jan	275	275	275	275	275	275
24-Jan	275	275	275	275	275	275
25-Jan	275	275	275	275	275	275
26-Jan	275	275	275	275	275	275
27-Jan	275	275	275	275	275	275
28-Jan	275	275	275	275	275	275
29-Jan	275	275	275	275	275	275
30-Jan	275	275	275	275	275	275
31-Jan	275	275	275	275	275	275
1-Feb	275	275	275	275	275	275
2-Feb	275	275	275	275	275	275
3-Feb	275	275	275	275	275	275
4-Feb	275	275	275	275	275	275
5-Feb	275	275	275	275	275	275
6-Feb	275	275	275	275	275	275
7-Feb	275	275	275	275	275	275
8-Feb	275	275	275	275	275	275
9-Feb	275	275	275	275	275	275
10-Feb	275	275	275	275	275	275
11-Feb	275	275	275	275	275	275
12-Feb	275	275	275	275	275	275
13-Feb	275	275	275	275	275	275
14-Feb	275	275	275	275	275	275
15-Feb	2000	2000	2000	2000	1500	1500
16-Feb	4000	4000	4000	4000	3000	3000
17-Feb	6000	6000	6000	6000	3000	3000
18-Feb	6000	6000	6000	6000	2500	2500
19-Feb	6000	6000	6000	5500	2000	2000
20-Feb	6000	6000	6000	5000	1500	1500
21-Feb	6000	6000	6000	4500	1000	1000

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
22-Feb	5500	5500	5500	4000	500	500
23-Feb	5000	5000	5000	3500	275	275
24-Feb	4500	4500	4500	3000	275	275
25-Feb	4000	4000	4000	3000	275	275
26-Feb	3500	3500	3500	3000	275	275
27-Feb	3000	3000	3000	3000	275	275
28-Feb	3000	3000	3000	3000	275	275
1-Mar	3000	3000	3000	3000	275	275
2-Mar	3000	3000	3000	3000	275	275
3-Mar	3000	3000	3000	3000	275	275
4-Mar	3000	3000	3000	3000	275	275
5-Mar	3000	3000	3000	3000	275	275
6-Mar	3000	3000	3000	3000	275	275
7-Mar	3000	3000	3000	3000	275	275
8-Mar	3000	3000	3000	3000	275	275
9-Mar	3000	3000	3000	3000	275	275
10-Mar	3000	3000	3000	3000	275	275
11-Mar	3000	3000	3000	3000	275	275
12-Mar	3000	3000	2500	2500	275	275
13-Mar	3000	3000	2000	2000	275	275
14-Mar	3000	3000	1500	1500	275	275
15-Mar	3000	3000	1000	1000	1000	1000
16-Mar	3000	3000	1000	1000	1000	1000
17-Mar	3000	3000	1000	1000	1000	1000
18-Mar	3000	3000	1000	1000	1000	1000
19-Mar	3000	3000	1000	1000	1000	1000
20-Mar	3000	3000	1000	1000	1000	1000
21-Mar	3000	3000	1000	1000	1000	1000
22-Mar	3000	3000	1000	1000	1000	1000
23-Mar	3000	3000	1000	1000	1000	1000
24-Mar	3000	3000	1000	1000	1000	1000
25-Mar	3000	3000	1000	1000	1000	1000
26-Mar	3000	3000	1000	1000	1000	1000
27-Mar	3000	3000	1000	1000	1000	1000
28-Mar	3000	3000	1000	1000	1000	1000
29-Mar	3000	3000	1000	1000	1000	1000
30-Mar	3000	3000	1000	1000	1000	1000

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
31-Mar	3000	3000	1000	1000	1000	1000
1-Apr	3000	3000	1500	1500	1500	1500
2-Apr	3000	3000	1500	1500	1500	1500
3-Apr	3000	3000	1500	1500	1500	1500
4-Apr	3000	3000	1500	1500	1500	1500
5-Apr	3000	3000	1500	1500	1500	1500
6-Apr	3000	3000	1500	1500	1500	1500
7-Apr	3000	3000	1500	1500	1500	1500
8-Apr	3000	3000	1500	1500	1500	1500
9-Apr	3000	3000	1500	1500	1500	1500
10-Apr	3000	3000	1500	1500	1500	1500
11-Apr	3000	3000	1500	1500	1500	1500
12-Apr	3000	3000	1500	1500	1500	1500
13-Apr	3000	3000	1500	1500	1500	1500
14-Apr	3000	3000	1500	1500	1500	1500
15-Apr	3000	3000	1500	1500	1500	1500
16-Apr	3000	3000	2000	2000	2000	2000
17-Apr	3000	3000	2000	2000	2000	2000
18-Apr	3000	3000	2000	2000	2000	2000
19-Apr	3000	3000	2000	2000	2000	2000
20-Apr	3000	3000	2000	2000	2000	2000
21-Apr	3000	3000	2000	2000	1500	1500
22-Apr	3000	3000	2000	2000	1000	1000
23-Apr	3000	3000	2000	2000	500	500
24-Apr	3000	3000	2000	2000	275	275
25-Apr	3000	3000	2000	2000	275	275
26-Apr	3000	3000	2000	2000	275	275
27-Apr	3000	3000	2000	2000	275	275
28-Apr	3000	3000	2000	2000	275	275
29-Apr	3000	3000	2000	2000	275	275
30-Apr	3000	3000	2000	2000	275	275
1-May	3000	3000	2500	2500	275	275
2-May	3000	3000	2500	2500	275	275
3-May	3000	3000	2500	2500	275	275
4-May	3000	3000	2500	2500	275	275
5-May	3000	3000	2500	2500	275	275
6-May	3000	3000	2500	2500	275	275

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
7-May	3000	3000	2500	2500	275	275
8-May	3000	3000	2500	2500	275	275
9-May	3000	3000	2500	2500	275	275
10-May	3000	3000	2500	2500	275	275
11-May	3000	3000	2500	2500	275	275
12-May	3000	3000	2500	2500	275	275
13-May	3000	3000	2500	2500	275	275
14-May	3000	3000	2500	2500	275	275
15-May	3000	3000	2500	2500	275	275
16-May	4000	3000	2400	2000	275	275
17-May	4000	3000	2300	1500	275	275
18-May	4000	3000	2200	1000	275	275
19-May	4000	3000	2100	500	275	275
20-May	4000	3000	2000	275	275	275
21-May	4000	3000	1900	275	275	275
22-May	4000	3000	1800	275	275	275
23-May	4000	3000	1700	275	275	275
24-May	4000	3000	1600	275	275	275
25-May	4000	3000	1500	275	275	275
26-May	4000	3000	1400	275	275	275
27-May	4000	3000	1300	275	275	275
28-May	4000	3000	1200	275	275	275
29-May	4000	3000	1100	275	275	275
30-May	4000	3000	1000	275	275	275
31-May	4000	3000	900	275	275	275
1-Jun	4000	3000	800	275	275	275
2-Jun	4000	3000	700	275	275	275
3-Jun	4000	3000	600	275	275	275
4-Jun	4000	3000	500	275	275	275
5-Jun	4000	3000	275	275	275	275
6-Jun	4000	3000	275	275	275	275
7-Jun	4000	3000	275	275	275	275
8-Jun	4000	3000	275	275	275	275
9-Jun	4000	3000	275	275	275	275
10-Jun	4000	3000	275	275	275	275
11-Jun	4000	3000	275	275	275	275
12-Jun	4000	3000	275	275	275	275

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
13-Jun	4000	3000	275	275	275	275
14-Jun	4000	3000	275	275	275	275
15-Jun	4000	3000	275	275	275	275
16-Jun	3900	2900	275	275	275	275
17-Jun	3800	2800	275	275	275	275
18-Jun	3700	2700	275	275	275	275
19-Jun	3600	2600	275	275	275	275
20-Jun	3500	2500	275	275	275	275
21-Jun	3400	2400	275	275	275	275
22-Jun	3300	2300	275	275	275	275
23-Jun	3200	2200	275	275	275	275
24-Jun	3100	2100	275	275	275	275
25-Jun	3000	2000	275	275	275	275
26-Jun	2900	1900	275	275	275	275
27-Jun	2800	1800	275	275	275	275
28-Jun	2700	1700	275	275	275	275
29-Jun	2600	1600	275	275	275	275
30-Jun	2500	1500	275	275	275	275
1-Jul	2400	1400	275	275	275	275
2-Jul	2300	1300	275	275	275	275
3-Jul	2200	1200	275	275	275	275
4-Jul	2100	1100	275	275	275	275
5-Jul	2000	1000	275	275	275	275
6-Jul	1900	900	275	275	275	275
7-Jul	1800	800	275	275	275	275
8-Jul	1700	700	275	275	275	275
9-Jul	1600	600	275	275	275	275
10-Jul	1500	500	275	275	275	275
11-Jul	1400	275	275	275	275	275
12-Jul	1300	275	275	275	275	275
13-Jul	1200	275	275	275	275	275
14-Jul	1100	275	275	275	275	275
15-Jul	1000	275	275	275	275	275
16-Jul	900	275	275	275	275	275
17-Jul	800	275	275	275	275	275
18-Jul	700	275	275	275	275	275
19-Jul	600	275	275	275	275	275

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
20-Jul	500	275	275	275	275	275
21-Jul	275	275	275	275	275	275
22-Jul	275	275	275	275	275	275
23-Jul	275	275	275	275	275	275
24-Jul	275	275	275	275	275	275
25-Jul	275	275	275	275	275	275
26-Jul	275	275	275	275	275	275
27-Jul	275	275	275	275	275	275
28-Jul	275	275	275	275	275	275
29-Jul	275	275	275	275	275	275
30-Jul	275	275	275	275	275	275
31-Jul	275	275	275	275	275	275
1-Aug	275	275	275	275	275	275
2-Aug	275	275	275	275	275	275
3-Aug	275	275	275	275	275	275
4-Aug	275	275	275	275	275	275
5-Aug	275	275	275	275	275	275
6-Aug	275	275	275	275	275	275
7-Aug	275	275	275	275	275	275
8-Aug	275	275	275	275	275	275
9-Aug	275	275	275	275	275	275
10-Aug	275	275	275	275	275	275
11-Aug	275	275	275	275	275	275
12-Aug	275	275	275	275	275	275
13-Aug	275	275	275	275	275	275
14-Aug	275	275	275	275	275	275
15-Aug	275	275	275	275	275	275
16-Aug	275	275	275	275	275	275
17-Aug	275	275	275	275	275	275
18-Aug	275	275	275	275	275	275
19-Aug	275	275	275	275	275	275
20-Aug	275	275	275	275	275	275
21-Aug	275	275	275	275	275	275
22-Aug	275	275	275	275	275	275
23-Aug	275	275	275	275	275	275
24-Aug	275	275	275	275	275	275
25-Aug	275	275	275	275	275	275

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
26-Aug	275	275	275	275	275	275
27-Aug	275	275	275	275	275	275
28-Aug	275	275	275	275	275	275
29-Aug	275	275	275	275	275	275
30-Aug	275	275	275	275	275	275
31-Aug	275	275	275	275	275	275
1-Sep	275	275	275	275	275	275
2-Sep	275	275	275	275	275	275
3-Sep	275	275	275	275	275	275
4-Sep	275	275	275	275	275	275
5-Sep	275	275	275	275	275	275
6-Sep	275	275	275	275	275	275
7-Sep	275	275	275	275	275	275
8-Sep	275	275	275	275	275	275
9-Sep	275	275	275	275	275	275
10-Sep	275	275	275	275	275	275
11-Sep	275	275	275	275	275	275
12-Sep	275	275	275	275	275	275
13-Sep	275	275	275	275	275	275
14-Sep	275	275	275	275	275	275
15-Sep	275	275	275	275	275	275
16-Sep	275	275	275	275	275	275
17-Sep	275	275	275	275	275	275
18-Sep	275	275	275	275	275	275
19-Sep	275	275	275	275	275	275
20-Sep	275	275	275	275	275	275
21-Sep	275	275	275	275	275	275
22-Sep	275	275	275	275	275	275
23-Sep	275	275	275	275	275	275
24-Sep	275	275	275	275	275	275
25-Sep	275	275	275	275	275	275
26-Sep	275	275	275	275	275	275
27-Sep	275	275	275	275	275	275
28-Sep	275	275	275	275	275	275
29-Sep	275	275	275	275	275	275
30-Sep	275	275	275	275	275	275

	Tuolumne	Stanislaus & Merced	Stanislaus, Tuolumne, and Merced Rivers			
DATE	WET	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
Flow Volumes Acre-Feet	1,110,926	986,493	632,329	575,615	325,063	325,063
Percent Unimpaired Stanislaus River		54%	50%	65%	50%	71%
Percent Unimpaired Tuolumne River	37%		30%	39%	28%	38%
Percent Unimpaired Merced River		61%	60%	79%	60%	82%

United States
Environmental Protection Agency

Region 10
Office of Water

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EPA Region 10 Guidance For Pacific Northwest State and Tribal Temperature Water Quality Standards

Acknowledgments

The *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* is a product of a three year interagency effort involving the Idaho Department of Environmental Quality, Oregon Department of Environmental Quality, Washington Department of Ecology, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Nez Perce Tribe, Columbia River Inter-Tribal Fish Commission (representing its four governing tribes: the Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes and Bands of the Yakima Nation, and the Confederated Tribes of the Warm Springs Reservation of Oregon), and EPA Region 10.

John Palmer of EPA Region 10's Office of Water chaired an interagency policy workgroup and was the principal author of the guidance with assistance from the following workgroup members: Randy Smith and Dru Keenan of EPA Region 10's Office of Water; Dave Mabe and Don Essig of the Idaho Department of Environmental Quality; Mark Charles and Debra Sturdevant of the Oregon Department of Environmental Quality; Dave Peeler and Mark Hicks of the Washington Department of Ecology; Russ Strach, Jeff Lockwood, and Robert Anderson of the National Marine Fisheries Service; Stephen Zylstra, Elizabeth Materna, and Shelley Spalding of the U.S. Fish and Wildlife Service; Barbara Inyan of the Nez Perce Tribe, and Patti Howard and Dale McCullough of the Columbia River Inter-Tribal Fish Commission.

The scientific and technical foundation for the guidance, as reflected in six scientific papers, was developed by an interagency technical workgroup led by Dru Keenan and Geoff Poole of the EPA Region 10. Other members of the technical workgroup were: Chris Mebane and Don Essig of the Idaho Department of Environmental Quality; Debra Sturdevant of the Oregon Department of Environmental Quality; Mark Hicks of the Washington Department of Ecology; Jeff Lockwood of the National Marine Fisheries Service; Elizabeth Materna and Shelley Spalding of the U.S. Fish and Wildlife Services; Dale McCullough of the Columbia River Inter-Tribal Fish Commission; John McMillan of the Hoh Tribe; Jason Dunham of the U.S. Forest Service, and John Risley and Sally Sauter of the U. S. Geological Service. Marianne Deppman of EPA Region 10 provided organizational and facilitation support for the technical workgroup.

Two independent scientific peer review panels were convened to provide comment on various aspects of the guidance and the scientific issue papers. The peer review scientists are identified in the peer review reports, which are referenced in Section X of the guidance.

EPA issued two public review drafts, the first in October, 2001 and the second in October, 2002, and received valuable comments from the public that helped shape the guidance.

An EPA review team consisting of the following individuals also provided valuable input into the development of the guidance: Carol Ann Siciliano of EPA's Office of General Counsel; Cara Lalley, Lars Wilcut, and Jim Keating of EPA's Office of Water; Adrianne Allen, Keith Cohon, and Rich McAllister of EPA Region 10's Office of Regional Counsel; Paula Vanhaagen, Marcia Lagerloef, Kerianne Gardner, Robert Robichaud, Kristine Koch, Kathy Collins, Patty McGrath, Mike Lidgard, Christine Psyk, Jannine Jennings, Rick Parkin, and Jayne Carlin of EPA Region 10's Office of Water; Ben Cope and Peter Leinenbach of EPA Region 10's Office of Environmental Assessment; and Derek Poon and Steve Ralph of EPA Region 10's Office of Ecosystems and Communities.

EPA gratefully acknowledges the above individuals, members of the peer review panels, and the public for their participation and valuable input into the development of the guidance. Although members of the organizations listed above contributed to the development of the guidance, this guidance ultimately reflects the views of EPA.

This report should be cited as:

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To obtain a copy of this guidance free of charge, contact:

EPA Region 10's Public Environmental Resource Center
Phone: 1-800-424-4372

This guidance, along with other supporting material, is available on the internet at:

www.epa.gov/r10earth/temperature.htm

Forward

The goal of the Clean Water Act (CWA) is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters and, where attainable, to achieve water quality that provides for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water. As a means of meeting this goal, section 303(c) of the CWA requires States and authorized Tribes to adopt water quality standards (WQS) and requires the U.S. Environmental Protection Agency (EPA) to approve or disapprove those standards.

At this time, many Pacific Northwest salmonid species are listed as threatened or endangered under the Endangered Species Act (ESA). As a result, the ESA requires that EPA must insure that its approval of a State or Tribal WQS is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of their critical habitat.

Water temperature is a critical aspect of the freshwater habitat of Pacific Northwest salmonids. Those salmonids listed as threatened or endangered under the ESA and other coldwater salmonids need cold water to survive. Human-caused increases in river water temperatures have been identified as a factor in the decline of ESA-listed salmonids in the Pacific Northwest. State and Tribal temperature WQS can play an important role in helping to maintain and restore water temperatures to protect Pacific Northwest salmonids and aid in their recovery. For these reasons, EPA in collaboration with others, developed this guidance to better describe appropriate water temperatures to protect Pacific Northwest salmonids.

The *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* is intended to assist States and Tribes to adopt temperature WQS that EPA can approve consistent with its obligations under the Clean Water Act (CWA) and the Endangered Species Act (ESA). This guidance document, however, does not substitute for applicable legal requirements; nor is it a regulation itself. Thus, it does not impose legally binding requirements on any party, including EPA, other federal agencies, the states, or the regulated community. Comments and suggestions from readers are encouraged and will be used to help improve the available guidance as EPA continues to build experience and understanding of water temperature and salmonids.

L. John Iani, Regional Administrator
U.S. EPA Region 10
Seattle, WA 98101

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EPA Region 10 Guidance
for
Pacific Northwest State and Tribal Temperature Water Quality Standards

I. Introduction

This guidance describes an approach that EPA Region 10 encourages States and authorized Tribes (Tribes) in the Pacific Northwest to use when adopting temperature water quality standards (WQS) to protect coldwater salmonids. The recommendations in this guidance are intended to assist States and Tribes to adopt temperature WQS that EPA can approve consistent with its obligations under the Clean Water Act (CWA) and the Endangered Species Act (ESA). This guidance specifically addresses the following coldwater salmonid species in the Pacific Northwest: chinook, coho, sockeye, chum, and pink salmon; steelhead and coastal cutthroat trout; and bull trout. The information provided in this guidance may also be useful for States and Tribes to protect other coldwater salmonid species that have similar temperature tolerances but are not explicitly addressed in this guidance.

This guidance provides recommendations to States and Tribes on how they can designate uses and establish temperature numeric criteria for waterbodies that help meet the goal of "protection and propagation of fish, shellfish, and wildlife" in section 101(a)(2) of the CWA. States or Tribes that choose to adopt new or revised temperature WQS must submit those standards to EPA for review and approval or disapproval. CWA section 303(c)(2)(A). EPA expects to be able to expedite its review of revised temperature standards that follow the recommendations in this guidance. States and Tribes that choose to follow the recommendations in this guidance, particularly those described in Section V, may wish to reference this guidance when submitting new or revised salmonid use designations and supporting criteria to EPA for approval.

EPA action on State and Tribal WQS that are consistent with this guidance is expected to be significantly expedited because the scientific rationale in support of the State and Tribal WQS would in large part already be described and supported by EPA, and by the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (the Services). However, because this is a guidance document and not a regulation, EPA cannot bind itself to approve a WQS submission that follows the recommendation of this guidance. Furthermore, the Services cannot bind themselves to future consultation determinations (i.e., a "no jeopardy" determination) under the ESA. So even though EPA expects the review process to be significantly expedited if this guidance is followed, EPA and the Services must still examine every WQS submission on a case-by-case basis, taking into consideration any public comments received or other new information.

It is also important to note that this guidance does not preclude States or Tribes from adopting temperature WQS different from those described here. EPA would approve any temperature

WQS that it determines are consistent with the applicable requirements of the CWA and its obligations under the ESA. Because this guidance reflects EPA's current analysis of temperature considerations for Pacific Northwest salmonid species, EPA intends to consider it when reviewing Pacific Northwest State and Tribal temperature WQS or promulgating federal temperature WQS in Idaho, Oregon, or Washington.

Temperature WQS are viewed by EPA and the Services as an important tool for the protection and recovery of threatened and endangered salmonid species in the Pacific Northwest. Attaining criteria and protecting existing cold temperatures for waters used by these salmonids will help maintain and improve their habitat and aid in their recovery. Meeting temperature WQS, however, should be viewed as part of the larger fish recovery efforts to restore habitat. Wherever practicable, implementation actions to restore water temperatures should be integrated with implementation actions to improve habitat in general, and should be targeted first toward those reaches within a basin that will provide the biggest benefit to the fish. It should also be noted that the actions needed to improve water temperatures are, in many cases, the same as those needed to improve other fish habitat features. For example, restoring a stream's riparian vegetation can reduce water temperature as well as reduce sediment erosion, provide over bank micro-habitat, and add fallen wood to the river that over time creates pools and a more diverse stream habitat preferred by salmonids.

This guidance was developed with the assistance of representatives of the Pacific Northwest States, the Services, and the Columbia River Inter-Tribal Fish Commission (CRITFC) Tribes. As part of developing this guidance, EPA, with the assistance of technical experts from Federal, State, and Tribal organizations, developed five technical issue papers and a technical synthesis report summarizing technical issues related to water temperature and salmonids. These reports represent the technical foundation of this guidance and summarize the latest literature related to temperature and salmonids. See Section X, References, at the end of this guidance for a list of these technical papers.

II. Regulatory Background

The goal of the CWA is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters and, where attainable, to achieve water quality that provides for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water. See CWA section 101(a)(2). As a means of meeting this goal, section 303(c) of the CWA requires States and Tribes to adopt WQS that include designated uses and water quality criteria to protect those designated uses. In addition, Federal WQS regulations require States and Tribes to adopt a statewide antidegradation policy and identify methods to implement such policy. See 40 C.F.R. § 131.12. States and Tribes may also adopt into their standards policies generally affecting the application and implementation of WQS, such as mixing zones and variances. See 40 C.F.R. § 131.13.

EPA is required to approve or disapprove new or revised State and Tribal WQS under section 303(c) of the CWA to ensure they are consistent with the requirements of the CWA and EPA's implementing regulations. See CWA section 303(c)(3). New or revised State and Tribal WQS are not in effect for CWA purposes until they are approved by EPA. If EPA disapproves a new or revised WQS submitted by a State or Tribe, or if the EPA Administrator determines that a new or revised WQS is necessary to meet the requirements of the CWA, EPA must propose and promulgate appropriate WQS itself, unless appropriate changes are made by the State or Tribe. See CWA section 303(c)(4).

Where EPA determines that its approval of State or Tribal WQS may affect threatened or endangered species or their critical habitat, the approval action is subject to the procedural and substantive requirements of section 7(a)(2) of the ESA. Section 7(a)(2) of the ESA requires EPA to ensure, in consultation with the Service(s), that any action it takes is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat. Under the ESA regulations, such consultations can be concluded informally where EPA determines that its action is not likely to adversely affect listed species or critical habitat, and where the Service(s) concur with that finding in writing. See 50 C.F.R. § 402.13. Where EPA does not make such a determination, or where the Service(s) do not concur in writing, the ESA regulations require EPA to engage in formal consultation, which results in the issuance of a biological opinion by the Service(s). See 50 C.F.R. § 402.14. If the Service(s) anticipate that "take" will occur as a result of the action, the opinion in most cases will include required reasonable and prudent measures and associated terms and conditions to minimize such take, along with an incidental take statement providing EPA legal protection from ESA section 9 take liability for its approval action. See 50 C.F.R. § 402.14(i). Section 7(a)(1) of the ESA requires EPA to use its authorities to carry out programs for the conservation of endangered and threatened species. The ESA, however, does not expand EPA's authorities under the CWA. EPA approval or disapproval decisions regarding State and Tribal WQS must be authorized by the CWA and EPA's implementing regulations.

In addition, EPA has a federal trust relationship with federally recognized Pacific Northwest tribes. In the Pacific Northwest, federal courts have affirmed that certain tribes reserved through treaty the right to fish at all usual and accustomed fishing places and to take a fair share of the fish destined to pass through such areas. *See* Puyallup Tribe v. Department of Game, 391 U.S. 392 (1968); Washington v. Passenger Fishing Vessel, 443 U.S. 658 (1979); United States v. Winans, 198 U.S. 371 (1905). EPA's approval of a State or Tribal WQS, or promulgation of its own WQS, may impact the habitat that supports the treaty fish. EPA has a responsibility to ensure that its WQS actions do not violate treaty fishing rights.

Water Quality Standards set the water quality goals for specific waterbodies and serve as a regulatory basis for other programs, such as National Pollutant Discharge Elimination System (NPDES) permits, listings of impaired water bodies under CWA section 303(d), and total maximum daily loads (TMDLs). In general, NPDES permits contain effluent limitations to meet WQS; section 303(d) lists identify those water bodies where the WQS are not being met; and TMDLs are mathematical calculations indicating the pollutant reductions needed to meet WQS.

III. Relationship of Guidance to EPA's 304(a) Criteria for Water Temperature

Under CWA section 304(a), EPA issues national criteria recommendations to guide States and Tribes in developing their WQS. When EPA reviews a State or Tribal WQS submission for approval under section 303(c) of the CWA, it must determine whether the adopted designated uses and criteria are consistent with the CWA and EPA's regulations. See CWA section 303(c)(3). Specifically, 40 C.F.R § 131.11 requires States and Tribes to adopt water quality criteria that are based on sound scientific rationale and contain sufficient parameters or constituents to protect the designated uses. For waters with multiple use designations, the criteria must support the most sensitive use. See 40 C.F.R. § 131.11(a). When establishing criteria, States should: (1) establish numerical values based on 304(a) guidance, or 304(a) guidance modified to reflect site-specific conditions, or other scientifically defensible methods; or (2) establish narrative criteria or criteria based upon biomonitoring methods where numerical criteria cannot be established or to supplement numerical criteria. See 40 C.F.R. § 131.11(b).

EPA develops its section 304(a) criteria recommendations based on a uniform methodology that takes into account a range of species' sensitivities to pollutant loadings using certain general assumptions; therefore, the national recommendations are generally protective of aquatic life. However, these criteria recommendations may not be protective of all aquatic life designated uses in all situations. It may be appropriate for States and Tribes to develop different water quality criteria using current data concerning the species present, and taking into account site-specific or regional conditions. EPA approval or disapproval would not depend on whether a criterion adopted by a State or Tribe is consistent with a particular guidance document, such as this guidance or the national 304(a) criteria recommendations, but rather on whether the State or Tribe demonstrates that the criterion protects the most sensitive designated use, as required by section 303(c) of the CWA and EPA's WQS regulations.

EPA's current 304(a) criteria recommendations for temperature can be found in *Quality Criteria for Water 1986*, commonly known as the "gold book." The freshwater aquatic life criteria described in this 1986 document were first established in 1977, and were not changed in the 1986 document. In general, EPA's national temperature recommendations for salmonids and other fish consist of formulas to calculate the protective temperatures for short-term exposure and a maximum weekly average exposure. Protective short term temperature exposure is based on subtracting 2°C from the upper incipient lethal temperature (the temperature at which fifty percent of the sample dies). Protective weekly average temperature exposure is based on the optimal growth temperature plus 1/3 the difference between the optimal growth temperature and the upper incipient lethal temperature. Using these formulas and EPA data for coho and sockeye salmon, the 1986 document calculates suggested temperature criteria for short-term exposure as 22°C (sockeye) and 24°C (coho) and a maximum weekly average exposure of 18°C for both species.

Based on extensive review of the most recent scientific studies, EPA Region 10 and the Services believe that there are a variety of chronic and sub-lethal effects that are likely to occur to Pacific Northwest salmonid species exposed to the maximum weekly average temperatures calculated using the current 304(a) recommended formulas. These chronic and sub-lethal effects include reduced juvenile growth, increased incidence of disease, reduced viability of gametes in adults prior to spawning, increased susceptibility to predation and competition, and suppressed or reversed smoltification. It may be possible for healthy fish populations to endure some of these chronic impacts with little appreciable loss in population size. However, for vulnerable fish populations, such as the endangered or threatened salmonids of the Pacific Northwest, EPA and the Services are concerned that these chronic and sub-lethal effects can reduce the overall health and size of the population.

For these reasons, the national assumptions made when developing the section 304(a) criteria recommendations for temperature may not necessarily protect the vulnerable coldwater salmonids in the Pacific Northwest. EPA Region 10, therefore, has developed this guidance to assist Pacific Northwest States and Tribes in developing temperature criteria that protect the coldwater salmonids in the Pacific Northwest identified above.

IV. Water Temperature and Salmonids

IV.1. Importance of Temperature for Salmonids

Water temperatures significantly affect the distribution, health, and survival of native salmonids in the Pacific Northwest. Since salmonids are ectothermic (cold-blooded), their survival is dependent on external water temperatures and they will experience adverse health effects when exposed to temperatures outside their optimal range. Salmonids have evolved and thrived under the water temperature patterns that historically existed (i.e., prior to significant anthropogenic impacts that altered temperature patterns) in Pacific Northwest streams and rivers. Although evidence suggests that historical water temperatures exceeded optimal conditions for salmonids at times during the summer months on some rivers, the temperature diversity in these unaltered rivers provided enough cold water during the summer to allow salmonid populations as a whole to thrive.

Pacific salmon populations have historically fluctuated dramatically due to climatic conditions, ocean conditions, and other disturbances. High water temperatures during drought conditions likely affected the historical abundance of salmon. In general, the increased exposure to stressful water temperatures and the reduction of suitable habitat caused by drought conditions reduce the abundance of salmon. Human-caused elevated water temperatures significantly increase the magnitude, duration, and extent of thermal conditions unsuitable for salmonids.

The freshwater life histories of salmonids are closely tied to water temperatures. Cooling rivers in the autumn serve as a signal for upstream migrations. Fall spawning is initiated when water temperatures decrease to suitable temperatures. Eggs generally incubate over the winter or early spring when temperatures are coolest. Rising springtime water temperatures may serve as a cue for downstream migration.

Because of the overall importance of water temperature for salmonids in the Pacific Northwest, human-caused changes to natural temperature patterns have the potential to significantly reduce the size of salmonid populations. Of particular concern are human activities that have led to the excess warming of rivers and the loss of temperature diversity.

IV.2. Human Activities That Can Contribute to Excess Warming of Rivers and Streams

Rivers and streams in the Pacific Northwest naturally warm in the summer due to increased solar radiation and warm air temperature. Human changes to the landscape have magnified the degree of river warming, which adversely affects salmonids and reduces the number of river segments that are thermally suitable for salmonids. Human activities can increase water temperatures by increasing the heat load into the river, by reducing the river's capacity to absorb heat, and by eliminating or reducing the amount of groundwater flow which moderates temperatures and provides cold water refugia. Specific ways in which human development has caused excess warming of rivers are presented in Issue Paper 3 and are summarized below:

1) Removal of streamside vegetation reduces the amount of shade that blocks solar radiation and increases solar heating of streams. Examples of human activities that reduce shade include forest harvesting, agricultural land clearing, livestock grazing, and urban development.

2) Removal of streamside vegetation also reduces bank stability, thereby causing bank erosion and increased sediment loading into the stream. Bank erosion and increased sedimentation results in wider and shallower streams, which increases the stream's heat load by increasing the surface area subject to solar radiation and heat exchange with the air.

3) Water withdrawals from rivers for purposes such as agricultural irrigation and urban/municipal and industrial use result in less river volume and generally remove cold water. The temperatures of rivers with smaller volumes equilibrates faster to surrounding air temperature, which leads to higher maximum water temperatures in the summer.

4) Water discharges from industrial facilities, wastewater treatment facilities and irrigation return flows can add heat to rivers.

5) Channeling, straightening, or diking rivers for flood control and urban and agricultural land development reduces or eliminates cool groundwater flow into a river that moderates summertime river temperatures. These human actions can reduce two forms of groundwater flow. One form is groundwater that is created during over-bank flooding and is slowly returned to the main river channel to cool the water in the summer. A

second form is water that is exchanged between the river and the riverbed (i.e. hyporheic flow). Hyporheic flow is plentiful in fully functioning alluvial rivers systems.

6) Removal of upland vegetation and the creation of impervious surfaces associated with urban development increases storm runoff and reduces the amount of groundwater that is stored in the watershed and slowly filters back to the stream in the summer to cool water temperatures.

7) Dams and their reservoirs can affect thermal patterns in a number of ways. They can increase maximum temperatures by holding waters in reservoirs to warm, especially in shallow areas near shore. Reservoirs, due to their increased volume of water, are more resistant to temperature change which results in reduced diurnal temperature variation and prolonged periods of warm water. For example, dams can delay the natural cooling that takes place in the late summer-early fall, thereby harming late summer-fall migration runs. Reservoirs also inundate alluvial river segments, thereby diminishing the groundwater exchange between the river and the riverbed (i.e., hyporheic flow) that cools the river and provides cold water refugia during the summer. Further, dams can significantly reduce the river flow rate, thereby causing juvenile migrants to be exposed to high temperatures for a much longer time than they would under a natural flow regime.

It should also be noted that some human development can create water temperatures colder than an unaltered river. The most significant example of this occurs when cold water is released from the bottom of a thermally stratified reservoir behind a dam.

IV.3. Human-Caused Elevated Water Temperature as a Factor in Salmonid Decline

Many reports issued in the past decade have described the degradation of freshwater salmonid habitat, including human-caused elevated temperatures, as a major factor in salmonid decline. The following provides a brief summary of some of these reports:

National Marine Fisheries Service's Listing and Status Reviews for Pacific Northwest Salmonids

The National Marine Fisheries Service (NMFS) identified habitat concerns (including alteration of ambient stream water temperatures) as one of the factors for decline of listed west coast steelhead (NMFS 1996), west coast chinook (NMFS 1998), and Snake River spring/summer chinook salmon (Mathews and Waples 1991). Specific effects attributed to increased temperatures by NMFS include increased juvenile mortality, increased susceptibility and exposure to diseases, impaired ability to avoid predators, altered migration timing, and changes in fish community structure that favor competitors of salmonids. NMFS included high water temperatures among risk factors related to the listings under the ESA of the following evolutionarily significant units (ESUs) of chinook salmon: Puget Sound, Lower Columbia River, Snake River spring/summer, and Upper Willamette (Myers et al. 1998). NMFS also noted high water temperatures in its analyses of risk factors related to the ESA listings of Upper Willamette River steelhead and Ozette Lake sockeye.

U.S. Fish and Wildife Service Listing and Status Reviews for Bull Trout

When listing bull trout in the Columbia River and Coastal-Puget Sound population segments, USFWS identified activities such as forestry, agriculture, and hydropower that have degraded bull trout habitat and specifically have resulted in increased stream temperatures. Bull trout are found primarily in colder streams, although individual fish are found in larger river systems. Water temperature above 15°C is believed to limit bull trout distribution and this may partially explain their patchy distribution within a watershed. The strict cold water temperature needs of bull trout make them particularly vulnerable to human activities identified by USFWS that warm spawning and rearing waters.

Return to the River Reports by the Independent Science Group

The Independent Scientific Group is a group of scientists chartered by the Northwest Power Planning Council to provide independent scientific advice to the Columbia River Basin Fish and Wildlife Program. In their 1996 Return the River report (updated in 2000), they include a section discussing the effects of elevated temperature on salmonids as part of their overall discussion of freshwater habitats. The report states:

> "Temperature is a critical habitat variable that is very much influenced by regulation of flow and impoundments. The mainstem reservoirs are relatively shallow and heat up in late summer causing concern for salmon survival. The lower reaches of some key tributaries also are very warm in late summer because they are dewatered by irrigation withdrawals. Due to the extreme importance of temperature regimes to the ecology of salmonids in the basin, temperature information merits special attention as a key habitat descriptor (Coutant 1999)."
>
> "Water temperatures in the Columbia River basin have been altered by development and are, at times, suboptimal or clearly detrimental for salmonids. High temperatures alone can be directly lethal to both juvenile and adult salmonids in the Snake River in summer under recent conditions based on generally accepted thermal criteria and measured temperatures."

Oregon Coastal Salmon Restoration Initiative

The Oregon Coastal Salmon Restoration Initiative (1997) included water temperature as a factor for decline in populations of Oregon coastal coho salmon, noting that:

> "Water temperatures are too warm for salmonids in many coastal streams. Altered water temperatures can adversely affect spawning, fry emergence, smoltification, maturation

> period, migratory behavior, competition with other aquatic species, growth and disease resistance."

Summer Chum Salmon Conservation Initiative

The Summer Chum Salmon Conservation Initiative (2000) for the Hood Canal and Strait of Juan de Fuca region listed elevated water temperature in its limiting factor analysis, noting that:

> "Elevated temperatures impede adult passage, cause direct mortality, and accelerate development during incubation leading to diminished survival in subsequent life stages."

Interior Columbia Basin Ecosystem Management Project

The aquatic habitat assessment for the Interior Columbia Basin Ecosystem Management Project (Lee et al. 1997) indicates that:

1. Changes in riparian canopy and shading, or other factors influencing stream temperatures, are likely to affect some, if not most, bull trout populations.
2. In desert climates, the loss of riparian canopy has been associated with elevated water temperature and reduced redband trout abundance.
3. Loss of vegetation has resulted in stream temperatures that have far exceeded those considered optimal for Lahontan Cutthroat Trout.
4. Water temperatures in reaches of the John Day, upper Grande Ronde, and other basins in eastern Oregon commonly exceed the preferred ranges and often exceed lethal temperatures for chinook salmon.

Northwest Indian Fisheries Commission - Critical Habitat Issues by Basin for Natural Chinook Stocks in the Coastal and Puget Sound Areas of Washington State

In this report, the Northwest Indian Fisheries Commission reviewed the habitat issues for the basins in the coastal and Puget Sound areas of Washington State, and identified elevated temperature as a critical habitat issue in 12 out of 15 basins reviewed.

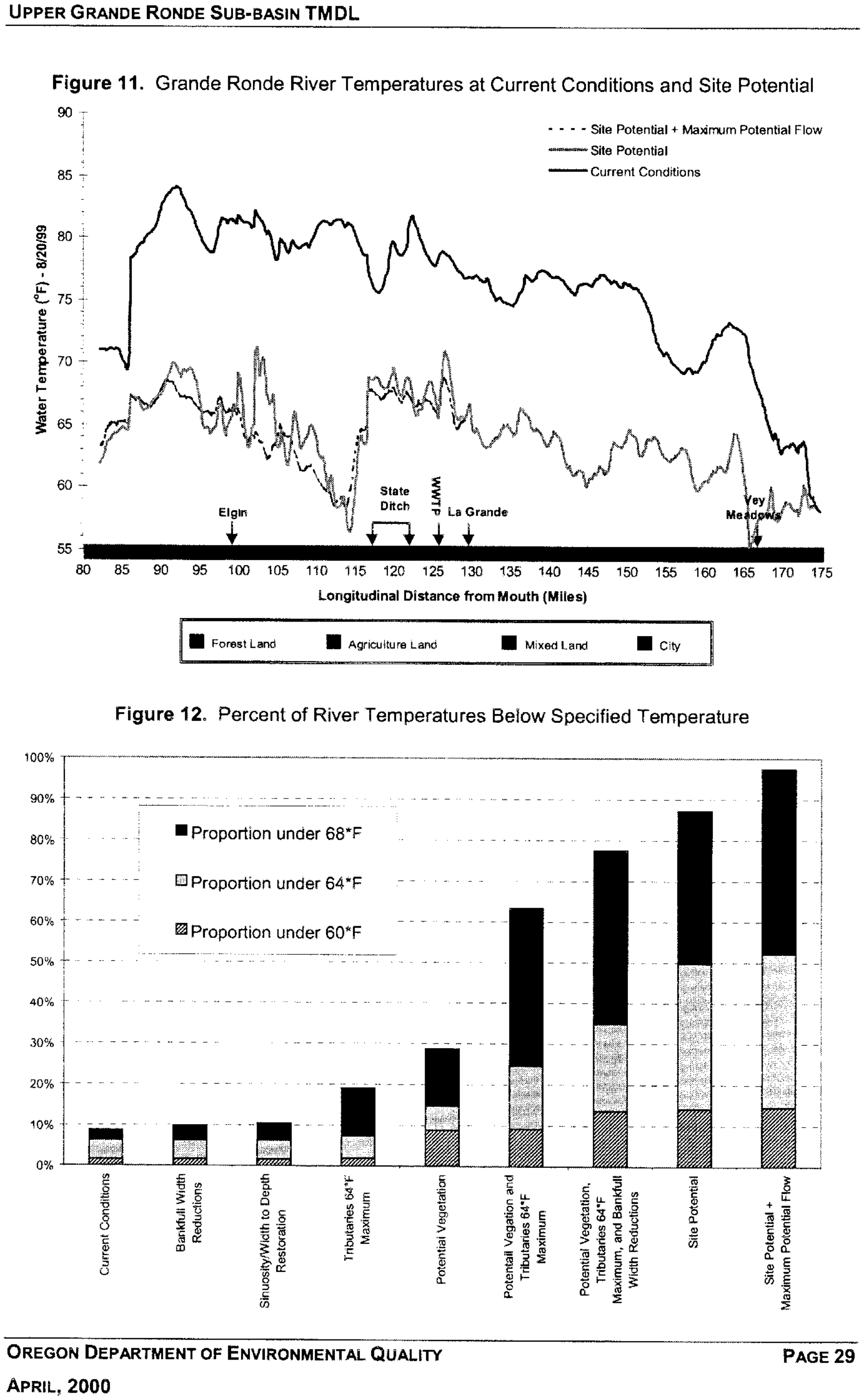
Other Basin and Watershed Studies

Numerous scientific studies of habitat and elevated water temperature impacts on salmon, steelhead and resident native fish have been completed in the Pacific Northwest over the past two decades. The Northwest Power Planning Council is in the process of developing habitat assessments and restoration strategies for all the sub-basins of the Columbia River Basin. In many of these sub-basin summaries (e.g., Okanogan, Methow, Wenatchee, Yakima, Tucannon, Grande Ronde, Umatilla, and John Day draft summaries - see www.cbfwa.org) elevated temperatures are cited as a major factor contributing to salmonid decline. These and other studies elsewhere in the Pacific Northwest provide a consistent view of the importance of restoring temperatures suitable for coldwater salmonds to aid in their recovery.

One specific study worth noting is by Theurer et al. (1985) in the Tucannon River in southeastern Washington. This study shows how human-caused changes in riparian shade and channel morphology contributed to increased water temperatures, reduced available spawning and rearing space, and diminished production of steelhead and chinook salmon. Using a physically-based water temperature model, the authors concluded that approximately 24 miles of spawning and rearing habitat had been made unusable in the lower river due to temperature changes. If the temperatures were restored, they estimated chinook adult returns would increase from 884 that currently exist to 2240 (near historic levels) and that chinook rearing capacity would increase from 170,000 to 430,000. The authors state that the change in temperature regime caused by the loss of riparian vegetation alone is sufficient to explain the reduction in salmonid population in the Tucannon River, while noting that increased sediment input also has played a subsidiary role.

Another similar analysis was done by Oregon Department of Environmental Quality (ODEQ, 2000) for the upper Grande Ronde River as part of their TMDL for this river. ODEQ modeling showed that restoration of riparian shade, channel width and depth, and water flow would drastically reduce maximum temperatures. As shown in Figure 1 (Figures 11 and 12 in ODEQ 2000), over 90% of the river currently exceeds 68°F (20°C), but with full restoration that percentage drops to less than 5%. Similarly, the percentage of the river that exceeds 64°F (18°C) is reduced from over 90% to less than 50% with full restoration. This represents nearly 50 additional miles that are colder than 18°C, which is a very large increase in available rearing habitat. Although actual estimates of increased fish production were not calculated in this study, one might expect similar results as those calculated for the Tucannon River.

Although temperature is highlighted here as a factor in the decline of native salmonid populations, it by no means is the only factor in their decline. Certainly, degradation of habitat unrelated to temperature (e.g., impassable barriers to spawning and rearing areas and physical destruction or inundation of spawning grounds), fishing harvest, and hatchery operations have all played a role in their decline. However, as described above, elevated temperatures are an important factor in the decline of salmonids and restoring suitable temperature regimes for salmonids is a critical element in protecting salmonid populations.



UPPER GRANDE RONDE SUB-BASIN TMDL

Figure 11. Grande Ronde River Temperatures at Current Conditions and Site Potential

Figure 12. Percent of River Temperatures Below Specified Temperature

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Figure 1. Grande Ronde River temperature modeling using ODEQ's Heat Source Model, showing site potential.

IV.4. General Life Histories of Salmonids and When Human-Caused Elevated Water Temperatures May Be a Problem

Different salmonid species have evolved to take advantage of the Pacific Northwest's cold water environment in different ways. Each species has a unique pattern of when and where they use the rivers, and even for a specific species this pattern of use may change from year to year. This diversity in freshwater life history is a critical evolutionary trait that has allowed salmonids to persist in a freshwater environment that naturally fluctuates and has natural disturbances.

Below is a general summary of the freshwater life history strategies for some of the coldwater salmonids. This summary is intended to provide a "big picture" understanding of how each of these fish use Pacific Northwest rivers and to highlight when and where human elevated water temperatures have impacted these fish. As noted above, because of their life history diversity, the discussion below may be an over-generalization for some situations. Further, because this general discussion on fish distribution is simplified for purposes of understanding, it is not intended to be used as a basis for salmonid use designations.

Chinook Salmon

Adult spring chinook salmon generally leave the ocean and enter Pacific Northwest rivers in the spring (April - June) and swim upstream to hold and spawn in the mid-to-upper reaches of river basins. Spawning generally occurs in late summer and fall (August - October). Egg and alevin incubation extends over the winter and fry generally emerge in the early spring (March - May). Juveniles rear in their natal streams and lower in the basin for a year, then migrate out to the ocean the following spring. Human-caused elevated temperatures can adversely affect spring chinook when adults hold and begin to spawn in the late-summer/early fall and throughout the summer when juveniles rear. Human-caused elevated temperatures in these mid-to-upper reaches can "shrink" the available habitat for adult holding/spawning and juvenile rearing limiting spring chinook to habitat higher in the watershed.

Adult fall chinook salmon generally enter Pacific Northwest rivers in the summer (July - August) and swim upstream to hold and spawn in the lower reaches of mainstem rivers and large tributaries. Spawning generally occurs in the fall (October - December). For example, Snake River fall chinook migrate past Bonneville dam from August-October and spawn in the Snake River below Hells Canyon Dam and the lower reaches of the Clearwater, Grand Ronde, Imnaha, and Tucannon rivers. Fry emerge from March through April and begin their downstream migration several weeks after emergence. Downstream migration occurs mainly in the spring under existing conditions, but may extend throughout the summer in some areas (e.g., Columbia River). Historically, juvenile fall chinook out-migrated throughout the summer months, but today human-caused elevated temperatures have made this impossible in some rivers (e.g., Yakima river). Human-caused elevated temperatures can adversely affect fall chinook in lower river reaches during the summer months when the adults are migrating upstream and holding to spawn and when juveniles are migrating downstream. Human-caused elevated temperatures in the early fall may also delay spawning.

Coho Salmon

Adult coho salmon generally enter Pacific Northwest rivers in the fall (late September through October) and spawn in low gradient 4th and 5th order streams in fall-winter. Fry emerge in the spring. Juvenile coho rear for 1 to 2 years prior to migrating to sea during the spring. Juvenile coho salmon may migrate considerable distances upstream to rear in lakes or other river reaches suitable for rearing. Coho salmon are most predominant in the rivers of the coastal mountains of Washington and Oregon and the west-slopes of the Washington Cascades. Wild coho populations were extirpated years ago in the Umatilla (OR), Yakima (WA), and Clearwater (ID) rivers but they are now being re-introduced in these rivers. Human-caused elevated temperatures can adversely affect coho salmon in the summer months when juveniles are rearing and in early fall when adults start migrating. Human-caused elevated temperatures may render waters unsuitable for rearing, thereby “shrinking” the amount of available habitat.

Sockeye Salmon

Adult sockeye salmon generally enter freshwater from mid summer through early fall and migrate up to lakes and nearby tributaries to spawn in the fall. Juveniles generally rear in lakes from 1 to 3 years, then migrate to the ocean in the spring. Pacific Northwest lakes that support sockeye include Redfish (Idaho), Okanogan, Wenatchee, Baker, Washington, Sammamish, Quinault, and Osoyoos. Historically, there were many other lakes in the Pacific Northwest used by sockeye. Human-caused elevated temperatures can adversely affect sockeye adult salmon as they migrate upstream in the mid-to-late summer.

Chum Salmon

Adult chum salmon generally enter freshwater in late-summer and the fall and spawn (October - December) in the low reaches and side channels of major rivers just upstream from tidewater areas. Upon emergence, juveniles begin their short migration to saltwater which generally occurs between March and June. Juveniles will rear in estuaries for a while prior to entering the ocean. Human-caused elevated temperatures can adversely affect adult chum salmon as they migrate upstream in the late summer.

Pink Salmon

Adult pink salmon generally enter freshwater in late summer and spawn in the lower reaches of large rivers in late summer and early fall. Like chum, juveniles will migrate to saltwater soon after emerging in the late winter. Human-caused elevated temperatures can adversely affect adult pink salmon as they migrate upstream in the late summer.

Steelhead Trout

Adult steelhead enter Pacific Northwest rivers throughout the year, but can generally be divided into a summer run (May - October) and a winter run (November-June). Both runs typically spawn in the spring. Summer steelhead enter freshwater sexually immature and generally travel greater distances to spawn than winter steelhead, which enter freshwater sexually mature (i.e. with well-developed gonads). All steelhead runs upstream of the Dalles Dam are summer steelhead. Fry generally emerge from May through July and juvenile steelhead will rear in the mid-upper reaches of river basins for 1-2 years (sometimes 3 or 4 years) before migrating to the ocean in the spring. Human-caused elevated temperatures can adversely affect steelhead in the summer months when the juveniles are rearing in the mid-upper reaches. Human-caused elevated temperatures may render waters unsuitable for rearing, thereby “shrinking” the amount of available habitat. Human-caused elevated temperatures also can adversely affect summer run adults as they migrate upstream during the summer as well as eggs and fry that incubate into July in some watersheds.

Bull Trout

Bull trout generally are freshwater fish (although the adults of a few populations enter saltwater estuaries). Adult bull trout generally migrate upstream in the spring and summer from their feeding grounds (lower reaches in a basin for migrating fluvial forms or a lake for adfluvial forms) to their spawning grounds higher in the basin. Bull trout generally spawn in September-October, but in some watersheds spawning can occur as early as July. Bull trout have a long incubation time with fry emergence generally from March through May. Juveniles will rear in their natal streams for 2-4 years, then the migratory forms will migrate downstream to more productive feeding grounds (i.e., lower river reaches or lakes) in the spring, but some fall downstream migration has also been noted. Human-caused elevated temperatures can adversely affect summer juvenile rearing in the upper reaches where elevated temperatures have rendered water unsuitable for rearing, thereby “shrinking” the amount of available habitat. Adults migrating upstream to spawn in the summer can also experience adverse effects from human-elevated temperatures. Additionally, migratory adults can be adversely affected by the loss of cold water refugia due to human activities.

V. EPA Region 10 Recommendations for Pacific Northwest State and Tribal Temperature WQS

EPA Region 10 offers the following recommendations to assist States and Tribes in adopting temperature WQS that fully support coldwater salmonids in the Pacific Northwest. The recommendations are intended to assist States and Tribes to adopt temperature WQS that EPA can approve consistent with its obligations under the CWA and the ESA. As noted in Section I, Pacific Northwest States and Tribes that adopt temperature WQS consistent with these recommendations can expect an expedited review by EPA and the Services, subject to new data and information that might be available to during that review.

EPA Region 10 recommends that States and Tribes adopt new or revised temperature WQS that incorporate each of the following elements for the protection of salmonid designated uses. Each of these elements is discussed in more detail below:

1) Coldwater Salmonid Uses and Numeric Criteria to Protect Those Uses;

2) Provisions to Protect Water Temperatures That Are Currently Colder Than the Numeric Criteria; and

3) Provisions to Protect Salmonids from Thermal Plume Impacts.

If a State or Tribe decides to adopt new or revised temperature WQS, it is free, of course, to adopt WQS that are different than these recommendations. EPA would evaluate these submissions on a case-by-case basis to determine if it can approve the WQS consistent with its obligations under the CWA and the ESA.

V.1. Coldwater Salmonid Uses and Numeric Criteria to Protect Those Uses

Tables 1 and 2 provide a summary of the important water temperature considerations for each life stage for salmon and trout, and bull trout: spawning, egg incubation, and fry emergence; juvenile rearing; and adult migration. Each temperature consideration and associated temperature values noted in Tables 1 and 2 includes a reference to the relevant technical issue papers prepared in support of this guidance (or other studies) that provide a more detailed discussion of the supporting scientific literature. The temperatures noted in Tables 1 and 2 form the scientific basis for EPA's recommended numeric criteria to protect coldwater salmonids in the Pacific Northwest, which are presented in Tables 3 and 4.

V.1.A. Overall Context for Recommended Uses and Criteria

In addition to Tables 1 and 2, there are a number of other general factors that EPA considered in recommending coldwater salmonid uses and numeric criteria to protect those uses. These factors

Table 1 - Summary of Temperature Considerations For Salmon and Trout Life Stages

Life Stage	Temperature Consideration	Temperature & Unit	Reference
Spawning and Egg Incubation	*Temp. Range at which Spawning is Most Frequently Observed in the Field	4 - 14°C (daily avg)	Issue Paper 1; pp 17-18 Issue Paper 5; p 81
	* Egg Incubation Studies		
	- Results in Good Survival	4 - 12°C (constant)	Issue Paper 5; p 16
	-Optimal Range	6 - 10°C (constant)	
	*Reduced Viability of Gametes in Holding Adults	> 13°C (constant)	Issue Paper 5; pp 16 and 75
Juvenile Rearing	*Lethal Temp. (1 Week Exposure)	23 - 26°C (constant)	Issue Paper 5; pp 12, 14 (Table 4), 17, and 83-84
	*Optimal Growth		
	- unlimited food	13 - 20°C (constant)	Issue Paper 5; pp 3-6 (Table 1), and 38-56
	- limited food	10 - 16°C (constant)	
	*Rearing Preference Temp. in Lab and Field Studies	10 - 17°C (constant) < 18°C (7DADM)	Issue Paper 1; p 4 (Table 2). Welsh et al. 2001.
	*Impairment to Smoltification	12 - 15°C (constant)	Issue Paper 5; pp 7 and 57-65 Issue Paper 5; pp 7 and 57-65
	*Impairment to Steelhead Smoltification	> 12°C (constant)	
	*Disease Risk (lab studies)		Issue Paper 4, pp 12 - 23
	-High	> 18 - 20°C (constant)	
	- Elevated	14 - 17°C (constant)	
	- Minimized	12 - 13°C (constant)	
Adult Migration	*Lethal Temp. (1 Week Exposure)	21- 22°C (constant)	Issue Paper 5; pp 17, 83 - 87
	*Migration Blockage and Migration Delay	21 - 22°C (average)	Issue Paper 5; pp 9, 10, 72-74. Issue Paper 1; pp 15 - 16
	*Disease Risk (lab studies)		
	- High	> 18 - 20°C (constant)	Issue Paper 4; pp 12 - 23
	- Elevated	14 - 17°C (constant)	
	- Minimized	12- 13°C (constant)	
	*Adult Swimming Performance		
	- Reduced	> 20°C (constant)	Issue Paper 5; pp 8, 9, 13, 65 - 71
	- Optimal	15 - 19°C (constant)	
	* Overall Reduction in Migration Fitness due to Cumulative Stresses	> 17-18°C (prolonged exposures)	Issue Paper 5; p 74

Table 2 - Summary of Temperature Considerations For Bull Trout Life Stages

Life Stage	Temperature Consideration	Temperature & Unit	Reference
Spawning and Egg Incubation	*Spawning Initiation	< 9°C (constant)	Issue Paper 5; pp 88 - 91
	*Temp. at which Peak Spawning Occurs	< 7°C (constant)	Issue Paper 5; pp 88 - 91
	*Optimal Temp. for Egg Incubation	2 - 6°C (constant)	Issue Paper 5; pp 18, 88 - 91
	*Substantially Reduced Egg Survival and Size	6 - 8°C (constant)	Issue Paper 5; pp 18, 88 - 91
Juvenile Rearing	*Lethal Temp. (1 week exposure)	22 - 23°C (constant)	Issue Paper 5; p 18
	*Optimal Growth - unlimited food - limited food	12 - 16 °C (constant) 8 - 12°C (constant)	Issue Paper 5; p 90. Selong et al 2001. Bull trout peer review, 2002.
	*Highest Probability to occur in the field	12 - 13 °C (daily maximum)	Issue Paper 5; p 90. Issue Paper 1; p 4 (Table 2). Dunham et al., 2001. Bull trout peer review, 2002.
	*Competition Disadvantage	>12°C (constant)	Issue Paper 1; pp 21- 23. Bull trout peer review, 2002.

and EPA's recommended approach for considering these factors (described below) provide the overall context for EPA's salmonid use and criteria recommendations.

Coldwater Salmonid Uses

Coldwater salmonids are considered a sensitive aquatic life species with regard to water temperatures and are a general indicator species of good aquatic health. EPA, therefore, believes it is appropriate for States and Tribes in the Pacific Northwest to focus on coldwater salmonids when establishing temperature criteria to support aquatic life.

Under EPA's WQS regulations, States and Tribes must adopt appropriate uses and set criteria to protect those uses. See 40 C.F.R § 131.10(a). Because Pacific Northwest salmonids have multiple freshwater life stages with differing temperature tolerances, it is generally appropriate to designate uses based on life stages. In addition, EPA's WQS regulations allow States and Tribes to adopt seasonal uses where a particular use applies for only a portion of the year. See 40 C.F.R § 131.10(f). EPA's recommended approach is for States and Tribes to utilize both of these use designation options in order to more precisely describe where and when the different coldwater salmonid uses occur.

In this guidance, EPA recommends seven coldwater salmonid uses (see Tables 3 and 4). Four uses apply to the summer maximum temperature condition and three apply to specific locations and times for other times of the year (except for some instances when these uses may apply during the period of summer maximum temperatures).

Focus on Summer Maximum Conditions

In general, increased summertime temperatures due to human activities are the greatest water temperature concern for salmonids in the Pacific Northwest, although temperatures in the late spring and early fall are also a concern in some areas. EPA therefore believes it is appropriate that temperature criteria focus on the summer maximum conditions to protect the coldwater salmonid uses that occur then. Generally, improving river conditions to reduce summer maximum temperatures will also reduce temperatures throughout the summer and in the late spring and early fall (i.e., shift the seasonal temperature profile downward). Thus, the data indicate that, because of the natural annual temperature regime, providing protective temperatures during the summer maximum period will in many areas provide protective temperatures for more temperature sensitive uses that occur other times of the year.

In some areas, however, more temperature-sensitive salmonid uses (e.g., spawning, egg incubation, and steelhead smoltification) that occur in the spring-early summer or late summer-fall may not be protected by meeting the summer maximum criterion. Thus, in addition to summer maximum criteria, EPA also recommends criteria be adopted to protect these more temperature-sensitive uses when and where they occur. Doing so provides an added degree of protection for those situations where control of summer maximum temperatures is inadequate to protect these more temperature-sensitive uses. An additional reason for having these seasonal uses is to provide protection for rivers that are flow-regulated, which can alter the natural annual temperature pattern.

In recommending protective summer maximum criteria, EPA took into consideration that meeting a criterion during the warmest period of the summer (e.g., warmest week) will result in cooler temperatures during other times in the summer. The duration of exposure to near summer maximum conditions, however, can vary from one to two weeks in some areas to over a month in other areas.

Optimal, Harmful, and Lethal Temperatures for Salmonids

Each salmonid life stage has an optimal temperature range. Physiological optimum temperatures are those where physiological functions (e.g., growth, swimming, heart performance) are optimized. These temperatures are generally determined in laboratory experiments. Ecological optimum temperatures are those where fish do best in the natural environment considering food availability, competition, predation, and fluctuating temperatures. Both are important considerations when establishing numeric criteria. Exposure to temperatures above the optimal range results in increased severity of harmful effects, often referred to as sub-lethal or chronic effects (e.g., decreased juvenile growth which results in smaller, more vulnerable fish; increased susceptibility to disease which can lead to mortality; and decreased ability to compete and avoid predation), as temperatures rise until at some point they become lethal (See Table 1 and 2). Water temperatures below the optimal range also cause sub-lethal effects (e.g., decreased growth); however, this is generally a natural condition (with the exception of cold water releases from a storage dam) and is not the focus of this guidance.

When determining the optimal range for bull trout and salmon/trout juvenile rearing, EPA looked at both laboratory and field data and considered both physiological and ecological aspects. Optimal growth under limited food rations in laboratory experiments, preference temperatures in laboratory experiments where fish select between a gradient of temperatures, and field studies on where rearing predominately occurs are three independent lines of evidence indicating the optimal temperature range for rearing in the natural environment. As highlighted in Tables 1 and 2 (and shown in detail in the technical issue papers) these three lines of evidence show very consistent results, with the optimal range between 8 - 12°C for bull trout juvenile rearing and between 10 - 16°C for salmon and trout juvenile rearing.

Use of the 7 Day Average of the Daily Maximum (7DADM) Unit of Measurement

The recommended metric for all of the following criteria is the maximum 7 day average of the daily maxima (7DADM). This metric is recommended because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day. Thus, it reflects an average of maximum temperatures that fish are exposed to over a week-long period. Since this metric is oriented to daily maximum temperatures, it can be used to protect against acute effects, such as lethality and migration blockage conditions.

This metric can also be used to protect against sub-lethal or chronic effects (e.g., temperature effects on growth, disease, smoltification, and competition), but the resultant cumulative thermal exposure fish experience over the course of a week or more needs to be considered when selecting a 7DADM value to protect against these effects. EPA's general conclusion from studies on fluctuating temperature regimes (which is what fish generally experience in rivers) is that fluctuating temperatures increase juvenile growth rates when mean temperatures are colder than the optimal growth temperature derived from constant temperature studies, but will reduce growth when the mean temperature exceeds the optimal growth temperature (see Issue Paper 5, pages 51-56). When the mean temperature is above the optimal growth temperature, the "mid-point" temperature between the mean and the maximum is the "equivalent" constant temperature. This "equivalent" constant temperature then can be directly compared to laboratory studies done at constant temperatures. For example, a river with a 7DADM value of 18°C and a 15°C weekly mean temperature (i.e., diurnal variation of ± 3°C) will be roughly equivalent to a constant laboratory study temperature of 16.5°C (mid-point between 15°C and 18°C). Thus, both maximum and mean temperatures are important when determining a 7DADM value that is protective against sub-lethal/chronic temperature effects.

For many rivers and streams in the Pacific Northwest, the 7DADM temperature is about 3°C higher than the weekly mean (Dunham, et al. 2001; Chapman, 2002). Thus, when considering what 7DADM temperature value protects against chronic effects, EPA started with the constant temperatures that scientific studies indicate would be protective against chronic effects and added 1-2°C degrees (see Table 1 for summary of studies done under constant temperatures). For bull trout waters, EPA started with the constant temperatures that scientific studies indicate would be protective for chronic effects and added about 0.5°C because bull trout waters typically have less diurnal variation. Following this general procedure takes into account the maximum and mean temperature (i.e., reflects a "mid-point") when protecting for growth and other sub-lethal effects.

It is important to note that there are also studies that analyzed sub-lethal effects based on maximum or 7DADM temperature values which need not be translated for purposes of determining protective 7DADM temperatures. For example, there are field studies that assess probability of occurrence or density of a specific species based on maximum temperatures (Issue Paper 1, Haas (2001), Welsh et al. (2001)). These field studies represent an independent line of evidence for defining upper optimal temperature thresholds, which complements laboratory studies.

It is also important to note that there are confounding variables that are difficult to account for but are important to recognize. For instance, the amount of diurnal variation in rivers and streams in the Pacific Northwest varies considerably; therefore, the difference between the 7DADM and the weekly mean will vary. The difference between the 7DADM temperature and the weekly mean may be less than 1°C for rivers with little diurnal variation and as high as 9°C for streams with high diurnal variation (Dunham et al., 2001). Another variable is food availability. The temperature for which there is optimal juvenile growth depends on the food supply. Optimal growth temperatures under limited food supply are lower than those under unlimited/satiated food supply. Generally, EPA believes that laboratory studies under limited food availability are most reflective of environmental conditions fish typically experience. However, there are likely situations where food is abundant, with the result that optimal growth temperatures would be higher. Thus, a particular 7DADM numeric criteria will be more protective in situations where there is high diurnal variation and/or abundant food and will be less protective in situations where there is low diurnal variation and limited food.

Unusually Warm Conditions

In order to have criteria that protect designated uses under the CWA, EPA expects that the criteria would need to apply nearly all the time. However, EPA believes it is reasonable for a State or Tribe to decide not to apply the numeric temperature criteria during unusually warm conditions for purposes of determining if a waterbody is attaining criteria. One possible way for a State or Tribe to do this would be to explain in its WQS that it will determine attainment with the numeric temperature criterion based on the 90th percentile of the yearly maximum 7DADM values calculated from a yearly set of values of 10 years or more. Thus, generally speaking, the numeric criteria would apply 9 out 10 years, or all but the hottest year. Another way may be to exclude water temperature data when the air temperature during the warmest week of the year exceeds the 90th percentile for the warmest week of the year based on a historical record (10 years or more) at the nearest weather reporting station.

A State or Tribe wishing to consider adopting a provision to account for unusually warm conditions might be able to justify that decision by pointing out that extreme annual peaks in water temperature typically caused by drought conditions are a natural component of the environment and then concluding, as a matter of policy, that these infrequent conditions should not drive attainment determinations. Salmonids may experience some adverse effects during these periods, but by definition, they would be infrequent. It is important to note that not taking into account unusually warm conditions should only be for CWA 303(d) listing purposes when determining if a waterbody is in attainment with temperature WQS. NPDES permitted facilities should not be exempt from applicable temperature effluent limits during these periods.

Even assuming that a State or Tribe decides to account for unusually warm conditions in its temperature WQS, attainment determinations should be based on all climatic conditions except for the extreme condition in order to protect the salmonid designated uses. Thus, given that river temperatures exhibit year-to-year variation in their maximum 7DADM values, the average maximum 7DADM value from a yearly series, as a statistical matter, would need to be lower than the numeric criteria in order to meet the criteria 9 out of 10 years. Therefore, in most years, the maximum 7DADM temperature would also probably need to be lower than the numeric criteria in order to meet the criteria in the warm years. EPA took this into consideration when it formulated its numeric criteria recommendations.

A De Minimis Temperature Increase Allowance

A State or Tribe may, if it has not already done so, wish to consider adopting a provision in its WQS that allows for a de minimis temperature increase above the numeric criteria or the natural background temperature. A State or Tribe might choose to include a de minimis increase allowance as a way of accounting for monitoring measurement error and tolerating negligible human impacts. The data and information currently available to EPA appear to indicate that an increase on the order of 0.25°C for all sources cumulatively (at the point of maximum impact) above fully protective numeric criteria or natural background temperatures would not impair the designated uses, and therefore might be regarded as de minimis.

Numeric Criteria Should Apply Upstream of the Furthest Downstream Extent of Use

Water quality criteria must protect the relevant designated uses. See 40 C.F.R. § 131.11(a). Therefore, a criterion should apply to all the river miles for which a particular use is designated, including the lowest point downstream at which the use is designated. Because streams generally warm progressively in the downstream direction, waters upstream of that point will generally need to be cooler in order to ensure that the criterion is met downstream. Thus, a waterbody that meets a criterion at the furthest downstream extent of use will in many cases provide water cooler than the criterion at the upstream extent of the use. EPA took this into consideration when it formulated its numeric criteria recommendations.

EPA also believes that the numeric criteria should apply upstream of the areas of actual use because temperatures in upstream waters significantly affect the water temperatures where the actual use occurs and upstream waters are usually colder. Of course, if a more sensitive use is designated upstream, the more protective criterion would apply upstream. See 40 C.F.R. § 131.11(a).

Selection of Protective Criteria for the Recommended Salmon Uses

As described above, numeric criteria that apply to uses that occur during the summer maximum period are intended to apply to the warmest times of the summer, the warmest years (except for extreme conditions), and the lowest downstream extent of use. Because of the conservative nature of this application, EPA believes that it is appropriate to recommend numeric criteria near the warmer end of the optimal range for uses intended to protect high quality bull trout and salmon/trout rearing (see Section V.1.C for use descriptions). EPA expects that adopting a numeric criterion near the warmer end of the optimal range that is applied to the above conditions is likely to result in temperatures near the middle of the optimal range for most of the spring through fall period in the segments where most of the rearing use occurs. EPA has identified two reasons for this. First, if the criterion is met at the summer maximum, then temperatures will be lower than the criterion during most of the year. Second, because the criterion would apply at the furthest point downstream where the use is designated, temperatures will generally be colder across the full range of the designated use.

EPA also recognizes that salmonids will use waters that are warmer than their optimal thermal range and further recognizes that some portions of rivers and streams in the Pacific Northwest naturally (i.e., absent human impacts) were warmer than the salmonid optimal range during the period of summer maximum temperatures. To account for these realities, EPA is also recommending two salmonid uses (see Section V.1.C) during the period of summer maximum temperatures where the recommended numeric criteria exceed the optimal range, but provide protection from lethal conditions and sub-lethal effects that would significantly adversely affect these uses.

If applied collectively, EPA believes its recommended salmonid uses and associated numeric criteria, if attained, will support healthy sustainable salmonid populations. However, EPA notes that it must still consider any new or revised temperature WQS submitted by a State or Tribe on a case-by-case basis and must take into account any new information made available to EPA at that time.

Determining the Spatial Extent of the Recommended Salmonid Uses

It is well recognized that the current distribution of salmonids in the Pacific Northwest has significantly shrunk and is more fragmented than their historical distribution due to human development. It is also unlikely that the current distribution of salmonids will provide for sustainable salmonid populations. EPA believes that, in order to meet the national goal of providing for the protection and propagation of fish wherever attainable, salmonid use designations should be of sufficient geographic and temporal scope to support sustainable levels of use. This is because, unless the designated use specifically provides otherwise, a salmonid use reasonably implies a healthy and sustainable population. Because of the importance of restoring healthy salmonid populations in the Pacific Northwest, EPA Region 10 advises States and Tribes not to limit salmonid use designations to where and when salmonid uses occur today when assigning uses in areas with thermally degraded habitat.

For areas with degraded habitat, EPA recommends that coldwater salmonid uses be designated in waters where the defined use currently occurs or is suspected to currently occur, and where there is reasonable potential for that use to occur (e.g., if temperatures or other habitat features, including fish passage improvements, were to be restored in areas of degraded habitat). In most areas of degraded habitat, temperatures have risen, thereby forcing salmonids upstream to find suitable water temperatures for rearing and spawning. As a result, the downstream extent of current use is likely farther upstream than it was prior to habitat degradation. For areas with minimal habitat degradation, where human impacts have not likely altered fish distribution, EPA recommends use designations based on where the use currently occurs or is suspected to currently occur.

EPA's recommendations for designating the spatial extent of the various salmonid uses are described below in Sections V.1.C and V.1.D. The goal of these recommendations is to include the potential use areas for each salmonid use where the habitat has been degraded due to human impacts. For example, for the bull trout rearing use and the salmon/trout core rearing use, which are intended to protect waters of moderate to high density rearing use, EPA recommends that for areas of degraded habitat, these uses cover the downstream extent of low density rearing that currently occurs during the period of maximum summer temperatures (typically July and August). The concept here is that waters where rearing currently occurs in low density during the summer is a reasonable approximation of waters that could support moderate to high density use if the temperature were reduced.

EPA fully recognizes the difficulties in spatially designating the recommended salmonid uses. First, information on fish distribution, particularly juvenile rearing distribution, is sparse in many locations. For example, in some situations there may be fairly good information on spawning areas, but minimal information on juvenile rearing distribution. In those situations, a State or

Tribe could consider using the spawning distribution along with inferences drawn from what information exists on juvenile rearing as the primary basis for designating the bull trout and the core salmon and trout rearing uses. Second, there is a fair degree of both inter-annual and seasonal variability in fish distribution. Third, there is no bright line that defines degraded habitat; rather there is a spectrum from non-degraded to highly degraded.

States and Tribes, therefore, should use the best available scientific information (e.g., the types of information described in Sections V.1.C and V.1.D) and make well-reasoned judgments when designating the various salmonid uses. In some cases, that may mean extrapolating from limited information and making generalizations based on stream order, size, and elevation. Thus, EPA recognizes there is an inherent element of subjectivity to designating the recommended salmonid uses. However, because the recommended salmonid uses are fairly broad scale (applying to large areas of a river basin), EPA believes that the recommended use designations are reasonable given the current level of information. If a State or Tribe decides to revise its salmonid use designations and submit them to EPA for approval, it should include a description of the information and judgments it made to determine the spatial extent of its salmonid uses.

Lastly, EPA also believes that better information on fish distribution is valuable for both CWA and ESA purposes and that adopting the recommended salmonid use designations (or others justified by the best available scientific information) will provide impetus to acquire more and better information in the future.

V.1.B. EPA Region 10's Recommended Salmonid Uses and Numeric Criteria

EPA Region 10's recommended coldwater salmonid uses and criteria to protect those uses are presented in Tables 3 and 4. Table 3 describes uses that occur during the summer maximum temperature conditions. Designating the uses in Table 3 would result in apportioning a river basin to up to 4 salmonid use categories with associated criteria (e.g., 12°C, 16°C, 18°C, and 20°C). The colder criteria would apply in the headwaters and the warmer criteria would apply in the lower river reaches, which is consistent with the typical thermal and salmonid use patterns of rivers in the Pacific Northwest during the summer. It should be noted, however, that there may be situations where a warmer use and criteria would apply upstream of a colder use and criteria (e.g., where a relatively large cold tributary enters a warmer river, which significantly cools the river).

Table 4 describes coldwater salmonid uses that generally occur at times other than during the summer maximum period, except for some circumstances. EPA recommends that these criteria apply when and where these uses occur and may potentially occur.

Table 3. Recommended Uses & Criteria That Apply To Summer Maximum Temperatures

Notes: 1) "7DADM" refers to the Maximum 7 Day Average of the Daily Maximums; 2) "Salmon" refers to Chinook, Coho, Sockeye, Pink, and Chum salmon; 3) "Trout" refers to Steelhead and coastal cutthroat trout

Salmonid Uses During the Summer Maximum Conditions	**Criteria**
Bull Trout Juvenile Rearing	12°C (55°F) 7DADM
Salmon/Trout "Core" Juvenile Rearing *(Salmon adult holding prior to spawning, and adult and sub-adult bull trout foraging and migration may also be included in this use category)*	16°C (61°F) 7DADM
Salmon/Trout Migration plus Non-Core Juvenile Rearing	18°C (64°F) 7DADM
Salmon/Trout Migration .	20°C (68°C) 7DADM, plus a provision to protect and, where feasible, restore the natural thermal regime

Table 4. Other Recommended Uses & Criteria

Notes: 1) "7DADM" refers to the Maximum 7 Day Average of the Daily Maximums; 2) "Salmon" refers to Chinook, Coho, Sockeye, Pink, and Chum salmon; 3) "Trout" refers to Steelhead and coastal cutthroat trout;

Salmonid Uses	**Criteria**
Bull Trout Spawning	9°C (48°F) 7DADM
Salmon/Trout Spawning, Egg Incubation, and Fry Emergence	13°C (55°F) 7DADM
Steelhead Smoltification	14°C (57°F) 7DADM

V.1.C. Discussion of Uses and Criteria Presented in Table 3

Bull Trout Juvenile Rearing - 12°C 7DADM

EPA recommends this use for the protection of moderate to high density summertime bull trout juvenile rearing near their natal streams in their first years of life prior to making downstream migrations. This use is generally found in a river basin's upper reaches.

EPA recommends a 12°C maximum 7DADM criterion for this use to: (1) safely protect juvenile bull trout from lethal temperatures; (2) provide upper optimal conditions under limited food for juvenile growth during the period of summer maximum temperature and optimal temperature for other times of the growth season; (3) provide temperatures where juvenile bull trout are not at a competitive disadvantage with other salmonids; and (4) provide temperatures that are consistent with field studies showing where juvenile bull trout have the highest probability to occur (see Table 2).

EPA recommends that the spatial extent of this use include: (1) waters with degraded habitat where high and low density juvenile bull trout rearing currently occurs or is suspected to currently occur during the period of maximum summer temperatures, except for isolated patches of a few fish that are spatially disconnected from more continuous upstream low density use; (2) waters with minimally-degraded habitat where moderate to high density bull trout rearing currently occurs or is suspected to currently occur during the period of maximum summer temperatures; (3) waters where bull trout spawning currently occurs; (4) waters where juvenile rearing may occur and the current 7DADM temperature is 12°C or lower; and (5) waters where other information indicates the potential for moderate to high density bull trout rearing use during the period of maximum summer temperatures (e.g., recovery plans, bull trout spawning and rearing critical habitat designations, historical distributions, current distribution in reference streams, studies showing suitable rearing habitat that is currently blocked by barriers that can reasonably be modified to allow passage, or temperature modeling).

Salmon and Trout "Core" Juvenile Rearing - 16°C 7DADM

EPA recommends this use for the protection of moderate to high density summertime salmon and trout juvenile rearing. This use is generally found in a river basin's mid-to-upper reaches, downstream from juvenile bull trout rearing areas. However, in colder climates, such as the Olympic mountains and the west slopes of the Cascades, it may be appropriate to designate this use all the way to the saltwater estuary.

Protection of these waters for salmon and trout juvenile rearing also provides protection for adult spring chinook salmon that hold throughout the summer prior to spawning and for migrating and foraging adult and sub-adult bull trout, which also frequently use these waters.

EPA recommends a 16°C maximum 7DADM criterion for this use to: (1) safely protect juvenile salmon and trout from lethal temperatures; (2) provide upper optimal conditions for juvenile growth under limited food during the period of summer maximum temperatures and optimal temperatures for other times of the growth season; (3) avoid temperatures where juvenile salmon and trout are at a competitive disadvantage with other fish; (4) protect against temperature-induced elevated disease rates; and (5) provide temperatures that studies show juvenile salmon and trout prefer and are found in high densities (see Table 1).

EPA recommends that the spatial extent of this use include: (1) waters with degraded habitat where high and low density salmon and trout juvenile rearing currently occurs or is suspected to currently occur during the period of maximum summer temperatures, except for isolated patches of a few fish that are spatially disconnected from more continuous upstream low density use; (2) waters with minimally-degraded habitat where moderate to high density salmon and trout juvenile rearing currently occurs or is suspected to currently occur during the period of maximum summer temperatures; (3) waters where trout egg incubation and fry emergence and salmon spawning currently occurs during the summer months (mid-June through mid-September); (4) waters where juvenile rearing may occur and the current 7DADM temperature is 16°C or lower; (5) waters where adult and sub-adult bull trout foraging and migration occurs during the period of summer maximum temperatures; and (6) waters where other information indicates the potential for moderate to high density salmon and trout rearing use during the period of maximum summer temperatures (e.g., recovery plans, critical habitat designations, historical distributions, current distribution in reference streams, studies showing suitable rearing habitat that is currently blocked by barriers that can reasonably be modified to allow passage, or temperature modeling).

Please note that at this time EPA is recommending that adult and sub-adult bull trout foraging and migration be included in this use category as opposed to establishing a separate use and associated criterion. Our current knowledge of bull trout migration timing and their *main channel* temperature preference is limited, but we do know that they prefer water temperatures less than 15°C, that they take advantage of cold water refugia during the period of summer maximum temperatures, and that spawning adults move toward spawning grounds during the period of summer maximum temperatures. EPA, therefore, believes its recommended approach would protect migrating and foraging bull trout because average river temperatures will likely be below 15°C, a fair amount of cold water refugia is expected in rivers that attain a maximum 7DADM of 16°C, and maximum temperatures below 16°C are likely to occur upstream of the downstream point of this use designation where most bull trout migration and foraging is likely to occur during the period of summer maximum temperatures. As more is learned about adult and sub-adult bull trout foraging and migration, EPA, in consultation with the U.S. Fish and Wildlife Service, may reconsider this recommendation.

Salmon and Trout Migration Plus Non-Core Juvenile Rearing - 18°C 7DADM

EPA recommends this use for the protection of migrating adult and juvenile salmonids and moderate to low density salmon and trout juvenile rearing during the period of summer maximum temperatures. This use designation recognizes the fact that salmon and trout juveniles will use waters that have a higher temperature than their optimal thermal range. For water bodies that are currently degraded, there is likely to be very limited current juvenile rearing during the period of maximum summer temperatures in these waters. However, there is likely to be more extensive current juvenile rearing use in these waters during other times of the year. Thus, for degraded waters, this use designation could indicate a potential rearing use during the period of summer maximum temperatures if maximum temperatures are reduced.

This use is generally found in the mid and lower part of a basin, downstream of the Salmon and Trout Core Juvenile Rearing use. In many river basins in the Pacific Northwest, it may be appropriate to designate this use all the way to a river basin's terminus (i.e., confluence with the Columbia River or saltwater).

EPA recommends an 18°C maximum 7DADM criterion for this use to: (1) safely protect against lethal conditions for both juveniles and adults; (2) prevent migration blockage conditions for migrating adults; (3) provide optimal or near optimal juvenile growth conditions (under limited food conditions) for much of the summer, except during the summer maximum conditions, which would be warmer than optimal; and (4) prevent adults and juveniles from high disease risk and minimize the exposure time to temperatures that can lead to elevated disease rates (See Table 1).

The upstream extent of this use designation is largely driven by where the salmon and trout core juvenile rearing use (16°C) is defined. It may be appropriate to designate this use downstream to the basin's terminus, unless a salmon and trout migration use (20°C) is designated there. Generally, for degraded water bodies, this use should include waters where juvenile rearing currently occurs during the late spring-early summer and late summer-early fall, because those current uses could indicate potential use during the period of summer maximum temperatures if temperatures were to be reduced.

Salmon and Trout Migration - 20°C 7DADM plus a provision to protect and, where feasible, restore the natural thermal regime

EPA recommends this use for waterbodies that are used almost exclusively for migrating salmon and trout during the period of summer maximum temperatures. Some isolated salmon and trout juvenile rearing may occur in these waters during the period of summer maximum temperatures, but when it does, such rearing is usually found only in the confluence of colder tributaries or other areas of colder waters. Further, in these waters, juvenile rearing was likely to have been mainly in cold water refugia areas during the period of maximum temperatures prior to human alteration of the landscape. It should also be noted that most fish migrating in these waters do so in the spring-early summer or in the fall when temperatures are cooler than the summer maximum temperatures, but some species (e.g., late migrating juvenile fall chinook; adult summer chinook, fall chinook, summer steelhead, and sockeye) may migrate in these waters during the period of summer maximum temperatures.

This use is probably best suited to the lower part of major rivers in the Pacific Northwest, where based on best available scientific information, it appears that the natural background maximum temperatures likely reached 20°C. When designating the spatial extent of this use, EPA expects the State or Tribe to provide information that suggests that natural background maximum temperatures reached 20°C. However, EPA does not expect the State or Tribe to have conducted a process-based temperature model (see Section VI.3 below for a discussion on methods to demonstrate natural background temperatures). If a State or Tribe determines that the natural background temperature is higher than 20°C for a particular location and wants to establish a numeric criterion higher than 20°C, it should follow the procedures described in Section VI.1.B for the establishment of site-specific numeric criteria based on natural background conditions.

To protect this use, EPA recommends a 20°C maximum 7DADM numeric criterion *plus* a narrative provision that would require the protection, and where feasible, the restoration of the natural thermal regime. EPA believes that a 20°C criterion would protect migrating juveniles and adults from lethal temperatures and would prevent migration blockage conditions. However, EPA is concerned that rivers with significant hydrologic alterations (e.g., rivers with dams and reservoirs, water withdrawals, and/or significant river channelization) may experience a loss of temperature diversity in the river, such that maximum temperatures occur for an extended period of time and there is little cold water refugia available for fish to escape maximum temperatures. In this case, even if the river meets a 20°C criterion for maximum temperatures, the duration of exposure to 20°C temperatures may cause adverse effects in the form of increased disease and decreased swimming performance in adults, and increased disease, impaired smoltification, reduced growth, and increased predation for late emigrating juveniles (e.g., fall chinook in the Columbia and Snake Rivers). Therefore, in order to protect this use with a 20°C criterion, it may be necessary for a State or Tribe to supplement the numeric criterion with a narrative provision to protect and, where feasible, restore the natural thermal regime for rivers with significant hydrologic alterations.

Critical aspects of the natural thermal regime that should be protected and restored include: the spatial extent of cold water refugia (generally defined as waters that are 2°C colder than the surrounding water), the diurnal temperature variation, the seasonal temperature variation (i.e., number of days at or near the maximum temperature), and shifts in the annual temperature pattern. The narrative provision should call for the protection, and where feasible, the restoration of these aspects of the natural temperature regime. EPA notes that the *protection* of existing cold water refugia should already be provided by the State's or Tribe's antidegradation provisions or by the cold water protection provisions discussed in Section V.2 below. Thus, the new concept introduced by the narrative provision EPA recommends here is the *restoration* of the natural thermal regime, where feasible.

Although some altered rivers, such as the Columbia and Snake, experience similar summer maximum temperatures today as they did historically, there is a big difference between the temperatures that fish experience today versus what they likely experienced historically. Unaltered rivers generally had a high degree of spatial and temporal temperature diversity, with portions of the river or time periods that were colder than the maximum river temperatures. These cold portions or time periods in an otherwise warm river provided salmonids cold water refugia to tolerate such situations. The loss of this temperature diversity may be as significant to salmon and trout in the Columbia and Snake Rivers and their major tributaries as maximum temperatures. Therefore, protection and restoration of temperature diversity is likely critical in order for salmonids to migrate through these waters with minimal thermal stress.

The areas where relatively cold tributaries join the mainstem river and where groundwater exchanges with the river flow (hyporheic flow) are two critical areas that provide cold water refugia for salmonids to escape maximum temperatures. As described in Issue Paper 3 and the *Return to the River* report (2000), alluvial floodplains with a high level of groundwater exchange historically provided high quality habitat that served as cold water refugia during the summer for large rivers in the Columbia River basin (and other rivers of the Pacific Northwest). These alluvial reaches are interspersed between bedrock canyons and are like beads on a string along the river continuum. Today, most of the alluvial floodplains are either flooded by dams, altered through diking and channelization, or lack sufficient water to function as refugia. Efforts to restore these alluvial river functions and maintain or cool down tributary flows will probably be critical to protect this use.

As noted above, EPA recommends that States and Tribes include a natural thermal regime narrative provision to accompany the 20°C numeric criterion. If a State or Tribe chooses to do so, TMDL allocations would reflect the protection, and where feasible, the restoration of the cold water refugia and other aspects of the natural thermal regime described above. If it is impracticable to quantify allocations to restore the natural thermal regime in the TMDL load allocations, then the TMDL assessment document should qualitatively address the human impacts that alter the thermal regime. Plans to implement the TMDL (e.g., watershed restoration plans) should include measures to restore the potential areas of cold water refugia and the natural daily and seasonal temperature patterns. See Section VI.2.B below for a similar discussion regarding TMDLs designed to meet temperature targets exceeding 18°C.

V.1.D. Discussion of Uses and Criteria Presented in Table 4

As discussed in Section V.1.B above, EPA recommends additional uses and criteria that would generally apply during times other than the period of summer maximum temperatures. These additional uses and criteria are intended to provide an added degree of protection for those situations where control of the summer maximum temperature is inadequate to protect these sensitive uses. EPA's recommendations assume that when these uses do occur during the time of summer maximum temperatures, these more sensitive uses and associated numeric criteria would apply.

In many situations, if the summer maximum criteria are attained (e.g., 12°C, 16°C, 18°C, 20°C), EPA expects that temperatures will be low enough due to typical spring warming and fall cooling patterns to support the uses described below. However, in developing this guidance, EPA did not assess data in sufficient detail to determine the extent to which these uses are protected vis-a-vis the summer maximum criterion. With respect to spawning and egg incubation, EPA is most concerned about protecting spawning and egg incubation that occurs during, or soon before or after, the period of summer maximum temperatures (e.g., spring chinook, summer chum, and bull trout spawning that occurs in the mid-to-late summer, and steelhead trout egg incubation that extends into the summer months).

In waters where there is a reasonable basis in concluding that control of the summer maximum criterion sufficiently protects some or all of the uses described below, it may be reasonable not to designate some of all of these specific salmonid uses (i.e., the use will be protected by the summer maximum criterion).

Bull Trout Spawning - 9°C 7DADM

EPA recommends this use for the protection waterbodies used or potentially used by bull trout for spawning, which generally occurs in the late summer-fall in the upper basins (the same waters that bull trout juveniles use for summer rearing). EPA recommends a 9°C maximum 7DADM criterion for this use and recommends that the use apply from the average date that spawning begins to the average date incubation ends (the first 7DADM is calculated 1 week after the average date that spawning begins). Meeting this criterion at the onset of spawning will likely provide protective temperatures for egg incubation (2 - 6°C) that occurs over the winter assuming the typical annual thermal pattern.

Salmon and Trout Spawning, Egg Incubation, and Fry Emergence - 13°C 7DADM

EPA recommends this use for the protection of waterbodies used or potentially used for salmon and trout spawning, egg incubation, and fry emergence. Generally, this use occurs: (a) in spring-early summer for trout (mid-upper reaches); (b) in late summer-fall for spring chinook (mid-upper reaches) and summer chum (lower reaches); and (c) in the fall for coho (mid-reaches), pink, chum, and fall chinook (the latter three in lower reaches). EPA recommends a 13°C maximum 7DADM criterion to protect these life stage uses for salmon and trout and recommends that this use apply from the average date that spawning begins to the average date incubation ends (the first 7DADM is calculated 1 week after the average date that spawning begins). Meeting this criterion at the onset of spawning for salmon and at the end of incubation for steelhead trout will likely provide protective temperatures for egg incubation (6 - 10°C) that occurs over the winter (salmon) and spring (trout), assuming the typical annual thermal pattern.

Steelhead Trout Smoltification - 14°C 7DADM

EPA recommends this use for the protection of waters where and when the early stages of steelhead trout smoltification occurs or may occur. Generally, this use occurs in April and May as steelhead trout make their migration to the ocean. EPA recommends a 14°C maximum 7DADM steelhead smoltification criterion to protect this sensitive use. As described in Table 1, steelhead smoltification can be impaired from exposure to greater than 12°C constant temperatures. The greatest risk to steelhead is during the early stages of smoltification that occurs in the spring (April and May). For the Columbia River tributaries, 90% of the steelhead smolts are typically past Bonneville dam by the end of May (Issue Paper 5, pg 59), indicating that applying this criterion at the mouths of major tributaries to the Columbia River in April and

May will likely protect this use. Applying this criterion to the Columbia River itself is probably unnecessary because the more temperature-sensitive early stages of smoltification occur in the tributaries. If steelhead in the early smoltification process are exposed to higher temperatures than the recommended criterion, they may cease migration or they may migrate to the ocean undeveloped, thereby reducing their estuary and ocean survival.

V.2. Provisions to Protect Water Temperatures That Are Currently Colder Than The Numeric Criteria

One of the important principles in protecting populations at risk for any species is to first protect the existing high quality habitat and then to restore the degraded habitat that is adjacent to the high quality habitat. Further, EPA's WQS regulations recognize the importance of protecting waters that are of higher quality than the criteria (in this case, waters that are colder than numeric temperature criteria). See 40 C.F.R. § 131.12. EPA, therefore, believes it is important to have strong regulatory measures to protect waters with ESA-listed salmonids that are currently colder than EPA's recommended criteria. These waters likely represent the last remaining strongholds for these fish.

Because the temperatures of many waters in the Pacific Northwest are currently higher than the summer maximum criteria recommended in this guidance, the high quality, thermally optimal waters that do exist are likely vital for the survival of ESA-listed salmonids. Additional warming of these waters will likely cause harm by further limiting the availability of thermally optimal waters. Further, protection of these cold water segments in the upper part of a river basin likely plays a critical role in maintaining temperatures downstream. Thus, in situations where downstream temperatures currently exceed numeric criteria, upstream temperature increases to waters currently colder than the criteria may further contribute to the non-attainment downstream, especially where there are insufficient fully functioning river miles to allow the river to return to equilibrium temperatures (Issue Paper 3). Lastly, natural summertime temperatures in Pacific Northwest waters were spatially diverse, with areas of cold-optimal, warm-optimal, and warmer than optimal water. The 18°C and 20°C criterion described in Table 3 and the natural background provisions and use attainability pathways described in Section VI are included in this guidance as suggested ways to address those waters that are warmer than optimal for salmonids. EPA believes it is important, however, for States and Tribes to balance the effects of the warmer waters by adopting provisions to protect waters that are at the colder end of their optimal thermal range.

EPA, therefore, recommends that States and Tribes adopt strong regulatory provisions to protect waterbodies with ESA-listed salmonids that currently have summer maximum temperatures colder than the State's or Tribe's numeric criteria. EPA believes there are several ways a State or Tribe may do this. One approach could be to adopt a narrative temperature criterion (or alternatively include language in its antidegradation rules) that explicitly prohibits more than a de minimis increase to summer maximum temperatures in waters with ESA-listed salmonids that are currently colder than the summer maximum numeric criteria. Another approach could be to identify and designate waterbodies as ecologically significant for temperature and either establish site-specific numeric criteria equal to the current temperatures or prohibit temperature increases above a de minimis level in these waters. States and Tribes following this latter approach should conduct a broad survey to identify and designate such waters within the state (or tribal lands). For non-summer periods it may be appropriate to set a maximum allowable increase (e.g., 25% of the difference between the current temperature and the criterion) for waters with ESA-listed salmonids where temperatures are currently lower than the criteria.

Provisions to protect waters currently colder than numeric criteria can also be important to ensure numeric criteria protect salmonid uses. As discussed in Section V.1.A, the recommended criteria in this guidance are based in part on the assumption that meeting the criteria at the lowest downstream point at which the use is designated will likely result in cooler waters upstream. Cold water protection provisions as described here provide more certainty that this will be true. Further, if a State chooses to protect some or all of the sensitive uses in Table 4 (e.g., spawning) by using only the summer maximum criteria, it may also be necessary to protect waters currently colder than the summer maximum numeric criteria in order to assure that these sensitive uses are protected. Further, as described in Section V.1.B, protecting existing cold water is likely important in river reaches where a 20°C numeric criterion applies to protect salmon and trout migration use.

V.3. Provisions to Protect Salmonids from Thermal Plume Impacts

EPA recommends that States and Tribes add specific provisions to either their temperature or mixing zone sections in their WQS to protect salmonids from thermal plume impacts. Specifically, language should be included that ensures that thermal plumes do not cause instantaneous lethal temperatures; thermal shock; migration blockage; adverse impact on spawning, egg incubation, and fry emergence areas; or the loss of localized cold water refugia. The following are examples from the scientific literature of potential adverse impacts that may result from thermal plumes, and EPA's recommendations to avoid or minimize those impacts.

- Exposures of less than10 seconds can cause instantaneous lethality at 32°C (WDOE, 2002). Therefore, EPA suggest that the maximum temperature within the plume after 2 seconds of plume travel from the point of discharge does not exceed 32°C.

- Thermal shock leading to increased predation can occur when salmon and trout exposed to near optimal temperatures (e.g., 15°C) experience a sudden temperature increase to 26 - 30°C for a short period of time (Coutant, 1973). Therefore, EPA suggests that thermal plumes be conditioned to limit the cross-sectional area of a river that exceeds 25°C to a small percent of the river (e.g., 5 percent or less).

- Adult migration blockage conditions can occur at 21°C (Table 1). Therefore, EPA suggests that the cross-sectional area of a river at or above 21°C be limited to less than 25% or, if upstream temperature exceeds 21°C, the thermal plume be limited such that 75% of the cross-sectional area of the river has less than a de minimis (e.g., 0.25°C) temperature increase.

- Adverse impacts on salmon and trout spawning, egg incubation, and fry emergence can occur when the temperatures exceed 13°C (Table 1). Therefore, EPA suggests that the thermal plume be limited so that temperatures exceeding 13°C do not occur in the vicinity of active spawning and egg incubation areas, or that the plume does not cause more than a de minimis (e.g., 0.25°C) increase in the river temperature in these areas.

VI. Approaches to Address Situations Where the Numeric Criteria are Unachievable or Inappropriate

There are likely to be some streams and rivers in the Pacific Northwest where the criteria recommended in this guidance cannot be attained or where the criteria recommendations would otherwise be inappropriate. The following approaches are available under EPA's regulations to address these circumstances. See 40 C.F.R. Part 131. EPA describes these approaches below and recommends when it believes each approach may be appropriate.

It is important to note that most of these approaches are subject to EPA review and approval on a case-by-case basis (either in the form of a WQS, TMDL, or a 303(d) list approval), and where appropriate, are subject to consultation with the Services and affected Tribes.

VI.1. Alternative Criteria

The following are three possible ways to establish alternative numeric criteria that would apply to a specific location.

VI.1.A. Site-Specific Numeric Criteria that Supports the Use

Under this approach, the State or Tribe would demonstrate that conditions at a particular location justify an alternative numeric criterion to support the designated salmonid use. See 40 C.F.R. § 131.11(b)(1)(ii). One example may be the adoption of a 13°C 7DADM criterion (instead of EPA's recommended 12°C criterion) to protect bull trout rearing use in areas where competition with other fish is minimal and food sources are abundant. Another example may be where there is exceptionally high natural diurnal temperature variation and where the maximum weekly mean temperature is within the optimal temperature range but, because of the high diurnal variation, summer maximum temperatures exceed the State or Tribe's numeric criteria. In this situation, a State or Tribe may choose to develop a site-specific numeric criterion based on a metric other that the 7DADM (e.g., a maximum weekly mean criterion plus a daily maximum criterion). There may be other situations as well when an alternative site-specific criterion would be appropriate. The State or Tribe would need to provide a clear description of the technical basis and methodology for deriving the alternative criterion and describe how it fully supports the designated use when it submits the criterion to EPA for approval. See 40 C.F.R. § 131.11(a).

VI.1.B. Numeric Criteria Based on Estimates of Natural Background Temperatures

Under this approach a State or Tribe could establish numeric criteria based on an estimate of the natural background temperature conditions. This would be another form of site-specific criteria under 40 C.F.R. § 131.11(b)(1)(ii). Natural background temperatures are those that would exist in the absence of human-activities that alter stream temperatures. States or Tribes following this approach may elect to adopt a single numeric criterion for a particular stream segment, such as a lower mainstem river, or adopt a numeric profile (i.e., a range of numbers typically colder in the headwaters and warmer downstream) for a whole watershed or sub-basin.

EPA views numeric criteria that reflect natural background conditions to be protective of salmonid designated uses because river temperatures prior to human impacts clearly supported healthy salmonid populations. Thus, when establishing site-specific numeric criteria in this manner, EPA believes it is unnecessary to modify the use designations. For example, if a State has designated a waterbody as salmon/trout core juvenile rearing use with an associated numeric criterion of 16°C 7DADM and later estimates the natural background temperature is 18°C 7DADM, the 18°C 7DADM could be adopted as a site-specific criterion that fully supports the salmon and trout core juvenile rearing use. A State or Tribe may also want to modify the spatial extent of its various salmonid use designations within the basin if the estimates of natural background provide new information that warrants such revisions. Additionally, at the time the State revises a salmonid use for a waterbody (e.g., designating a salmon/trout migration use), it could choose to establish a numeric criterion based on natural background conditions for that particular waterbody (e.g., 22°C 7DADM), which may be different from the generally applicable numeric criterion to support that use in the State's WQS (e.g., 20°C 7DADM).

States and Tribes following this approach will need to submit any such new or revised numeric criteria to EPA for approval and must include the methodology for determining the natural background condition. See 40 C.F.R. §§ 131.6 & 131.11(a). An alternative to establishing numeric criteria based on natural background conditions as described here is to adopt a narrative natural background provision, which would then be used in CWA section 303(d) listings, TMDLs, and NPDES permits as described in Section VI.2.

VI.1.C. Numeric Criteria In Conjunction with a Use Attainability Analysis

In situations where it appears that the numeric criterion or natural background provision (see Section VI.2) cannot be attained and the appropriateness of the designated use is in question, a State or Tribe could conduct a use attainability analysis (UAA) pursuant to 40 C.F.R. §§ 131.3(g) & 131.10. If it can be demonstrated that the current designated use is not attainable due to one of the factors at 40 C.F.R § 131.10(g), the State or Tribe must then adopt a different use appropriate to that water. See 40 C.F.R. § 131.10(a). In most cases, EPA expects that the appropriate use would be the most protective salmonid use that is attainable. The State or Tribe must then adopt a temperature criterion sufficient to protect that new use. See 40 C.F.R. § 131.11. EPA notes that, in all cases, uses attained since 1975, referred to as "existing uses," must be protected. See 40 C.F.R Part 131.10(h)(1). The new use could be described as a "compromised" or "degraded" salmonid use. It should be noted that a "compromised" or "degraded" level of use may be appropriate during part of the year (e.g., summer), but that an unqualified, healthy salmonid use may be attainable other times of the year and therefore may be the appropriate use then.

Examples of factors at 40 C.F.R. § 131.10(g) that could preclude attainment of the use include: human caused conditions or sources of pollution that cannot be remedied or would cause more environmental damage to correct than to leave in place; dams, diversions or other types of hydrologic modifications that cannot be operated in such a way as to result in the attainment of the use; and controls more stringent than those required by sections 301(b) and 306 of the CWA that would result in substantial and widespread economic and social impact.

Whenever a State or Tribe adopts new or revised designated uses, such as those described here, it is changing its WQS. Therefore, the State or Tribe must make the proposed change available for public notice and comment and must submit the new use and associated criteria, together with the supporting UAA, to EPA for review and approval. See CWA section 303(c)(1) & (c)(2)(A); 40 C.F.R. §§ 131.5 & 131.6. EPA recommends that a UAA seeking to demonstrate human impacts (including dams, diversions, or other hydrologic modifications) that prevent attainment of the current use, should include a full assessment of all possible mitigation measures and their associated costs when demonstrating which mitigation measures are not feasible. EPA's decision to approve or disapprove a use and criteria change associated with a UAA will need to be made on a case-by-case basis, taking into account the information available at the time, and where appropriate, after consultation with the Services and affected Tribes.

VI.2. Use of a State's or Tribe's "Natural Background" Provisions

If it has not already done so, a State and Tribe may wish to consider adopting *narrative* natural background provisions in its WQS that would automatically take precedence over the otherwise applicable numeric criteria when natural background temperatures are higher than the numeric criteria. See 40 C.F.R. § 131.11(b)(2). If adopted by a State or Tribe and approved by EPA, narrative natural background provisions would be the applicable water quality criteria for CWA purposes when natural background temperatures are higher than the numeric criteria and would be utilized in 303(d) listings of impaired waterbodies, TMDLs, and NPDES permits in such situations. As discussed in Section V.1.B above, a State could also consider adopting a specific numeric criterion that reflects natural background temperatures (rather than leave natural background temperatures to case-by-case interpretation). The discussion here, however, assumes that a State or Tribe has not done so and instead has adopted a *narrative* natural background provision and would interpret it when necessary for CWA purposes.

VI.2.A. 303(d) Listings

If it can be demonstrated that a particular waterbody exceeds a temperature numeric criterion due to natural conditions (or natural conditions plus a de mimimis human impact, if a State or Tribe has this allowance in its WQS - see Section V.1.A), then the waterbody need not be listed on a State's or Tribe's 303(d) list. Such waterbodies would not be considered impaired because they would be meeting the narrative natural background provisions of the WQS. These waterbodies should be identified as an attachment to a State's or Tribe's section 303(d) list submission to EPA along with the demonstration that these waters do not exceed the natural background provision.

For situations where waterbodies exceed the applicable numeric criteria due to a combination of apparent natural background conditions and known or suspected human impacts (above a de minimis impact level, if applicable), it would be appropriate to list those waters on the 303(d) list because the waters would be exceeding the narrative natural background provision because of the human impacts. The TMDL process, described below, will provide the opportunity to distinguish the natural sources from the human caused sources.

VI.2.B. TMDLs

A State's or Tribe's narrative natural background provisions can be utilized in TMDLs to set water quality targets and allocate loads when natural background conditions are higher than the otherwise applicable numeric criteria. When doing so, estimated temperatures associated with natural background conditions would serve as the water quality target for the TMDL and would be used to set TMDL allocations. Thus, the TMDL would be written to meet the WQS natural background provision, and the load reductions contemplated by the TMDL would be equivalent to the removal of the human impacts (or all but de minimis human impacts, if applicable). It should be noted that if a State or Tribe has a de minimis temperature increase allowance above natural background temperatures (see Section V.1.A), the TMDL allocations should be based on attaining the natural background temperature plus the de minimis temperature allowance (e.g., natural background temperature plus 0.25°C).

When estimating natural background conditions, States and Tribes should use the best available scientific information and the techniques described in Section VI.3 below. For TMDLs, this usually includes temperature models. Those human impacts that cannot be captured in a model (e.g., loss of cooling due to loss of hyporheic flow, which is water that moves between the stream and the underlying streambed gravels) should be identified in the TMDL assessment document (i.e., supporting material to the TMDL itself) along with rough or qualitative estimates of their contribution to elevated water temperatures. Estimates of natural conditions should also be revisited periodically as our understanding of the natural system and temperature modeling techniques advance.

When using natural background maximum temperatures as TMDL targets and to set TMDL allocations, the TMDL assessment document should assess other aspects of the natural thermal regime including the spatial extent of cold water refugia (which, generally are defined as waters that are ≥2°C colder than the surrounding water), the diurnal temperature variation, seasonal temperature variation (i.e., number of days at or near the maximum temperature), and shifts in the annual temperature pattern. Findings from this assessment should be integrated into the TMDL and its allocations to the extent possible. For example, if possible, TMDL allocations should incorporate restoration of the diurnal and seasonal temperature regime and cold water refugia that reflect the natural condition. If it is impracticable to address these impacts quantitatively through allocations, then the TMDL assessment document should qualitatively discuss the human activities that modify these aspects of the natural thermal regime. Plans to implement the TMDL should include measures to restore and protect these unique aspects of the natural condition.

EPA believes it is particularly important for the TMDL itself or the TMDL assessment document to address the above aspects of the natural thermal regime for waterbodies where the natural background maximum 7DADM temperature exceeds 18°C and where the river has significant hydrologic alterations (e.g., dams and reservoirs, water withdrawals, and/or significant river channelization) that have resulted in the loss of temperature diversity in the river or shifted the natural temperature pattern. For example, there may be situations where the natural background maximum temperatures exceed 18°C, but historically the exposure time to maximum temperatures was limited due to the comparatively few number of hours in a day that the water reached these temperatures, the comparatively few number of days that reached these temperatures, and plentiful cold water refugia from cold tributary flows and hyporheic flow in alluvial floodplains where salmonids could avoid the maximum water temperatures.

If human impacts as identified at 40 C.F.R. 131.10(g) are determined to prevent attainment of the natural background conditions, the State or Tribe should follow the UAA process described in Section VI.1.C above and revise the use and adopt numeric criteria that would support a revised use. This new numeric criteria, if approved by EPA, would then be the temperature target in the TMDL and used to set load allocations.

Before determining that some of the human impacts preclude use attainment and pursuing a UAA, EPA Region 10 encourages States to develop and begin implementing TMDLs that reflect the applicable numeric criteria or natural background provisions and allow some time for implementation to proceed. EPA Region 10 encourages this approach because it is often the case that at the time a TMDL is developed there is little information on all the possible implementation measures and their associated costs, which may be important to justify a UAA. Further, after feasible implementation measures are completed, there will be better information as to what is the actual attainable use and associated water temperatures. If information is available at the time, however, it is possible for a State to conduct a UAA concurrently with the TMDL development process and, if appropriate, to revise the designated use and adopt new applicable numeric criteria for use when establishing the TMDL.

VI.2.C. NPDES Permits

When a permitting authority is establishing a temperature water quality-based effluent limit for an NPDES source, it must base the limit on the applicable water quality standards, which could be the numeric criteria or, if applicable, the narrative natural background provision. See 40 C.F.R. § 122.44(d)(1). EPA expects that, in most cases, the natural background temperature will be interpreted and expressed for the first time in a TMDL, but it is possible for the natural background temperature to be determined outside the context of a TMDL, although this would be unusual given the complexities involved in estimating natural background temperatures.

VI.3. Overview of Methods to Estimate Natural Background Temperatures

There are a number of different ways of estimating natural background temperature conditions for the purposes of either adopting a site-specific criterion (see Section VI.1.B) or interpreting a narrative natural background provision (see Section VI.2). These include: (1) demonstrating that current temperatures reflect natural background conditions, (2) using a non-degraded reference stream for comparison, (3) using historical temperature data, (4) using statistical or computer simulation models, and (5) assessing the historical distribution of salmonids. There may be other ways as well. Each approach has its strengths and weaknesses and therefore may or may not be most appropriate for a given situation. Moreover, all of these approaches have uncertainty, which should be quantitatively described where possible. EPA encourages the use of a combination of approaches to estimate natural background temperatures, where feasible. Below is an overview of the five approaches listed above.

Demonstrating That Current Temperatures Reflect Natural Background Conditions

Under this approach, the past and present human activities that could impact the river temperatures are documented and a technical demonstration is made that the human activities do not currently impact temperatures. This approach is most applicable to non-degraded watersheds (e.g., state and national parks, wilderness areas, and protected state and national lands). These watersheds can be used as “reference” streams for estimating the natural background temperatures of degraded streams (see below). If there is a small human impact on temperatures, it may also be possible to estimate the human impact and subtract it from current temperatures to calculate the natural background temperatures.

Comparisons to a Reference Stream

It is often reasonable to assume that the natural background temperatures of a thermally degraded stream are similar to that of a non-degraded stream, so long as the location, landscape context, and physical structure of the stream are sufficiently similar. The challenge to this approach is finding a reference stream that is of similar location, landscape context, and physical structure. Because large rivers are unique and most in the Pacific Northwest have been significantly impacted by human activities, this approach is most applicable to smaller streams where a reference stream with current temperatures at natural background conditions exist.

Historical Data

For some rivers, historical temperature data are available that reflect temperatures prior to human influences on the river's temperature regime, and can be used as an estimate of natural background temperatures. Factors that lend uncertainty to historic temperature data are the uncertain nature of the quality of the data and whether or not humans affected temperature prior to data collection. Further, historical temperature data often do not adequately capture the spatial and/or temporal variability in stream temperature due to limited spatial or temporal sampling. Historical data may be useful, however, for verifying estimates of modeled natural background temperatures.

Temperature Models

Two major methods have been commonly used for water quality modeling in the United States over the last 20 years: 1) statistical models, which are based on observed relationships between variables and are often used in conjunction with measurements from a reference location, and 2) process-based models, which attempt to quantify the natural processes acting on the waterbody. Process-based models are often employed when no suitable reference locations can be identified.

Statistical models, also referred to as empirical models, estimate the thermal conditions of streams by using statistics to find correlations between stream temperature and those landscape characteristics that control temperature (e.g., elevation, latitude, aspect, riparian cover, etc.). The equations in statistical models describe the observed relationships in the variables as they were measured in a specific location. If the specific location is a non-degraded reference stream, then the model can be used to estimate natural background conditions in degraded streams. Statistical models have the advantage of being relatively simple, as they rely on general data and statistics to develop correlations.

The comparability between the reference waterbody where the statistical correlations are generated and the assessment waterbody strongly affects the applicability of statistical models. Uncertainties in statistical model results increase with increasing dissimilarity between the landscape characteristics of the reference and assessment water bodies. Uncertainties also increase when models do not include landscape characteristics that control important processes affecting the water temperature. For these reasons, statistical models are best suited for small headwater streams or for generalized predictions across a large landscape.

Process models, also referred to as simulation models, are based on mathematical characterizations of the current scientific understanding of the critical processes that affect water temperature in rivers. The equations are constructed to represent the observed or expected relationships and are generally based on physical or chemical principles that govern the fate and transport of heat in a river (e.g., net heat flux from long-wave radiation, direct short wave radiation, convection, conduction, evaporation, streamside shading, streambed friction, and water's back radiation) (Bartholow, 2000).

Estimating water temperature with a process model is generally a two-step process. As a first step, the current river temperatures are estimated with the input parameters (e.g., amount of shade provide by the canopy and river depth, width, and flow) reflecting current conditions and the model error is calculated by comparisons of the model estimate to actual temperature measurements. The second step involves changing the model input parameters to represent natural conditions, which results in a model output that predicts the natural background conditions. In recent years, increases in computer processing power have led to the development of distributed process models, which incorporate a high degree of spatial resolution. These models use Geographical Information Systems (GIS), remotely-sensed data, and site-specific data to vary the model's input parameters at different locations in the waterbody or the landscape.

Unlike statistical models, process models do not rely upon data from reference locations, so they can be used for rivers that have no suitable natural reference comparisons available. Thus, process models are well suited for estimating natural conditions for larger streams and rivers. Although powerful, process models are by no means infallible. Errors can arise when there are locally important factors that the model does not address, or when there is a great deal of uncertainty in input parameters that strongly influence the model results.

In addition to estimating natural background conditions, process-based models are useful for understanding the basic mechanisms influencing water temperature in a watershed, understanding the relative contributions from different sources at different locations, understanding cumulative downstream impacts from various thermal loads, performing "what if" scenarios for different mitigation options, and setting TMDL allocations.

Historical Fish Distributions

Maps of historic salmonid distributions and their time of use can provide rough estimates of natural background temperatures. Where and when salmonids existed historically likely provided temperatures suitable for salmonids and, as described in this guidance, we have a fairly good understanding of suitable temperatures for various life stages of salmonids.

VII. Using EPA's Guidance to Change Salmonid Use Designations

The States of Idaho, Oregon, Washington and Pacific Northwest Tribes with WQS currently have salmonid use designations that are less spatially and temporally specific than those recommended in Section V.1 of this guidance. For instance, several States and Tribes employ broad salmonid use designations (e.g., migration, rearing, spawning) that apply generally to an entire basin or watershed. EPA's recommendations in Section V.1 are intended to assist States and Tribes with broad use designations to more precisely define when and where the different salmonid uses currently occur or may potentially occur within a basin.

For example, at the present time, a State may have a spawning use designated for an entire basin (or large waterbody), but not specify the waterbody segments or times of year to which that use designation should apply. After considering information that indicates where and when spawning currently occurs or may potentially occur, that State might decide that only certain locations and times in the basin should be designated for spawning. This same situation may also occur in the context of rearing and migration uses.

The intent of EPA's recommendations is to encourage States and Tribes, through these types of use refinements, to adopt a suite of interdependent salmonid uses. This suite of uses, in essence, would function as a single aquatic life use designation for the protection, at all life stages, of a sustainable salmonid population. Consequently, EPA believes that, as a general matter, use designations within a basin that reflect, at the appropriate times and places, the complete suite of uses to protect healthy salmonid populations at all life stages would fully protect the CWA section 101(a)(2) aquatic life uses. EPA, therefore, would not expect a UAA to accompany such use refinements as long as the overall sustainable salmonid population use is still being protected. See 40 C.F.R. § 131.10(k). It should be noted, however, that these types of use refinements are changes to a State's of Tribe's WQS and therefore require public notice and review and EPA approval.

VIII. Temperature Limits for NPDES Sources

Section 301(b)(1)(C) of the CWA requires the achievement of NPDES effluent limitations as necessary to meet applicable WQS. EPA Region 10's general practice is to require that numeric criteria be met at end-of-pipe in impaired waterbodies (i.e., those that exceed water quality criteria). However, EPA Region 10 believes that in some situations numeric criteria end-of-pipe effluent limits for temperature may not be necessary to meet applicable WQS and protect salmonids in impaired waters. This is because the temperature effects from point source discharges generally diminish downstream quickly as heat is added and removed from a waterbody through natural equilibrium processes. The effects of temperature are unlike the effects of chemical pollutants, which may remain unaltered in the water column and/or accumulate in sediments and aquatic organisms. Further, temperature impairments in Pacific Northwest waters are largely caused by non-point sources. However, there may be situations where numeric criteria (or near numeric criteria) end-of-pipe effluent limits would be warranted, such as where a point source heat discharge is significant relative to the size of the river.

If a facility discharging heat into an impaired waterbody is seeking an effluent limit that is different than end-of-pipe numeric criteria, it should undertake a comprehensive temperature study. EPA recommends that regulatory authorities develop guidance on the content of these studies and on how alternative effluent limits may be developed that protect salmonids. EPA recommends that a temperature study, at a minimum, should consist of the following:

- A detailed engineering evaluation of sources of heat and possible measures to eliminate/reduce the heat sources and/or mitigate the effect of the heat sources. This could, for example, take the form of an engineering analysis of manufacturing processes or an investigation of sources of heat into publically-owned treatment plants. The engineering evaluation should include cost estimates for the possible temperature reduction measures.

- A modeling evaluation to determine a preliminary temperature effluent limit that meets the numeric criterion for the waterbody (or natural background temperature if applicable - see Section VI.2.C). For instance, it may be appropriate to use a simple energy balance equation (U.S. EPA, 1996) to calculate an effluent temperature that would ensure any downstream temperature increase above the numeric criterion (or natural background temperature) is de minimis (e.g., less than 0.25°C) after complete mixing. This approach assumes the State's or Tribe's WQS includes a de minimis temperature allowance as described in Section V.1.A. When using this approach, EPA recommends that the upstream water temperatures be assumed to be at the numeric criterion (or natural background temperature) and that a river flow be used that minimizes the percentage of the flow utilized for mixing purposes (e.g., 25% of 7Q10). The preliminary temperature effluent limit using this method should not exceed the current effluent temperature. In some situations it may be appropriate to utilize more complex modeling than described here (e.g., waters with multiple point source impacts).

- An evaluation of localized impacts of the thermal plume on salmonids based on plume modeling. The physical characteristics of the thermal plume (e.g., a 3-dimensional profile of temperatures) can be estimated using a near-field dilution model and adequate input data to run the model (e.g., river and effluent temperatures and flows). The preliminary effluent temperature derived from above (i.e., the effluent temperature derived from the energy balance equation or the current effluent temperature, whichever is lower) should be used in the model along with the current river temperature and flow for the seasons of concern. The preliminary effluent limit should be lowered, if necessary, to ensure that the localized adverse impacts on salmonids described in Section V.3 are avoided or minimized.

The results of these evaluations should be used to assist in the development of the final permit effluent limit in waters where a temperature TMDL has yet to be completed. Modeling evaluations, such as those described above, should be used in temperature TMDLs to help set wasteload allocations that can be used as temperature limits in NPDES permits. It may not be practicable, however, to complete near-field plume modeling for some or all point sources in large-scale temperature TMDLs. In these situations, the TMDL should indicate that the thermal plume modeling be done during permit development, which may result in an effluent limit lower than the TMDL wasteload allocation.

EPA Region 10 also believes that water quality trading may hold some promise to meet temperature WQS in a cost-effective manner that is beneficial for salmonids. In particular, a point source may be able to seek trades with non-point sources as a mechanism to meet its NPDES obligations. For example, a point source may help secure non-point controls beyond minimum state requirements, such as re-vegetation of a river's riparian zone, and use those temperature reductions to help meet its temperature reduction obligations. EPA encourages the use of this potentially valuable approach to help attain temperature WQS.

IX. The Role of Temperature WQS in Protecting and Recovering ESA-Listed Salmonids and Examples of Actions to Restore Suitable Water Temperatures

EPA Region 10 and the Services believe that State and Tribal temperature WQS can be a valuable tool to protect and aid in the recovery of threatened and endangered salmonid species in the Pacific Northwest. The following are three important ways that temperature WQS, and measures to meet WQS, can protect salmonid populations and thereby aid in the recovery of these species. The first is to protect existing high quality waters (i.e., waters that currently are colder than the numeric criteria) and prevent any further thermal degradation in these areas. The second is to reduce maximum temperatures in thermally degraded stream and river reaches immediately downstream of the existing high quality habitat (e.g., downstream of wilderness areas and unimpaired forest lands), thereby expanding the habitat that is suitable for coldwater salmonid rearing and spawning. The third is to lower maximum temperatures and protect and restore the natural thermal regime in lower river reaches in order to improve thermal conditions for migration.

The following are examples of specific on-the-ground actions that could be done to meet temperature WQS, protect salmonid populations and also aid in the recovery of threatened and endangered salmonid species. Logically, these example actions are oriented toward reversing the human activities that can contribute to excess warming of river temperatures described in Section IV.2. See Issue Paper 3, Coutant (1999), and Return to the River (2000) for more detailed discussion. EPA encourages and hopes to help facilitate these types of actions and recognizes that collaborative efforts with multiple stakeholders holds the most promise to implement many of these measures.

- Replant native riparian vegetation
- Install fencing to keep livestock away from streams
- Establish protective buffer zones to protect and restore riparian vegetation
- Reconnect portions of the river channel with its floodplain

- Re-contour streams to follow their natural meandering pattern
- Increase flow in the river derived from more efficient use of water withdrawals
- Discharge cold water from stratified reservoirs behind dams
- Lower reservoirs to reduce the amount of shallow water in "overbank" zones
- Restore more natural flow regimes to allow alluvial river reaches to function
- Restore more natural flow regimes so that river temperatures exhibit a more natural diurnal and seasonal temperature regime

EPA and the Services acknowledge that efforts are underway on the part of some landowners, companies, non-profit organizations, tribes, local and state governments, and federal agencies in the Pacific Northwest to take actions to protect and restore suitable temperatures for salmonids and improve salmonid habitat generally. A few examples of broad-scale actions to improve temperatures for salmonids are: the Aquatic Conservation Strategy of the Northwest Forest Plan (federal lands); the State of Washington's forest protection regulations; and timber company Habitat Conservation Plans (HCPs), particularly the Simpson HCP, which was done concurrent with a temperature TMDL. Additionally, there are small-scale projects, which are too numerous to list here (e.g., tree plantings, fencing, and re-establishing the natural meandering channel of small streams), that have already contributed or will contribute to improved thermal conditions for salmonids. These efforts represent a good direction and start in the process of restoring stream temperatures in the Pacific Northwest.

EPA and the Services believe it is important to highlight these examples of on-the-ground actions to recognize their contribution to improving water temperatures, to demonstrate their feasibility, and to provide a model for others to take similar actions.

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Recommended Streamflow Schedules To Meet the AFRP Doubling Goal in the San Joaquin River Basin

27 September 2005

Introduction

The goal of the Anadromous Fish Restoration Program (AFRP) is to make all reasonable efforts to at least double natural production of anadromous fish in California's Central Valley streams on a long-term, sustainable basis. However, production of fall-run Chinook salmon (Chinook Prod) between 1992 and 2004 has declined by 28% in the Stanislaus River, 46% in the Tuolumne River, and increased by only 4% in the Merced River, which is a hatchery supported stream, compared to the 1967-1991 baseline period. Evidence is provided here that the declines in salmon production primarily resulted from a reduction in the frequency and magnitude of spring flooding in the San Joaquin River Basin during the 1992-2004 period compared to the baseline period. Additional evidence is provided that the most likely means of increasing adult production would be to increase flows during February and March to substantially increase the survival of juveniles in the lower half of the tributaries and the San Joaquin River and thereby increase the production of smolts, and then to increase flows between April and mid-June to increase smolt survival. It is also likely that production can be further increased by (1) providing fall pulse flows that help minimize the number of adult salmon that stray to the Sacramento Basin when Delta export rates are high and minimize delays of adults in the Delta that may impair gamete viability; (2) gradually ramping down spring flows during June to facilitate riparian vegetation recruitment and thereby increase the input of allochthonous organic matter and food into the aquatic habitat; and (3) increasing summer flows to increase the survival of juvenile Central Valley steelhead and Chinook yearlings.

The population models described below suggest that the physical habitat in the Stanislaus, Tuolumne, and Merced rivers can support the progeny of no more than 2,000 spawners. If true, restoring the spawning, rearing, and/or floodplain habitats should substantially increase salmonid production in all three tributaries. However, it is likely that habitat restoration by itself will not increase juvenile production, unless flows are increased to increase the amount of rearing habitat, the frequency of floodplain inundation, and thereby increase juvenile survival.

There is also a slight possibility that increasing flows during spawning in early November to increase the amount of habitat with suitable water temperatures would reduce redd superimposition and thereby increase juvenile production; however, screw trap data from the Stanislaus River, which are presented below, do not support this hypothesis.

Ten analyses that were used to justify and determine the flow schedules needed to help achieve the AFRP doubling goal are summarized below:

1. Relationships between salmon recruitment and flow in the Stanislaus and Tuolumne rivers;
2. Relationships between juvenile survival and flow in the Stanislaus River;
3. Salmon production models for the San Joaquin River Basin;
4. Spring flows required to double fall-run Chinook salmon populations;
5. Fall pulse flows required for adult passage through the Delta;
6. Fall flows required for spawning and incubation habitat;
7. Ramping down spring flows to promote riparian vegetation;
8. Summer flows required to increase habitat for yearling steelhead and salmon;
9. The effect of Delta Exports rate reductions on Chinook salmon production; and
10. Comparison of Flow Schedules for a 53% increase in production and doubling.

1. Relationships Between Salmon Recruitment And Flow In The Stanislaus And Tuolumne Rivers

Fall-run Chinook salmon production in the San Joaquin River Basin is well correlated with flow, particularly in the San Joaquin River at Vernalis, during the spring when the juveniles are migrating from the tributaries (Mesick 2005). Mesick's analysis converts production, which consists of several different cohorts of fish that all return to spawn in the tributaries during the same year, into recruitment, which consists of same-aged adults that all migrated through the Basin as juveniles during the same year. This conversion requires age data to segregate escapement into cohorts, which was not collected on the Merced River until 1988; therefore, these analyses that compare the baseline and post-baseline periods could only be done for the Tuolumne and Stanislaus rivers.
Comparing the regressions of average flow in the San Joaquin River at Vernalis for the March through May period and salmon recruitment suggests that the slope of the regressions has declined by about 10% for the Stanislaus River (Figure 1) and 20% for the Tuolumne River (Figure 2); however, statistical tests cannot be conducted to determine the significance of the declines because the tests can only be conducted if the variances of the two regressions are not significantly different (Snedecor and Cochran 1989) and *F*-tests indicate that the variances of the baseline and 1992-2002 regressions were significantly different ($p \leq 0.01$). Therefore, most if not all of the declines in production observed in the Stanislaus and Tuolumne rivers since 1992 are a result of a lower frequency of wet years during the 1992-2004 period compared to the baseline period. For example, the average March through May flows at Vernalis during the slightly wet years (San Joaquin River Index of 4.0 to 5.0 million acre feet) ranged between 5,000 and 10,000 cfs during the 1992-2004 period and between 15,000 and 20,000 cfs during the baseline period (Figure 3). The lower flood magnitudes observed after 1992 are primarily due to differences in climate because the large San Joaquin reservoirs that capture all or most of flood flows were all completed prior to 1992: New Melones was completed in 1980, New Don Pedro was completed in 1971, and New Exchequer was completed in 1966.

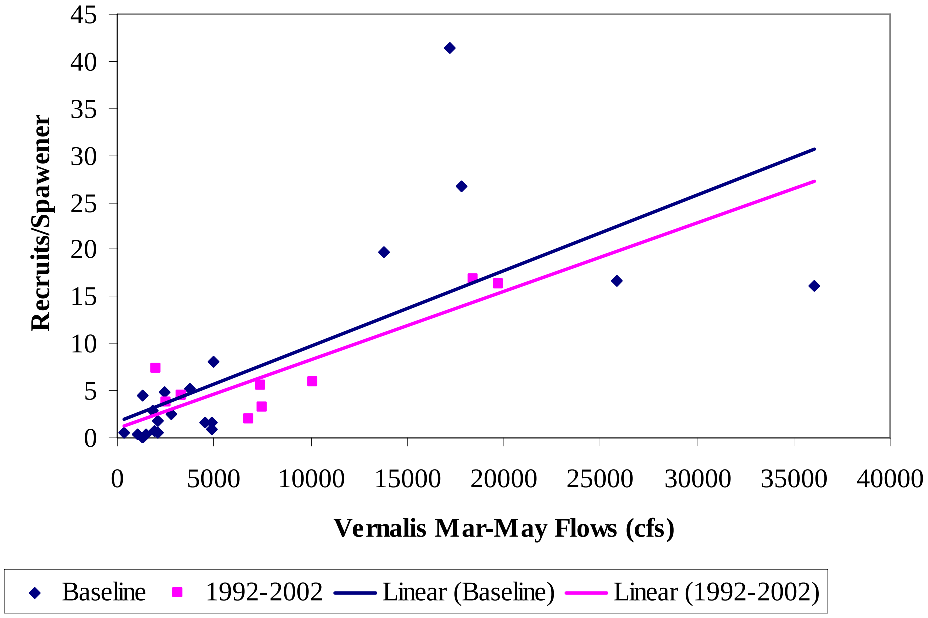

Figure 1. The relationship between the number of fall-run Chinook salmon recruits/spawner to the lower Stanislaus River and the average flow in the San Joaquin River at Vernalis between 1 March and 31 May during the 1967-1991 baseline period and the 1992-2002 AFRP period. The lines labeled as “linear” show the linear regression models for each period. The adjusted R-Squared for the linear regression model is 0.50 for the 1967 to 2002 dataset.

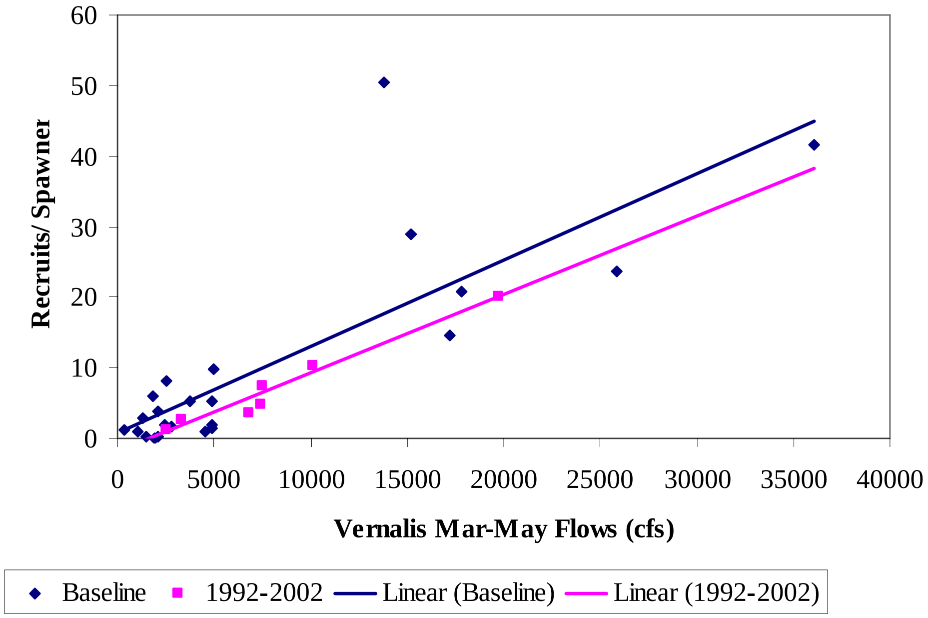

Figure 2. The relationship between the number of fall-run Chinook salmon recruits/spawner to the lower Tuolumne River and the average flow in the San Joaquin River at Vernalis between 1 March and 31 May during the 1967-1991 baseline period and the 1992-2002 AFRP period. The lines labeled as “linear” show the linear regression models for each period. The adjusted R-Squared for the linear regression model is 0.59 for the 1967 to 2002 dataset.

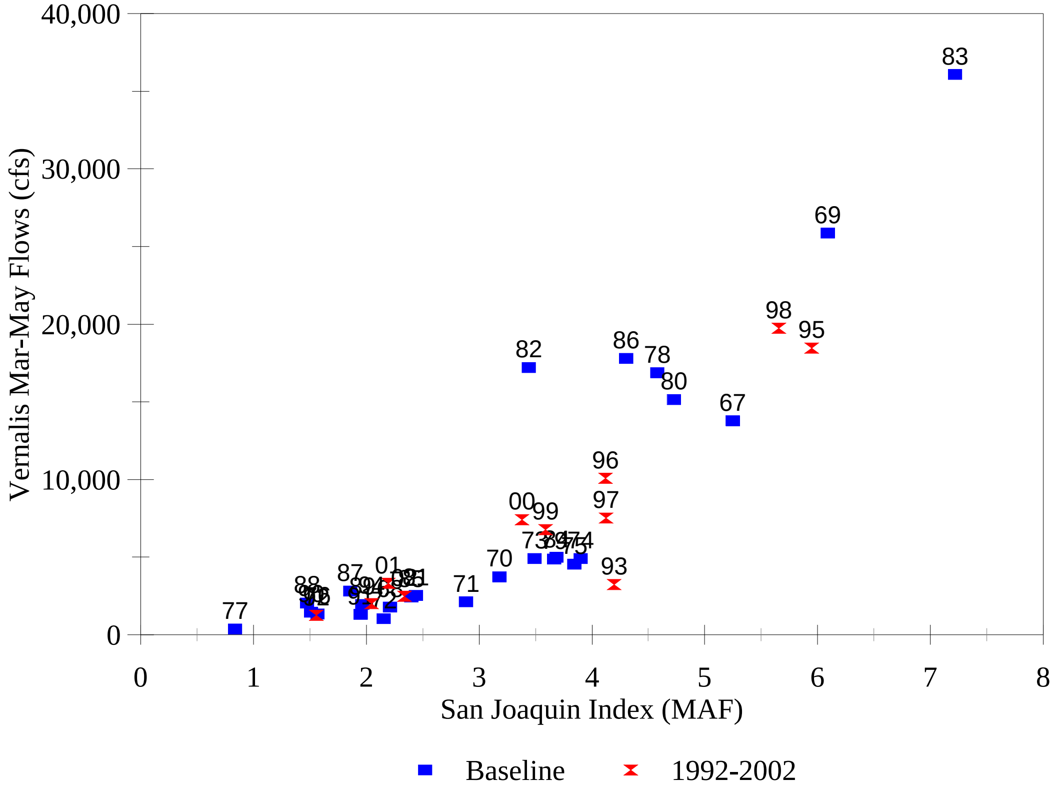

Figure 3. The relationship between the mean March through May flow in the San Joaquin River at Vernalis and the San Joaquin Index in millions of acre-feet (MAF) for the baseline and 1992-2002 periods.

2. Relationships between juvenile survival and flow in the Stanislaus River

The survival of fry and parr migrating and rearing in the Stanislaus River between Oakdale and Caswell State Park is highly dependent on flow between March and early June and presumably the same is true for the Tuolumne and Merced rivers. Many more fry, parr, and smolts were captured in the Stanislaus River at the Caswell traps when the flow at Ripon in February and March ranged between 1,000 and 5,000 cfs during above normal and wet years (1998-2000) than when it was typically less than 600 cfs during dry and normal years (2001-2004; Appendix 1). The fact that more juveniles passed the downstream Caswell trap (RM 5) than the upstream Oakdale trap (RM 40) in April and May during the above normal and wet years strongly suggests that high February and March flows may be needed for fry and parr to rear in the lower river. It is also likely that the extended periods of high flows in April, May and early June during the above normal and wet years were responsible for the high survival rates of migrating smolts. Supporting evidence is provided by the strong correlations between adult recruitment and Vernalis flows in March, April, May, and June (Mesick 2005). The relatively weak correlations between recruitment and Vernalis flows in February suggest that February flows may be as important as those between March and mid June. It is assumed that high flows in February through mid June would also be important for juvenile salmonids in the Tuolumne and Merced rivers as well.

3. Salmon production models for the San Joaquin River Basin

Regression equations were computed for the number of Chinook salmon recruits per spawner in each of the San Joaquin River tributaries (Mesick 2005) and the average flow at Vernalis during April and May for the purpose of estimating the amount of flow required to double populations. It was assumed that the magnitude of flow during April and May was more directly related to juvenile salmon survival because this is the period when most of the smolt-sized fish are migrating[1] and water temperatures are in the range that may affect smolt survival[2]. Vernalis flows were used in the model instead of tributary reservoir releases for two reasons. First, juvenile survival in the Stanislaus River is much more highly correlated with flow at Vernalis (adjusted-$R^2 = 0.53$) than with flow at Goodwin Dam in the Stanislaus River (adjusted-$R^2 = 0.16$), which suggests that Delta flows are more important than tributary flows (Mesick 2005). Second, there were insufficient flow data at Snelling to estimate reservoir releases in the Merced River during the entire AFRP baseline period, which precludes model development based on tributary flows.

Stanislaus River model: Recruits/Spawner = 0.0008611 * April-May Vernalis Flows + 1.17688. The adjusted-R^2 was 0.53 with a probability level of 0.0000 for the model developed with the estimates for 1983 to 2002. Recruitment was computed by multiplying the model's predicted number of recruits/spawner by the number of spawners. It was assumed that recruitment increased linearly until 2,000 spawners, after which and there was no further change in recruitment as the number of spawners exceeded 2,000 fish. This assumption reflects the relationship between stock and the total estimated number of juveniles passing the Oakdale Screw trap between 1996 and 2004 (Mesick 2005). Figure 4 compares the recruitment estimates based on escapement surveys (Mesick 2005) with the model results.

Tuolumne River model: Recruits/Spawner = 0.00140 * April-May Vernalis Flows + 0.18957. The adjusted-R^2 was 0.65 with a probability level of 0.0000 for the model developed with the estimates for 1980 to 2002. Recruitment was computed by multiplying the estimated number of recruits/spawner by the estimated number of spawners. It was assumed that recruitment increased linearly until 2,000 spawners, after which there was no further change in recruitment aas the number of spawners exceeded 2,000 fish. This assumption was made because the model's adjusted-R^2 declined to 0.44 and then to 0.32 as the spawner-recruit inflection point was increased to 3,000 and 4,000 spawners respectively. Figure 5 compares the recruitment estimates based on escapement surveys (Mesick 2005) with the model results.

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[1] CDFG Mossdale Trawl Data presented to the State Water Resources Control Board in Spring 2005.

[2] Vernalis Adaptive Management Plan technical reports produced by the San Joaquin River Group Authority.

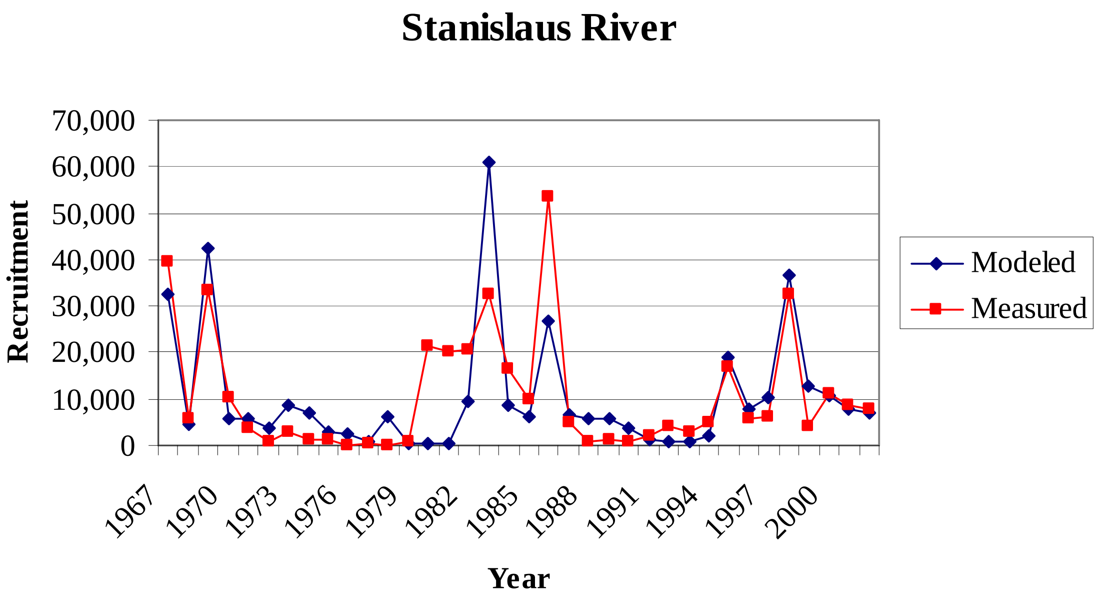

Figure 4. Adult Chinook salmon recruitment to the Stanislaus River from 1967 to 2002 based on escapement surveys (Measured) and regression model predictions (Modeled).

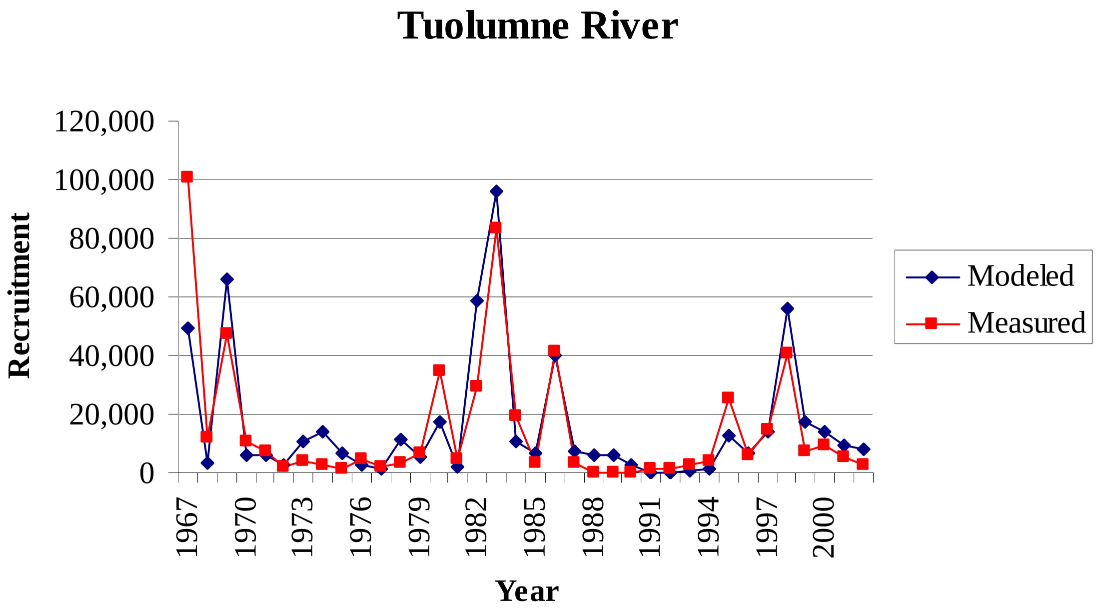

Figure 5. Adult Chinook salmon recruitment to the Tuolumne River from 1967 to 2002 based on escapement surveys (Measured) and regression model predictions (Modeled).

Merced River model: Recruits/Spawner = 0.000554 * April-May Vernalis Flows + 0.07938. The adjusted-R^2 was 0.61 with a probability level of 0.0000 for the model developed with the estimates for 1980 to 2002. The recruitment estimates between 1980 and 1986 were based on Age 2 estimates from the Tuolumne River whereas the later estimates were based on length-frequency derived Age 2 estimates from the Merced River (Mesick 2005). Recruitment was computed by multiplying the estimated number of recruits/spawner by the estimated number of spawners. It was assumed that each fish collected in the Merced River Fish Hatchery, up to the approximate hatchery's capacity of 1,000 spawners, contributed twice the in-river production compared to naturally spawning adults. It was also assumed that recruitment increased linearly until 2,000 in-river spawners, after which there was no further change in recruitment after the number of spawners exceeded 2,000 fish. This assumption was made because the physical condition of the spawning and rearing habitat in the Merced River is more degraded than those habitats in the Stanislaus and Tuolumne rivers[3]. In addition, the number of recruits produced per spawner in the Merced River is substantially lower than in the Tuolumne and Stanislaus rivers, and so it is highly unlikely that the habitat in the Merced River can support the progeny of more than 2,000 spawners. Figure 6 compares the recruitment estimates based on escapement surveys (Mesick 2005) with the model results.

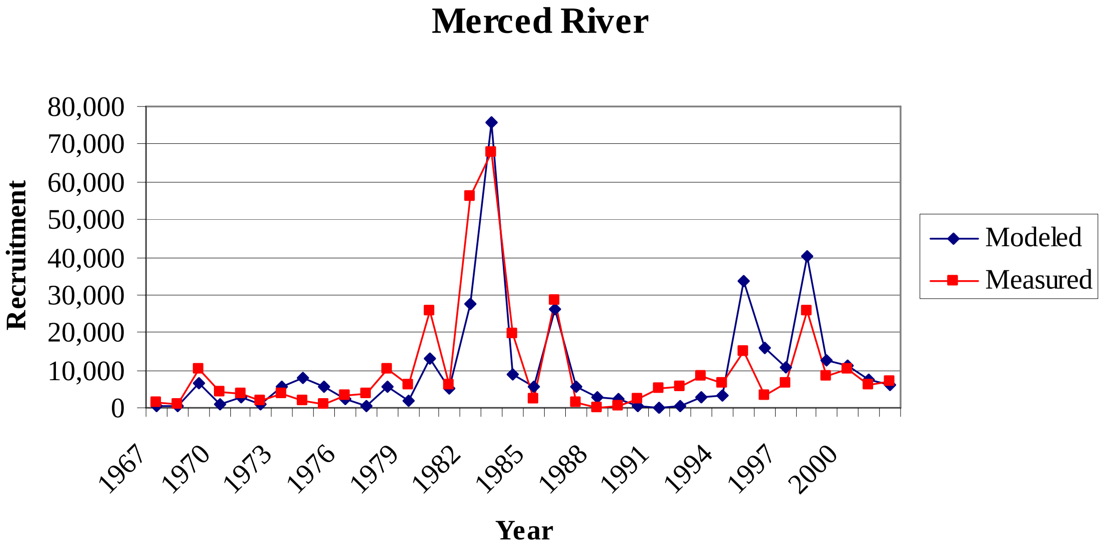

Figure 6. Adult Chinook salmon recruitment to the Merced River from 1967 to 2002 based on escapement surveys (Measured) and regression model predictions (Modeled).

4. Spring flows required to double fall-run Chinook salmon populations

To use the above recruitment models to estimate the amount of flow at Vernalis that would be needed to double salmon production in the San Joaquin Basin, it is necessary to maintain the historical conditions that formed the basis of the model. This means that each of the three San Joaquin River tributaries must maintain the similar contributions to Vernalis flows as well as maintain a similar hydrograph. Based on the estimated annual unimpaired flows, the Stanislaus River contributes 28%, the Tuolumne River contributes

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[3] The physical condition of the Merced, Tuolumne, and Stanislaus rivers was visually assessed by Carl Mesick, USFWS, during boat surveys in 2005, 2004, and 2002 respectively.

49%, and the Merced River contributes 23% of Vernalis flows historically. To convert the modeled flows into monthly averages for March, April, and May in a functional flow schedule, a constant percentage of the average unimpaired historical flow (1901 to 2004) was used for each month. For example, the Merced River Model indicates that an average flow of 3,480 cfs would be needed for the months of April and May during wet years to double production. The flow schedule was determined by multiplying the average unimpaired flow during wet years by 76.86%, which computes to a March flow of 2,279 cfs, an April flow of 2,559 cfs, and a May flow of 4,402 cfs. Suitable February flows were assumed to be either half of March flows or a minimum of 350-500 cfs, which was slightly lower than the recommended March flow.

Two sets of recommended flows were developed. The first set of flows simply extended the Vernalis flow standards in the State Water Resources Control Board's 1995 Water Quality Control Plan from April 15 to May 15 to April 1 to May 30, and then proportioned the flow during each month between March and May to match the natural hydrograph. Based on all three recruitment models, the total modeled population for the San Joaquin River Basin would increase by 53% from 36,494 fish during the AFRP baseline period to 55,945 fish, if the flows in Table 1 were implemented. The increase in recruitment varies between the three tributaries: 59% for the Stanislaus River, 42% for the Tuolumne River, and 57% for the Merced River, because the populations respond differently in terms of the effects of flow on juvenile survival and increases in spawner abundance. Historically, spawner abundance limited recruitment more frequently on the Stanislaus and Merced rivers than in the Tuolumne River and so an increase in flow would improve both spawner abundance as well as smolt survival in the Stanislaus and Merced rivers to a greater degree than for the Tuolumne River, and thereby, produce the largest increases in recruitment in the Stanislaus and Merced rivers. The rate that recruitment increases with flow would be expected to decline after spawner abundance consistently reaches the habitat's capacity of 2,000 fish.

The second set of flows would be expected to double the total predicted San Joaquin Basin recruitment from 36,494 fish during the AFRP baseline period to 72,916 fish. The increase in recruitment varies considerably between the three tributaries: 114% for the Stanislaus River, 86% for the Tuolumne River, and 112% for the Merced River. The following table indicates the average flow for February, March, April, and May in the Stanislaus, Tuolumne, and Merced rivers that would be expected to double salmon production for the basin.

Table 1. The average flow (cfs) for February, March, April, and May for the Stanislaus, Tuolumne, and Merced rivers that would be expected to achieve a 53% increase in total predicted Chinook salmon production for the basin.

	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
			Stanislaus		
February	674	500	500	500	450
March	1,348	814	571	545	462
April	1,641	1,364	1,109	1,065	814
May	2,541	1,902	1,520	1,146	845
			Tuolumne		
February	1,060	638	500	500	500
March	2,119	1,276	883	922	874
April	2,532	1,881	1,792	1,586	1,420
May	4,284	3,605	2,646	2,395	1,702
			Merced		
February	600	500	450	350	300
March	1,200	613	480	383	329
April	1,347	1,022	832	808	654
May	2,317	1,687	1,339	1,038	783
			Total		
February	2,333	1,638	1,450	1,350	1,250
March	4,667	2,703	1,933	1,850	1,665
April	5,520	4,266	3,733	3,459	2,888
May	9,142	7,194	5,505	4,579	3,331

Table 2. The average flow (cfs) for February, March, April, and May in the Stanislaus, Tuolumne, and Merced rivers that would be expected to double the total predicted Chinook salmon production for the basin.

	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
			Stanislaus		
February	1,280	787	514	500	500
March	2,560	1,573	1,028	927	785
April	3,117	2,636	1,998	1,811	1,385
May	4,827	3,676	2,738	1,950	1,438
			Tuolumne		
February	2,013	1,212	794	784	744
March	4,027	2,424	1,589	1,568	1,487
April	4,811	3,574	3,225	2,696	2,415
May	8,139	6,850	4,763	4,072	2,895
			Merced		
February	1,140	582	500	500	500
March	2,279	1,165	864	651	559
April	2,559	1,941	1,498	1,375	1,112
May	4,402	3,205	2,410	1,766	1,332
			Total		
February	4,433	2,581	1,809	1,784	1,744
March	8,866	5,162	3,481	3,146	2,832
April	10,487	8,151	6,721	5,883	4,912
May	17,369	13,732	9,912	7,787	5,665

5. Fall pulse flows required for adult passage through the Delta

Poor water quality in the deep-water ship channel near Stockton and excessive exports at the State Water Project and Central Valley Project at Tracy in October can either delay the upstream migration of adults or cause them to stray to the Sacramento River basin.

Delayed Adult Migration

Hallock and others (1970) showed that radio-tagged adult Chinook salmon delayed their migration at Stockton whenever dissolved oxygen (DO) concentrations were less than 5 mg/l and/or water temperatures exceeded about 65 ^{o}F in October. DO concentrations near Stockton in October were greater than 5 mg/l from 1983, when DWR began monitoring, to 1990, but were lower than 5 mg/l for most of October in 1991 and 1992. The Head of the Old River Barrier was installed in fall 1992 to maximize flows in the deep water ship channel, but it did not correct the problem until late October (Figure 7). In 1993, DO levels were low until about 10 October and it is likely that pulse flows that raised Vernalis flows to about 4,000 cfs on 7 October were responsible for increasing DO levels at Stockton (Figure 7). Similarly in 1994, DO levels were low until 15 October when pulse flows raised Vernalis flows to about 2,000 cfs (Figure 7). In 1995, DO levels were at least 6 mg/l in October when Vernalis flows ranged about 3,000 cfs to 6,000 cfs through mid October. DO levels were low or greatly fluctuated in 1996 until 13 October when pulse flow releases increased Vernalis flows from 2,000 to about 3,000 cfs (Figure 7).

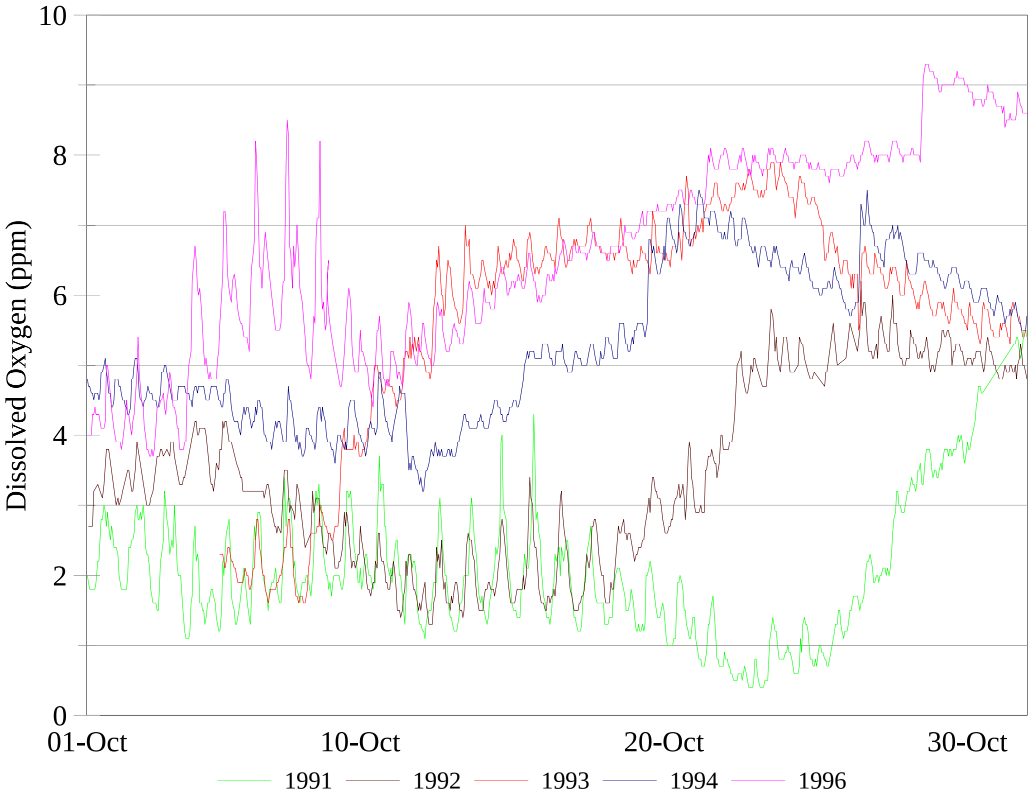

Figure 7. Hourly dissolved oxygen measurements at the Department of Water Resources' Burns Cut Off Road monitoring station during October in 1991 through 1994 and in 1996.

There are concerns that delaying the migration of adult salmon in the deep-water ship channel near Stockton may reduce gamete viability if the fish are exposed to high temperatures for prolonged periods. Egg survival at the Merced River Hatchery increased from a mean of 46% from 1990 to 1992 during the peak of the drought to a mean of 77% from 1993 to 1999 after fall pulse flows were made[4]. A more in-depth

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[4] Merced River Hatchery Production Reports by CDFG

analysis should be conducted to determine whether the mid-October pulse flows help maintain gamete viability in Chinook salmon migrating in the Delta.

Adult Straying

Delta export rates at the State Water Project and Central Valley Project were increased to near maximum (about 9,600 cfs) in fall 1996 and in subsequent years to “make-up” for reduced pumping rates during the spring outmigration period to improve salmon smolt survival (Mesick 2001). The adult fall-run salmon are migrating upstream through the Delta primarily in October typically when San Joaquin River flows at Vernalis are low (Mesick 2001). It is likely that when exports are high relative to San Joaquin River flows, little if any San Joaquin River water reaches the San Francisco Bay where it may be needed to help guide the salmon back to their natal stream. An analysis by Mesick (2001) of the recovered adult salmon with coded-wire-tags (CWT) that had been reared at the Merced River Fish Facility and released in one of the San Joaquin tributaries suggests straying occurred when more than 400% of Vernalis flows were exported at the CVP and SWP Delta pumping facilities. The analysis indicates that during mid October from 1987 through 1989 when export rates exceeded 400% of Vernalis flows, straying rates ranged between 11% and 17% (Figure 8). In contrast, straying rates were estimated to be less than 3% when Delta export rates were less than about 300% of San Joaquin River flow at Vernalis during mid-October. Between 1993 and 2002, pulse flow releases from the San Joaquin tributaries and/or reductions in Delta exports for 10 days in mid-October have kept Delta export rates to less than 300% of the San Joaquin River flow at Vernalis (Figure 8).

To maintain high levels of gamete viability in migrating salmon and minimize straying during periods of high exports (i.e., export no more than 300% of Vernalis flows), it is recommended that a 1,000-cfs pulse flow should be released for 10 days in mid-October from each of the three San Joaquin River tributaries.

6. Fall flows required for spawning and incubation habitat

Adult Chinook salmon typically crowd into the uppermost six miles of habitat in the Tuolumne and Merced rivers, and to a lesser extent the Stanislaus River, in early November. Crowding of spawning is thought to be detrimental because the rate of redd superimposition, where females either destroy or bury the eggs in pre-existing redds, would be abnormally high and thereby reduce the production of juvenile fish. Crowding may be a result of inadequate fall spawning flows that result in excessively warm temperatures in the downstream areas. Although the percentage of spawners that use the downstream areas increases as water temperatures decline with declining air temperatures, there is no evidence that increased fall flows reduces spawner crowding or improves juvenile production (Figure 9).

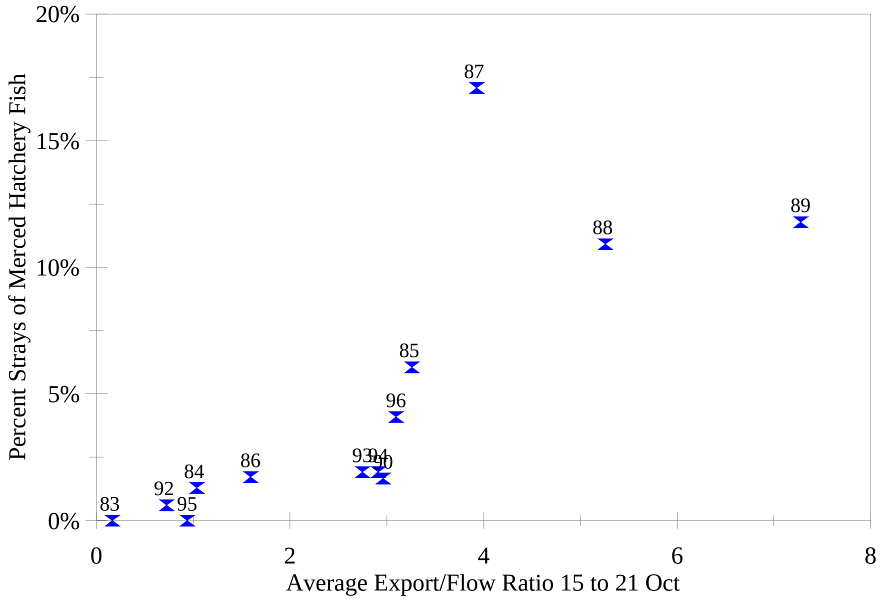


Figure 8. Estimated percent of adult CWT Chinook salmon that were reared at the Merced River Hatchery, released in the San Joaquin basin as juvenile salmon, and subsequently strayed to the Sacramento River and eastside tributary basins to spawn relative to the average ratio of the export rate at the CVP and SWP pumping facilities in the Delta to the flow rate in the San Joaquin River at Vernalis between 15 and 21 October from 1983 to 1996.

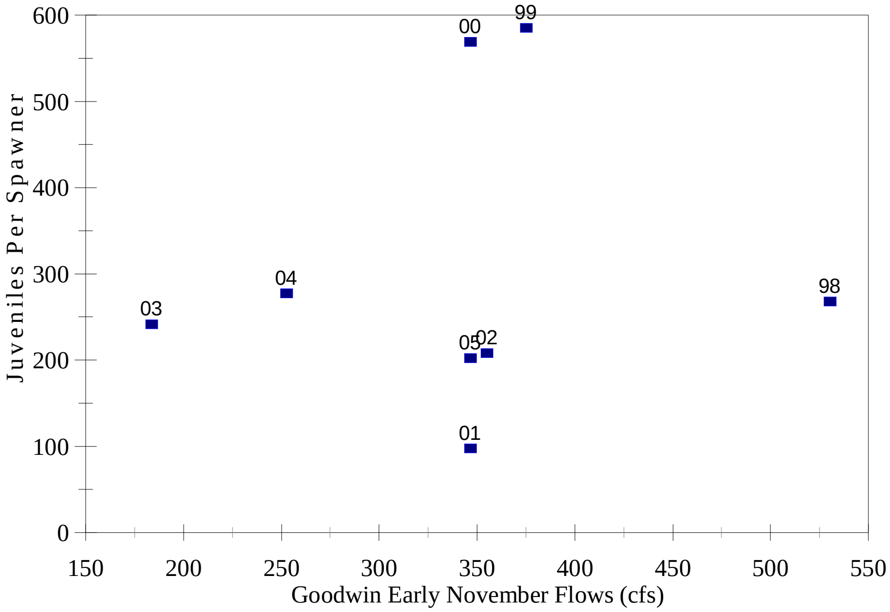


Figure 9. Relationship between the estimated number of juvenile salmon passing Oakdale per spawner and the Goodwin Dam flow release in early November in the Stanislaus River from 1998 to 2004.

It is recommended that studies should be conducted to determine the relationship between the magnitude of fall spawning flows and juvenile production in the Tuolumne and Merced rivers where spawner crowding is high. In the meantime, it is recommended that fall flows should be based on the optimum amount of physical habitat as determined by the PHABSIM model: 300 cfs for the Stanislaus River, 175-300 cfs for the Tuolumne River, and 200-250 cfs for the Merced River. These flows should be implemented from late October following the pulse flows until the end of January when flows begin to increase for juvenile rearing.

7. Ramping down spring flows to promote riparian vegetation

A likely benefit of spring flooding is the flushing of food and organic matter that produces food from the floodplains into the rivers where it can benefit juvenile salmonids. A healthy riparian forest is an integral component of the food chain.

A key factor for successful riparian recruitment is ensuring that the general rate of stage decline during the recession limb of flood control releases is gradual enough to support riparian seedling establishment. Another important issue is the timing of the recession limb. Recruitment flows should be targeted from mid-April to late-May to improve cottonwood recruitment and mid-May to late June to benefit black willow.

Research on a variety of cottonwood and willow species suggests that 1 to 1.5 inches/day is the maximum rate of water table decline for seedling survival (McBride et al. 1989; Segelquist et al. 1993; Mahoney and Rood 1992, 1998; Amlin and Rood 2002). However, a recent manipulation experiment of Fremont cottonwood, black willow, and narrow leaf willow seedlings found that water table declines of one inch or more resulted in 80% mortality within 60 days, even when the water table was maintained near the soil surface for several weeks before drawdown (Stillwater Sciences, unpublished data). Therefore more conservative rates may be appropriate. Flow recession rates of 100 to 300 cfs/day in the San Joaquin Basin are thought to prevent seedling desiccation under the assumed 1 inch/day maximum root growth rate.

A secondary benefit of a gradual ramp down of flows during June would be to increase juvenile salmon survival. Juvenile salmon migrate from the tributaries through early June and it is likely that they require 10 to 14 days to complete their migration through the Delta.

To promote the riparian vegetation recruitment and enhance the survival of juvenile salmon through the Delta, it is recommended that flows should be gradually ramped down at a constant rate between May 31 and June 30.

8. Summer flows required to increase habitat for yearling steelhead and salmon

Naturally produced juvenile steelhead typically rear in fresh water for two years before smolting and it is likely that successful rearing must occur in the tributaries because of the unsuitable conditions that occur in the Delta during the summer. The physical habitat is most suitable for rearing steelhead in the 12-mile reach below the lowermost dams in the Stanislaus, Tuolumne, and Merced rivers. Although it would be preferable to provide water that is cooler than 65^{o}F throughout the entire 12-mile reach during all water year types, doing so would require an unreasonable volume of water and could possibly exhaust the cold water pool in the primary reservoirs. A more reasonable alternative would be to maintain suitable water temperatures in at least a 5-mile reach, which presumably would be sufficient to sustain a population.

It is recommended that a block of water should be allocated in each of the tributaries to manage flows on a daily basis so that water temperatures do not exceed 65 ^{o}F in the uppermost 5-mile reach between July 1 and mid October when the pulse flows begin. Flow management should be based on the new water temperature model for the Stanislaus River and on empirical flow-water temperature data for the Tuolumne (Figure 10) and Merced rivers until new models can be developed. It is anticipated that summer flows will range between 150 and 325 cfs depending on air temperatures and the desired length of river with suitable water temperatures.

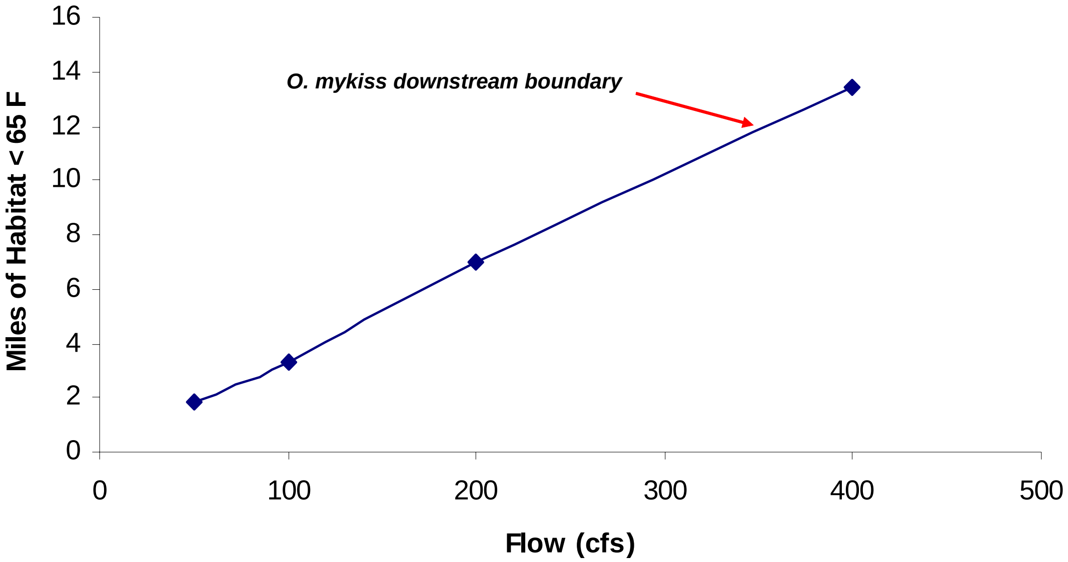


Figure 10. Relationship between the flow from La Grange Dam and the amount of habitat with water temperatures less than 65^{o}F in the Tuolumne River based on a simple water temperature model (EA Engineering, Science, and Technology 1991).

9. The effect of Delta Exports rate reductions on Chinook salmon production

Export rates at the State's Harvey O. Banks pumping facilities (SWP) and the Federal pumping facilities at Tracy (CVP) have been substantially reduced during the VAMP period (typically April 15 to May 15) since 1996 to improve the survival of outmigrating smolts. However, the numbers of recruits-per-spawners in the Stanislaus and Tuolumne rivers are similar since the export reductions began in 1996 compared to the years when exports were high prior to 1996 (Figures 11 and 12). This suggests that reducing exports below 400% of Vernalis flows for 31 days has had no detectable affect on adult recruitment. If true, experimental water transfers that increase flows in the San Joaquin Basin tributaries as prescribed above could be captured at the SWP and CVP pumping facilities without affecting the expected increase in salmonid recruitment.

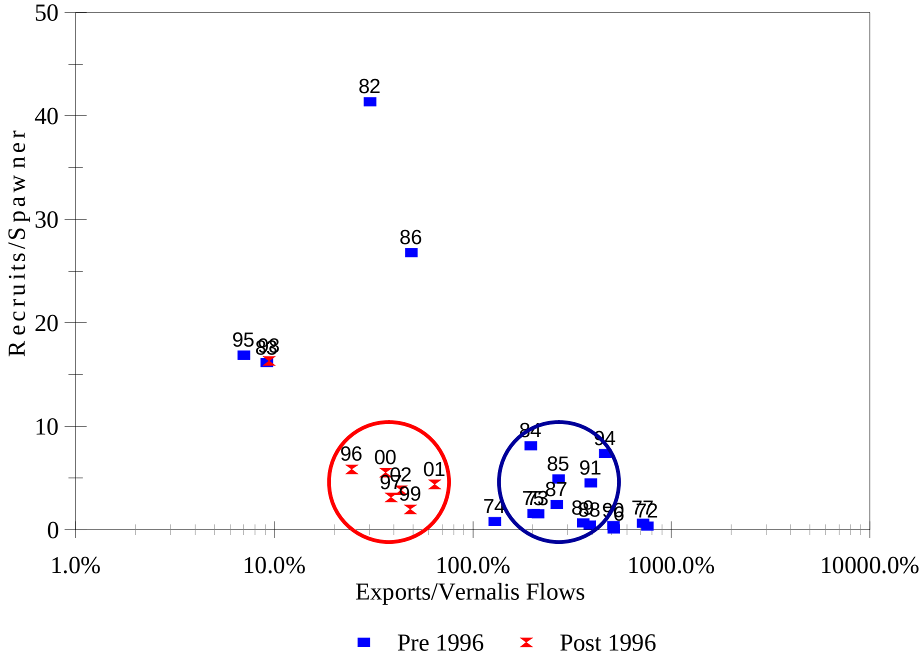


Figure 11. The relationship between the number of fall-run Chinook salmon recruits/spawner to the lower Stanislaus River and the average ratio of combined CVP and SWP exports to the flow in the San Joaquin River at Vernalis between 15 April and 15 May from 1972 to 2002. Exports were reduced during this period since 1996 (Blue Symbols) to improve the survival of outmigrating smolts.

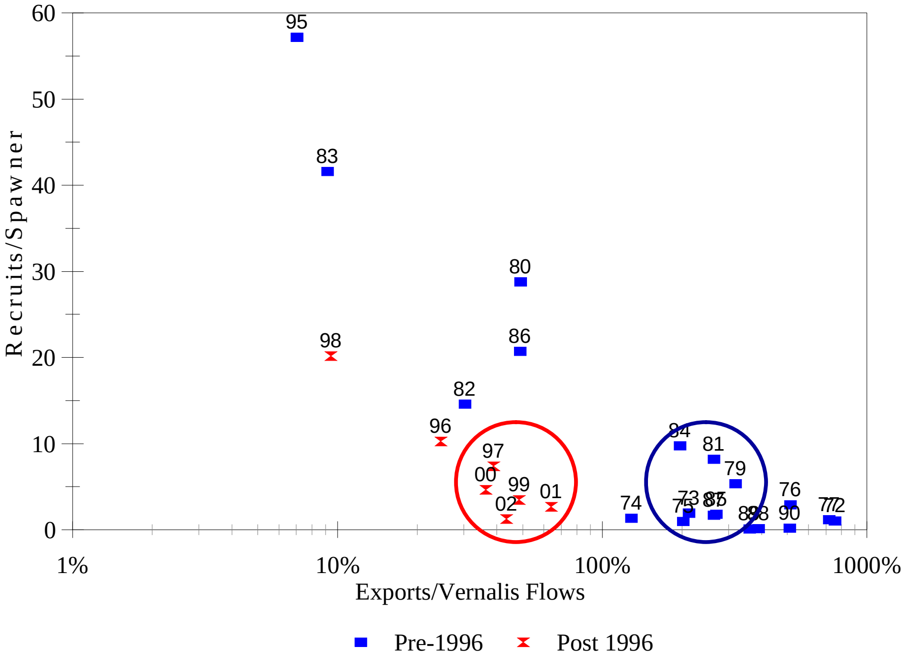
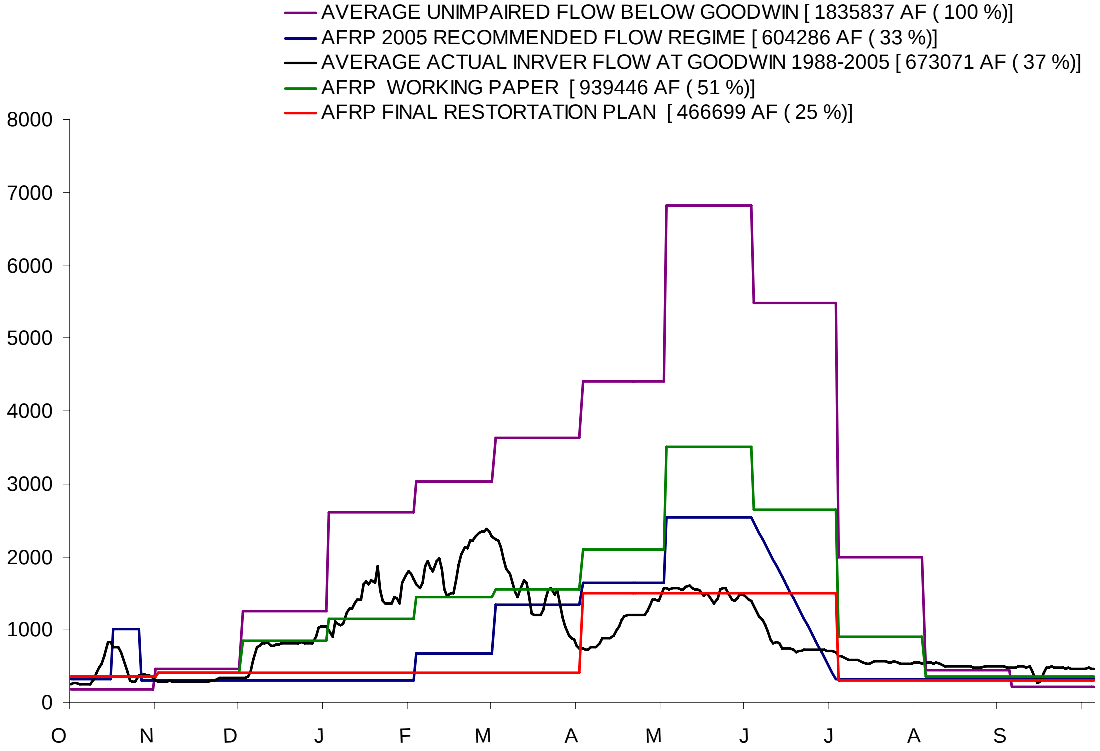


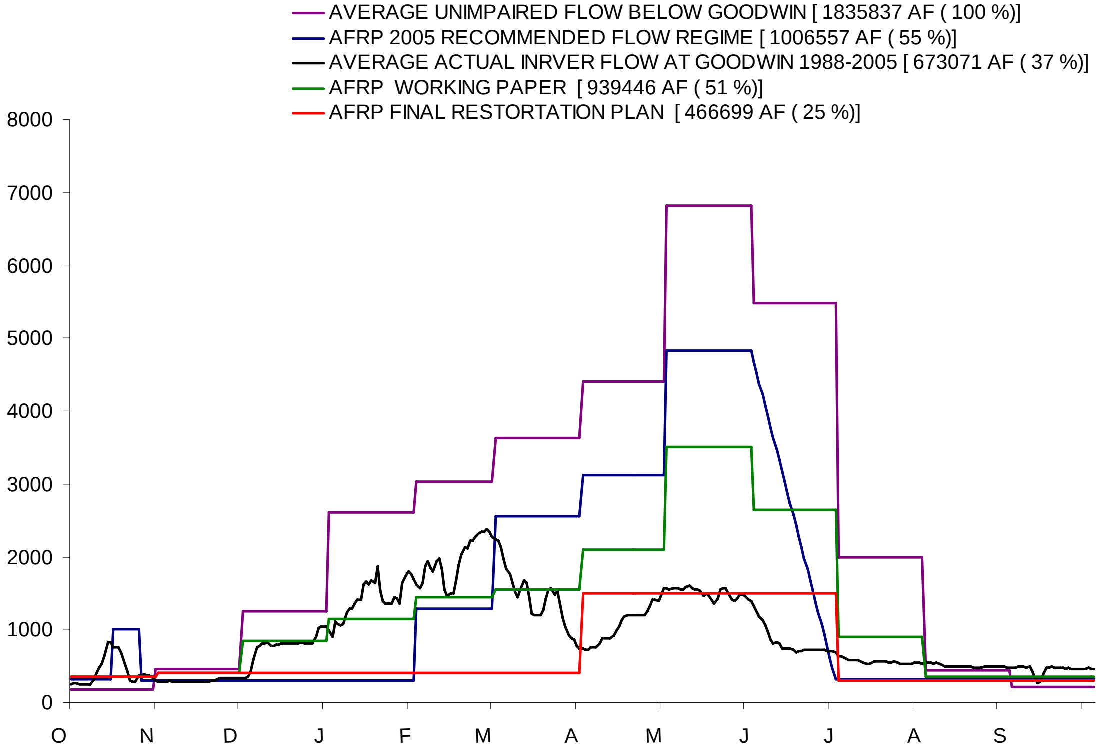
Figure 12. The relationship between the number of fall-run Chinook salmon recruits/spawner to the lower Tuolumne River and the average ratio of combined CVP and SWP exports to the flow in the San Joaquin River at Vernalis between 15 April and 15 May from 1972 to 2002. Exports were reduced during this period since 1996 (Blue Symbols) to improve the survival of outmigrating smolts.

10. Comparison of Flow Schedules: Stanislaus River

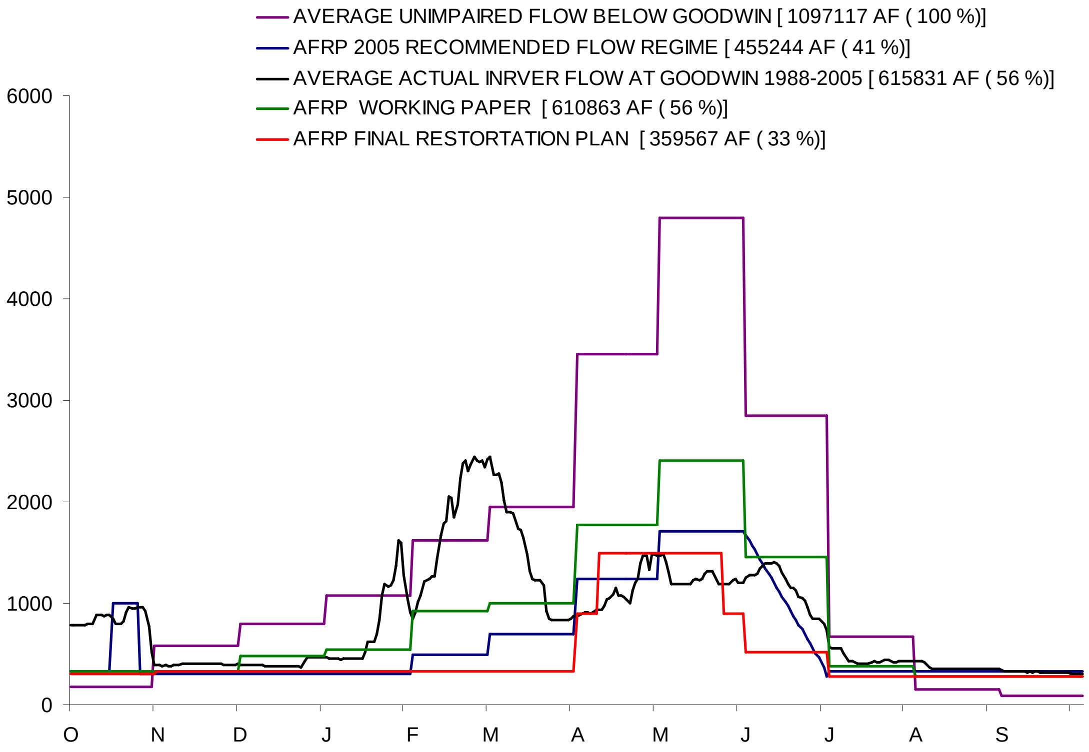
Wet Year – 69% Increase



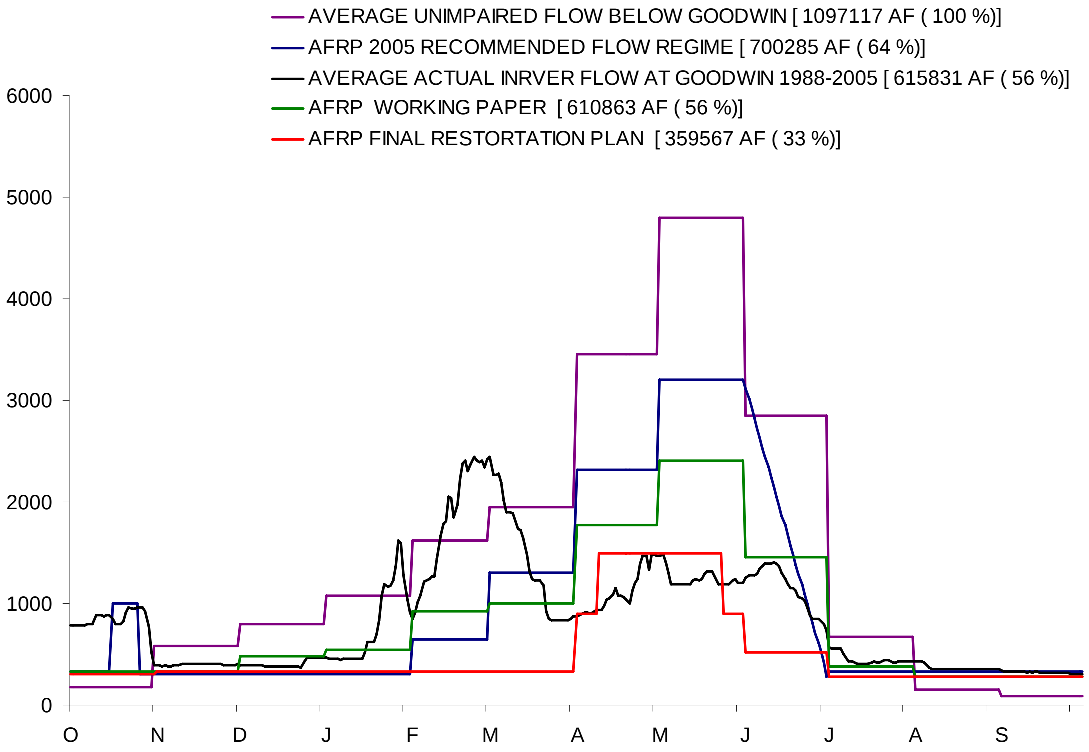
Wet Year – Doubling (114%)



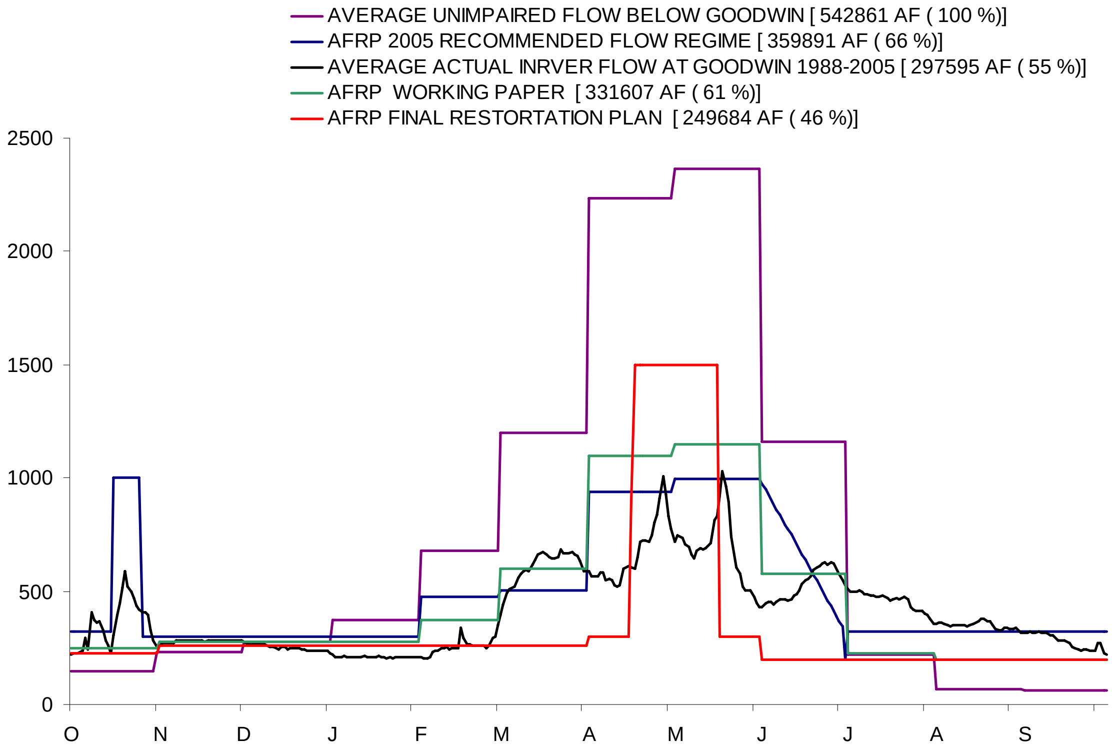
Stanislaus River: Normal Year – 69% Increase



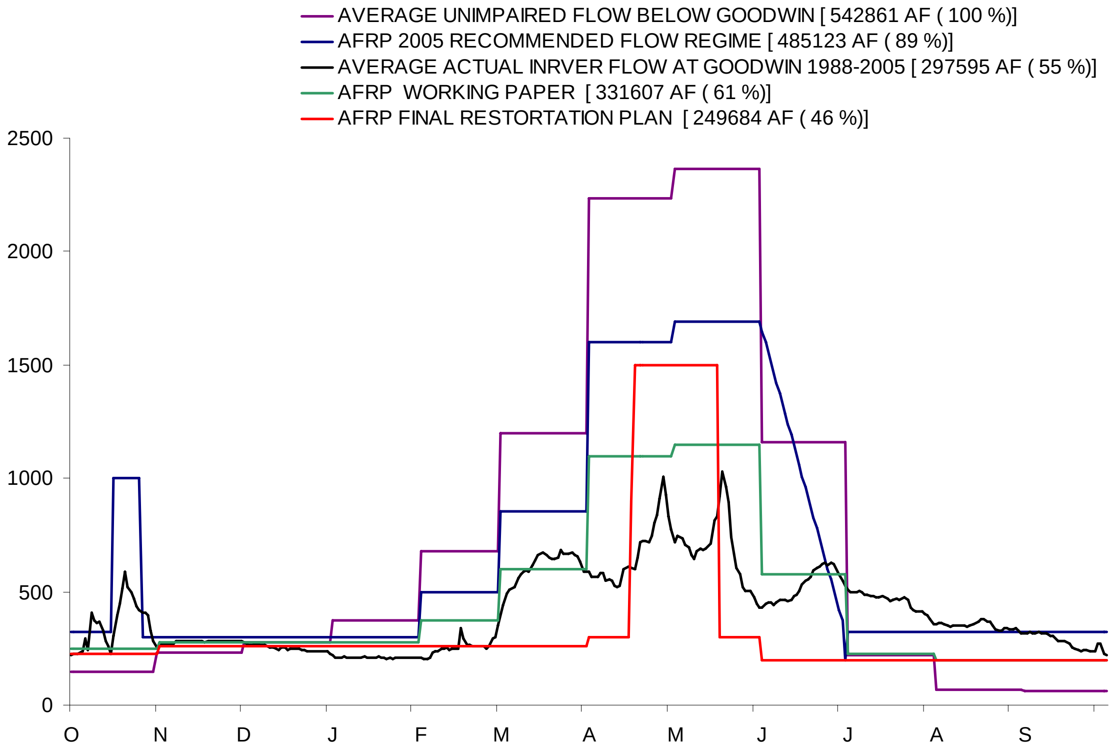
Normal Year – Doubling (114%)



Stanislaus River: Dry Year – 69% Increase

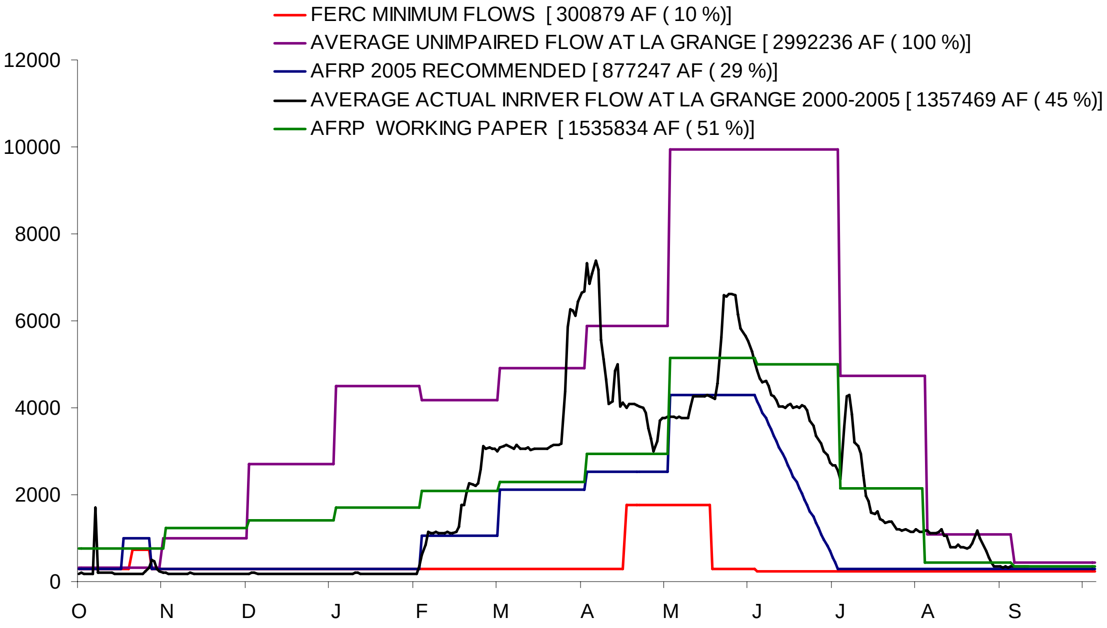


Dry Year – Doubling (114%)

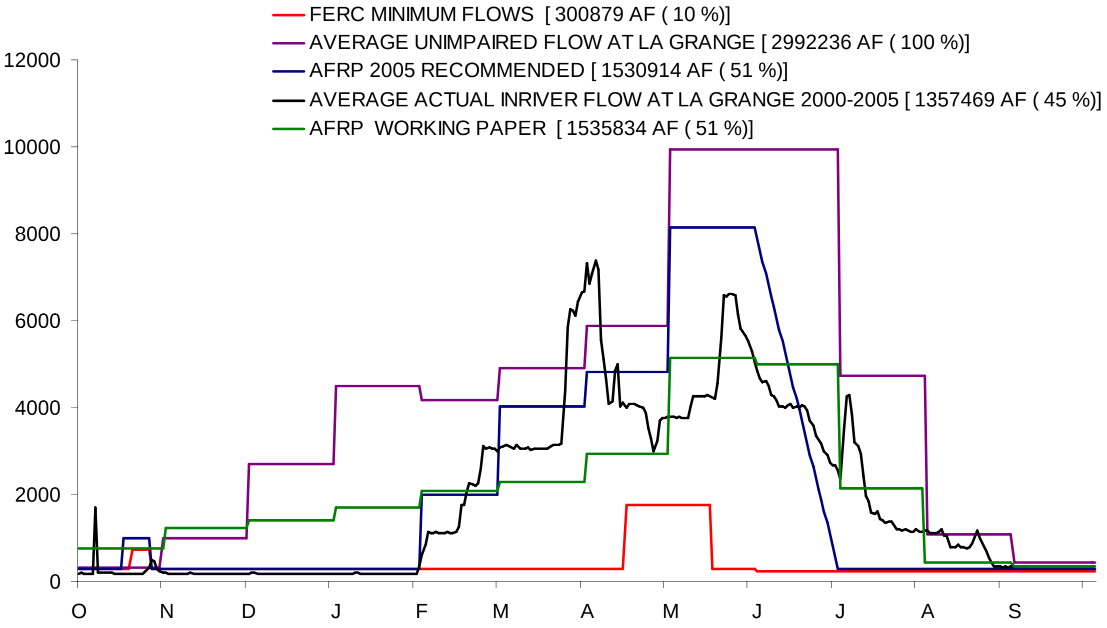


11. Comparison of Flow Schedules: Tuolumne River

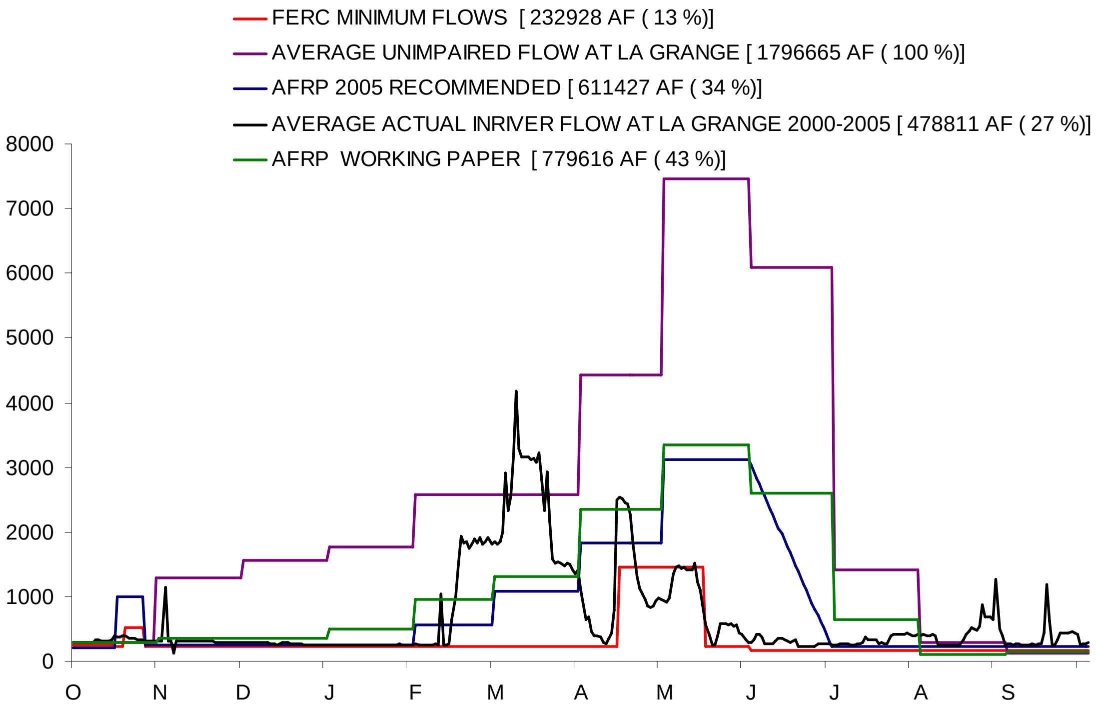
Wet Year – 42% Increase



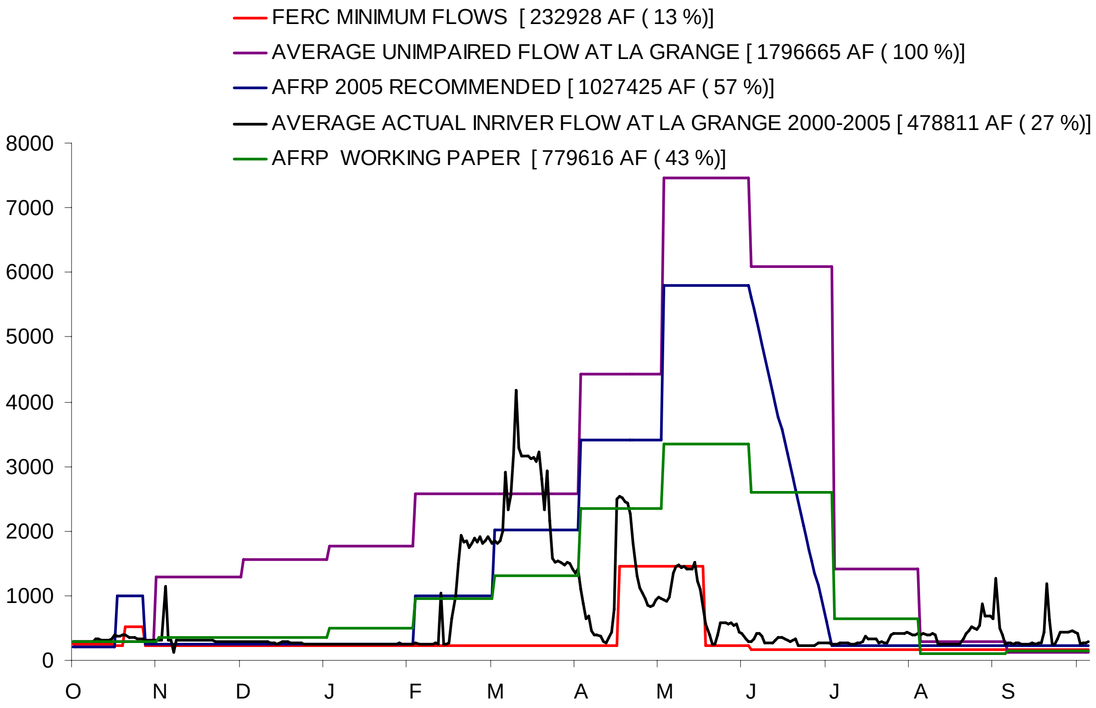
Wet Year – Doubling (86%)



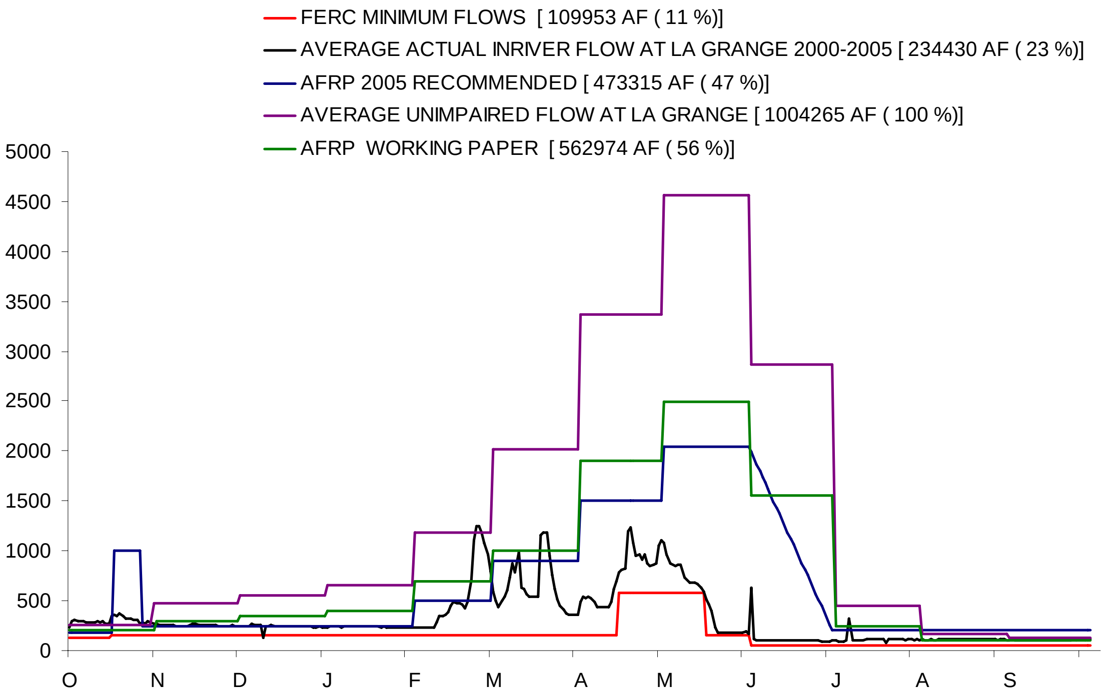
Tuolumne River: Normal Year – 42% Increase



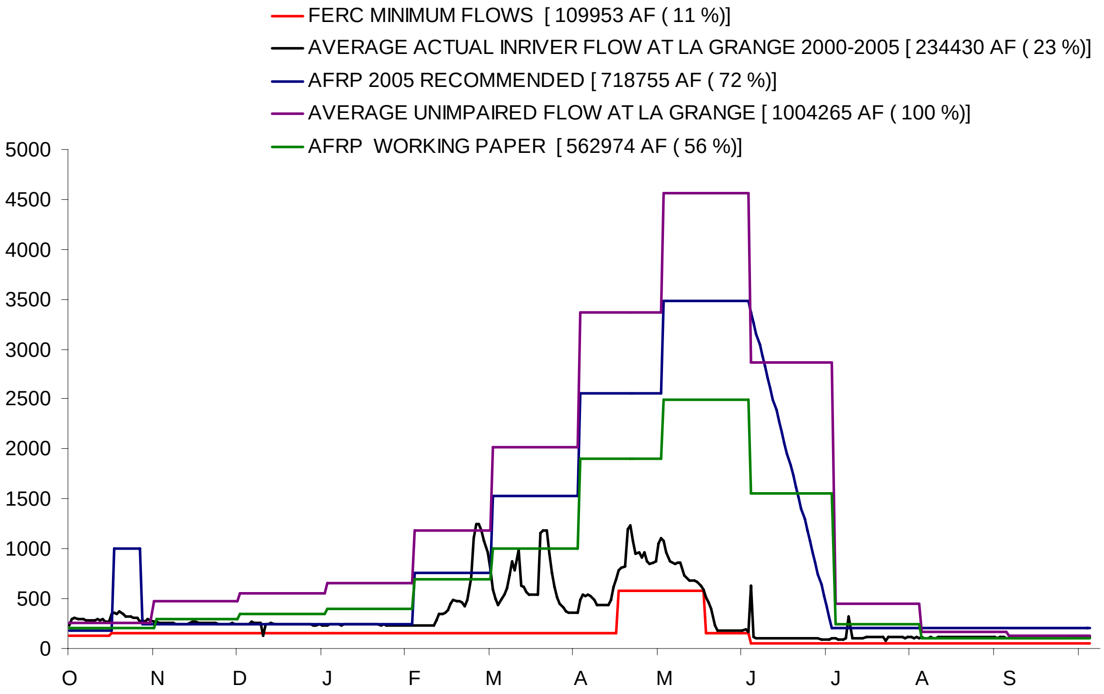
Normal Year – Doubling (86%)



Tuolumne River: Dry Year – 42% Increase

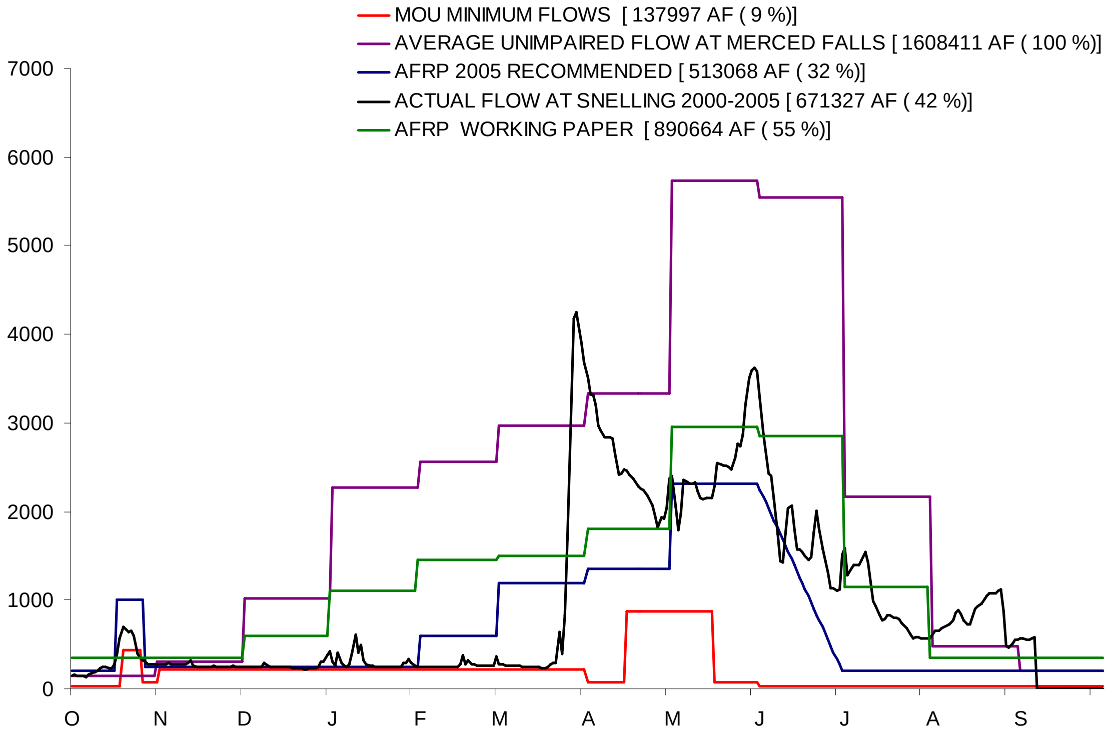


Dry Year – Doubling (86%)

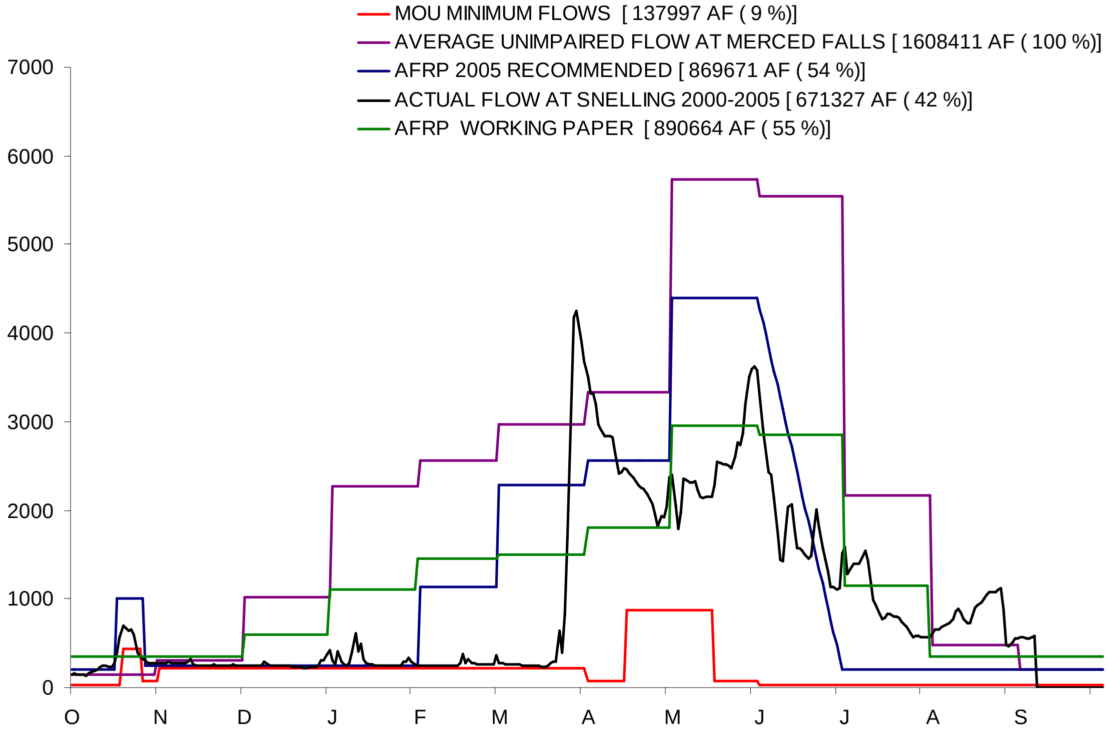


12. Comparison of Flow Schedules: Merced River

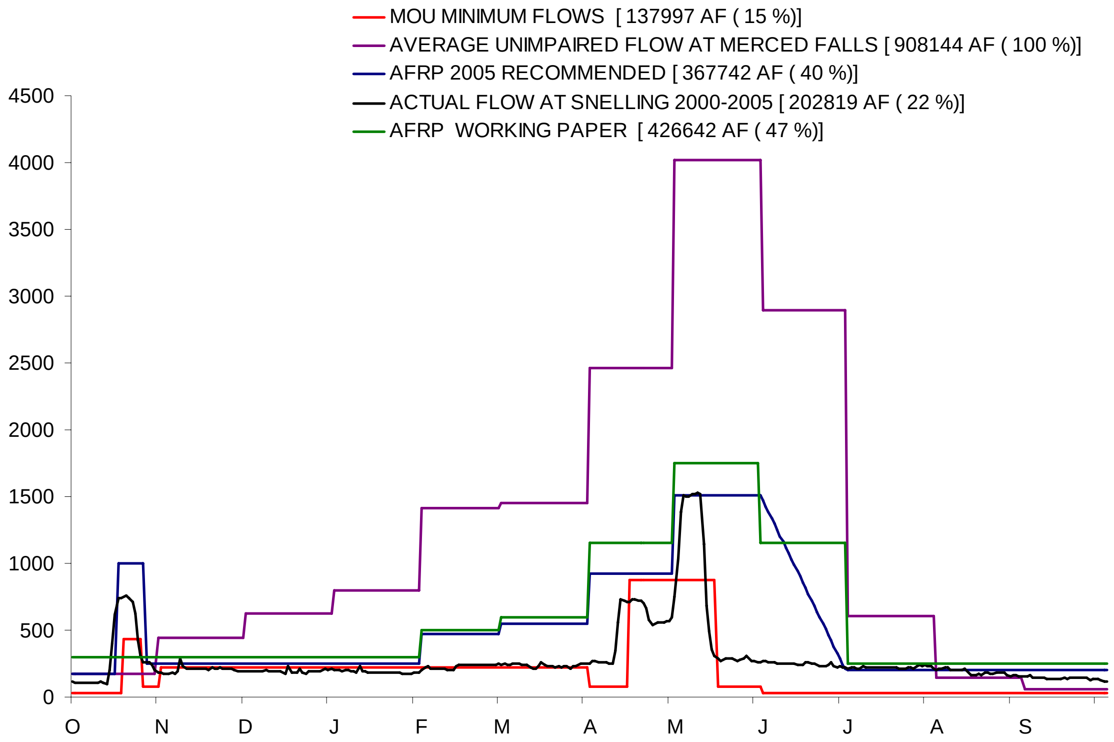
Wet Year – 85% Increase



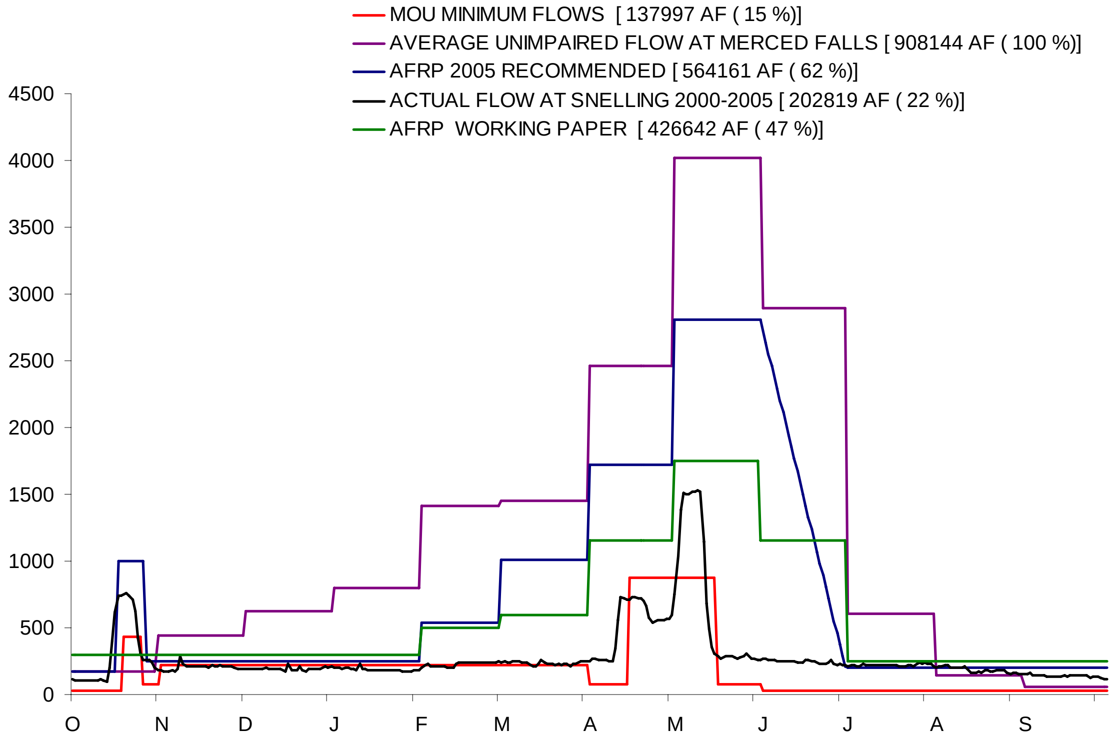
Wet Year – Doubling (134%)



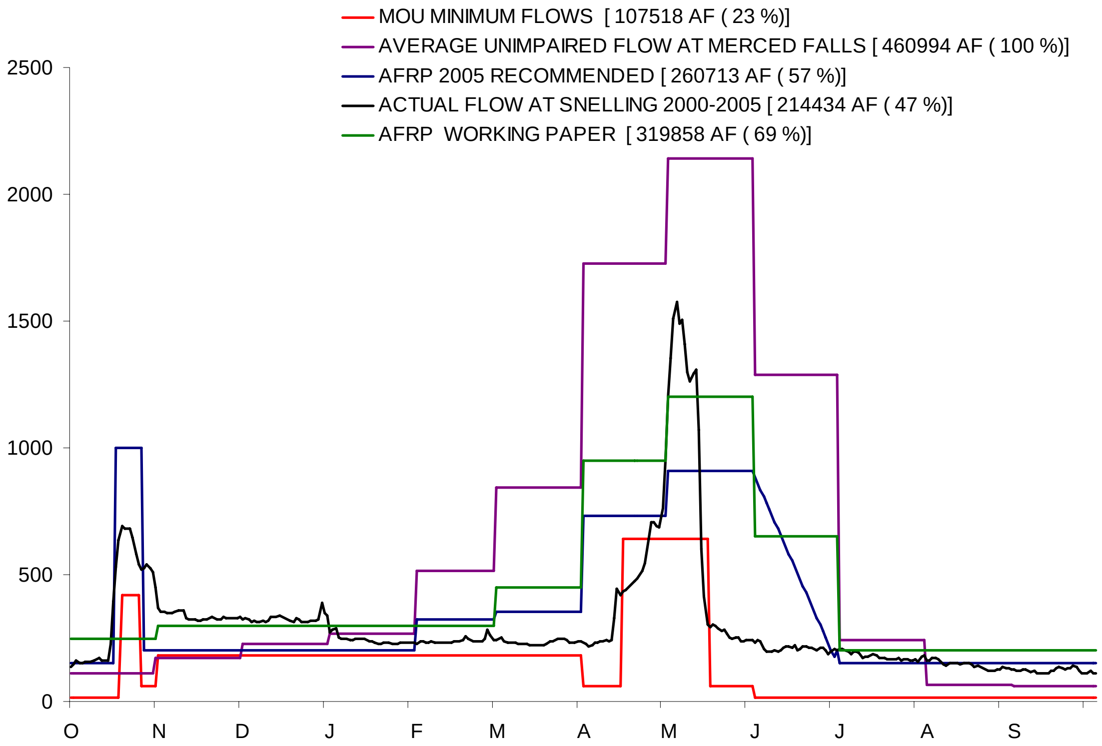
Merced River: Normal Year – 85% Increase



Normal Year – Doubling (134%)



Merced River: Dry Year – 85% Increase



Dry Year – Doubling (134%)

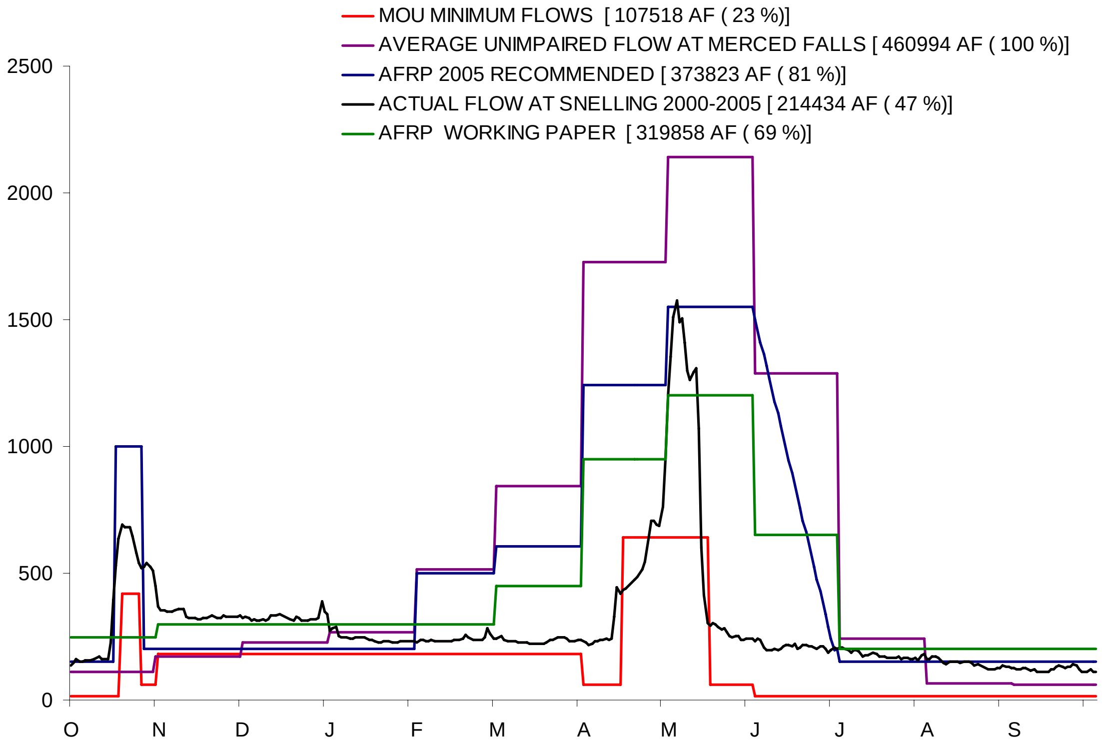


Table 3. The total annual volume of water (acre-feet) and percentage of unimpaired flows required to increase Chinook production by an average of 53% and 100% in the Stanislaus, Tuolumne, and Merced rivers.

	WET	ABOVE NORMAL	BELOW NORMAL	DRY	CRITICAL
53% Increase					
Stanislaus	604,286	487,578	422,911	384,882	334,899
	33%	*38%*	*48%*	*60%*	*73%*
Tuolumne	877,247	673,275	549,579	510,996	435,634
	29%	*32%*	*37%*	*44%*	*50%*
Merced	513,068	394,518	340,966	279,861	241,566
	32%	*38%*	*47%*	*52%*	*61%*
Doubling					
Stanislaus	1,006,557	785,985	614,584	525,231	445,016
	55%	*62%*	*70%*	*82%*	*97%*
Tuolumne	1,530,914	1,169,192	885,659	783,854	653,656
	51%	*55%*	*59%*	*68%*	*76%*
Merced	869,671	624,749	503,572	404,055	343,591
	54%	*59%*	*69%*	*75%*	*86%*

Appendix 1

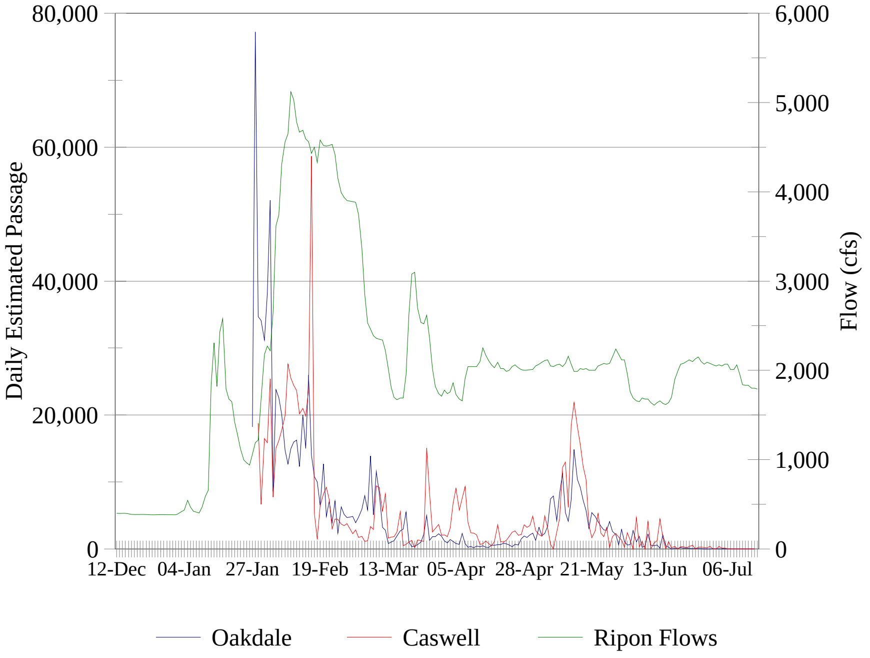


Figure 1. The relationship between the estimated daily passage at the Oakdale and Caswell Park screw traps and the mean daily flow at Ripon in the Stanislaus River between 12/12/97 and 7/1598, a wet year. Overall juvenile survival between the Oakdale and Caswell traps was 95% in 1998.

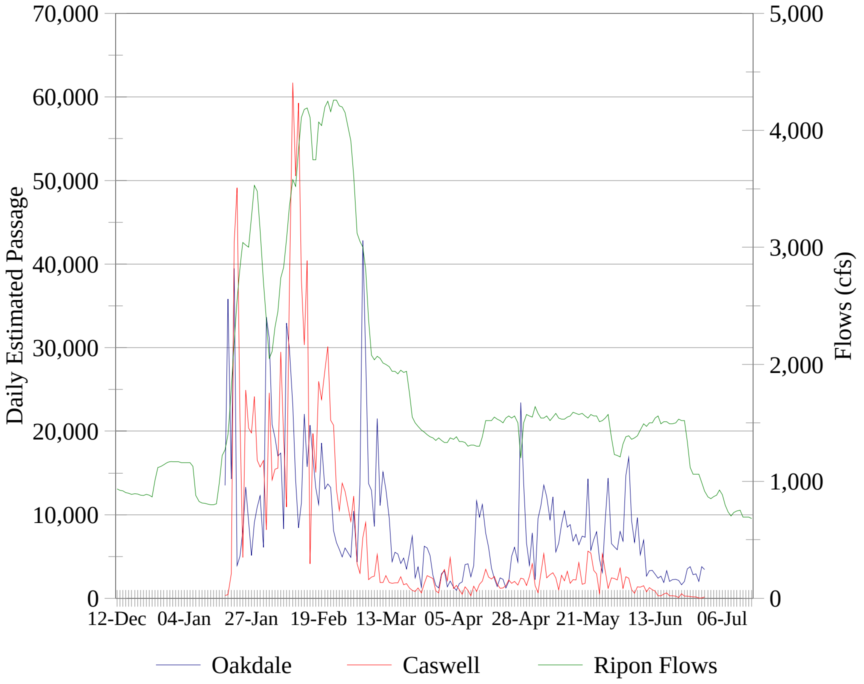


Figure 2. The relationship between the estimated daily passage at the Oakdale and Caswell Park screw traps and the mean daily flow at Ripon in the Stanislaus River between 12/12/98 and 7/15/99, an above normal year. Overall juvenile survival between the Oakdale and Caswell traps was 83% in 1999.

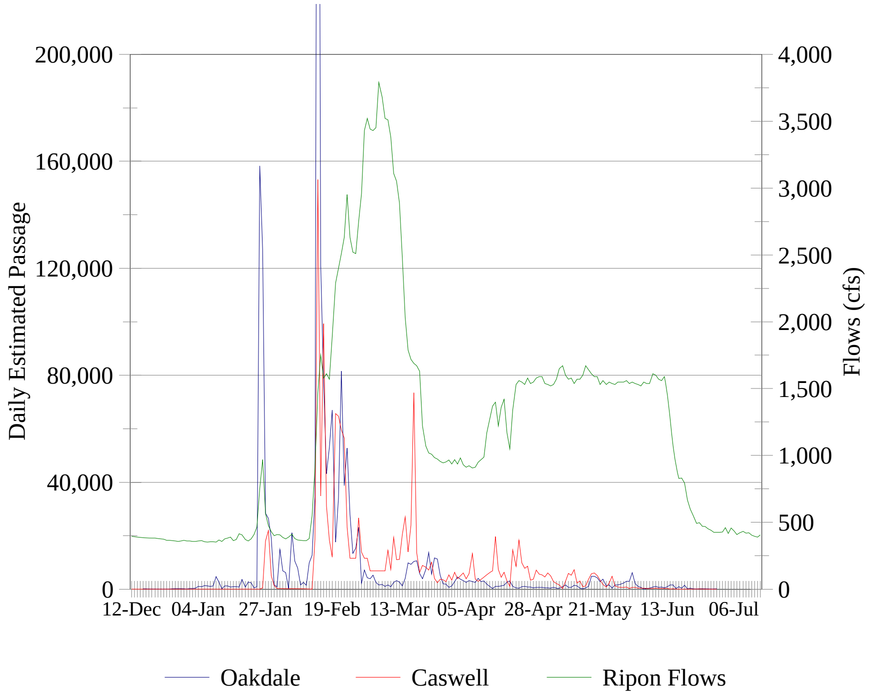


Figure 3. The relationship between the estimated daily passage at the Oakdale and Caswell Park screw traps and the mean daily flow at Ripon in the Stanislaus River between 12/12/99 and 7/15/00, an above normal year. Overall juvenile survival between the Oakdale and Caswell traps was 74% in 2000.

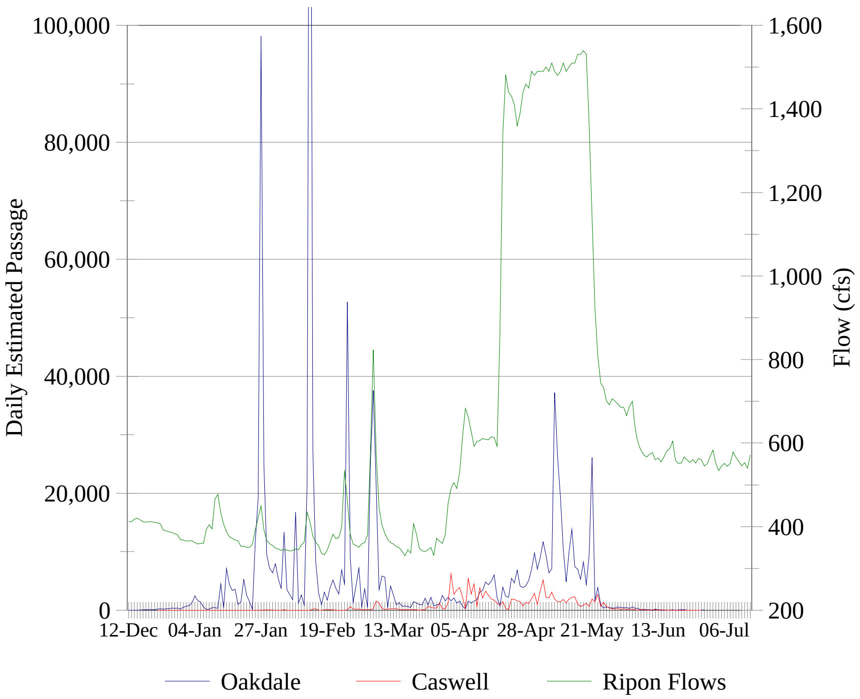


Figure 4. The relationship between the estimated daily passage at the Oakdale and Caswell Park screw traps and the mean daily flow at Ripon in the Stanislaus River between 12/12/00 and 7/15/01, a dry year. Overall juvenile survival between the Oakdale and Caswell traps was 11% in 2001.

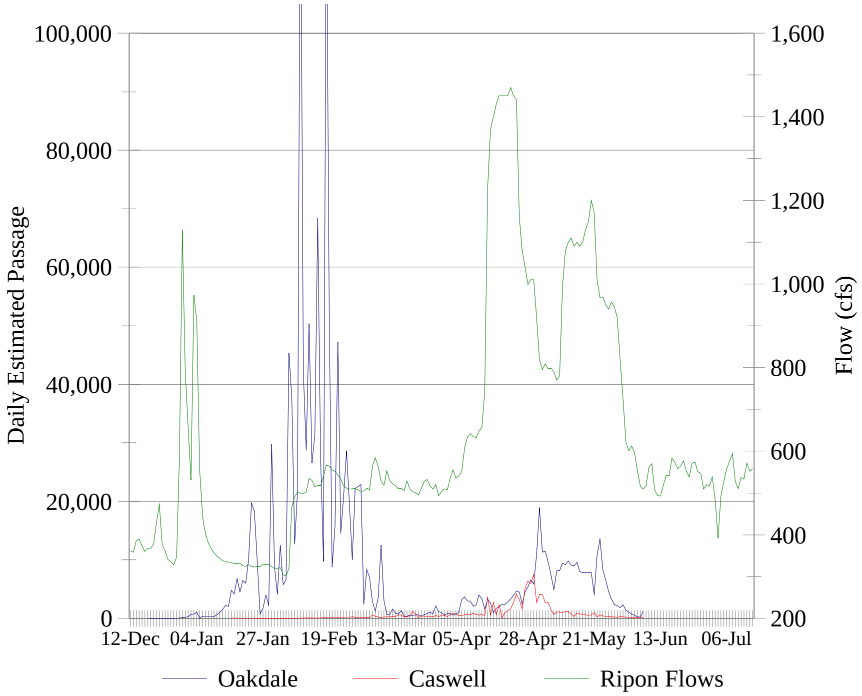


Figure 5. The relationship between the estimated daily passage at the Oakdale and Caswell Park screw traps and the mean daily flow at Ripon in the Stanislaus River between 12/12/01 and 7/15/02, a dry year. Overall juvenile survival between the Oakdale and Caswell traps was 7% in 2002.

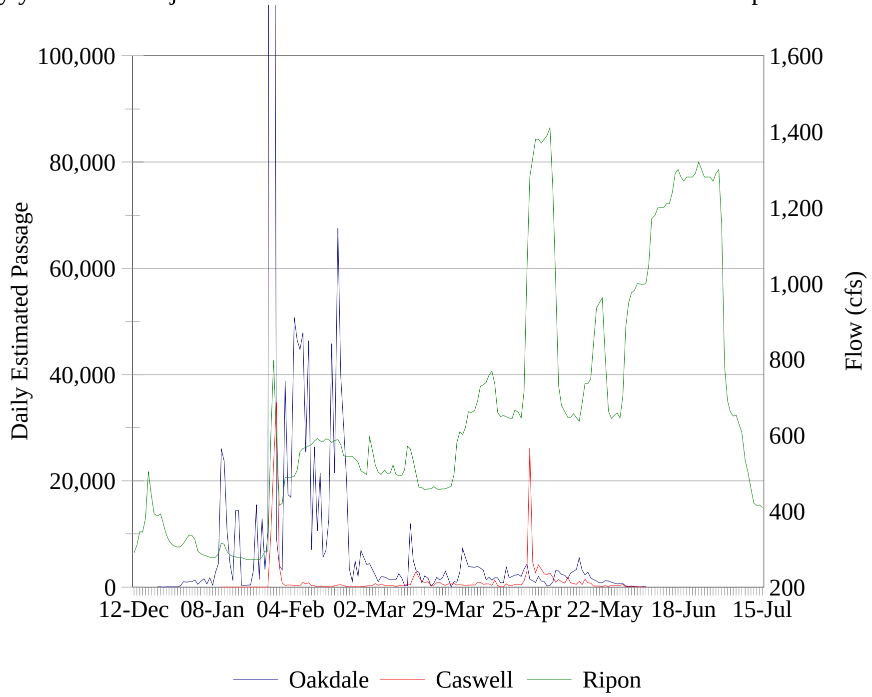


Figure 6. The relationship between the estimated daily passage at the Oakdale and Caswell Park screw traps and the mean daily flow at Ripon in the Stanislaus River between 12/12/02 and 7/15/03, a below normal year. Overall juvenile survival between the Oakdale and Caswell traps was 11% in 2003.

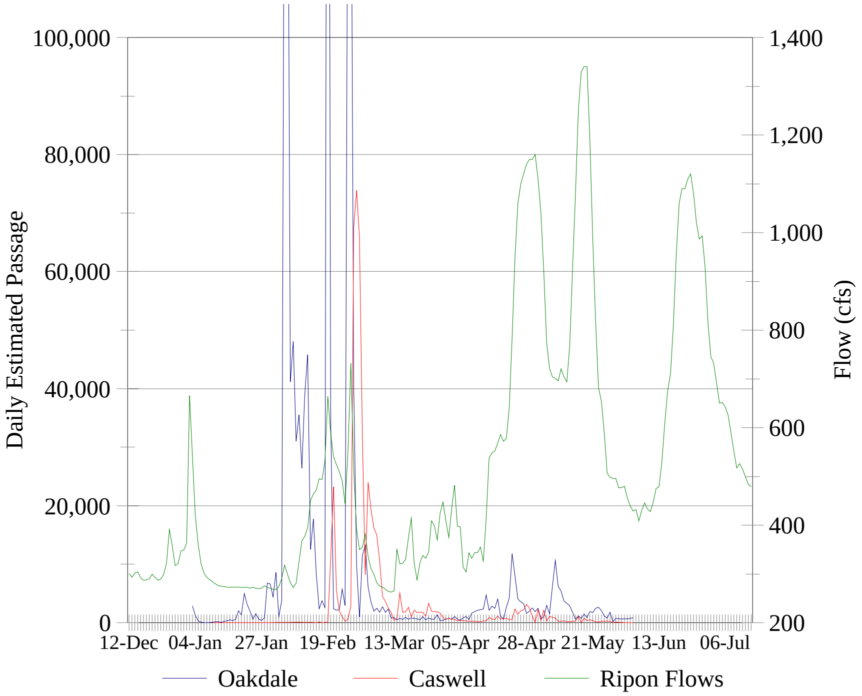


Figure 7. The relationship between the estimated daily passage at the Oakdale and Caswell Park screw traps and the mean daily flow at Ripon in the Stanislaus River between 12/12/03 and 7/15/04, a dry year. Overall juvenile survival between the Oakdale and Caswell traps was 30% in 2004.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

In response reply to:
2008/09022

JUN - 4 2009

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

Dear Mr. Glaser:

This document transmits NOAA's National Marine Fisheries Service's (NMFS) final biological opinion and conference opinion (Opinion, enclosure 1) based on NMFS review of the proposed long-term operations of the Central Valley Project and State Water Project (hereafter referred to as CVP/SWP operations) in the Central Valley, California, and its effects on listed anadromous fishes and marine mammal species, and designated and proposed critical habitats, in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). This final Opinion is based on information provided in the Bureau of Reclamation's (Reclamation) October 1, 2008, transmittal letter and biological assessment (BA), discussions between NMFS and Reclamation staff, declarations filed pursuant to Pacific Coast Federation of Fishermen Association *et al. v.* Gutierrez *et al.* 1:06-cv-245-OWW-GSA (E.D. Cal. 2008), comments received from Reclamation, peer review reports from CALFED and the Center for Independent Experts, and an extensive literature review completed by NMFS staff. A complete administrative record of this consultation is on file at the NMFS Sacramento Area Office.

Based on the best available scientific and commercial information, NMFS' final Opinion concludes that the CVP/SWP operations are likely to jeopardize the continued existence of Federally listed:

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

NMFS also concludes that the proposed action is likely to destroy or adversely modify the designated critical habitats of:

- Sacramento River winter-run Chinook salmon,

- Central Valley spring-run Chinook salmon, and
- Central Valley steelhead, and
- proposed critical habitat for the Southern DPS of North American green sturgeon.

The final Opinion concludes that the CVP/SWP operations are not likely to jeopardize the continued existence of Central California Coast steelhead (O. *mykiss*).

The conference opinion concerning proposed critical habitat for Southern DPS of North American green sturgeon does not take the place of a biological opinion under section 7(a)(2) of the ESA unless and until the conference opinion is adopted as a biological opinion when the proposed critical habitat designation for the Southern DPS of North American green sturgeon becomes final. Adoption may occur if no significant new information is developed, and no significant changes to the project are made that would alter the contents, analyses, or conclusions of this Opinion.

Take of threatened green sturgeon is currently not prohibited by Section 9 of the ESA. When the rule proposed on May 21, 2009 (74 FR 23822) under section 4(d) of the ESA becomes effective as a final rule, all take of threatened green sturgeon not in conformance with that rule will be prohibited under the ESA. Upon the effectiveness of the final green sturgeon take rule, compliance with this Incidental Take Statement provides exemption for take under section 7(o).

The ESA provides that if NMFS has reached a jeopardy or adverse modification conclusion, it must identify a reasonable and prudent alternative (RPA) to the proposed action that is expected to avoid the likelihood of jeopardy to the species and adverse modification of designated and proposed critical habitat, if such an alternative action can be offered. NMFS includes with this Opinion a RPA that we believe meets all four regulatory requirements, as set forth in 50 CFR 402.02. This has been a very challenging consultation for our agencies due to its complexity, long-term nature, and importance to the people of California and the resources we are required to manage. NMFS and Reclamation have had extensive discussions on the preparation of the BA, the draft Opinion, and the draft RPA, and while NMFS understands that Reclamation may have reservations with portions of the Opinion, NMFS understands that it is a package that Reclamation can accept. Because this is a jeopardy Opinion, Reclamation is required (402.15(b)) to notify NMFS "...of its final decision on the action." NMFS, therefore, requests that Reclamation provide NMFS with timely notification as to your agency's final decision.

Also enclosed are Essential Fish Habitat (EFH) Conservation Recommendations for Pacific Coast Salmon species, as required by the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) as amended (16 U.S.C. 1801 *et seq.*; enclosure 2). NMFS EFH analysis concludes that the CVP/SWP operations will adversely affect EFH for Pacific Coast Salmon species in the action area. The RPA that was developed for the ESA-listed salmon was designed to avoid jeopardy and adverse modification for those species but it also has substantial benefits to Pacific salmon EFH, and commercially valuable Central Valley fall-run Chinook salmon. Pursuant to the MSFCMA, Conservation Recommendations are also provided to further reduce adverse effects on EFH.

I want to express my sincere appreciation to you and to your staff for their professionalism and commitment to find a solution that comports with our various Federal mandates. You have my commitment that NMFS will continue to be close partner with Reclamation, CA Department of Water Resources, CA Fish and Game, and US Fish and Wildlife Service as we embark on implementation. I also look forward to continuing our participation with Reclamation, partner agencies and stakeholders in the Bay Delta Conservation Planning effort, a very important action to boost habitat improvements in the Delta and counterbalance some of the aging infrastructure limitations. If you have any questions regarding this consultation, please contact Mr. Garwin Yip, of my staff, at (916) 930-3611 or via e-mail at garwin.yip@noaa.gov.

Sincerely,

Rodney R McInnis

Rodney R. McInnis
Regional Administrator

Enclosures:
- Enclosure 1: Biological and conference opinion on the long-term operations of the Central Valley Project and State Water Project
    - Appendix 1: Project Description
    - Appendix 2: Supporting documents for the RPA
    - Appendix 3: Fall-run and late fall-run Chinook salmon analysis
    - Appendix 4: Responses to CALFED peer review recommendations
    - Appendix 5: Technical memorandum for the San Joaquin actions
- Enclosure 2: EFH Conservation Recommendations

cc: Copy to file ARN: 151422SWR2004SA9116
NMFS-PRD, Long Beach, CA
Ron Milligan, Reclamation, 3310 El Camino Avenue, Suite 300, Sacramento, CA 95821
Lester Snow, CA DWR
Don Koch, CA DFG
Ren Lohoefener, FWS

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Endangered Species Act
Section 7 Consultation

BIOLOGICAL OPINION
and CONFERENCE OPINION

on the

LONG-TERM OPERATIONS OF THE CENTRAL VALLEY PROJECT AND STATE WATER PROJECT

National Marine Fisheries Service
Southwest Region

June 4, 2009

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thermal stress in juvenile steelhead are associated with exposure to daily mean water temperatures above 65°F. Data were obtained from http://cdec.water.ca.gov/.

Figure 6-33a and b. Exceedence plots of modeled water temperatures in the lower American River near Watt Avenue during June (a) and July (b) (CVP/SWP operations BA figures 10-114 and 10-115, respectively). For this analysis, the 65°F line was added in red because visible symptoms of thermal stress in juvenile steelhead are associated with exposure to daily mean water temperatures above 65°F.

Figures 6-34a and b. Exceedence plots of modeled water temperatures in the lower American River near Watt Avenue during August (a) and September (b) (CVP/SWP operations BA figures 10-116 and 10-117, respectively). For this analysis, the 65°F line was added in red because visible symptoms of thermal stress in juvenile steelhead are associated with exposure to daily mean water temperatures above 65°F.

Figure 6-35. Stanislaus and San Joaquin river temperatures and flow at selected locations in a dry year, actual measured water temperatures (2001, CVP/SWP operations BA figure 11-20).

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BIOLOGICAL OPINION AND CONFERENCE OPINION

ACTION AGENCY:	U.S. Bureau of Reclamation Central Valley Operations Office
ACTIVITY:	Long-Term Operations of the Central Valley Project and State Water Project
CONSULTATION CONDUCTED BY:	NOAA's National Marine Fisheries Service Southwest Region
FILE NUMBER:	2008/09022
DATE ISSUED:	

1.0 BACKGROUND AND CONSULTATION HISTORY

1.1 Purpose

The purpose of this document is to present NOAA's National Marine Fisheries Service's (NMFS) biological and conference opinion (Opinion), about whether the U.S. Bureau of Reclamation's (Reclamation) proposed long-term operations of the Central Valley Project (CVP), operated in coordination with the State Water Project (SWP; hereafter referred to as CVP/SWP operations, the proposed action, or the project), is likely to jeopardize the continued existence of the following species:

- Endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*, hereafter referred to as winter-run)
- Threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*, hereafter referred to as spring-run)
- Threatened Central Valley (CV) steelhead (*O. mykiss*)
- Threatened Central California Coast (CCC) steelhead (*O. mykiss*)
- Threatened Southern Distinct Population Segment (DPS) of North American green sturgeon (*Acipenser medirostris*, hereafter referred to as Southern DPS of green sturgeon)
- Endangered Southern Resident killer whales (*Orcinus orca*, hereafter referred to as Southern Residents)

or destroy or adversely modify the designated critical habitat of the above salmon and steelhead species, or proposed critical habitat for Southern DPS of green sturgeon. This Opinion is based on the best scientific and commercial information available.

1.2 Background

Alterations to the natural hydrologic systems of the Sacramento and San Joaquin River basins began in the late 1800s, accelerating in the early 1900s, including the construction of three dams owned and operated by Reclamation, a fourth dam owned and operated by the California Department of Water Resources (DWR), and a multitude of pumps and hundreds of miles of gravity-fed water diversions constructed and operated by private water users and by Reclamation and DWR. None of the major dams were constructed with fish ladders to pass anadromous fish and, as a result, salmon and steelhead have effectively been blocked from accessing the upper reaches of the basin. Beginning in 1993, Shasta and Keswick Dam releases on the upper Sacramento River have been managed to provide cold water to the spawning habitat below Keswick Dam as per requirements of NMFS' winter-run biological opinion on the operations of the CVP and SWP.

1.3 Coordinated Operations Agreement

In November 1986, the U.S. Federal government and DWR signed the Coordinated Operation Agreement (COA), which 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. Congress, through Public Law 99-546, authorized and directed the Secretary of the Interior to execute and implement the COA. Under the COA, Reclamation and DWR agree to operate the CVP and SWP, respectively, under balanced conditions in a manner that meets Sacramento Valley and Delta needs while maintaining their respective water supplies, as identified in the COA. "Balanced conditions" are defined as periods when the CVP and SWP agree that releases from upstream reservoirs, plus unregulated flow, approximately equal water supply needed to meet Sacramento Valley in-basin uses and CVP/SWP exports. The COA is the Federal nexus for ESA section 7 consultation on operations of the SWP. In this CVP/SWP operations consultation, DWR is considered an applicant.

1.4 Consultation History

On October 22, 2004, NMFS issued its biological opinion on the proposed CVP/SWP operations (NMFS 2004c, hereafter referred to as 2004 CVP/SWP operations Opinion). Within that document was a consultation history that dated back to 1991, which is incorporated here by reference.

On April 26 and May 19, 2006, Reclamation requested reinitiation of consultation on CVP/SWP operations based on new species listings and designated critical habitats. In a June 19, 2006, letter to Reclamation, NMFS stated that there was not enough information in Reclamation's request to initiate consultation. NMFS provided a list of information required to fulfill the initiation package requirements [50 CFR 402.14(c)]. From May 2007, until May 29, 2008, NMFS participated in the following interagency forums, along with representatives from Reclamation, DWR, U.S. Fish and Wildlife Service (USFWS), and California Department of Fish and Game (CDFG), in order to provide technical assistance to Reclamation in its development of a biological assessment (BA) and reinitiation package.

- Biweekly interagency CVP/SWP operations meetings;
- Biweekly five agencies management meetings;
- Weekly directors' meetings; and
- Several modeling meetings.

In addition, NMFS provided written feedback on multiple occasions:

- Multiple e-mails from the USFWS (submitted on behalf of USFWS, NMFS, and CDFG) providing specific comments on various chapters of the draft CVP/SWP operations BA, including the legal setting (Chapter 1) and project description (Chapter 2);
- February 15, 2008, e-mails from NMFS to Reclamation, transmitting comments on species accounts for the anadromous salmonid species and green sturgeon (Chapters 3-6, and 8);
- A February 21, 2008, letter providing comments with regard to the development of the draft CVP/SWP operations BA, and in particular, the draft project description; and
- An April 22, 2008, list of threatened and endangered species and critical habitats that occur within areas affected by the proposed action.

On May 19, 2008, NMFS received Reclamation's May 16, 2008, request to reinitiate formal consultation on CVP/SWP operations. On May 30, 2008, Reclamation hand-delivered a revised BA containing appendices and modeling results. On June 10, 2008, NMFS issued a letter to Reclamation indicating that a reinitiation package was received, and that NMFS would conduct a 30-day sufficiency review of the BA received on May 30, 2008. On July 2, 2008, NMFS issued a letter to Reclamation, indicating that the BA was not sufficient to reinitiate formal consultation. NMFS described additional information necessary to reinitiate consultation. In addition, on July 17, 2008, NMFS offered additional comments on the BA via e-mail. Throughout July 2008, NMFS continued to participate in the interagency forums listed above to continue to provide technical assistance to Reclamation on its development of a final BA and complete reinitiation package. In addition, meetings were held between NMFS and Reclamation staff on August 8, September 9, and September 19, 2008, to discuss and clarify outstanding concerns regarding the modeling, Essential Fish Habitat (EFH), and project description information contained in the draft BA. On August 20 and September 3, 2008, NMFS received additional versions of the draft BA, hand-delivered to the NMFS Sacramento Area Office on digital video disc (DVD).

On October 1, 2008, the Sacramento Area Office received a hand-delivered letter from Reclamation, transmitting the following documents: (1) final BA on a DVD (Reclamation 2008a, hereafter referred to as the CVP/SWP operations BA), (2) Attachment 1: Comment Response Matrix, (3) Attachment 2: errata sheet; (4) Attachment 3: Additional modeling simulation information regarding Shasta Reservoir carryover storage and Sacramento River water temperature performance and exceedances; and (5) Attachment 4: American River Flow Management Standard 2006 Draft Technical Report. The letter and enclosures were provided in response to our July 2, 2008, letter to Reclamation, indicating that the BA was not sufficient to reinitiate formal consultation. In its October 1, 2008, letter, Reclamation also committed to providing, by mid-October 2008, the following: responses to comments and reinitiating consultation related to Pacific Coast Salmon EFH within the Central Valley, and (2) a request for conferencing and an analysis of effects of the continued long-term operation of the CVP and

SWP on proposed critical habitat for green sturgeon. On October 20, 2008, Reclamation provided to NMFS via e-mail the analysis of effects on the proposed critical habitat of Southern DPS of green sturgeon. In addition, on October 22, 2008, Reclamation provided to NMFS via e-mail supplemental information regarding the EFH assessment on fall-run Chinook salmon (hereafter referred to as fall-run). On November 21, 2008, NMFS issued a letter to Reclamation, indicating that Reclamation had provided sufficient information to reinitiate formal consultation on the effects of CVP/SWP operations, with the understandings that: (1) Reclamation is committed to working with NMFS staff to provide any additional information NMFS determines necessary to analyze the effects of the proposed action; and (2) NMFS is required to issue a final Opinion on or before March 2, 2009 (see section 1.5.8.2, below).

On December 11, 2008, NMFS issued a draft CVP/SWP operations Opinion for peer review through the CALFED Bay-Delta Program (CALFED) and the Center for Independent Experts (CIE), and also to Reclamation for review and comment. Details about the reviews are provided below in sections 1.5.6.2 and 1.5.6.3. Beginning the week of January 5, 2009, NMFS hosted weekly meetings with representatives from USFWS, CDFG, Reclamation, and DWR at the directors, managers, and technical levels, in addition to scheduling meetings on specific topics, to address, clarify, and resolve Reclamation's and DWR's comments on the draft Opinion and draft reasonable and prudent alternative (RPA).

On January 15, 2009, Reclamation sent NMFS an e-mail, transmitting an attached file with 2 pages to replace the North Bay Aqueduct section of the CVP/SWP operations BA on pages 13-49 and 13-50. In addition, section 3.1 of this Opinion documents additional changes to the CVP/SWP operations BA, specifically in Chapter 2 (project description).

This document is NMFS' Opinion on the proposed action, in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). The request for formal consultation was received on October 1, 2008. This final Opinion supersedes the 2004 CVP/SWP operations Opinion. This Opinion is based on: (1) the reinitiation package provided by Reclamation, including the CVP/SWP operations BA, received by NMFS on October 1, 2008; (2) the supplemental analysis of effects on the proposed critical habitat of Southern DPS of green sturgeon and supplemental information regarding the EFH assessment on fall-run; (3) other supplemental information provided by Reclamation; (4) declarations submitted in court proceedings pursuant to Pacific Coast Federation of Fishermen Association (PCFFA) *et al.* v. Gutierrez *et al.*; and (5) scientific literature and reports. A complete administrative record of this consultation is on file at the NMFS, Sacramento Area Office.

1.5 Key Consultation Considerations

1.5.1 Southern Oregon/Northern California Coast (SONCC) Coho Salmon

This Opinion analyzes the effects of the proposed action, including the Trinity River Division, on listed Central Valley anadromous fish species and Southern Residents (as it pertains to effects on Central Valley Chinook salmon availability as prey). NMFS is analyzing the effects of the proposed action on SONCC coho salmon in a separate biological opinion. Reclamation is currently in consultation with NMFS on this aspect of its operations.

After consideration of the complexity of the SONCC coho salmon consultation and availability of staff resources, NMFS is committed to completing the SONCC coho salmon consultation by September 30, 2009.

1.5.2 ESA Consultation on CVP and SWP Hatcheries

CVP and SWP hatcheries within the Central Valley include the Livingston Stone National Fish Hatchery (LSNFH), Coleman National Fish Hatchery, Feather River Fish Hatchery (FRFH), and Nimbus Fish Hatchery. The USFWS, which manages the LSNFH and Coleman National Fish Hatchery, has requested a separate ESA section 7 consultation on those hatcheries. Therefore, the effects of the ongoing operations of the LSNFH and Coleman National Fish Hatchery are not analyzed as part of the proposed action in this consultation. The FRFH is a mitigation hatchery for the impacts of DWR's Oroville Dam. Currently, the Federal Energy Regulatory Commission (FERC) is in consultation with NMFS on the effects of relicensing Oroville Dam (including the effects of FRFH). Therefore, the FRFH is not considered in this consultation.

The Trinity River Fish Hatchery is part of the Trinity River Division of the CVP. Consistent with how NMFS will address the effects on SONCC coho salmon (see section 1.5.1, above), NMFS will defer the consideration of effects from Trinity River Fish Hatchery, as it pertains to any effects on SONCC coho salmon, to the separate formal consultation currently in process.

The exception to the above consultation considerations on CVP and SWP hatcheries is that all Chinook salmon production from all Central Valley hatcheries (*i.e.,* Coleman National Fish Hatchery, LSNFH, FRFH, Nimbus Fish Hatchery, Mokelumne Fish Hatchery, and Merced Fish Hatchery), in addition to the Trinity River Fish Hatchery, are considered in the analysis of effects on Southern Residents in this Opinion because these runs provide forage for Southern Residents. The Molelume River Hatchery (funded and operated by CDFG) and Merced Fish Hatchery (funded by the East Bay Municipal Utilities District and operated by CDFG) are not CVP or SWP hatcheries, but they make up a portion of hatchery-produced Chinook salmon from the Central Valley.

In summary, of all the CVP and SWP hatcheries, aside from hatchery production for the Southern Residents, the specific operation of Nimbus Fish Hatchery will be analyzed in this consultation. Overall, the combined effects from hatchery-produced fish in the Central Valley are included in the environmental baseline.

Managers for each CVP and SWP hatchery are currently engaged in discussions with NMFS in their development of a Hatchery and Genetic Management Plan (HGMP), pursuant to section 4 of the ESA. The HGMPs will include long-range planning and management of fish species cultured at the hatcheries. To that end, the consultation and exemption of incidental take related to the continued operation of Nimbus Hatchery will sunset 2 years from the date of issuance of this Opinion. As adoption of an HGMP under section 4 of the ESA is a Federal action, NMFS will conduct an intra-agency section 7 consultation prior to adoption of the HGMP.

1.5.3 ESA Consultation Linkage to the Operation of Oroville Dam

The Oroville Complex (Oroville Dam and related facilities, including the FRFH) is part of the SWP. DWR has been operating the Oroville Complex under a FERC license and is currently undergoing a relicensing process with FERC. The FERC license expired in January 2007, and until a new license is issued, DWR operates to the existing FERC license. FERC is currently in consultation with NMFS regarding the effects of relicensing the Oroville Complex for 50 years. Because the effects of the Oroville Complex are considered in the ongoing FERC consultation, the effects of operation of Oroville Dam on listed fish within the Feather River is not considered in this consultation. The analytical cutoff point of the hydrologic effects in the FERC analysis is at the Feather River's confluence with the Sacramento River. The effects of the flows from the Oroville Complex on all listed fish under NMFS jurisdiction in the Sacramento River and Delta are considered in this consultation.

1.5.4 Individual Contracts

This consultation addresses the long-term operations of the CVP and SWP, and does not satisfy Reclamation's ESA section 7(a)(2) obligations for issuance of individual water supply contracts. Reclamation should consult with NMFS separately on their issuance of individual contracts. The analysis of effects of the proposed actions, however, assumes water deliveries under the contracts, as described and modeled in the BA.

NMFS requests that by June 4, 2010, Reclamation provide written notification to NMFS and the State Water Resources Control Board (SWRCB) of any contract that it believes is creates a nondiscretionary obligation to deliver water, including the basis for this determination and the quantity of nondiscretionary water delivery required by the contract. Any incidental take due to delivery of water to such a contractor is not be exempt from the ESA section 9 take prohibition in this Opinion.

1.5.5 Inspector General's Report for the 2004 CVP/SWP Operations Opinion

On October 8, 2004, 19 members of the U.S. House of Representatives submitted a letter to the inspectors general of the departments of Interior and Commerce, requesting a review of allegations that Reclamation, "…in its haste to finalize water contracts in California, has improperly undermined the required NOAA Fisheries environmental review process for the proposed long-term Operations, Criteria, and Plan (OCAP) for the Central Valley Project (CVP) and the State Water Project (SWP)." Subsequent to that request, the Department of Commerce Office of Inspector General (IG), audited the process used by NMFS to develop the 2004 CVP/SWP operations Opinion, with objectives to: (1) identify the review process used to issue the 2004 CVP/SWP operations Opinion on Reclamation's CVP and DWR's SWP, and (2) determine whether NMFS – in developing the 2004 CVP/SWP operations Opinion – followed the consultation process for issuing biological opinions that is defined by its policies, procedures, and normal practices. On July 8, 2005, Johnnie E. Frazier (Office of Audits, Seattle Regional Office) issued Final Report STL-17242-5-0001 to NMFS, which included the following findings: (1) The NMFS southwest regional office deviated from the agency's established consultation initiation process, and (2) The southwest regional office did not follow its process for ensuring the quality of the biological opinion.

Section 1.4 provides details regarding the consultation history leading up to the issuance of this CVP/SWP operations Opinion. In response to IG finding #1, on November 21, 2008, NMFS issued a letter to Reclamation, indicating that Reclamation had provided sufficient information to reinitiate formal consultation on the effects of CVP/SWP operations, with the understanding that: (1) Reclamation is committed to working with NMFS staff to provide any additional information NMFS determines necessary to analyze the effects of the proposed action.

To address IG finding #2, NMFS issued a series of documents to provide a clear and transparent description of the roles and responsibilities of regional staff in the review and clearance process for consultation documents. The review and clearance process for non-routine formal consultations (which includes highly controversial, novel, or precedent-setting biological opinions, including this CVP/SWP operations Opinion) requires signatures of the Area Fffice Section 7 Coordinator, Area Office Supervisor, Regional Section 7 Coordinator, NOAA General Counsel, and Assistant Regional Administrator for Protected Resources on a clearance sheet acknowledging that proper review procedures were followed, prior to final signature by the Regional Administrator. During the review process, consultation documents were reviewed for consistency with applicable policies, procedures and mandates; scientific accuracy; legal sufficiency; clear, effective, and efficient communication of analysis and reasoning; and compliance with required format, style, and tone.

As provided above, the IG's recommendations have been incorporated into NMFS' review process and current formal consultation on the CVP/SWP operations.

1.5.6 Independent Peer Reviews of the 2004 CVP/SWP Operations Opinion

In 2005, NMFS initiated peer reviews of its 2004 CVP/SWP operations Opinion through CALFED and the CIE. In general, the peer reviewers' charge was to evaluate and comment on the technical information, models, analyses, results, and assumptions that formed the basis for the assessment of the proposed long-term water operations of the CVP and SWP. In December 2005, CALFED issued its report and findings to NMFS. Also in 2005, Dr. Thomas E. McMahon (CIE reviewer) and Dr. Jean-Jacques Maguire (CIE reviewer) issued their report and findings to NMFS. Each of the reports had constructive recommendations for the 2004 CVP/SWP operations Opinion. As an added level of review, NMFS requested the NMFS-Southwest Fisheries Science Center (SWFSC) to evaluate the peer reviews. The NMFS-SWFSC issued a report to NMFS-Protected Resources Division on May 25, 2006, concluding that the three peer reviews offered generally valid and helpful critiques of the science underlying the 2004 CVP/SWP operations Opinion. The CVP/SWP operations BA and this Opinion considered and/or incorporated all of the substantive peer review recommendations, as appropriate.

1.5.7 Reviews throughout the Current Reinitiated CVP/SWP Operations Consultation

1.5.7.1 Temperature Management and Modeling Workshop

The peer reviews of the 2004 CVP/SWP operations Opinion identified several temperature-related concerns, with recommendations on how to address those concerns. In February and March, 2008, NMFS convened an interagency planning team, consisting of representatives from Reclamation, DWR, USFWS, CALFED, and NMFS, to develop the scope and agenda for a workshop intended to provide a forum for discussion of issues related to temperature modeling and management on the upper Sacramento River in support of the CVP/SWP operations BA and NMFS' Opinion. On April 1, 2008, CALFED convened the 1-day public workshop, which consisted of a series of presentations and question-and-answer periods with selected local agency representatives, in Sacramento, California. Topics discussed included anadromous species' temperature needs, recovery approach for listed Central Valley salmonids, operational practices to manage temperature of the Sacramento River, modeling and technical tools presently used for CVP stream management, and case studies of temperature management in other watersheds. Following the workshop, CALFED convened a Review Panel of independent subject matter experts to evaluate the technical and scientific approach used to manage temperature in CVP streams as presented in the workshop. The Review Panel provided a written synthesis of topics discussed during the workshop, their perspective of important issues, and available tools (with recommendations for their use) for addressing water temperature management in the upper Sacramento River, in support of NMFS' Central Valley Recovery Plan temperature objectives (Deas *et al*. 2008). The CVP/SWP operations BA and this Opinion considered and incorporated, as appropriate, the recommendations from Deas *et al*. (2008).

1.5.7.2 Peer Review of NMFS' 2008 Draft CVP/SWP Operations Opinion

NMFS sought peer reviews of its 2008 draft CVP/SWP operations Opinion through CALFED and the CIE. Each review involved a different approach and process.

The CALFED review format involves convening of a Panel of independent subject matter experts who review documents provided, then meet in a public workshop format where the Panel may interact with NMFS and other agency staff, ask questions and clarify information regarding their review charge. Following the workshop, the Panel produces a report of their findings and recommendations. This approach is beneficial in that the Panel has the opportunity to clear up potential misunderstandings regarding the information they have been provided so that their product is most likely to provide relevant feedback to NMFS, and there is the potential to discover useful input from attendees at the workshop, as well as from collaboration among reviewers.

The CALFED peer review of the draft CVP/SWP operations Opinion occurred in two phases. The first phase was to evaluate and comment on NMFS analytical framework that would form the basis for this CVP/SWP operations Opinion. On July 22, 2008, NMFS submitted its analytical framework document to CALFED for peer review. On August 5, 2008, CALFED convened a public workshop in Sacramento, California, which consisted of several presentations from NMFS staff on the ESA section 7 consultation process and the proposed analytical approach, followed by a questions-and-answers session from the peer review Panel to the NMFS presenters. At the end of the workshop, the Panel requested additional information from NMFS in order for it to provide meaningful feedback and recommendations to assist us in the development of the CVP/SWP operations Opinion. Specifically, the Panel requested a copy of the CVP/SWP operations BA, making it clear that their intention was not to peer review the CVP/SWP operations BA, but to understand the information presented in the CVP/SWP operations BA in order to better respond to the peer review charge for the analytical framework. In addition, the peer review panel requested two mock analyses to show them how we intended to utilize our analytical framework, and also how the recommendations from the peer review of the 2004 CVP/SWP operations Opinion were addressed in the current reinitiated CVP/SWP operations consultation. After NMFS fulfilled the peer review panel's requests (at the time, the most recent draft of the CVP/SWP operations BA was August 20, 2008), a follow-up public workshop via conference call was held on August 29, 2008, mainly in the form of a questions-and-answers session. On November 4, 2008, NMFS received a letter from CALFED, transmitting the Panel's October 31, 2008, document, "Independent Review of the 2008 NMFS Analytical Framework for its CVP/SWP operations Biological Opinion."

The second phase of the CALFED peer review was the review of a draft of the CVP/SWP operations Opinion in the current consultation. The purpose of this independent review was to obtain the views of experts not involved in the consultation on the use of the best available scientific and commercial information as it pertains to the development of the CVP/SWP operations Opinion. In addition, CIE peer reviewed a draft of the CVP/SWP operations Opinion in the current consultation. On December 11, 2008, NMFS submitted its draft CVP/SWP operations Opinion to CALFED and the CIE for peer review. As NMFS had draft conclusions of jeopardy for winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon, and adverse modification of designated critical habitats of winter-run, spring-run, CV steelhead, and proposed critical habitat for Southern DPS of green sturgeon, NMFS also provided the draft reasonable and prudent alternative (RPA) to CALFED for review. On January 8, 2009, CALFED convened a public workshop in Sacramento, California, which consisted of several presentations from NMFS staff, summarizing the effects analysis conducted in this consultation, followed by a questions-and-answers session from the Panel to the NMFS presenters. On January 26, 2009, NMFS received a letter from CALFED, transmitting the Panel's January 23, 2009, document, "Independent Review of a Draft Version of the 2009 NMFS CVP/SWP operations Biological Opinion" (Anderson *et al*. 2009).

The CALFED peer review approach also has been criticized for a potential lack of independence, as NMFS is a CALFED member agency. NMFS fully supports the CALFED criteria for independence in its reviews, but also sought independent peer review through the CIE.

The process for the CIE peer review is that CIE identifies a group of reviewers who will receive the materials for review. They conduct their reviews guided by "Terms of Reference," that is, a list of specific questions that NMFS requested to be answered in the peer review. The reviewers work independently, and after the specified review period, they provide individual review reports to CIE and NMFS.

On January 21, 2009, Dr. E. Eric Knudsen, Dr. Ian A. Fleming, and Dr. Richard A. Marston (CIE reviewers) issued their reports and findings to NMFS. Each of the peer review reports had constructive recommendations towards the development of a more scientifically robust final Opinion. However, in general, all of the peer reviewers and their reports acknowledged the incredibly complex proposed action, and that NMFS applied the best available information in its development of the draft Opinion. This Opinion, and its supporting administrative record, considered and/or incorporated all of the substantive peer review recommendations, as appropriate. NMFS also incorporated many of the suggested line edits from the peer review reports to improve the quality of this Opinion.

1.5.7.3 Reclamation's Review of the Draft CVP/SWP Operations Opinion

In addition to the CALFED and CIE peer reviews, on December 11, 2008, NMFS issued the draft CVP/SWP operations Opinion, draft RPA, and EFH Conservation Recommendations to Reclamation for its review and comments. On January 13, 2009, Reclamation provided its comments, in addition to transmitting comments from DWR. On March 3, 2009, NMFS issued a revised draft of its CVP/SWP operations Opinion and draft RPA to Reclamation for its review and comment. On March 20, 2009, Reclamation provided its comments, in addition to transmitting comments from DWR. DWR provided additional comments on April 20, April 28, and May 1, 2009. Many of Reclamation's and DWR's comments were consistent with and echoed those of the peer review reports. NMFS considered and/or incorporated all of Reclamation's and DWR's substantive comments, as appropriate.

1.5.8 Litigation and Settlement

1.5.8.1 USFWS' CVP/SWP Operations Consultation on Delta Smelt

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 USFWS 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. The court granted USFWS' request to extend its court-ordered deadline to complete the biological opinion to December 15, 2008.

The USFWS issued its biological opinion on December 15, 2008 (USFWS 2008a), with a jeopardy finding for Delta smelt, and adverse modification of Delta smelt designated critical habitat. In its biological opinion, the USFWS proposed an RPA for Reclamation to consider. On December 15, 2008, Reclamation issued a memorandum to the USFWS, provisionally accepting the USFWS' RPA, conditioned upon the further development and evaluation of RPA Components 3 and 4.

1.5.8.2 NMFS' CVP/SWP Operations Consultation

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 PCFFA *et al*. v. Gutierrez *et al*, 1:06-cv-245-OWW-GSA (E.D. Cal. 2008). The Court found that the Opinion issued by 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 operations. A Scheduling Order was filed by the court on July 24, 2008, and a further status conference was set for September 4, 2008. On October 21, 2008, Judge Wanger issued a ruling that California's canal water systems are placing wild salmon "unquestionably in jeopardy." However, he did not issue any court-ordered interim remedies pending a final NMFS Opinion, to be issued by March 2, 2009. A motion to extend the time for completion was filed on January 21, 2009. The court granted NMFS' request to extend its court-ordered deadline to complete the biological opinion to June 2, 2009.

1.6 Term of the Opinion

This biological opinion is effective through December 31, 2030.

changes needed for life in the ocean, and reach the ocean in a timely manner has been limited by operational conditions. Obstruction of access to historic spawning and rearing habitat requires CV steelhead to utilize these freshwater migration corridors at times that may not be optimal with respect to temperature, forage availability and exposure to predators.

Adult CV steelhead migrating upstream frequently are delayed entering the river owing to poor water quality conditions in the Delta. Fall attraction flows released for Fall Run typically improve conditions for steelhead migration also, hence steelhead tend to be observed on the Stanislaus River earlier in the year than in other Central Valley streams.

6.6 Delta Division

6.6.1 Deconstruct Actions in the Delta Division

The proposed action within the Delta is comprised of several different elements. Some of the elements, such as the proposed intertie between the Delta Mendota Canal and the California Aqueduct, were integrated into the assumptions for the CALSIM II modeling for the near future conditions (Study 7.1) and the future conditions (Study 8.0) and thus could not be analyzed separately without running the models individually with the explicit actions separated out from the combined assumptions. Others aspects of the action were modeled, such as export rates and gross channel hydraulics (flow rates, flow percentages, *etc.*) and could be assessed for their effects. NMFS chose to look at modeled water diversion actions in total, without disaggregating individual components of the water demands on the CVP and SWP actions in the Delta. NMFS assumed that the baseline conditions included the current natural and anthropogenic conditions in the Delta region (levees, dredging, contaminants, urban development, non-native species, predation, *etc.*) without the effects of the ongoing operations (*i.e.*, discretionary actions) of the Project.

In general, the effects of the actions in the Delta will result in: (1) increased export rates at the CVP and SWP facilities, resulting in increased salvage and loss at the CVP and SWP fish collection facilities, (2) alterations to the hydrodynamics in the Delta, resulting in increased vulnerabilities to entrainment into the central and southern Delta water ways, exposure to predation losses within the central and southern Delta waterways, delays in migration, increased residence time in the Delta due to delays in migration, and loss of migratory cues due to flow alterations, (3) exposure of green sturgeon to herbicides in Clifton court forebay, and (4) installation and operation of physical structures in the South Delta that will alter hydraulics, increase predation vulnerability and degrade habitat functions for listed salmonids and green sturgeon in the affected waterways.

The action elements analyzed by NMFS for the Delta Division are:

1. Exports from the CVP and SWP water diversions facilities which include changes in delta hydrodynamics, direct entrainment of listed fish at the project facilities, and indirect mortality within the delta related to exports and non-export factors;

2. Application of the copper based herbicide Komeen® to Clifton Court Forebay as part of the SWP aquatic weed control program;
3. The effects of the South Delta Improvement Program, Stage 1;
4. The effects of the Delta Cross Channel;
5. Contra Costa Water District diversions from delta facilities;
6. North Bay Aqueduct on Barker Slough; and
7. Vernalis Adaptive Management Plan effects.

In addition to the elements of the project action, the effects of climate change are assessed in conjunction with the implementation of the project actions. NMFS utilized the output of the climate change modeling presented in the BA to conduct this evaluation.

6.6.2 Proposed Delta Exports and Related Hydrodynamics

6.6.2.1 Deconstruct the Action

The proposed action will result in increased levels of water diversions from the CVP and SWP export facilities in the near future (Study 7.1) and future (Study 8.0) conditions over the current export levels (Study 7.0). Increased exports result in increased net flows towards the export facilities through the waterways of the central and south Delta. The effects of these increased exports are analyzed below in relation to the current level of exports. The effects of the current exports are discussed in both the environmental baseline and the current effects section. The temporal and spatial occurrence of listed fish in the Delta region as well as the baseline stressors have been described in Section 5.5, "*Status of the Species and Critical Habitat in the Delta Division.*"

6.6.2.2 Elements of the Action

6.6.2.2.1 Modeling Results for Proposed Delta Actions

Reclamation used the computer simulation models CALSIM II and DSM2 to model the effects of the proposed action. The effects modeled are based on the assumptions in the changes in operations and demands between the four CVP/SWP operations studies (6.0, 7.0, 7.1, and 8.0) as well as five climate change scenarios modeled in the future Study 9 series. (See CVP/SWP operations BA page 9-32 and 9-107, and table 9-4 for a more complete description of the models)

6.6.2.2.2 Delta Inflow

Total Delta inflow in the models is calculated as the sum of water entering the Delta from the Yolo bypass, the Sacramento River, the Mokelumne River, the Calaveras River, the Cosumnes River, and the San Joaquin River (at Vernalis). Historical Delta inflow for the period between 1980 and 1991 averaged 28 MAF, with the inflow from the Sacramento and San Joaquin rivers contributing approximately 75 percent of the inflow (DWR 1995). Based on the four modeling comparisons done for the CVP/SWP operations BA, the annual average Delta inflow decreases in all study comparisons when future long term annual average conditions are compared to current conditions (table 6-25). Although not specifically called out, north of Delta demands increase in the future with the addition of the Freeport Regional Water Project intake as well as increases in future demands for municipal and industrial (M&I) water deliveries and settlement contracts. The overall result is more water is diverted for upstream demands prior to reaching the Delta in the near future and future conditions.

Table 6-25. Differences in long-term average annual Delta inflow and the 1929 – 1934 drought as modeled under the four CVP/SWP operations studies (CVP/SWP operations BA table 12-1).

Difference in Thousand 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
Long-term annual average Total Delta Inflow	-69	-201	-270	-70
1929 -34 Annual average Total Delta Inflow	136	-272	-403	-130

The differences between studies 6.0, 7.0, 7.1, and 8.0 show relatively little difference in the 50th percentile flows (Total Delta inflow) when compared on a monthly basis (figure 6-37). The highest modeled inflows occur in the period from December through March due to flood flows and increased runoff in the basin. However, in all four modeling studies, there are distinct increases in Delta inflow during July to support increased pumping in below normal, dry, and critically dry year types (figures 6-38 through 6-43). Reclamation has stated that "current" model runs (6.0 and 7.0) have slightly higher inflow than the future runs (7.1 and 8.0) during the summer of dry and critically dry years due to the extra pumping required for EWA transfers being wheeled between the facilities. Since the future studies have limited EWA assets, this additional inflow is not required. Conversely, more water arrives in the Delta in June and July during above normal and below normal years in the future operations, apparently for export purposes. Summer time Delta inflow may have an effect on emigrating juvenile green sturgeon or their distribution in the Delta following emigration, based on the occurrence of juvenile green sturgeon at the South Delta salvage facilities in July and August. However, the lack of data concerning the movements of juvenile sturgeon during their downstream migration make definitive assessments difficult at best concerning the role of Delta inflow on their movements.

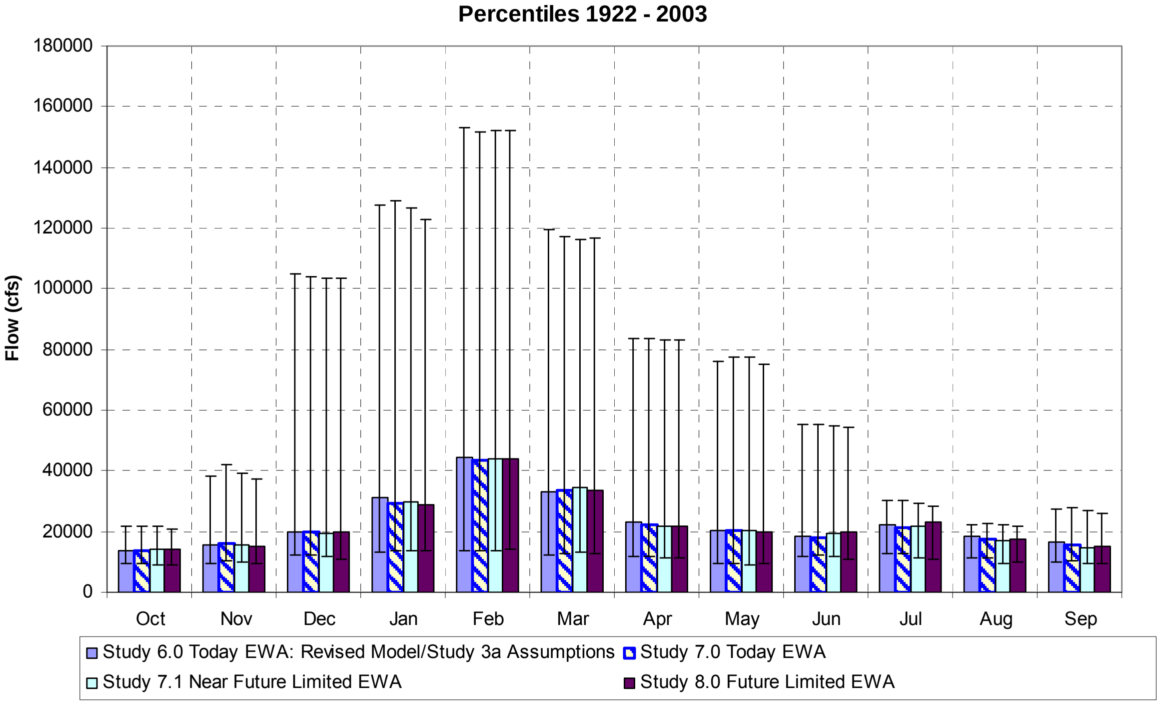

Figure 6-37. Monthly Delta inflow as measured at the 50th Percentile with 5th and 95th percentile whisker bars shown (CVP/SWP operations BA figure 12-2).

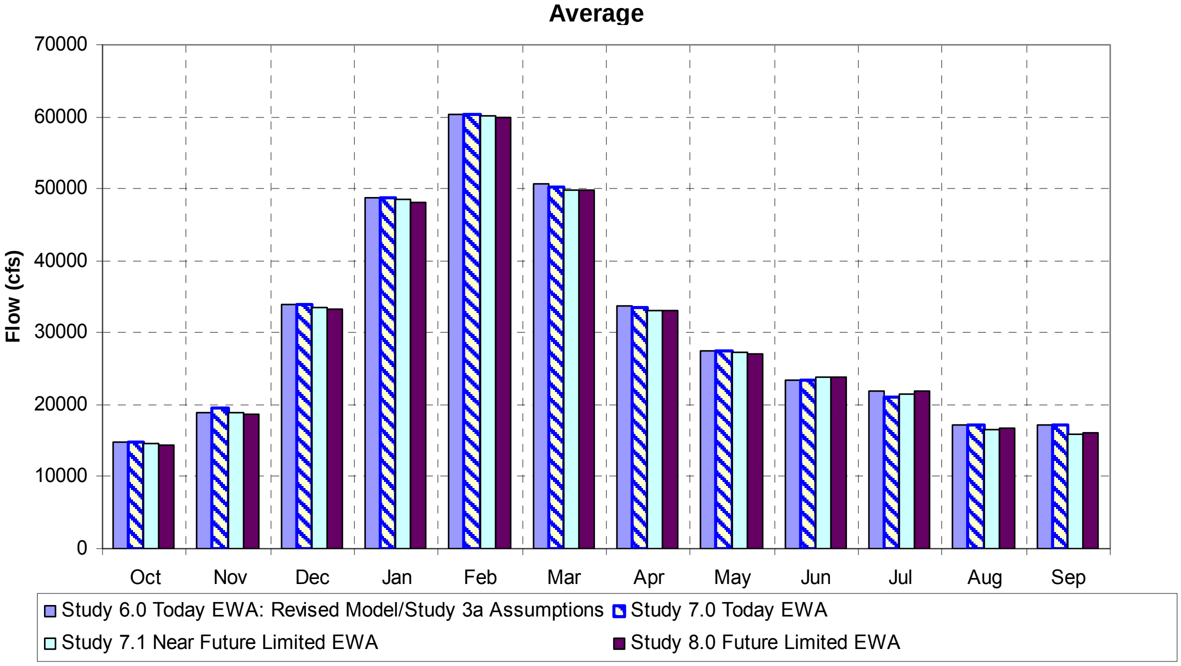

Figure 6-38. Average monthly Total Delta Inflow (CVP/SWP operations BA figure 12-3).

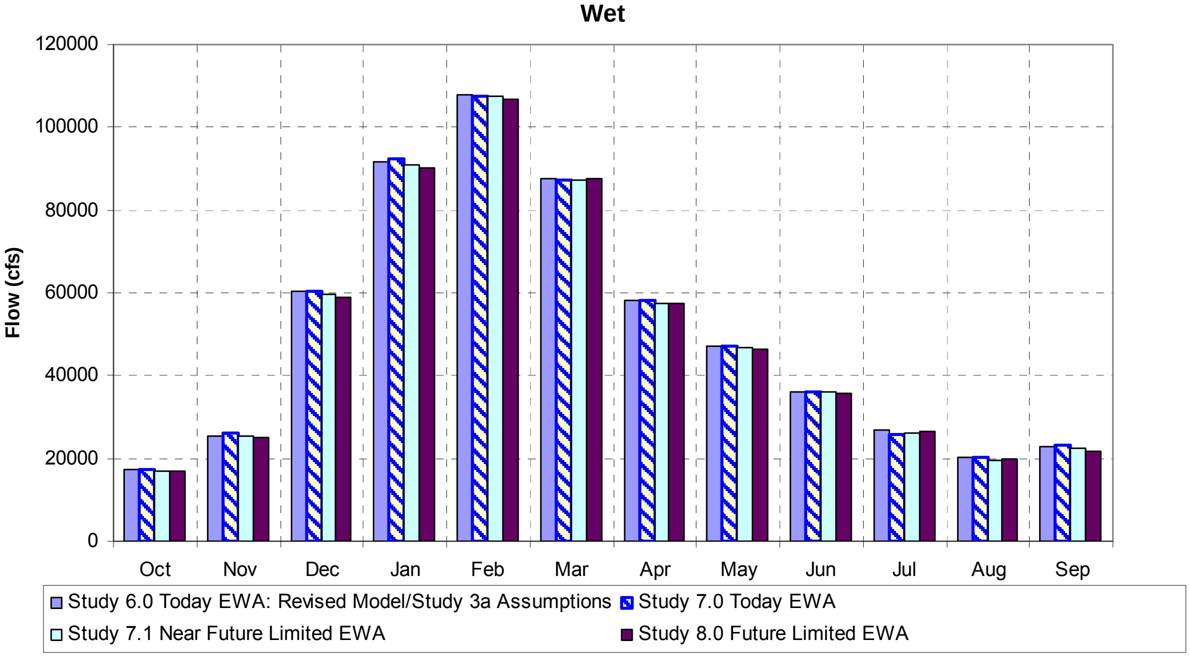

Figure 6-39: Average wet year (40-30-30[14]) monthly total Delta inflow (CVP/SWP operations BA figure 12-4).

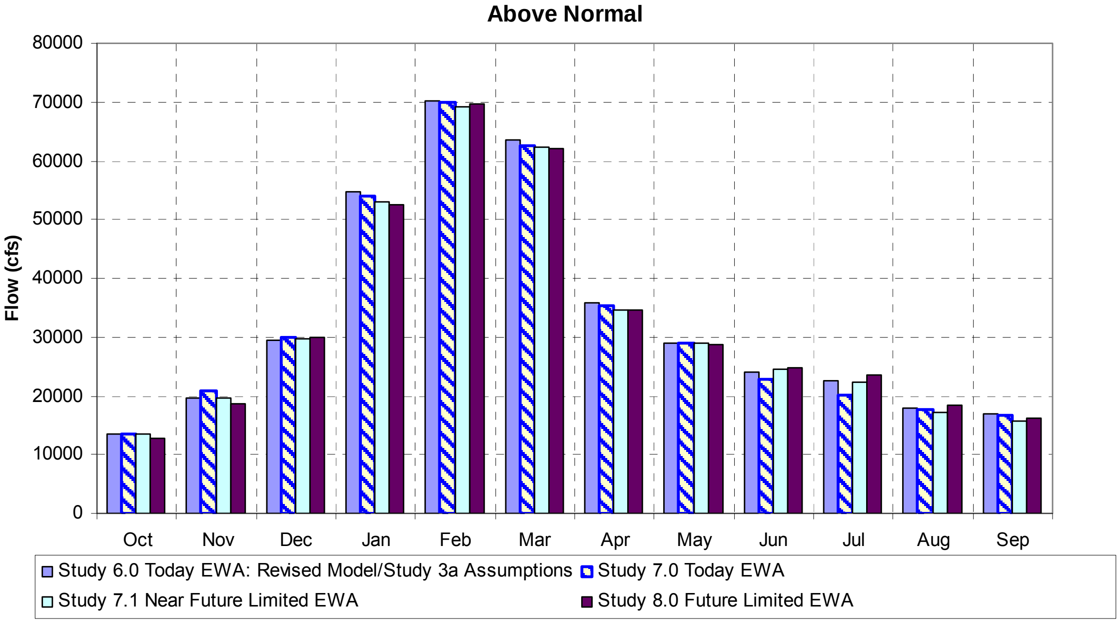

Figure 6-40: Average above normal year (40-30-30) monthly total Delta inflow (CVP/SWP operations BA figure 12-5).

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[14] 40-30-30, also known as the "Sacramento River Index," was "previously used to determine year type classifications under SWRCB Decision 1485," and is equal to 0.4 * Current Apr-Jul Runoff + 0.3 * Current Oct-Mar Runoff + 0.3 * Previous Year's Index, where runoff is the sum of unimpaired flow in MAF at: Sacramento River above Bend Bridge, Feather River at Oroville (aka inflow to Lake Oroville), Yuba River near Smartville, and American River below Folsom Lake; and previous year's index is a maximum 10.0 (http://cdec.water.ca.gov/cgi-progs/iodir/wsi).

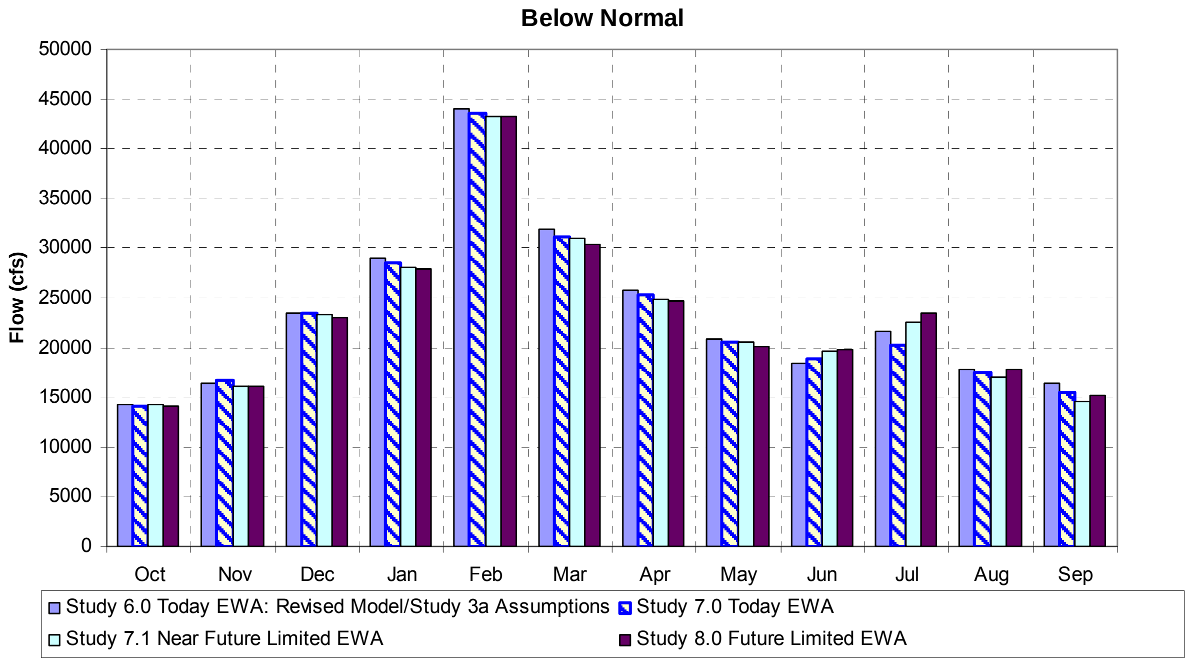


Figure 6-41: Average below normal year (40-30-30) monthly total Delta inflow (CVP/SWP operations BA figure 12-6).

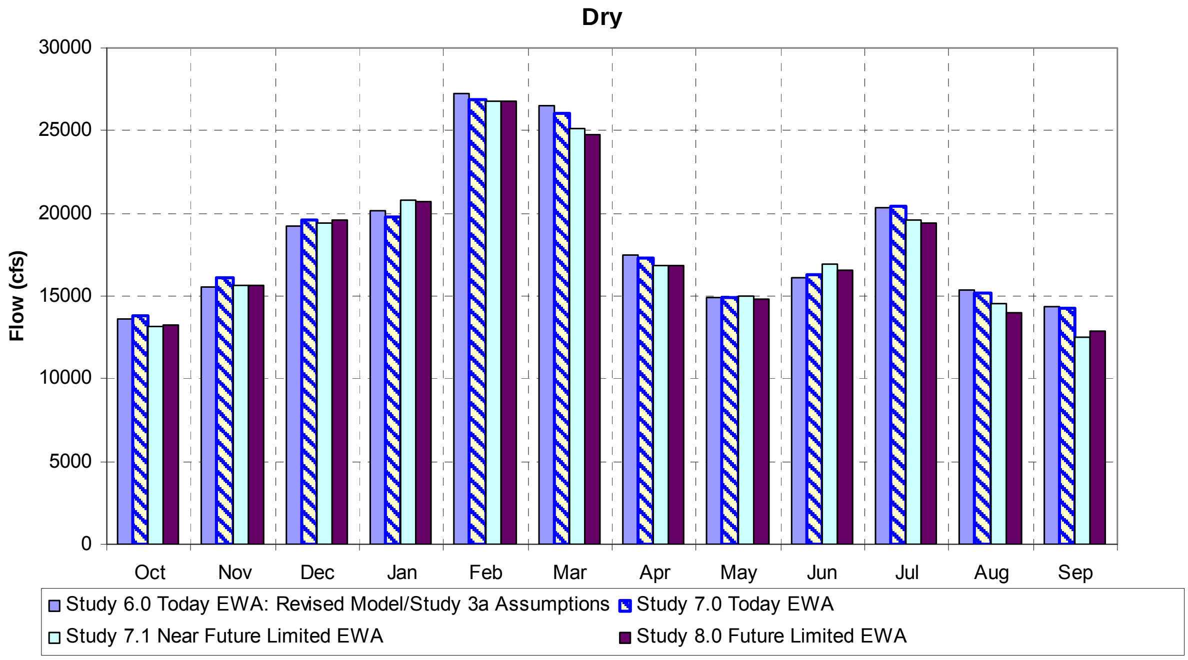


Figure 6-42: Average dry year (40-30-30) monthly total Delta inflow (CVP/SWP operations BA figure 12-7).

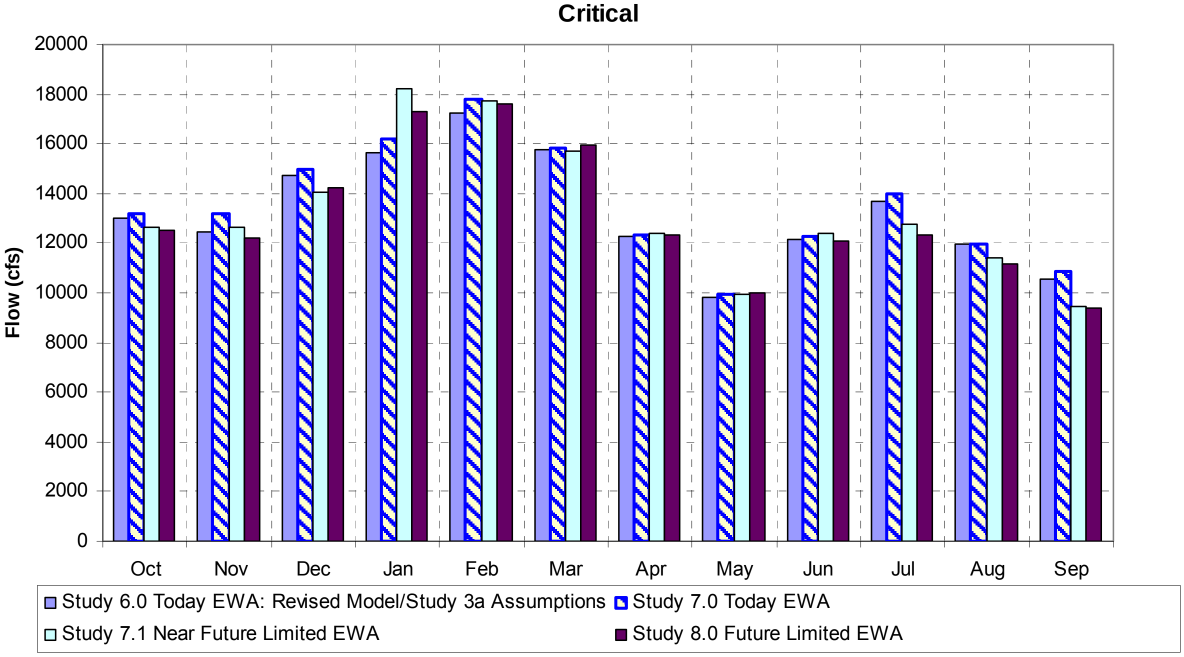


Figure 6-43: Average critically dry year (40-30-30) monthly total Delta inflow (CVP/SWP operations BA figure 12-8).

6.6.2.2.3 Delta Outflow

Historical Delta outflow values are described in DWR's Delta Atlas (DWR 1995). Of the 28 MAF of Delta inflow, approximately 19 MAF flows out to the ocean through the Delta. The remaining 9 MAF is captured by water diversions in the Delta, of which the CVP and SWP account for approximately 6 to 8 MAF (or 20 to 28 percent of the inflow) depending on water year type (DWR 1995; Healey *et al*. 2008; California, State of 2008). When comparing the differences between the future studies (7.1 and 8.0) with the current conditions (study 7.0), the average annual Delta outflow decreases by 300 to 400 TAF. Most of this decrease is seen in the immediate future (Study 7.1 compared to Study 7.0) with a reduction of 296 TAF. Study 8.0 reduces the delta outflow average an additional 104 TAF (see table 6-26). This represents an increase of approximately 5 percent in water "lost" in the Delta to diversions over historic conditions.

Table 6-26. Differences in long-term average annual Delta outflow and the 1929 – 1934 drought as modeled under the four CVP/SWP operations studies (CVP/SWP operations BA table 12-2).

Differences 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
Long-term Annual Average Total Delta Outflow	-149	-296	-400	-104
1929 -34 Annual average Total Delta Outflow	-93	-195	-164	32

The studies indicate that there are seasonal differences in the outflow, particularly in winter and spring. The biggest differences occur in below normal, dry, and critically dry years. The obvious differences are seen in late winter, where outflow increases are seen in Studies 6.0 and 7.0, when pumping reductions for "fish actions" are taken and thus, more water is allowed to flow out of the Delta. Conversely, these pumping reductions are not taken in the future since the models were designed with limited EWA assets available to the Projects. In general, the Delta outflow decreases during the winter and spring seasons are greater for the future studies (7.1 and 8.0) than they are for the current studies (6.0 and 7.0), indicating that less water is available to assist emigrating fish to leave the Delta during this period (figures 6-44 through 6-50).

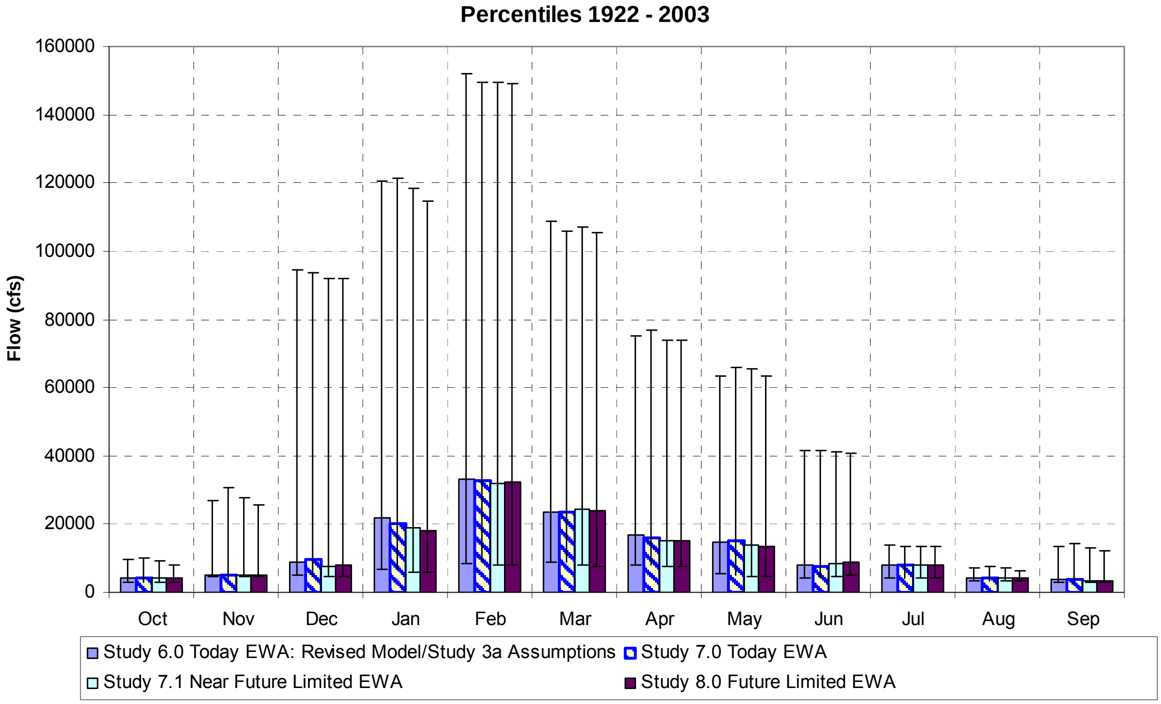


Figure 6-44. Monthly Delta outflow as measured at the 50th percentile with 5th and 95th percentile whisker bars shown (CVP/SWP operations BA figure 12-10).

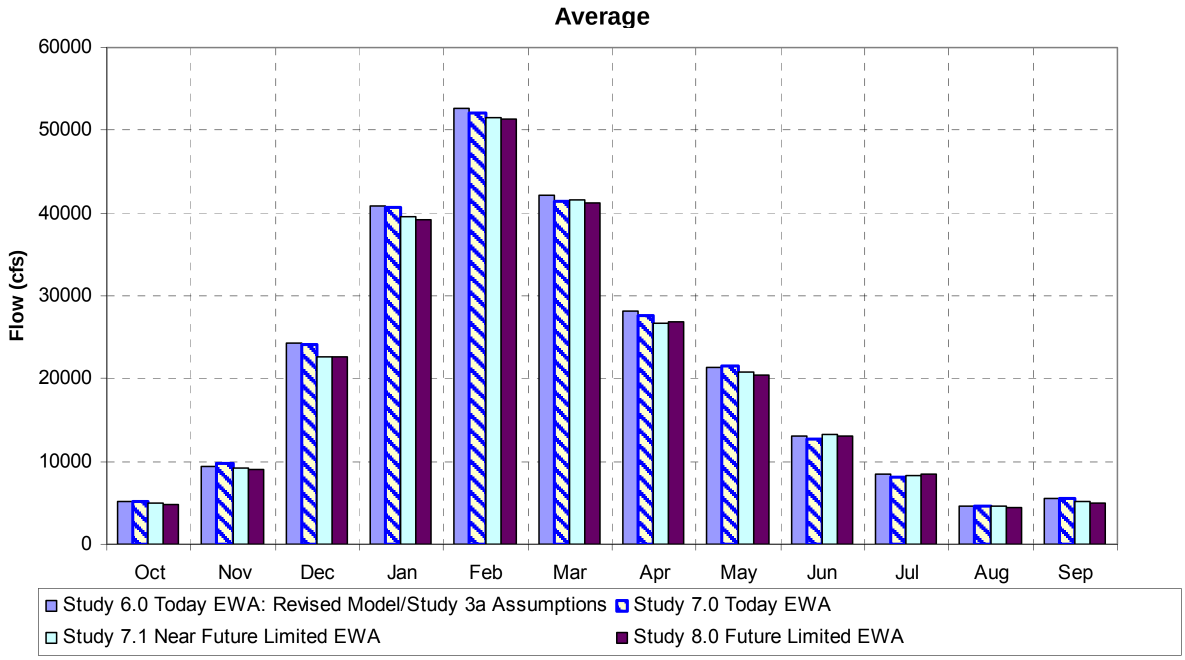


Figure 6-45. Average monthly total Delta outflow (CVP/SWP operations BA figure 12-11).

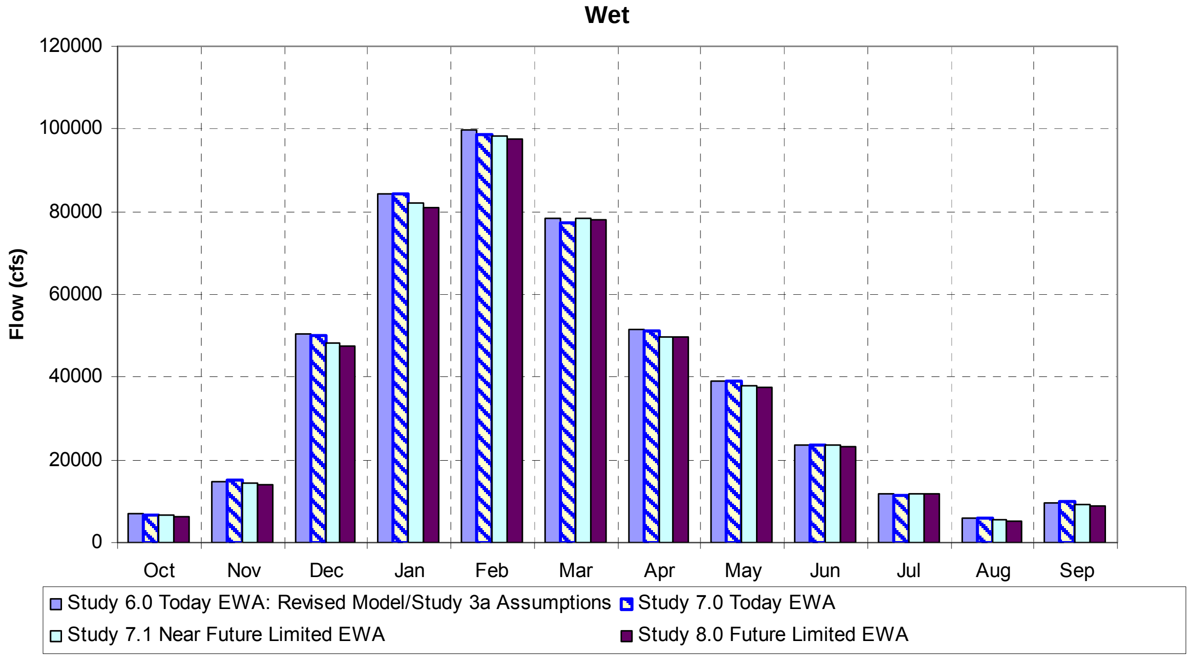


Figure 6-46. Average wet year (40-30-30) monthly delta outflow (CVP/SWP operations BA figure 12-12).

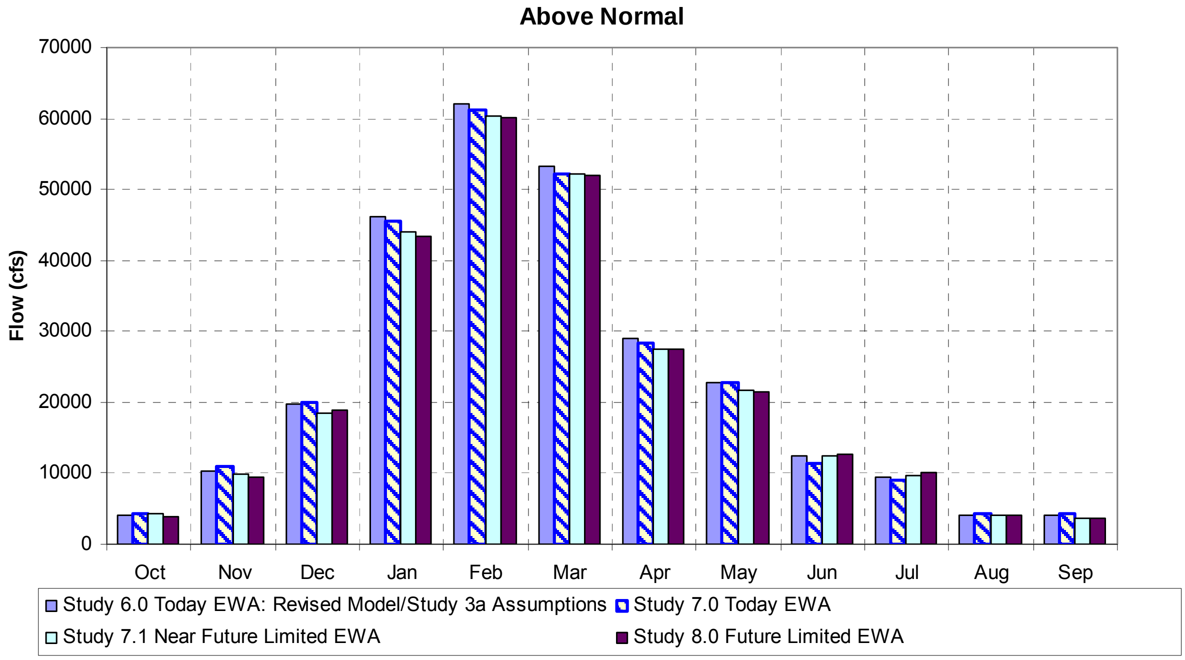


Figure 6-47. Average above normal year (40-30-30) monthly Delta outflow (CVP/SWP operations BA figure 12-13).

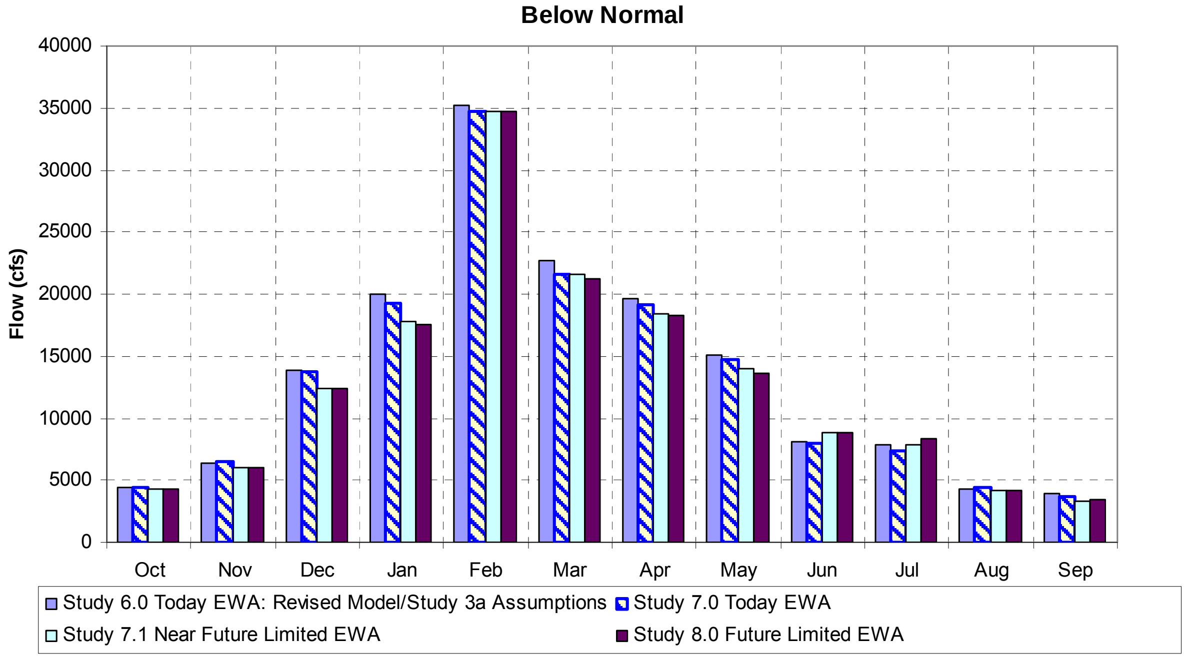


Figure 6-48. Average below normal year (40-30-30) monthly Delta outflow (CVP/SWP operations BA figure 12-14).

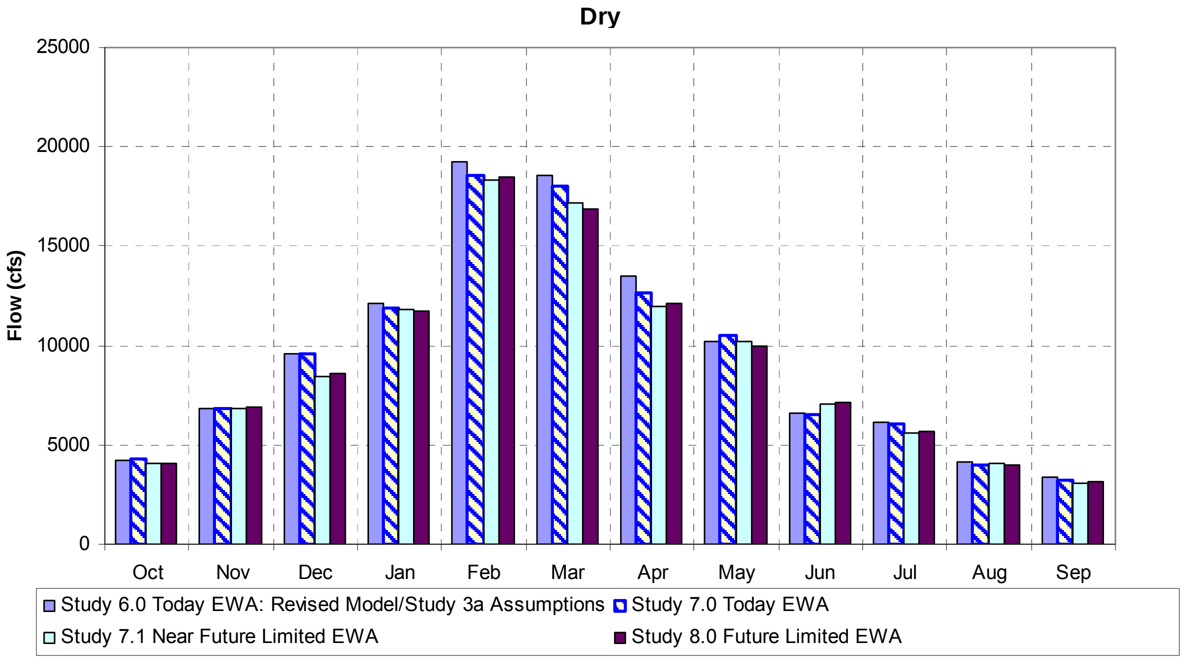


Figure 6-49. Average dry year (40-30-30) monthly Delta outflow (CVP/SWP operations BA figure 12-15).

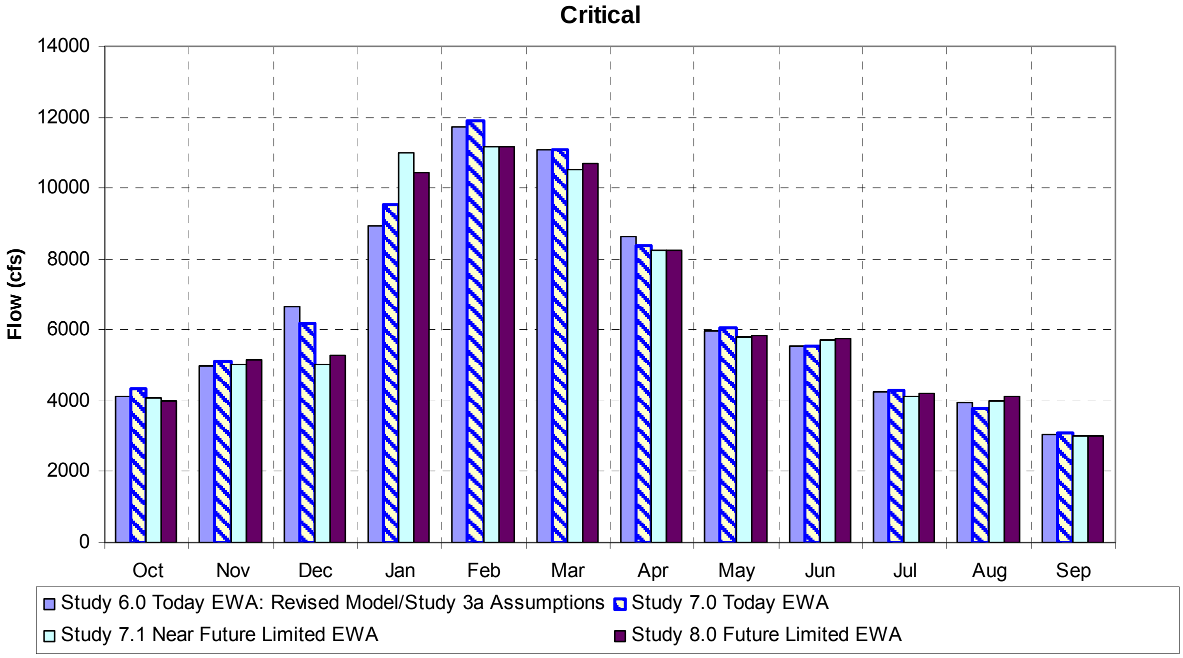


Figure 6-50. Average critically dry (40-30-30) monthly Delta outflow (CVP/SWP operations BA figure 12-16).

6.6.2.2.4 Exports from the Project Facilities

The exports modeled are Reclamation's at the Bill Jones Pumping Plant, the State's pumping at the Harvey O. Banks Pumping Plant, joint point diversions by Reclamation at Banks, and diversions for the Contra Costa Water District and the North Bay Aqueduct on Barker Slough. The future scenario, as modeled by Study 8.0, shows a pumping pattern with increased levels of exports due to the greater future demands south of the Delta, and reduced export curtailments due to EWA actions relative to current practices as modeled in studies 6.0 and 7.0. The near future condition, as represented by study 7.1, also shows an elevated pumping pattern compared to the current operations as represented by studies 6.0 and 7.0.

Reclamation indicates that pumping at the Bill Jones Pumping Plant is limited to 4,200 cubic feet per second (cfs) in studies 6.0 and 7.0, which represent current operations (no intertie). In studies 7.1 and 8.0, pumping rates at Jones are increased to a maximum of 4,600 cfs in anticipation of the Delta-Mendota Canal intertie with the California Aqueduct. The future conditions indicate that Reclamation will maximize its pumping during the months of November through January (*i.e.*, 4,600 cfs) as often as possible. Figure 6-51 (the 50th percentile monthly export rates) indicates that these maximum rates will occur in most months when conditions permit as illustrated by the 95th percentile whisker bars, leaving only April, May, and June below the maximum pumping rate. Wet years tend to present the conditions when Reclamation can take advantage of the intertie and maximal pumping at 4,600 cfs compared to other water year types (figures 6-52 through 6-57). The comparisons between the current studies (6.0 and 7.0) and the future studies (7.1 and 8.0) indicate that only in the months of March and April are pumping rates typically lower in the future operations than in the current operations. The month of May, particularly in drier water years, has higher pumping rates than current operations. In critically dry years, the future conditions have higher pumping rates during the October through May period compared to those seen in the current operations. In the current studies (6.0 and 7.0), pumping is reduced in December, January, and February by the 25 TAF restrictions imposed by the EWA Program. Additional reductions occur in all four studies during the VAMP export reductions, but only the current studies have additional reductions associated with the EWA expenditures to supplement the VAMP shoulders in May for continued export reductions. The future studies (7.1 and 8.0) do not include these additional export reductions, presumably due to the limited EWA assets available. All four studies indicate that pumping will increase during the summer (July through September) for irrigation deliveries. The future studies increase the most during wet and above normal water year types, reaching near maximal pumping rates, while the drier water year types show mixed increases between the different modeling runs.

The modeling studies completed for the CVP/SWP operations BA indicate that total Banks exports increase in December, January and February for studies 7.1 and 8.0 due to the lack of full EWA assets as compared to the full EWA assets modeled for the current conditions (Studies 6.0 and 7.0). The modeling also indicates that the 50th percentile pumping rates approach or exceed 7,000 cfs during wet years and can exceed 8,000 cfs during January and February at the 95th percentile (see figure 6-58). Furthermore, the reductions in pumping during the April and May VAMP export curtailment are less than under the current operational conditions. This is created by the lack of sufficient volumes of water available (including the 48,000 AF available in-Delta from the Yuba River Accord) to offset the export reductions at Banks. During summer months (July to September), the future operations are modeled to include an additional 500 cfs above the 6,880 cfs maximum to offset “fish” related export reductions earlier in the year. The average monthly pumping levels at Banks are shown in figure 6-59 and clearly indicate that on average, the future operational conditions will have higher pumping rates from December through May than under the present conditions. This trend holds through most of the water year types, with future pumping levels being equivalent to or higher than the current operations during the winter and spring months in just about all monthly comparisons (figures 6-60 through 6-64).

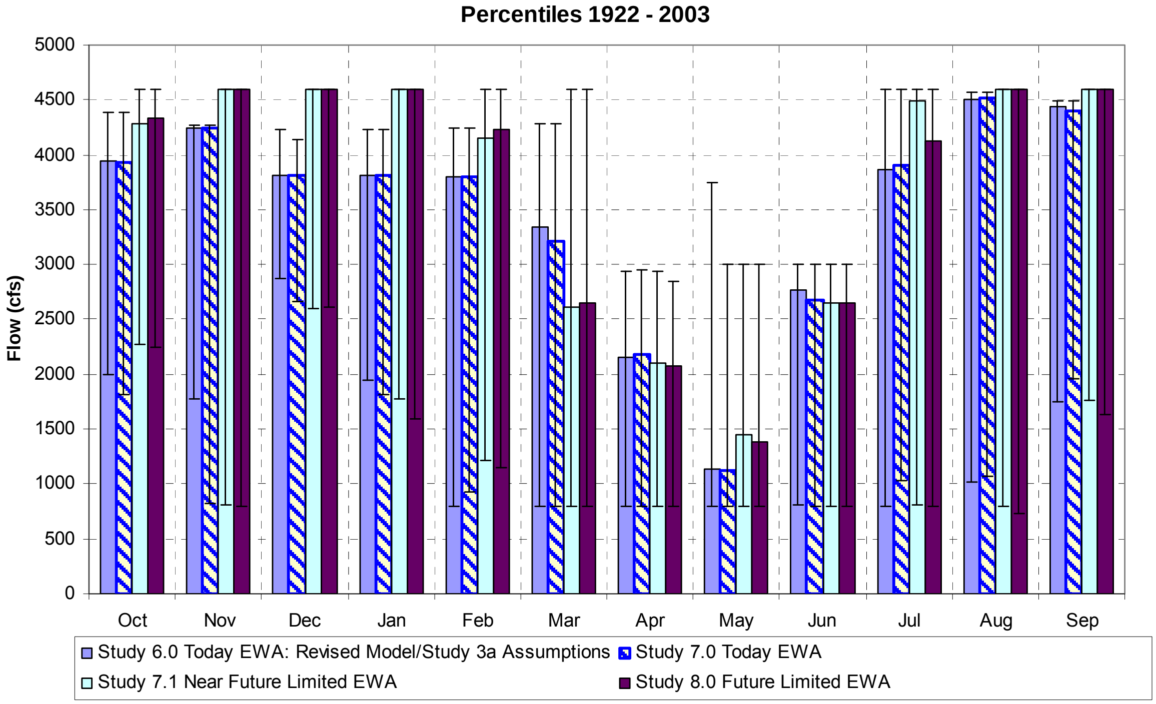


Figure 6-51. Monthly CVP export pumping rate, 50th percentile with 5th and 95th percentile whisker bars (CVP/SWP operations BA figure 12-18).

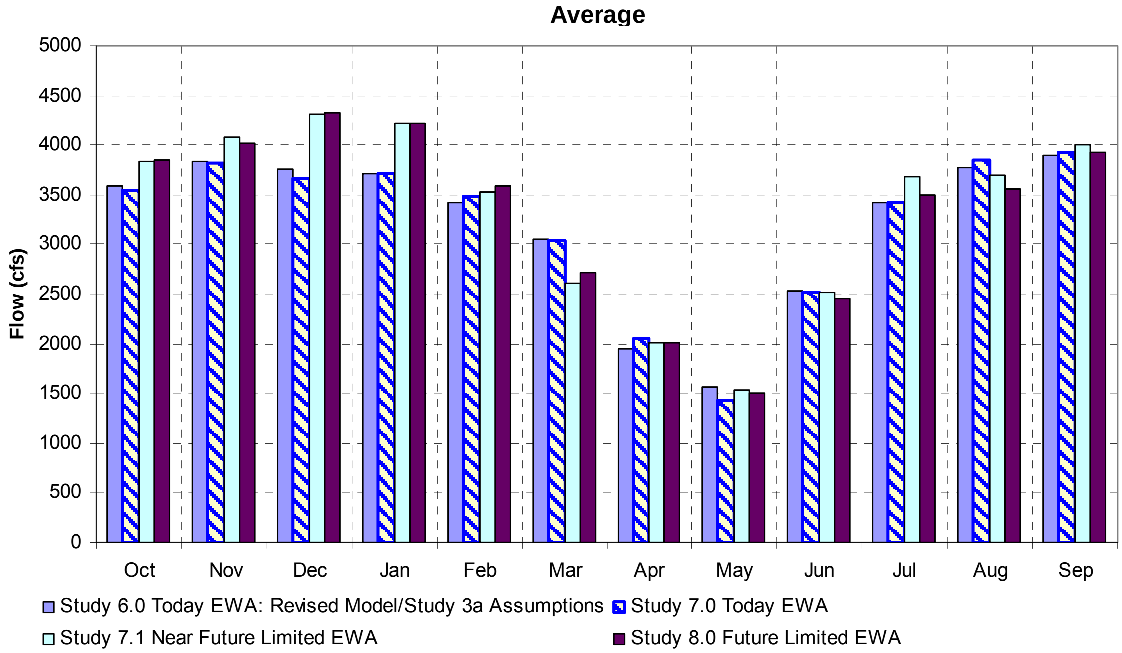


Figure 6-52. CVP monthly average export rate (CVP/SWP operations BA figure 12-19).

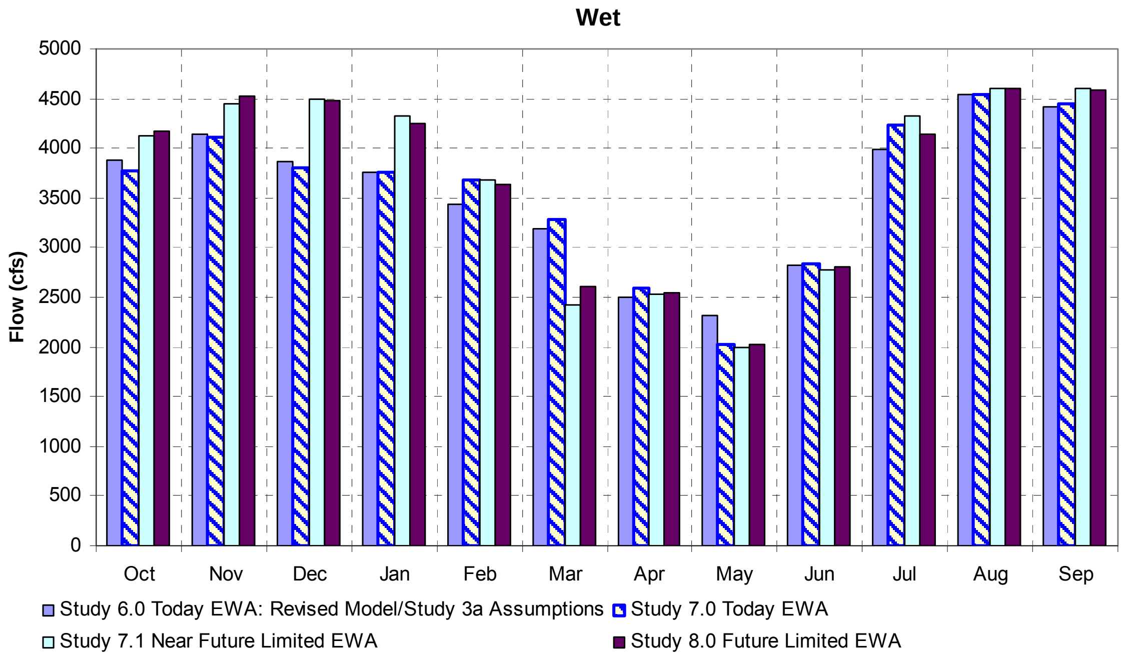


Figure 6-53. Average wet year (40-30-30) monthly CVP export rate (CVP/SWP operations BA figure 12-20).

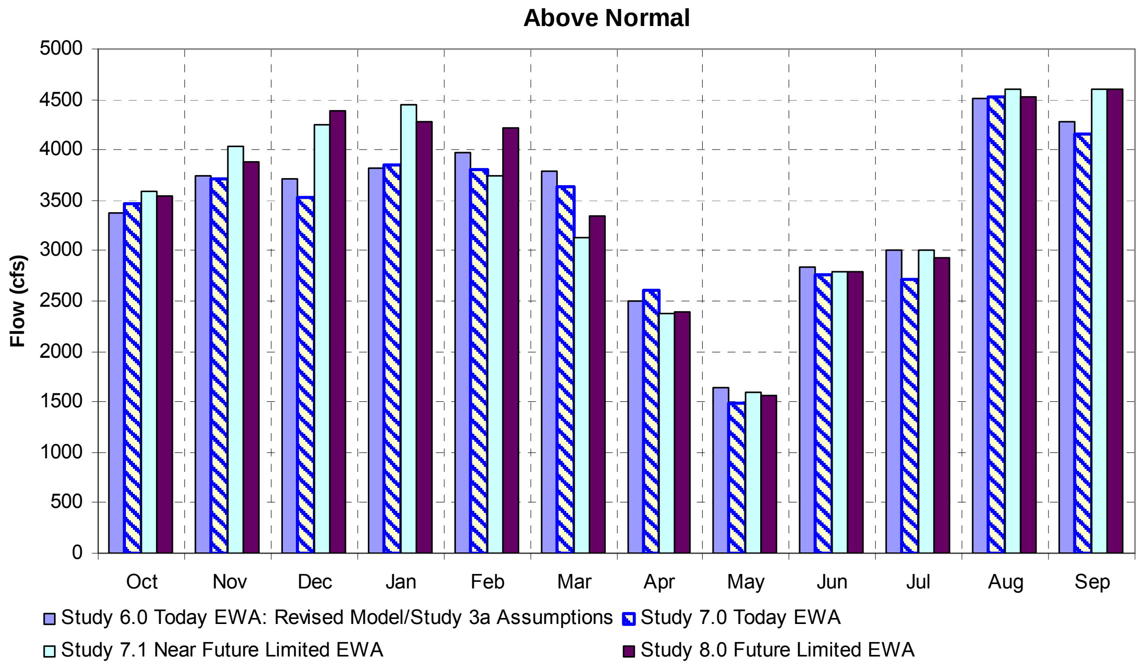


Figure 6-54. Average above normal year (40-30-30) monthly CVP export rate (CVP/SWP operations BA figure 12-21).

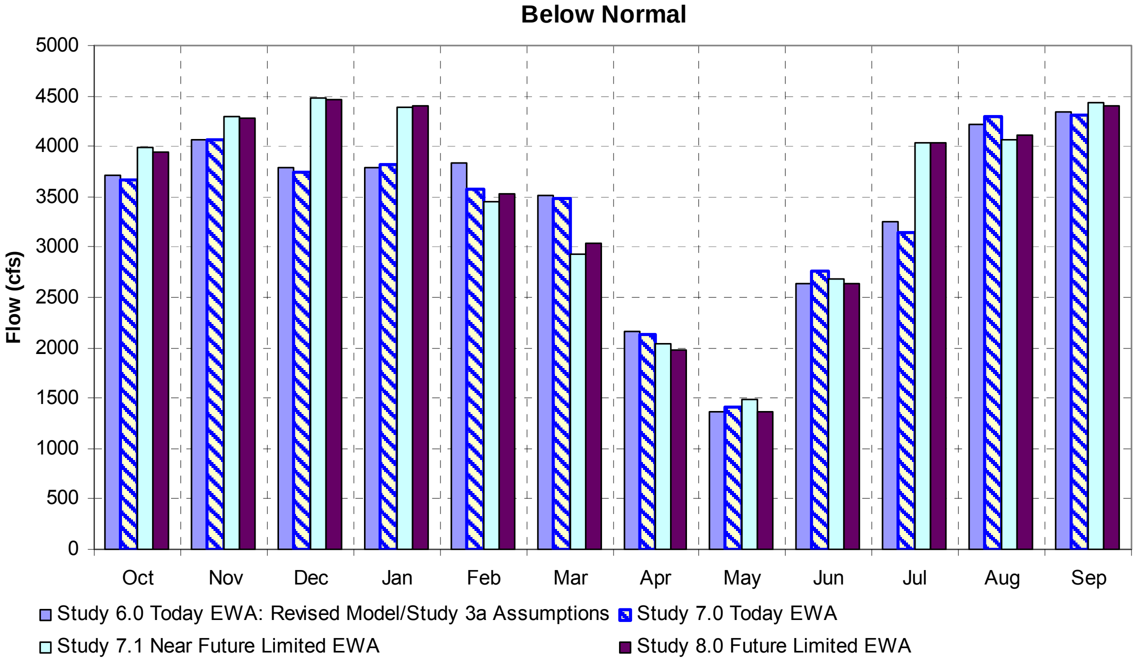


Figure 6-55. Average below normal year (40-30-30) monthly CVP export rate (CVP/SWP operations BA figure 12-22).

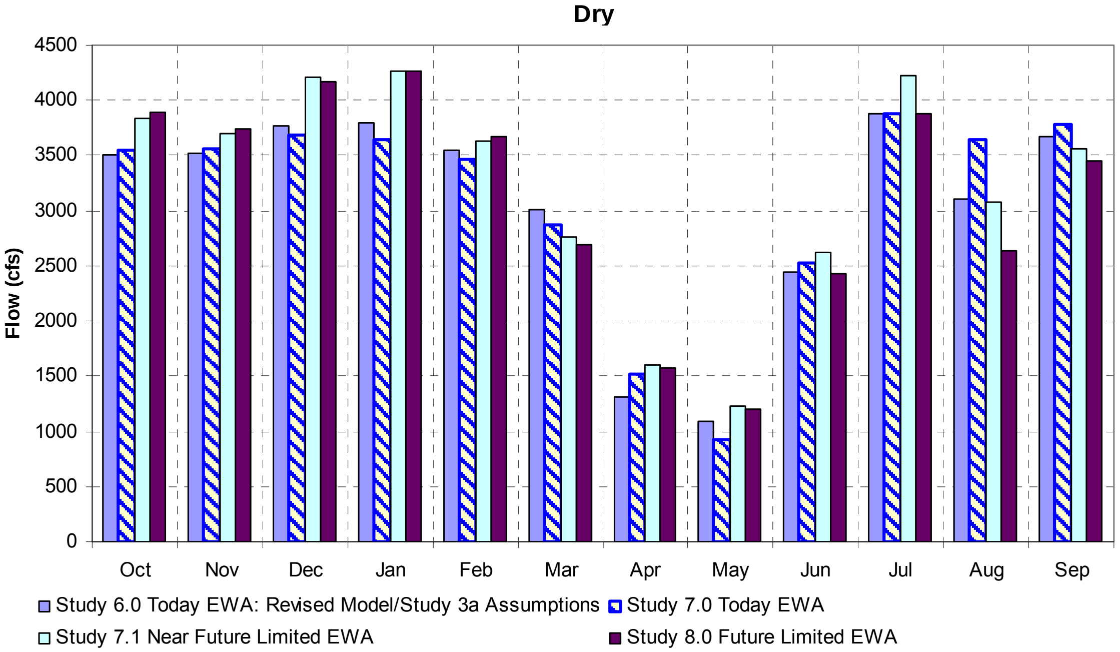


Figure 6-56. Average dry year (40-30-30) monthly CVP export rate (CVP/SWP operations BA figure 12-23).

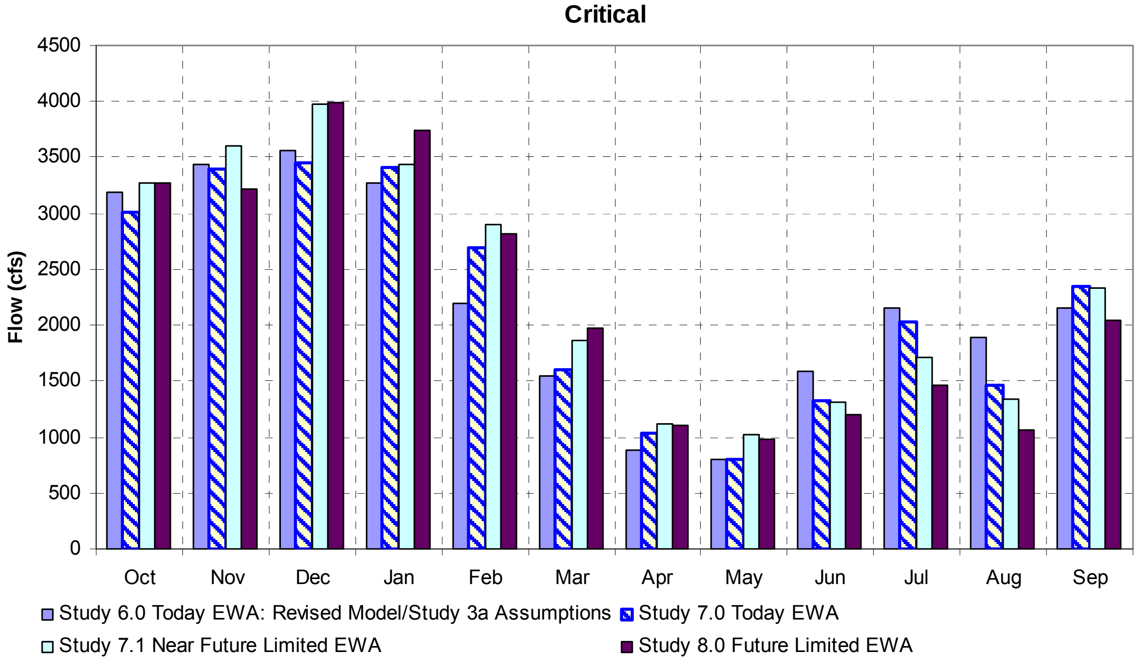


Figure 6-57. Average critically dry year (40-30-30) monthly CVP export rate (CVP/SWP operations BA figure 12-24).

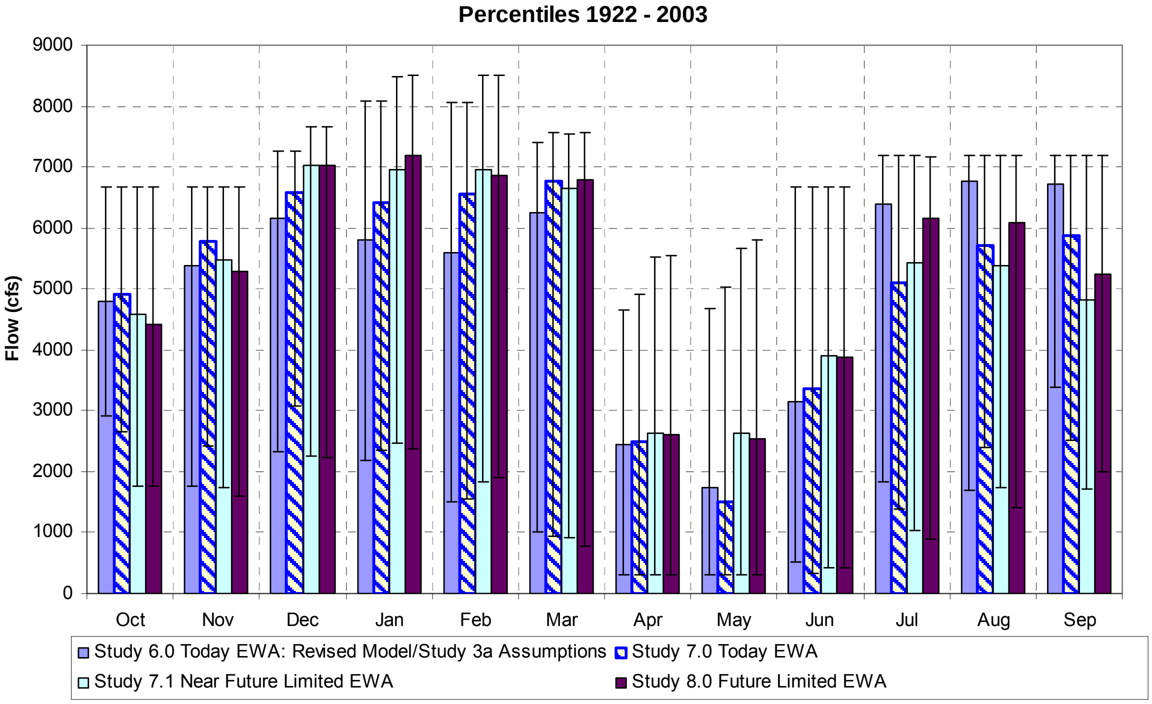


Figure 6-58. Monthly SWP export pumping rate, 50th percentile with 5th and 95th percentile whisker bars (CVP/SWP operations BA figure 6-25).

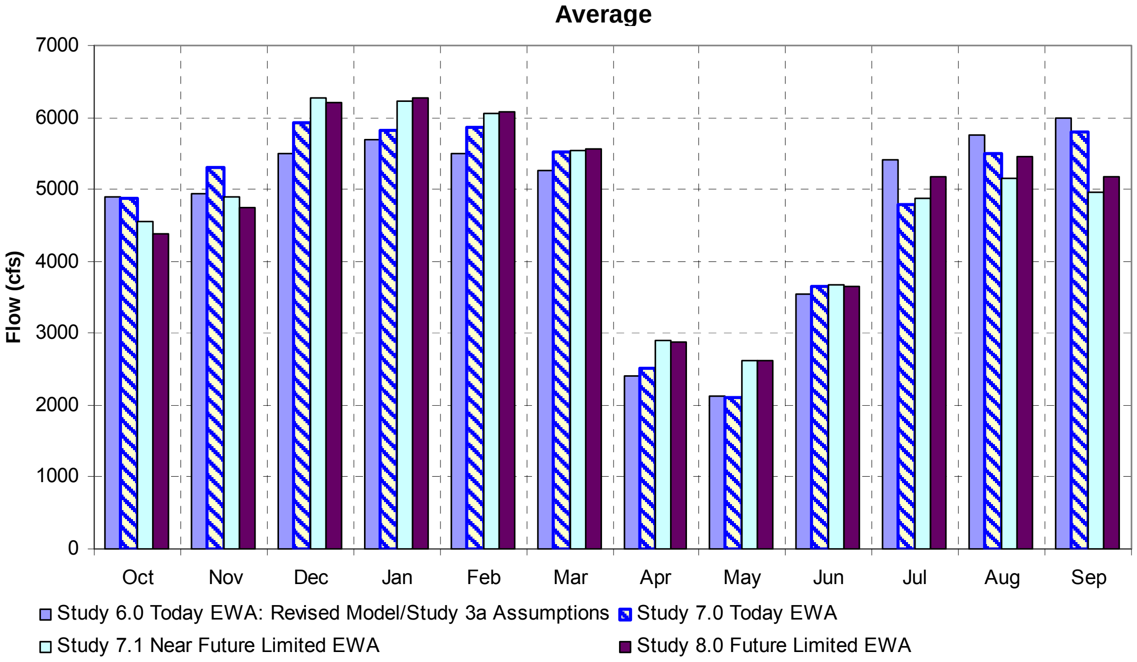


Figure 6-59. SWP monthly average export rate (CVP/SWP operations BA figure 12-26).

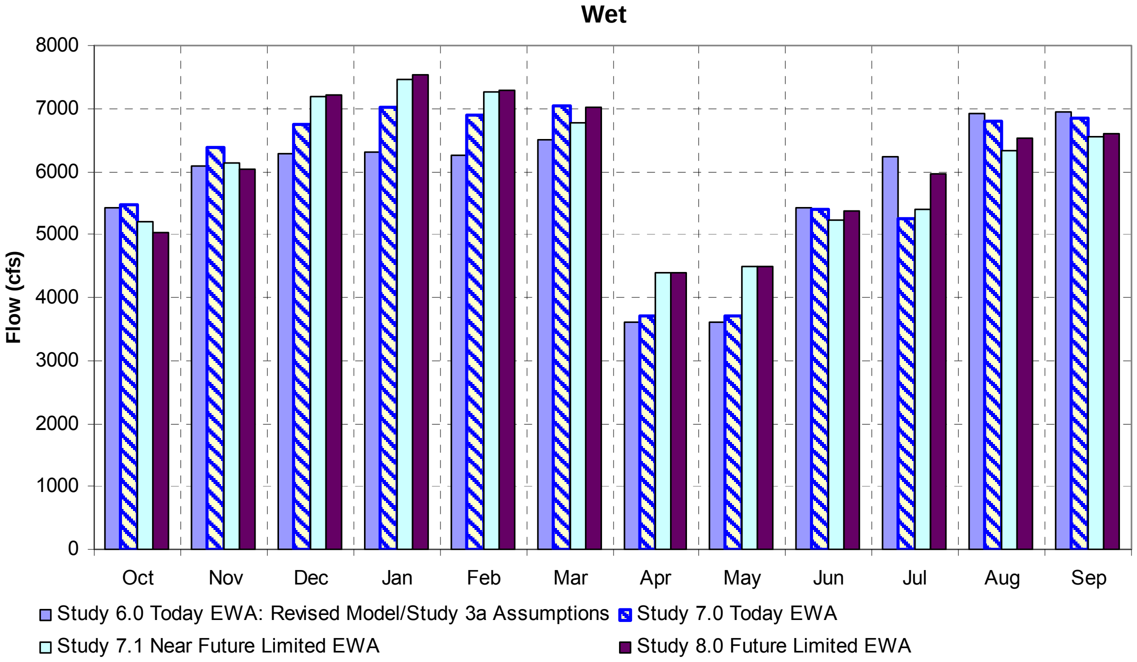


Figure 6-60. Average wet year (40-30-30) monthly SWP export rate (CVP/SWP operations BA figure 12-27).

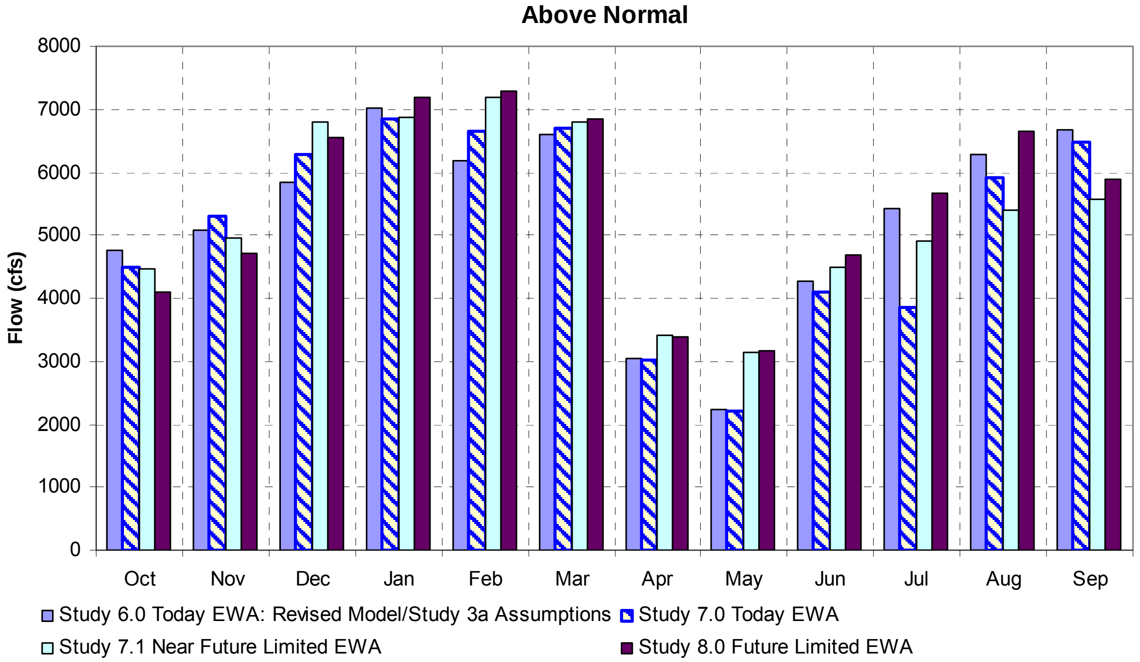


Figure 6-61. Average above normal year (40-30-30) monthly SWP export rate (CVP/SWP operations BA figure 12-28).

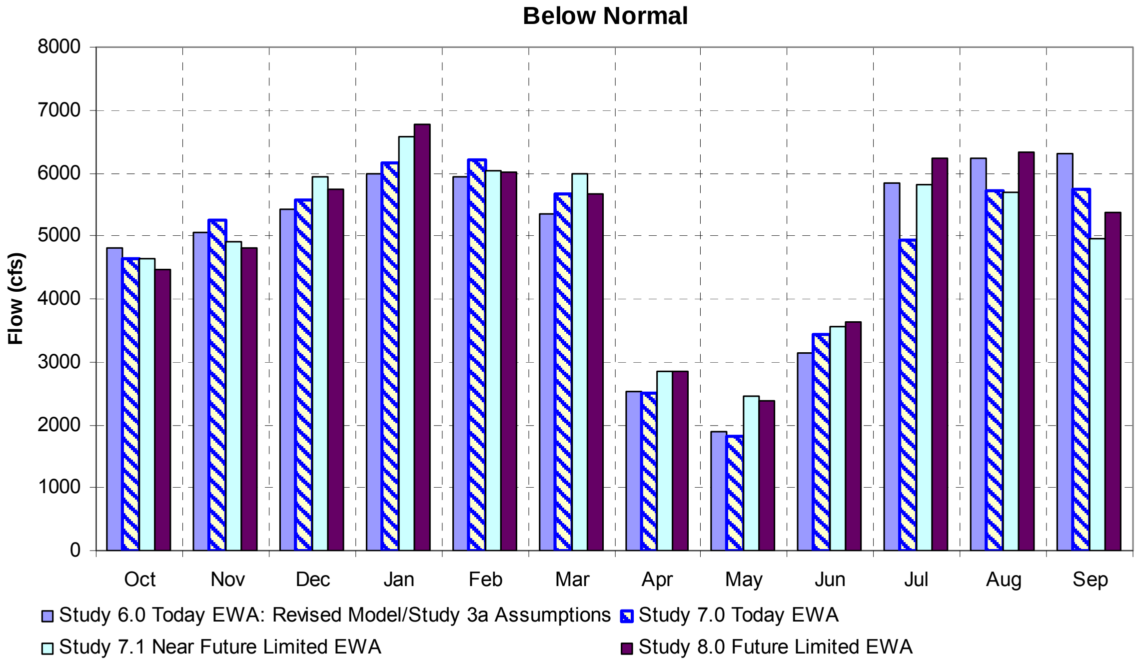


Figure 6-62. Average below normal year (40-30-30) monthly SWP export rate (CVP/SWP operations BA figure 12-29).

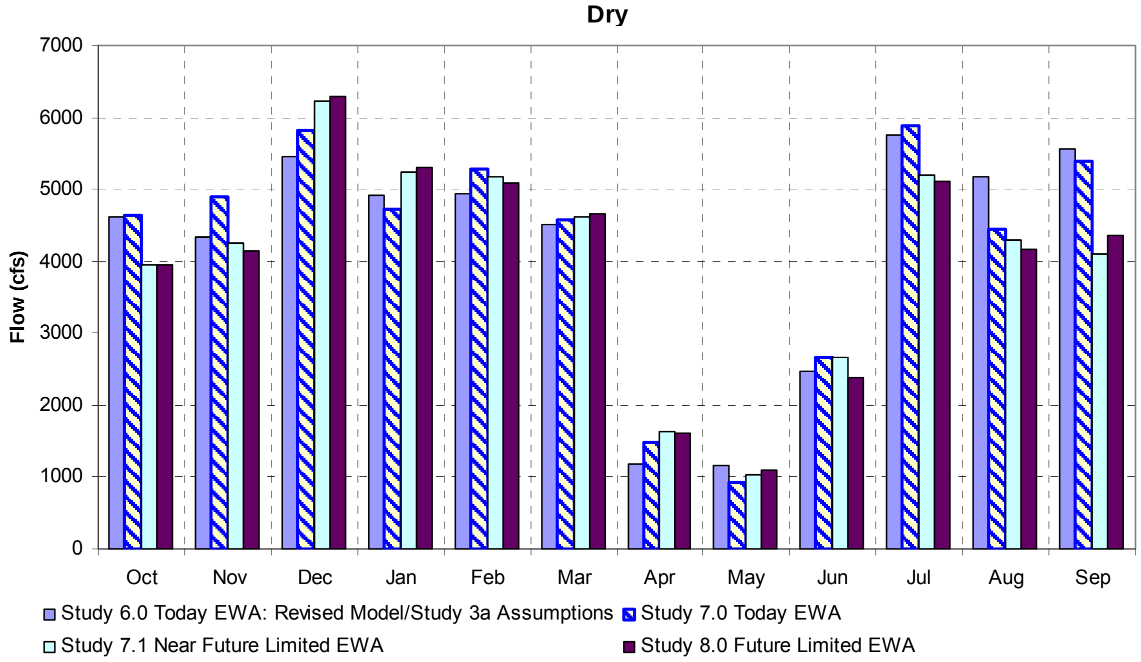


Figure 6-63. Average dry year (40-30-30) monthly SWP export rate (CVP/SWP operations BA figure 12-30).

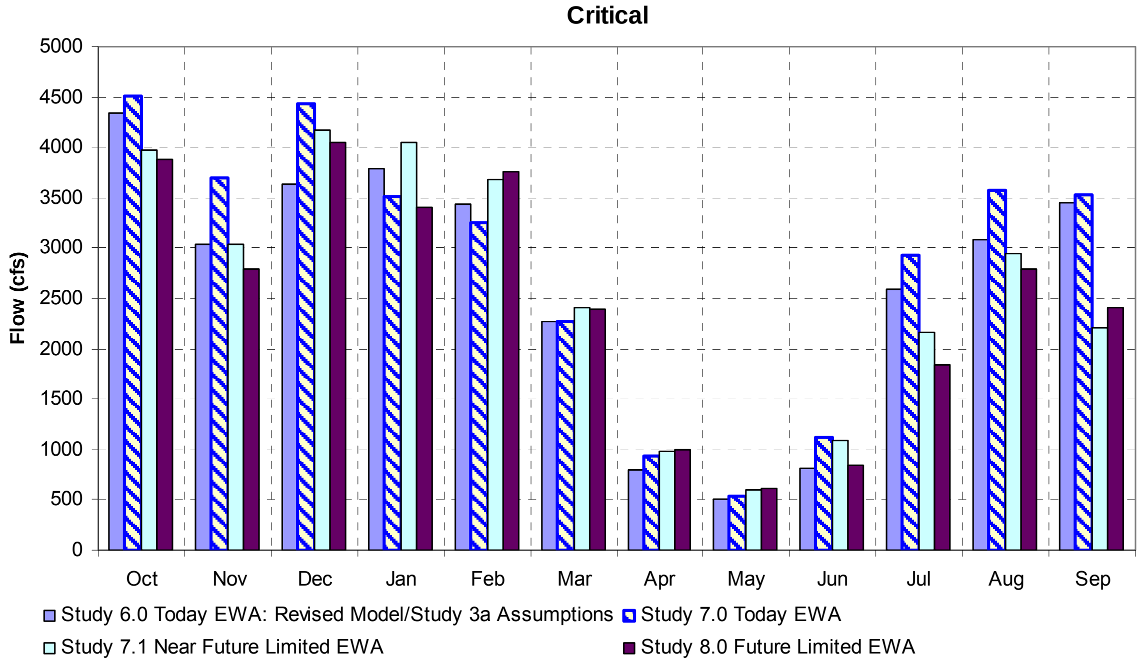


Figure 6-64. Average critically dry year (40-30-30) monthly SWP export rate (CVP/SWP operations BA figure 12-31).

Federal pumping at the Banks facility typically occurs in late summer and extends through October. Additional pumping to supply Cross Valley Contractors may occur during the winter months (November through March). The modeling indicates that the average Federal pumping at the Banks facility is approximately 80 TAF with the future operations having slightly higher pumping needs than the current operations as modeled in Study 7.0. Pumping in Study 7.1 is slightly higher (5 TAF) due to the lack of EWA wheeling relative to Study 7.0. The available capacity at Banks for Federal pumping is reduced in Study 8.0 due to increased SWP demands South of Delta, which reduces the frequency of the pumping availability for Federal use.

The Barker Slough pumping plant diverts water from Barker Slough into the North Bay Aqueduct (NBA) for delivery to Napa and Solano Counties. Current pumping capacity is 140 cfs due to limitations in the number of pumps at the facility. An additional pump is required to reach the pipeline design capacity of 175 cfs. During the past several years, daily pumping rates have ranged between 0 and 140 cfs. There has been no discernable trend in monthly pumping levels since 2000 (Dayflow database) although the annual pumping rate for water year 2007 was higher than in previous years (83 cfs). Seasonal pumping rates during the years 2005 to 2007 were 109 cfs in summer (June to August), 94 cfs in fall (September through November), 39 cfs in winter (December through February), and 36 cfs in spring (March through May). The recent historical data indicates that actual pumping levels are substantially less than those predicted in the CALSIM II current conditions scenario (Study 7.0) during the winter and spring months. For instance, the month of December has an average historical export rate of 52 cfs for the years 2005 through 2007. The estimated export rate for December from Study 7.0 is 116 cfs. The historical rate is only 44 percent of the modeled export rate. Similarly, the historical export rate for the month of April (2005 through 2007) is 31 cfs, while the estimate from Study 7.0 is 133 cfs. The historical export rate is only 23 percent of the modeled export rate.

During the summer, seasonal pumping rate for the modeled studies 7.0 and 7.1 are not substantially different from each other (average rates were 115 cfs and 107 cfs, respectively) but both were lower than the future condition modeled in Study 8.0 (135 cfs), a difference of 15 to 20 percent. The historical value for the summer season (2005 to 2007) is 109 cfs, relatively similar to the modeled current conditions. NBA diversions are lowest in fall, averaging 101 cfs in study 7.0, 99 cfs in study 7.1, and 123 cfs in study 8.0. The historical pumping rate during the fall (2005 to 2007) was 94 cfs. Modeled NBA diversions are highest during the winter months. There was very little difference between Studies 7.0 and 7.1 during the winter. However, study 8.0 differed from the other two studies, being greater in December (142 cfs versus 116cfs and 112 cfs) and lower in January (112 cfs versus 157 cfs and 155 cfs) and February (126 cfs versus 155 cfs and 154 cfs). All of the modeled pumping estimates are significantly greater than the historical average of 39 cfs for the period between December and February (2005 to 2007). Modeling estimates for the spring period also were substantially greater than the historical values from 2005 to 2007. The estimates for Study 8.0 export rates were also greater than those for Studies 7.0 and 7.1. For April, Study 8.0 had a diversion rate of 145 cfs while study 7.0 (133 cfs) and Study 7.1 (128 cfs) were lower, a difference of approximately 10 percent. For May, Study 8.0 also had a diversion rate of 145 cfs, which is approximately 25 percent higher than the estimated rates for Studies 7.0 and 7.1 (both 116 cfs). Study 8.0 estimated an export rate of 148 cfs for June, approximately 18 percent higher than the estimates for Study 7.0 (126 cfs), and Study 7.1 (123 cfs). The historical export rate for the spring period between 2005 and 2007 was 36 cfs.

Under the current operating parameters, the projects must comply with California State Water Resources Control Board (SWRCB) D-1641 limitations on the ratio of project exports to the volume of water entering the Delta during the year. This is termed the E/I ratio. The E/I ratio regulates the proportion of water that can be exported by the CVP and SWP in relation to the water that is entering the Delta and is thus available for export. During the summer and fall, E/I ratios are permitted to be higher (a maximum of 65 percent July through December) and therefore pumping rates are increased, allowing the facilities the flexibility to maximize exports (within the constraints of D-1641 and other regulatory limits) during the lower summer and fall Delta inflows. The E/I ratio is restricted to a 35 percent maximum during the February through June period when Delta inflows are typically higher. However, the actual volume of exports can increase significantly when the inflow volumes are high, while still maintaining the same overall E/I ratio. Furthermore, the E/I ratio is essentially determined by the flow volume of the Sacramento River, which comprises approximately 80 percent of the Delta river inflow. This creates a situation where the near field hydraulic conditions in the central and southern Delta waterways are affected to a greater extent than the northern delta waterways due to their proximity to the Project's points of diversion in the South Delta. The modeling for E/I ratios indicate that future operations (Studies 7.1 and 8.0) will have greater E/I ratios during the months of December, January, February, April, May and June compared to Studies 6.0 and 7.0, which typically allocated EWA assets in these months to decrease pumping levels. The limited EWA conditions in the future do not take any actions to reduce exports in the winter and only implement limited actions in the spring (*i.e.*, VAMP). Both current and future operations show increased E/I ratios in the summer months, except during dry and critically dry months, where the future models show decreases in some years. The CVP/SWP operations BA indicates that this is due to low reservoir storage or water quality issues, such as salinity, limiting the ability to pump. The modeling results indicate that due to the increased E/I ratios, the waterways of the South and Central Delta will experience more situations where flows towards the pumps are enhanced than under the current operating conditions.

In summary, historical average annual Delta inflow (1980 – 1991) is approximately 28 MAF (DWR 1995). Current operations divert approximately 6 to 8 MAF of water annually from the Delta (DWR 1995, CALFED 2008, State of California 2008). The modeling completed for the CVP/SWP operations BA indicates that Delta inflows will decrease approximately 200 to 300 TAF annually under the future conditions beyond those already occurring under the current operational scenario. The historical inflow has already been reduced by upstream water diversions to meet current demands in the Central Valley. The additional upstream withdrawals act on top of these withdrawals, thus further diminishing the volume of water reaching the Delta.

Likewise, annual Delta outflow will decrease approximately 300 to 400 TAF under the future operations as compared to the current operations (21 MAF). Most of this decrease will occur in the winter and spring due to limited EWA resources to decrease pumping levels during this time period. This exacerbates an already adverse situation for listed salmonids and green sturgeon created by the current CVP and SWP operations which have elevated winter/spring export levels. This period of elevated exports in winter and spring occurs during the season in which most salmonid runs emigrate through the Delta, as described in the environmental baseline. The lack of data for juvenile and sub-adult green sturgeon makes the effects determination less clear for this species of fish. Under the proposed action, the CVP will increase its pumping limits from 4,200 cfs to 4,600 cfs in response to the proposed intertie between the Delta-Mendota Canal and the California Aqueduct. Reclamation intends to maximize its pumping capacity between November and January by utilizing the 4,600 cfs capacity to its fullest extent. This will result in higher future pumping levels during this time period compared to the current operations, which will increase the exposure of early migrating salmonids to the effects of the exports. Modeling of future conditions also indicates that pumping will decrease, on average, in March and April. Future conditions also indicate that pumping in May will increase over current levels following the VAMP reductions, ultimately resulting in less protection for fish. This action will curtail the extent of post-VAMP shoulders. The future conditions also indicate that pumping will be increased, on average, during the summer in wet years compared to current operations. The modeling for the future SWP operations indicates that it will increase its exports in the months of December, January, and February to the greatest extent possible within the constraints of the regulatory environment. The rationale offered is that since it has limited EWA assets, the SWP will not be able to make any reductions in pumping for fish-related actions, which would normally be offset by EWA assets. The future modeling results also indicate that pumping rates will frequently be over 7,000 cfs during these months and as high as 8,000 cfs when San Joaquin River flows permit the additional capacity. Furthermore, average pumping rates are forecast to be higher during the December through May period than current averages, with less reductions occurring in April and May for VAMP due to less EWA assets available for fish protection measures.

This change in the export regime increases the vulnerability of listed salmonids emigrating through the Delta. The effects on listed green sturgeon are less clear due to the more ambiguous period of juvenile emigration into the Delta. Currently, the CVP and SWP have elevated export schedules during the early winter and late spring period (except for the period encompassing the VAMP experiment) to take advantage of higher flows of water passing through the Delta. The result of this export paradigm is that listed salmonids emigrating through the Delta with these flows are exposed to the increased exports.

The Federal use of the SWP facilities will amount to approximately 80 TAF per year, and will change little between the current and future conditions. Maximal usage of the SWP facilities by Reclamation will occur during the summer months and may result in an increase of up to 1,000 cfs of pumping in years with above normal hydrology, but is more likely to range between 400 and 600 cfs. The E/I ratios are more likely to be higher, on average, in the future compared to current operations, particularly during the critical salmonids migration months of December, January, February, April, May, and June. The explanation offered in the CVP/SWP operations BA is that the limited EWA assets will preclude pumping reductions to benefit fish.

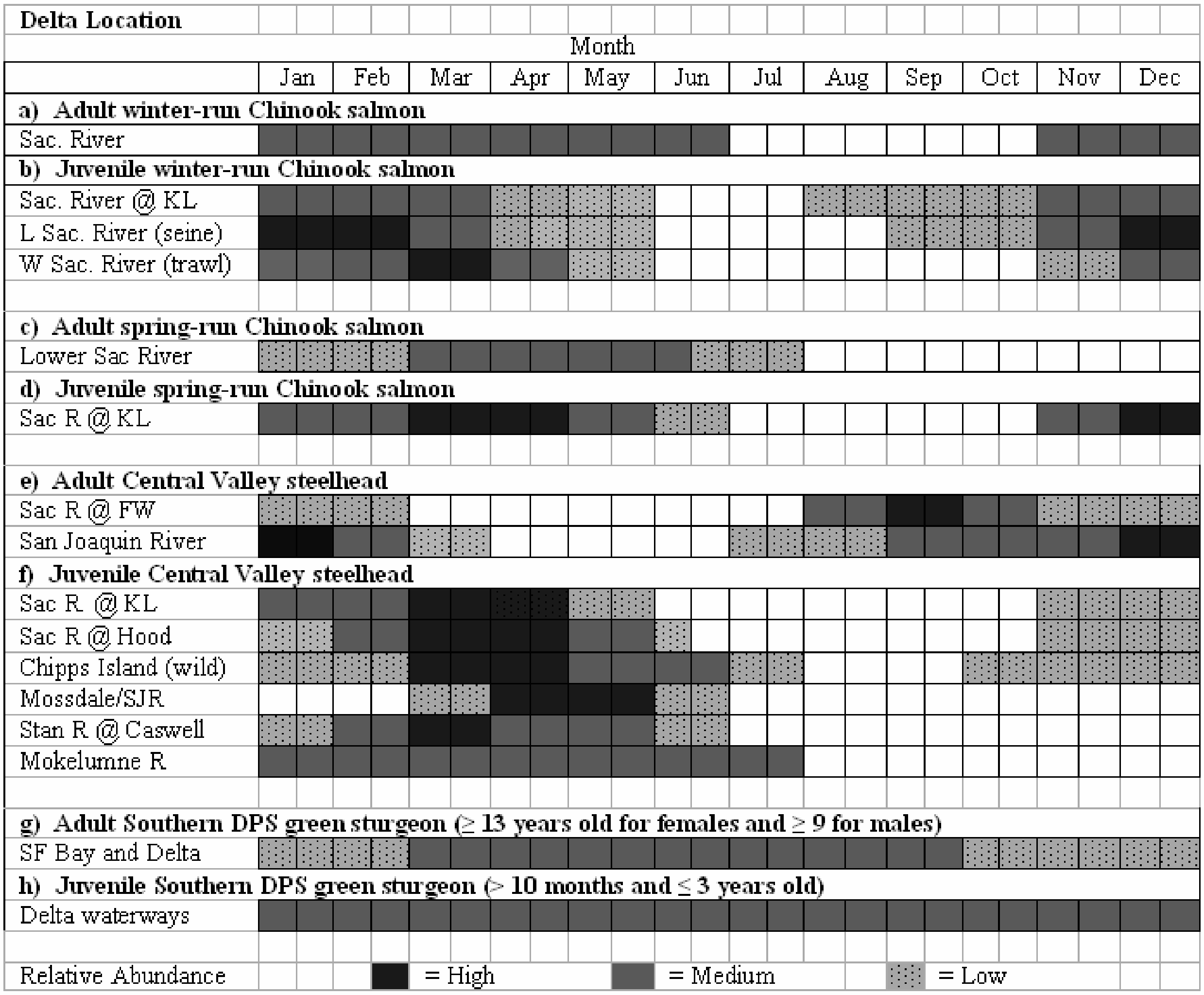
6.6.2.3 Assess Species Exposure

The Sacramento-San Joaquin Delta (figure 5-23) serves as the gateway through which all listed anadromous species in the Central Valley must pass through on their way to spawning grounds as adults or returning to the ocean as juveniles, or post-spawn steelhead and green sturgeon adults. For the purposes of this analysis, “exposure” is defined as the temporal and spatial co-occurrence of adult and juvenile (smolts and fry) life stages of the four listed species and the stressors associated with the proposed action. The temporal and spatial occurrence of each of the runs of Chinook salmon, CV steelhead, and green sturgeon in the Delta is intrinsic to their natural history and the exposure to the proposed action can be anticipated based on their timing and location.

6.6.2.3.1 Temporal Occurance

Table 6-27 provides the temporal distribution of listed anadromous fish species within the Delta.

Table 6-27. Temporal distribution of anadromous fish species within the Delta (KL = Knights Landing, FW = Fremont Weir).



Delta Location																								
	Month																							
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
a) Adult winter-run Chinook salmon																								
Sac. River	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩									▩	▩	▩	▩
b) Juvenile winter-run Chinook salmon																								
Sac. River @ KL	▩	▩	▩	▩	▩	▩	░	░	░	░					░	░	░	░	░	░	▩	▩	▩	▩
L Sac. River (seine)	■	■	■	■	▩	▩	░	░	░	░							░	░	░	░	▩	▩	■	■
W Sac. River (trawl)	▩	▩	▩	▩	■	■	▩	▩	░	░											░	░	▩	▩
c) Adult spring-run Chinook salmon																								
Lower Sac River	░	░	░	░	▩	▩	▩	▩	▩	▩	▩	░	░	░										
d) Juvenile spring-run Chinook salmon																								
Sac R @ KL	▩	▩	▩	▩	■	■	■	■	▩	▩	░	░									▩	▩	■	■
e) Adult Central Valley steelhead																								
Sac R @ FW	░	░	░	░											▩	▩	■	■	▩	▩	░	░	░	░
San Joaquin River	■	■	▩	▩	░	░							░	░	░	░	▩	▩	▩	▩	▩	▩	■	■
f) Juvenile Central Valley steelhead																								
Sac R @ KL	▩	▩	▩	▩	■	■	■	■	░	░											░	░	░	░
Sac R @ Hood	░	░	▩	▩	■	■	■	■	▩	▩	░										░	░	░	░
Chipps Island (wild)	░	░	░	░	■	■	■	■	▩	▩	▩	▩	░	░					░	░	░	░	░	░
Mossdale/SJR					░	░	■	■	■	■	░	░												
Stan R @ Caswell	░	░	▩	▩	■	■	▩	▩	▩	▩	░	░												
Mokelumne R	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩										
g) Adult Southern DPS green sturgeon (≥ 13 years old for females and ≥ 9 for males)																								
SF Bay and Delta	░	░	░	░	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	░	░	░	░	░	░
h) Juvenile Southern DPS green sturgeon (> 10 months and ≤ 3 years old)																								
Delta waterways	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩
Relative Abundance				■	= High					▩	= Medium						░	= Low						

6.6.2.3.1.1 Winter-Run

Adult winter-run first enter the San Francisco Bay Estuary from the Pacific Ocean starting in November. Adults continue to enter the bay throughout the winter months and into late spring

(May/June), passing through the Delta region as they migrate upriver towards their spawning grounds below Keswick Dam (CVP/SWP operations BA; USFWS 2001, 2003).

The main pulse of emigrating juvenile winter-run from the upper Sacramento River enter the Delta in December and January and can extend through April, depending on the water year type. Beach seines and mid-water trawls on the mainstem Sacramento River near the City of Sacramento indicate that some fish enter the Delta as early as mid-November and early December (USFWS 2001, 2003). Monitoring by the USFWS at Chipps Island in the western Delta indicates that winter-run are detected leaving the Delta from September through June, with a peak in emigration occurring in March and April. This peak in emigration timing is supported by the pattern of recoveries of winter-run sized Chinook salmon at the SWP's Skinner Fish Protection Facility and the CVP's Tracy Fish Collection Facility (TFCF) in the South Delta. In addition to the seasonal component of juvenile emigration, distinct increases in recovered fish appear to be correlated with high precipitation events and increases in-river flow and turbidity following rain events (USFWS 2001, 2003). Based on analysis of scales, winter-run smolts enter the ocean environment at an average fork length of 118 mm, indicating a freshwater residence time of approximately 5 to 9 months, most of which is presumed to occur upstream between RBDD and the Delta.

Juvenile winter-run are present in the waterways of the North Delta (*i.e.*, Sacramento River, Steamboat Slough, Sutter Slough, Miner Slough, and Cache Slough complex), Central Delta (Georgiana Slough, DCC, Snodgrass Slough, and Mokelumne River complex below Dead Horse Island), South Delta leading to the CVP and SWP pumping facilities including Old and Middle Rivers, and the interconnecting waterways between these main channels such as Victoria Canal, Woodward Canal, and Connection Slough, and the western Delta including the main channels of the San Joaquin and Sacramento rivers and Three Mile Slough. NMFS does not anticipate seeing adult winter-run upstream of Middle River on the San Joaquin River mainstem or within the waterways of the South Delta in any appreciable numbers. NMFS does not anticipate seeing any significant numbers of juvenile winter-run in the Eastern Delta near Stockton (*i.e.*, White Slough, Disappointment Slough, Fourteenmile Slough), or the mainstem of the San Joaquin River upstream of Columbia and Turner Cuts. Presence of winter-run adults and juveniles may occur in other parts of the Delta not described above.

6.6.2.3.1.2 Spring-Run

Adult spring-run enter the San Francisco Bay Estuary from the ocean in January to late February. They move through the Delta prior to entering the Sacramento River system. Spring-run show two distinct juvenile emigration patterns in the Central Valley. Fish may either emigrate to the Delta and ocean during their first year of life as YOY, typically in the following spring after hatching, or hold over in their natal streams and emigrate the following fall as yearlings. Typically, yearlings enter the Delta as early as November and December and continue to enter the Delta through at least March. They are larger and less numerous than the YOY smolts that enter the Delta from January through June. The peak of YOY spring-run presence in the Delta is during the month of April, as indicated by the recoveries of spring-run size fish in the CVP and SWP salvage operations and the Chipps Island trawls. Frequently, it is difficult to distinguish the YOY spring-run outmigration from that of the fall-run due to the similarity in their spawning and emergence times. The overlap of these two runs makes for an extended pulse of Chinook salmon smolts through the Delta each spring, frequently lasting into June.

Juvenile spring-run are present in the same waterways as winter-run in the North Delta, Central Delta, South Delta, and the interconnecting waterways, including the main channels of the San Joaquin and Sacramento rivers and Three Mile Slough. NMFS does not anticipate seeing any significant numbers of juvenile spring-run in the Eastern Delta or the mainstem of the San Joaquin River upstream of Columbia and Turner Cuts.

6.6.2.3.1.3 CV Steelhead

Adult steelhead have the potential to be found within the Delta during any month of the year. Unlike Chinook salmon, steelhead can spawn more than once, so post-spawn adults (typically females) have the potential to move back downstream through the Delta after completing their spawning in their natal streams. These fish are termed runbacks or kelts. Typically, adult steelhead moving into the Sacramento River basin begin to enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. Kelts are typically seen later in the spring following spawning. Steelhead entering the San Joaquin River basin are believed to have a later spawning run. Adults enter the system starting in late October through December, indicating presence in the Delta a few weeks earlier. Typically water quality in the lower San Joaquin River is marginal during this time, with elevated water temperatures and low DO levels presenting barriers to upstream migration. Early winter rains help to break up these barriers and provide the stimulus to adult steelhead holding in the Delta to move up river towards their spawning reaches in the San Joaquin River tributaries. Fish may continue entering the system through the winter months. Juvenile steelhead are recovered in the USFWS Chipps Island trawls from October through July. There appears to be a difference in the emigration timing between wild and hatchery-reared steelhead smolts. Adipose fin-clipped hatchery fish are typically recovered at Chipps Island from January through March, with the peak in recoveries occurring in February and March. This time period corresponds to the schedule of hatchery releases of steelhead smolts from the different Central Valley hatcheries (Nobriga and Cadrett 2003, CVP/SWP operations BA). The timing of wild steelhead (unclipped) emigration is more spread out. Emigration occurs over approximately 6 months, with peaks in February and March, based on salvage records at the CVP and SWP fish collection facilities. Individual unclipped fish first begin to be collected in fall and early winter, and may extend through early summer (June and July). Wild fish that are collected at the CVP and SWP facilities late in the season may be from the San Joaquin River system, based on the proximity of the basin to the pumps and the timing of the spring pulse flows in the tributaries (April-May). The size of emigrating steelhead smolts typically ranges from 200 to 250 mm in length, with wild fish tending to be at the upper end of this range (Nobriga and Cadrett 2003, CVP/SWP operations BA).

Given the multiple points of entry into the Delta system, CV steelhead are likely to be found in any of the waterways of the Delta, but particularly in the main channels leading to their natal river systems.

6.6.2.3.1.4 Southern DPS of Green Sturgeon

Adult green sturgeon enter the San Francisco Bay estuary in early winter (January/February) before initiating their upstream spawning migration into the Delta. Adults move through the Delta from February through April, arriving in the upper Sacramento River between April and June (Heublein 2006, Kelly *et al.* 2007). Following their initial spawning run upriver, adults may hold for a few weeks to months in the upper river (*i.e.*, GCID aggregation site; see Vogel 2005, 2008) or immediately migrate back down river to the Delta. Those fish that hold upriver move back downstream later in the fall. Radio-tagged adult green sturgeon have been tracked moving downstream from the GCID aggregation site past Knights Landing during the summer and fall into November and December, following their upstream migrations the previous spring. It appears that pulses of flow in the river “trigger” downstream migration in the late fall, similar to behavior exhibited by adult green sturgeon on the Rogue and Klamath River systems (Erickson *et al.* 2002, Benson *et al.* 2007).

Adults and sub-adults may also reside for extended periods in the western Delta as well as in Suisun and San Pablo bays. Like other estuaries along the west coast of North America, adult and sub-adult green sturgeon (from both Northern and Southern DPSs) frequently congregate in the tidal portions of the San Francisco Bay estuary during the summer and fall. It is not known exactly why these congregations occur, but they do not appear to be related to spawning activities, as most fish do not move upriver out of tidewater. Based on radio and acoustic tag data gathered to date from adult green sturgeon, fish that spawn in one river system do not spawn in other river systems.

Juveniles are believed to use the Delta for rearing for the first 1 to 3 years of their life before moving out to the ocean. Green sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. Juveniles are recovered at the SWP and CVP fish collection facilities year round and range in size from 136 mm to 774 mm, with an average size of 330 mm.

6.6.2.3.2 Spatial Distribution

6.6.2.3.2.1 Winter-Run

The main adult winter-run migration route through the Delta region is believed to be the mainstem of the Sacramento River. However, there is the potential for adults to “stray” into the San Joaquin River side of the Delta while on their upstream migration, particularly early in the migratory season (November and December). Significant amounts of Sacramento River water flow into the San Joaquin River side of the Delta through the DCC (when open in November, December, and January), Georgiana Slough, and Three Mile Slough. These sources of Sacramento River water can create false attraction into the lower San Joaquin River. Adult winter-run that choose this path would be delayed in their upstream migration while they mill in the lower San Joaquin River, searching for the distinctive olfactory cues of the Sacramento River. Adults could re-enter the Sacramento River through Georgiana Slough or the Delta reaches of the Mokelumne River system when the DCC is open. The extent of this delay and the proportion of adults moving into the lower San Joaquin River are unknown. Adult winter-run do not typically inhabit the San Joaquin River mainstem upstream of Middle River or within the waterways of the South Delta in any appreciable numbers (Yoshiyama *et al*. 1996, 1998, 2001.

Juvenile winter-run are present in the waterways of the North Delta (*i.e.*, Sacramento River, Steamboat Slough, Sutter Slough, Miner Slough, and Cache Slough complex), Central Delta (Georgiana Slough, DCC, Snodgrass Slough, and Mokelumne River complex below Dead Horse Island), South Delta leading to the CVP and SWP pumping facilities including Old and Middle Rivers, and the interconnecting waterways between these main channels such as Victoria Canal, Woodward Canal, and Connection Slough, and the western Delta including the main channels of the San Joaquin and Sacramento rivers and Three Mile Slough. Juvenile winter-run do not typically inhabit the channels of the Eastern Delta near Stockton (*i.e.*, White Slough, Disappointment Slough, Fourteenmile Slough), or the mainstem of the San Joaquin River upstream of Columbia and Turner Cuts.

6.6.2.3.2.2 Spring-Run

Currently, the only recognized populations of spring-run occur in the Sacramento River basin. Historical populations that occurred in the river basins to the south (*i.e.*, southern Sierra watersheds) have been extirpated. The main migration route for adult spring-run is the Sacramento River channel through the Delta. Similar to winter-run, adults may stray into the San Joaquin River side of the Delta due to the inflow of Sacramento River basin water through one of the interconnecting waterways branching off of the mainstem Sacramento River towards the San Joaquin River. Starting in February, the closure of the DCC radial gates minimizes the influence of this pathway, but flows in the channels of Georgiana and Three Mile Slough provide sufficient flows of water to the San Joaquin River to induce straying from "spurious" olfactory cues present in these waterways.

Juvenile spring-run are present in the same waterways as winter-run in the North Delta, Central Delta, South Delta and the interconnecting waterways, including the main channels of the San Joaquin and Sacramento rivers and Three Mile Slough. Juvenile spring-run do not typically inhabit the channels of the Eastern Delta or the mainstem of the San Joaquin River upstream of Columbia and Turner Cuts.

6.6.2.3.2.3 CV Steelhead

Populations of CV steelhead occur throughout the watersheds of the Central Valley; however, the primary population source occurs within the watersheds of the Sacramento River basin. Small, apparently self-sustaining populations of steelhead exist in the Mokelumne River system (although influenced by the Mokelumne River Hatchery steelhead program), the Calaveras River (natural) and the Stanislaus River (natural). Furthermore, otilith microchemistry analysis has shown that juvenile *O. mykiss* collected from the Tuolumne and Merced rivers had maternal steelhead origins (Zimmerman *et al*. 2008). Upstream migrating adult steelhead enter both the Sacramento River basin and the San Joaquin River basin through their respective mainstem river channels. Adult steelhead entering the Mokelumne River system (including Dry Creek and the Cosumnes River) and the Calaveras River system are likely to move up the mainstem San Joaquin River channel before branching off into the channels of their natal rivers. It is also likely that some adult steelhead bound for the San Joaquin River system may detour through the South Delta waterways and enter the San Joaquin River through the Head of Old River near Mossdale. However, due to the number of potential routes, the early entrance of adults into the Delta, and the potential for the DCC to remain open for a substantial portion of the upstream spawning migration, the "actual" route that an adult steelhead follows before committing to its natal watershed could be quite complex. Therefore, adult steelhead could be in any of the larger channels in the Delta region during their spawning migrations. Likewise, steelhead kelts could also be found in any of the channels of the Delta during their return to the ocean. Data for this particular life stage is lacking.

Outmigrating steelhead smolts enter the Delta primarily from the Sacramento River (North Delta region) and from the San Joaquin River (South Delta region). Steelhead smolts from the Mokelumne River system and the Calaveras River system enter the Eastern Delta. The Mokelumne River fish can either follow the north or south forks of the Mokelumne River through the Central Delta before entering the San Joaquin River at RM 22. Some fish may enter the San Joaquin River farther upstream if they diverge from the South Fork of the Mokelumne River into Little Potato Slough. Fish from the Calaveras River enter the San Joaquin River downstream of the Port of Stockton near RM 38. Steelhead smolts from the San Joaquin River basin enter the Delta at Mossdale. Prior to the installation of the Head of Old River Barrier (HORB) on approximately April 15 (start of VAMP), steelhead smolts exiting the San Joaquin River basin can follow either of two routes to the ocean. Fish may either stay in the mainstem of the San Joaquin River and move northwards towards the Port of Stockton and the Central Delta, or they may enter the South Delta through the Head of Old River and move northwards towards the lower San Joaquin River through Old and Middle rivers and their associated network of channels and waterways. When the HORB is not installed, approximately 50 percent of the San Joaquin River flow is directed into Old River. This percentage increases if the CVP and SWP are pumping at elevated levels. In fact, in low flow conditions with high pumping rates, the net flow in the mainstem of the San Joaquin between the Port of Stockton and Old River may reverse direction and flow upstream into the Head of Old River. When the HORB is installed, flow in the San Joaquin River is retained in the mainstem and fish are directed northwards towards the Port of Stockton and eventually through the Central Delta. Given the multiple points of entry into the Delta system, CV steelhead are likely to be found in any of the waterways of the Delta, but particularly in the main channels leading to their natal river systems.

6.6.2.3.2.4 Southern DPS of Green Sturgeon

Adult green sturgeon are presumed to primarily use the mainstem of the Sacramento River through the Delta when making their upstream spawning migrations. During high water conditions that result in the flooding of the Yolo bypass, adult green sturgeon may also utilize the floodplain of the Yolo bypass to move northwards from Cache Slough to the Sacramento River at Fremont Weir. During other times of the year, green sturgeon may be present in any of the waterways of the Delta, based on sturgeon tag returns. The draft report on the 2007 CDFG

Sturgeon Fishing Report Card (CDFG 2008) indicates that 311 green sturgeon were reported caught by sport anglers during 2007. Green sturgeon were caught in both the mainstem of the San Joaquin River between Sherman Island and Stockton (48 fish) and between Rio Vista and Chipps Island (62 fish), with most catches occurring in the fall, although fish were caught throughout the year in both reaches. Additional green sturgeon were caught and released in Suisun (30), Grizzly (14), and San Pablo (20) bays, as well as between Rio Vista and Knights Landing in the Sacramento River (16).

Juvenile and sub-adult green sturgeon are also found throughout the waters of the Delta. They have been recovered at the CVP and SWP fish collection facilities and from areas on the San Joaquin River near San Andreas Shoals.

6.6.2.4 Assess Species Response to the Proposed Action

6.6.2.4.1 Direct Entrainment Due to Exports

6.6.2.4.1.1 Tracy Fish Collection Facility - Current and Future Operations

The TFCF is located in the southwest portion of the Sacramento-San Joaquin Delta near the City of Tracy and Byron. It uses behavioral barriers consisting of primary and secondary louvers 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.

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 debris screen. The primary louvers allow water to pass through into the main Delta-Mendota intake channel and continue towards the Bill Jones Pumping Plant located several miles downstream. However, the openings between the louver slats are tight enough and angled against the flow of water in such a way as to prevent most fish from passing between them and, instead, guide them into one of four bypass entrances positioned along the louver arrays. The efficiency of the louver guidance array is dependent on the ratio of the water velocity flowing into the bypass mouth and the average velocity in the main channel sweeping along the face of the louver panels.

When south Delta hydraulic conditions allow, and within the original design criteria for the TFCF, the louvers are operated with the D-1485 objectives of achieving water approach velocities for striped bass of approximately 1 foot per second (fps) from May 15 through October 31, and for salmon of approximately 3 fps 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 50 years, the present-day TFCF is able to meet these conditions approximately 55 percent of the time. This indicates that 45 percent of the time, the appropriate velocities in the primary channel and the corresponding bypass ratio are not being met and fish are presumed to pass through the louvers into the main collection channel behind the fish screen leading to the pumps. The lack of compliance with the bypass ratios during all facility operations alters the true efficiency of louver salvage used in the expansion calculations and therefore under-estimates loss at the TFCF. The salvage estimates provided by the TFCF have not been recalculated to address these periods of noncompliance when the bypass ratios do not meet the specified operating criteria. The efficiency of the louvers is likely to vary in relation to the actual bypass ratio encountered.

Based on the project description, fish passing through the TFCF are required to be sampled for periods of no less than 20 minutes at intervals of every 2 hours when listed fish are present. This sampling protocol is expected to be implemented in the future operations of the TFCF. This is generally from December through June. Currently, sampling intervals are frequently 10 minutes every 2 hours, even though this sampling protocol is supposed to be used when listed fish are not present. Fish observed during sampling intervals are identified to 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. Fish may be held for up to 24 hours prior to loading into the tanker trucks. 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.

It has been known for some time that the efficiencies of the TFCF can be compromised by changes in hydrology, debris clogging the louvers, the size of the fish being entrained, and the number of predators present in the collection facilities (Reclamation 1994, 1995). The louvers were originally designed for fish >38 mm in length. Studies by Reclamation in 1993 tested three size ranges of Chinook salmon for primary, secondary, and overall louver efficiency. The test fish ranged in size from 58 mm to 127 mm with the averages of the three test groups being 74.3, 94.0, and 97.5 mm in length. The average efficiency of the primary louvers at the TFCF was found to be 59.3 percent (range: 13 - 82 percent) and the secondary louvers averaged 80 percent (range: 72 - 100 percent) for Chinook salmon. Overall efficiency averaged 46.8 percent (range 12 - 71.8 percent) for Chinook salmon. Recent studies (Reclamation 2008) have indicated that under the low pumping regimen required by the VAMP experiment, primary louver efficiencies (termed capture efficiencies in the report since only one bypass was tested) can drop to less than 35 percent at the TFCF. The reductions in pumping create low velocities in the primary channel, and the necessary primary bypass ratios (>1) cannot be maintained simultaneously with the secondary channel velocities (3.0 to 3.5 fps February 1 through May 31) required under D-1485. These study results indicate that loss of fish can potentially increase throughout the entire louver system if the entire system behaves in a similar way as the test section performed in the experiments. Screening efficiency for juvenile green sturgeon is unknown, although apparently somewhat effective given that green sturgeon, as well as white sturgeon, have been collected during fish salvage operations. Studies by Kynard and Horgan (2001) tested the efficiency of louvers at guiding yearling shortnose sturgeon (*Acipenser brevirostrum*) and pallid sturgeon (*Scaphirhynchus albus*) under laboratory conditions. They found that louvers were 96 to 100 percent efficient at guiding these sturgeon species past the experimental array and to the flume bypass. However, both sturgeon species made frequent contacts with the louver array with their bodies while transiting the louver array. The authors also found that sturgeon would rest at the junction between the louver array and the tank bottom for extended periods. This behavior may degrade the effectiveness of the louver array to guide fish towards the bypass.

In light of the data from the screen efficiency studies, the overall efficiency of the screens for Chinook salmon (46.8 percent) is approximately 62 percent of the "nominal" value of 75 percent efficient, the previously believed efficiency of the louvers. Bates and Jewett (1961 *op. cit.* Reclamation 1995) found the secondary louvers of the TFCF to be approximately 90 percent efficient for young Chinook salmon (> 38 mm in length), while Hallock *et al.* (1968) reported that the primary louvers had an efficiency of approximately 85 percent for similar-sized fish. This gives an overall efficiency of approximately 75 percent (0.90 x 0.85 = 0.765), which has been used in the calculations for determining salvage and loss at the TFCF. During the VAMP experimental period from approximately April 15 to May 15, the potential loss of Chinook salmon may be even greater. The efficiency of the primary louvers may only be 44 percent of the "standard" 80 percent efficiency originally claimed based on the 35 percent "capture" efficiency found in the low flow studies recently completed (Reclamation 2008). This essentially doubles the loss of fish moving through the screens due to the reduction in louver efficiency. It is likely that juvenile green sturgeon are also affected in a similar fashion as lower flows increase the potential for fish to slip through the angled louvers rather than being guided to the bypasses.

Currently, the louvers are cleaned from once to three times a day, depending on the debris load in the water. The salvage efficiency is significantly reduced during the louver cleaning process. During cleaning of the primary louvers, each one of the 36 individual louver panels is lifted by a gantry and cleaned with a stream of high-pressure water. The removal of the louver plate leaves a gap in the face of the louver array approximately 8 feet wide by 20 feet tall. The main pumps at the Bill Jones Pumping Plant continue to run during this process, pulling water through the gap in the louver array at a high velocity. The cleaning process for the primary array can take up to 3 hours to complete, during which time the efficiency of the louver system to screen fish is severely compromised. Similarly, the secondary louvers require that the four bypasses be taken off line to facilitate the cleaning of the louvers in the secondary channel. This process takes approximately 45 minutes to complete. When the bypasses are taken off line, fish are able to pass through the primary louvers due to the high primary channel velocity, which is often greater than the swimming capacity of the fish, pushing them through the louvers. Depending on the frequency of cleaning, screen efficiency is compromised from approximately 4 hours to 12 hours (1 to 3 cleaning cycles) per day, and substantial errors in the number of fish salvaged are likely to occur. Green sturgeon are also likely to be affected in a similar fashion by the removal of the louver screens during cleaning, perhaps even to a greater extent, since any gap along the bottom of the louver array where the louver panel comes in contact with the channel bottom could provide an access point to pass downstream of the louvers. Debris or sediment buildup could provide such a gap.

In response to the 2004 CVP/SWP operations Opinion issued by NMFS, Reclamation is conducting, or has proposed to conduct, studies designed to address the loss of listed fish caused by the louver cleaning operation (*Evaluation of the percent loss of salmonid salvage due to cleaning the primary and secondary louvers at the TFCF.* B. Bridges; principle investigator.

Report was scheduled to be completed by 2008), formulate alternative cleaning operations (*Design and evaluation of louvers and louver cleaners.* B. Mefford, R. Christensen, D. Sisneros, and J. Boutwell, principle investigators. Report was scheduled to be completed by 2008), and investigate the impacts of predators on juvenile Chinook salmon and Delta smelt in the primary channel (*Predator impacts on salvage rates of juvenile Chinook salmon and Delta smelt.* R. Bark, B. Bridges, and M.D. Bowen, principle investigators. This report is due in 2010). However, the project description does not contain any commitment to address these deficiencies and it may be several years before these reports and their proposed remedies transform the operations of the TFCF.

The TFCF will primarily have direct impacts on emigrating salmonids during their juvenile and smolt life history stages, as well as juvenile green sturgeon rearing in the south Delta region. These life history stages are vulnerable to the entrainment effects of the pumping actions of the Bill Jones Pumping Facility, which draws water from the channels of the South Delta to supply the Delta-Mendota Canal and furnish water to the CVP's water contractors south of the Delta. Adult fish are less susceptible to the effects of the screening process. However, some adverse effects have been observed in association with the trash racks in front of the screens. Adult fish cannot fit through the narrow gap between the steel slats on the trash rack. This serves as a physical barrier to their passage. Observations of sea lions "corralling" adult fall-run in front of the TFCF trash rack have been observed by TFCF staff and a NMFS biologist. In addition, adult sturgeon in moribund conditions have been observed impinged upon the trash rack. The causative factor for the sturgeon's initial condition is unknown, but the fish eventually perish against the racks unless rescued and rehabilitated in the aquaculture facility at the TFCF. Predation by sea lions on sturgeon at the TFCF has not been observed to the best of NMFS' knowledge. The anticipated effects of the screening operation upon juvenile salmon and smolts are the direct loss of fish through the louvers. Based upon the information already presented above, this could be more than half of the fish that encounter the screens initially (46.8 percent overall louver efficiency during normal operations, <35 percent overall efficiency during VAMP operations, potential total failure during screen cleaning operations). Fish that pass through the louver array are lost forever to the population. This loss represents not only the loss of individual fish, but a decline in the population abundance as a whole, as these fish represent the survivors of the initial downstream emigration from the spawning areas upstream to the Delta, a journey with its own intrinsically high rate of mortality. The initial loss of fish emigrating downstream in the Sacramento River may be potentially as high as 80 percent based on MacFarlane's (2008) acoustic tagging study. There is additional loss of these fish as they cross the Delta and arrive at the fish collection facilities.

Salmonids and sturgeon that are successfully screened still face adverse factors during the collection phase of the screening process. The physical process of screening exposes the fish to sustained flows along the face of the louver array, to which the fish will typically try to swim against before being entrained into the bypass orifice. Once entrained into the primary bypass, the fish is carried in a dark turbulent flow through the bypass pipeline to the secondary screening channel, where it is again screened by louvers into a second pipeline that finally discharges to the holding tanks for final collection and salvage. During this process, the fish are subjected to turbulent flows, encounters with the walls of the pipeline and screening channels, debris in the flow stream, and predators. This creates stressful conditions for the fish and reduces its physiological condition. These external stressors lead to the release of stress hormones (i.e., catecholamines and corticosteroids) from the fish's endocrine system. Following the release of these stress hormones, a stage of resistance occurs, during which the stress hormones induce changes in the physiological processes in the fish that either help repair any damage (*e.g.*, if the stressor caused a physical injury) or help the animal adapt to the stressors (*e.g.*, if the stressor is a change in environmental conditions like temperature or turbulence) by changing the rate of body functions beyond the "normal" range. If adaptation to the stressors is not possible, because of either the severity or prolongation of the challenge, exhaustion ensues followed by permanent malfunctioning, possibly disease, and ultimately death to the exposed fish (Fagerlund *et. al.* 1995). In other words, delayed responses to the stress of screening are very likely, and could lead to ultimate morbidity or mortality subsequent to the collection procedure. Due to the short period of "observation" of collected fish during the collection, handling, trucking and release (CHTR) process, the ultimate fate of the salvaged fish following release is unknown, particularly in the open Delta/ocean environment following release where additional environmental stressors are present and to which the emigrating fish will be exposed. The CHTR process will be described in more detail in a following section.

Based upon the projected increases in pumping rates modeled in the near future and future conditions (Studies 7.1 and 8.0), the number of fish entrained at the pumps is predicted to increase in proportion to the pumping increases and thus in general be greater than current levels, particularly in the early winter (December through February) and during the VAMP experiment. Furthermore, the proportion of fish salvaged may be overestimated while those lost to the system are likely to be underestimated using the current values for screening efficiencies (75 percent) rather than the 46.8 percent overall efficiency determined in the 1995 studies and the recent VAMP period studies (Reclamation 2008). This would indicate that the TFCF has a greater adverse impact than currently acknowledged. Specific effects to listed salmonid ESUs will be discussed in the salvage section below.

6.6.2.4.1.2 John E. Skinner Fish Protection Facilities – Current and Future Operations

The John E. Skinner Fish Protection Facility was built in the 1960s and designed to prevent fish from being entrained into the water flowing to the Harvey O. Banks Pumping Facility, which lifts water from the inlet canal into the California Aqueduct. The fish screening facility was designed to screen a maximum flow of 10,300 cfs. Water from the Delta is first diverted into Clifton Court Forebay, a large artificially flooded embayment that serves as a storage reservoir for the pumps, prior to flowing through the louver screens at the Fish Protection Facility. After water enters the forebay through the radial gates, it first passes a floating debris boom before reaching the trashrack. The floating debris boom directs large floating material to the conveyor belt that removes the floating material for disposal in an upland area. Water and fish flow under the floating boom and through a trashrack (vertical steel grates with 2-inch spacing) before entering the primary screening bays. There are 7 bays, each equipped with a flow control gate so that the volume of water flowing through the screens can be adjusted to meet hydrodynamic criteria for screening. Each bay is shaped in a "V" with louver panels aligned along both sides of the bay. The louvers are comprised of steel slats that are aligned 90 degrees to the flow of water entering the bay with 1-inch spacing between the slats. The turbulence created by the slats and water flowing through the slats guides fish to the apex of the "V" where bypass orifices are located. Fish entrained into the bypass orifice are carried through underground pipes to a secondary screening array. The older array uses the vertical louver design while the newer array uses a perforated flat plate design. Screened fish are then passed through another set of pipes to the holding tanks. Fish may be held in the holding tanks for up to 8 hours, depending on the density of salvaged fish and the presence of listed species.

Like the TFCF, the louvers are not 100 percent efficient at screening fish from the water flowing past them. Louver efficiency is assumed to be approximately 75 percent (74 percent, DWR 2005b) for calculating the loss through the system, although this value may eventually be shown to be incorrect (see TFCF discussion). Recent studies examining pre-screen predation in Clifton Court Forebay on steelhead smolts (DWR 2008) have tracked a tagged steelhead through the screens into the inlet channel leading to the Banks Pumping plant and then back into the forebay by the trash boom. This passage through the louvers occurred during a period of low pumping rates, indicating that this steelhead was able to negotiate the louvers and the water velocities flowing through it in both directions. Like the TFCF, the individual louver panels are lifted by a gantry crane from their position in the louver array and cleaned with high-pressure water stream to remove debris and vegetation that clog the louver slats. However, flow into each bay can be manipulated or turned off, thereby reducing potential loss through open louver racks. Nevertheless, it should be noted that any fish within the bay following the closure of the bay during cleaning would be vulnerable to loss through the open louver panel slots. This may be of greater concern for sturgeon based on their behavioral response to the louvers as previously described.

The Skinner Fish Protection Facility will primarily have direct impacts on emigrating salmonids during their juvenile and smolt life history stages, although adult salmon, steelhead, and sturgeon (both white and green) are also likely to be entrained into the forebay (adult striped bass move freely into and out of the forebay when hydraulic conditions at the radial gates permit it). Adult and juvenile sturgeon have been observed in the forebay and juveniles appear in the fish salvage collections. These juvenile salmonid life history stages are vulnerable to the entrainment effects of the pumping actions of the Harvey O. Banks Pumping Facility, which draws water from the channels of the South Delta to supply the California Aqueduct and furnish water to the SWP's water contractors. The anticipated effects of the screening operation are the direct loss of fish through the louvers. As discussed for the TFCF, this loss represents not only the loss of individual fish, but a decline in the Chinook salmon population abundance as a whole due to the loss of several hundred to several thousand individual fish annually at the SWP facilities. These fish represent the survivors of the initial downstream emigration from the upstream spawning areas to the Delta. This journey has its own intrinsically high rate of mortality. Overall loss during this portion of the emigration to the ocean may be potentially as high as 80 percent based on MacFarlane's (2008) acoustic tagging study. There is additional loss of these fish as they cross the Delta and arrive at the fish collection facilities, so that only a fraction of the downstream emigrating population survives to encounter the screens.

As previously described for the TFCF operations, salmonids and sturgeon that are successfully screened still face adverse factors during the collection phase of the screening process at the Skinner facility. Like the TFCF, fish are moved through bypass pipelines from the primary louvers to the secondary louver and thence to the collection tanks. Fish are subjected to stressful conditions during this phase of the salvage and collection operations. Following discharge to the collection tanks, fish are processed through the CHTR operation and returned to the western delta. Delayed responses to the stress of screening are very likely, as previously described in the discussion for the TFCF, and could lead to ultimate morbidity or mortality subsequent to the collection procedure (Fagerlund *et al.* 1995). Due to the short period of "observation" of collected fish during the CHTR process, the ultimate fate of the salvaged fish following release is unknown. The CHTR process will be described in more detail in a following section.

Based upon the projected increases in pumping rates modeled in the near future and future conditions (Studies 7.1 and 8.0) for the SWP, the number of fish entrained at the Skinner Fish Protection Facility is predicted to increase in proportion to the pumping increases and, thus, in general, be greater than current levels, particularly in the early winter (December through February) and during the VAMP experiment. The experimental data indicating that "large" fish, such as a steelhead smolt, can pass through the louvers in both directions calls into question the stated efficiency of the louvers in screening out fish in the size range of interest for listed salmonid species (DWR 2008). If the stated efficiencies for the louvers are less than expected, as appears to be the case for the TFCF, then the numbers of fish salvaged and the numbers of fish lost to the system is suspect. Like the TFCF, the impacts to listed salmonids (and potentially green sturgeon) would be greater than anticipated, both currently and in the modeled future. Regardless of the actual efficiencies of the louver screens, the increased pumping predicted by the modeling scenarios will increase the number of fish lost to the system and increase the adverse effects upon listed salmonids in general. Specific effects to listed salmonid ESUs/DPS and green sturgeon will be discussed in the salvage section below.

6.6.2.4.1.3 Clifton Court Forebay Predation Losses

Clifton Court Forebay is operated as a regulating reservoir for the SWP's Harvey O. Banks Pumping Plant in the tidally influenced southern Delta. The forebay allows the SWP to take in water during different portions of the tidal cycle, as permitted by water rights and legal constraints, contain the water by closing radial gates at the inlet of the forebay, and subsequently operating its pumps more efficiently. The forebay was created in 1969 by flooding a 2.6-mile by 2.1-mile tract of agricultural land near Byron, California, creating a 2,200-acre impoundment. The five radial gates at the inlet of the forebay leading to Old River are typically opened following the peak of the high tide and held open for a portion of the ebb tide when the water elevation outside the gates is higher than that inside the gates in the forebay. Water velocities passing through the gates typically approach 14 fps at maximal stage differential, and may for brief periods even surpass this. However, the design criteria for the gates discourage these excursions due to scouring through the mouth of the gates and the surrounding channel area. Currently, a very deep scour hole (approximately 60 feet deep) has formed just inside the forebay, adjacent to the location of the radial gates. When the gates are open, and the flow of water enters the forebay, numerous aquatic species, including many species of fish, are entrained. Included among these species of fish are Chinook salmon (including endangered winter-run and threatened spring-run), threatened CV steelhead, and threatened North American green sturgeon from the Southern DPS (DWR 2005, 2008).

Losses of fish entrained into Clifton Court Forebay occur during passage from the radial gates across the 2.1 miles of open water in the forebay to the salvage facility. This is termed pre-screen loss, and includes predation by fish and birds. Much of this pre-screen loss is thought to be attributable to predation by piscivorous fish, such as striped bass (Gingras 1997, DWR 2008). Gingrass (1997) described a series of survival studies conducted in Clifton Court Forebay using juvenile Chinook salmon and juvenile striped bass. Of the 10 studies cited, 8 evaluated losses of hatchery-reared juvenile Chinook salmon, and 2 evaluated losses of hatchery-reared juvenile striped bass. The calculated loss across Clifton Court Forebay ranged from 63 to 99 percent for juvenile Chinook salmon and 70 to 94 percent for the juvenile striped bass. Gingras (1997), however, opined that naïve hatchery fish introduced directly into Clifton Court Forebay may be more susceptible to predation than wild fish or fish already acclimated to the natural environment, but of hatchery origin (habituated fish). Gingras (1997) states that “introduction of experimental fish directly into Clifton Court Forebay may contribute a large portion of observed pre-screen loss, regardless of other experimental and/ or operational variables (*e.g.*, release group size, experimental fish size, degree of habituation, and export rate). Experimental fish are typically subject to varying degrees of (1) temperature shock (Orsi 1971, Coutant 1973, Kjelson and Brandes 1989), (2) altered salinity, and (3) altered light regime, in addition to turbulent flow and predation at the radial gates. Habituated fish entrained into Clifton Court Forebay would only be subject to turbulent flow and predation near the radial gates. The combined and differential effect of these “acute stressors” on experimental fish should increase vulnerability to predation (Coutant 1969, Orsi 1971, Olla *et al.* 1992, Young and Cech 1994, Mesa 1994, Cech *et al.* 1996).” Gingras (1997) also identified potential biases resulting from the calculation of salvage and pre-screen loss due to expansion of enumerated fish in the salvage counts and estimates of total fish released per experiment based on weight and lengths, effects of introducing large numbers of fish at one time on the efficiency of predators (protective schooling effect), and fish remaining in Clifton Court after the cessation of the experimental period which are not enumerated as surviving the experiment. However, Greene (2008) stated that “In light of Gingras 1997's recognition that introduction of experimental fish would increase the likelihood of predation found in the studies, it is my opinion that a pre-screen mortality rate of 75% at the SWP pumping facilities is a reasonable estimate of pre-screen mortality.” Additional predation rates by birds is unknown at this time, but observations by biologist at the forebay have indicated that bird density can be quite high for species that prey on fish as part of their diet, such as Double crested Cormorants (*Phalacrocorax auritus*), Great Egrets (*Ardea albus*), White Pelicans (*Pelacanus erythroryhnchus*), Clark’s Grebe (*Aechmophorus clarkia*), Western Grebes (*Aechmophorus occidentalis*), Great Blue Herons (*Ardea nerodias*) and several species of gulls.

A recent study was conducted (DWR 2008) utilizing hatchery steelhead (average size 245 ±5 mm) to examine the pre-screen loss for this species of fish. Results of this study concluded that steelhead of smolt size had a pre-screen loss rate within Clifton Court Forebay that ranged from 78 ± 4 percent to 82 ± 3 percent over the various replicates of the study. These values are similar to smaller Chinook salmon and juvenile striped bass studies conducted previously. The study also found that the screening loss at the Skinner Fish Protection Facility for tagged steelhead was 26 ± 7 percent. This level of screening is equivalent to 67 to 81 percent efficiency, which is comparable with the 75 percent overall efficiency stated for the facility previously. The study also verified that tagged steelhead could exit the forebay under the right hydraulic conditions and enter the channel of Old River. Tagged fish were recorded in Old River outside of the radial gates and one passive integrated transponder (PIT) tagged steelhead was recovered in the TFCF salvage after release in the forebay. In addition, the study also tagged large striped bass with acoustic transmitters and monitored their movements within the forebay. The study found that the striped bass typically moved between the radial gates and the inlet channel/debris boom area of the forebay, apparently congregating in these areas, perhaps to feed, while others moved into the northern area of the forebay. Several of the striped bass (16 of 30 tagged fish) were shown to have left the forebay and reenter Old River and the Delta. Striped bass leaving the forebay were detected as far away as the Golden Gate Bridge and above Colusa on the Sacramento River.

The studies described above (Gingras 1997, DWR 2008) indicate that mortality (*i.e.*, predation) is very high in the forebay for listed salmonids, whether they are smaller-sized Chinook salmon juveniles or larger smolt-sized steelhead. For every one fish salvaged, typically 4 to 5 fish entered the forebay (75 to 80 percent pre-screen loss). Based on the increased frequency of elevated pumping rates described in the near term and future modeling runs for the SWP, NMFS anticipates that substantial numbers of additional Chinook salmon and steelhead will be lost to predation in the forebay. This conclusion is based on the presumption that increased pumping will require the forebay to be operated in such a manner as to supply the additional volumes of water pumped by the Banks Pumping Plant over the current levels. Increased levels of pumping will draw down the forebay water elevation when the gates are closed. With each operation of the radial gates, the difference in hydrostatic head between the outside channel (following the peak of the high tide) and the elevation within the forebay will cause water to flow into the forebay. The greater the elevation differential, the greater the flow (velocity) into the forebay and the greater the volume of water moved in a unit time. This change has the potential to draw additional listed salmonids and green sturgeon into the forebay. The additional increases in the pumping rates seen in the period between December and May corresponds to the time period when listed salmonids are in the system, and thus vulnerable to the effects of the forebay operations. The proposed near term and future operations of the SWP, through the operations of the Clifton Court Forebay, will exert additional adverse effects upon the listed salmonid populations. The loss of these additional individual fish will further reduce the populations of listed salmonids (*i.e.*, the annual loss of hundreds to thousands of wild winter-run, spring-run, and CV steelhead, as enumerated in the annual salvage and loss reports presented by the Interagency Ecological Program for the San Francisco Estuary). These fish, which have survived to reach the South Delta, represent the survivors of the hundreds of thousand to millions of fry that hatched up river in their natal stream reaches. Loss of an appreciable number of these fish represent a loss of abundance in the current population, and perhaps a reduction in future productivity if these fish represent the “hardiest” fish of the current brood year, based on their surviving to the Delta (and through it to the South Delta). These fish represent those fish which have successfully hatched, successfully initiated exogenous feeding, avoided upstream predation during natal rearing, successfully negotiated the migratory corridor from natal rearing areas to the delta, and have shown the ability to avoid predation and successfully forage during their downstream migration through the delta. These fish have the necessary traits, both physiologically and behaviorally, to survive the multiple stressors encountered in the environment and thus, through natural selection, represent the best adapted fish to the current conditions in the Central Valley.

Green sturgeon may be entrained during any month of the year by the operations of the Clifton Court Forebay radial gates. It is unknown what percentage of these fish return to the waters of the Delta through the radial gates, like striped bass, or remain within the forebay for extended periods of time. Based on salvage data, it appears that green sturgeon juveniles are present in the forebay year round, but in varying numbers. NMFS expects that predation on green sturgeon during their stay in the forebay is minimal, given their size and protective scutes, but this has never been experimentally verified.

6.6.2.4.1.4 Collection, Handling, Trucking, and Release Operations

Following the successful screening and redirection of the entrained fish to the holding tanks, both the TFCF and the Skinner Fish Protection Facility engage in a process of CHTR to return the salvaged fish to the waters of the Delta outside the influence of the pumps (DWR 2005a, b). The following general description explains the CHTR procedure for both the TFCF and the Skinner Fish Protection Facility. During the collection phase, the fish are contained within large cylindrical holding tanks, which may collect fish for several hours (up to 24 hours at the TFCF). The holding times are a function of fish density and the presence of listed fish in the collection tanks. High densities or the presence of listed fish require more frequent salvage operations. During the collection phase of salvage, the tanks are dewatered, and the fish are collected in a large conical sample bucket that is lowered into the sump of the holding tank. Fish that are not immediately collected into the sample bucket are washed into the bucket with a stream of water, along with any debris that has accumulated in the holding tank (*i.e.*, plant material such as *Egeria densa* or sticks and branches). Once dewatering and final wash down have been completed, the sample bucket is lifted out of the holding tank by a gantry hoist and moved to either the handling - sorting platform adjacent to the holding tank or directly to the waiting tanker truck. The handling phase requires the collection facilities staff to sort through the collected fish at predetermined intervals (*i.e.*, 20 minute counts every 2 hours at the TFCF when listed fish are present) and identify the captured fish to species, enumerate the species taken, particularly the listed species, and provide data for estimating the salvage numbers for the total operation of the two facilities. These counts also determine the frequency that the other holding tanks must be drained and fish loaded into the trucks and transported to the release sites.

Fish are transferred to tanker trucks following the dewatering procedure in the large conical collecting baskets used in the draining of the holding tanks. Typically fish and the water that remains in the conical basket are released into the waiting truck through the hatch on the top of the truck. Frequently there is a high debris load in the conical collecting basket that is also transferred to the truck along with the fish and water in the basket. Numerous problems associated with fish density, debris load, and loading practices, as well as the physical stress of transport, have been identified as potential stressors to the transported fish, affecting eventual survival.

Fish are driven to one of four sites located in the western Delta. The TFCF releases its fish at a site on Horseshoe Bend on the Sacramento River or adjacent to the State Route 160 highway bridge in Antioch, California. The Skinner Fish Protection Facility releases its salvaged fish at a separate Horseshoe Bend release site, a site on Sherman Island on the north bank of the San Joaquin River, and shares the site at Antioch with the TFCF. Releases are made to the river through pipes that reach from the roadside to the river, and extend 100 or more feet offshore into deeper water. The pipes are typically primed with a flow of river water from onsite pumps to make sure that the walls of the pipe are wetted prior to fish being passed down the pipe to the river. Once the pipe has been primed with the river water, the valve on the tanker truck is opened and the contents of the truck are flushed into the release pipe, using a hose to help wash the tank's contents through the valve orifice with river water. The flow down the lumen of the pipe is turbulent and of fairly high velocity (aided by the injection of flushing flows into the start of the pipeline). Problems associated with the release operations have been identified and include, but are not limited to, high turbulence and shear forces in the pipeline during release; contact with debris during the release, causing injury or death; potential stranding of fish in the tanker truck due to debris clogging the orifice during dewatering; disorientation following release, creating higher potentials for predation; attraction of predators to the pipe outfall structure; delayed mortality due to injuries in the release procedure; and physiological shock due to water quality parameters changing too quickly during the release procedure (DWR 2005a, b).

Current estimates of mortality associated with the CHTR operations indicate that Chinook salmon experience approximately 2 percent mortality after 48 hours following the release of fish through the pipe. Additional mortality associated with predation is likely, but as of yet, experimental data is lacking. A study completed by DWR was expected to be issued by the end of 2008 which addresses the potential for post-release predation at the Delta release points. Estimates of post release predation rates given by DWR range from 10 percent to 30 percent for juvenile salmonids, depending on the density of predators at the release site and the number of fish released per episode (Orsi 1967, Pickard *et al.* 1982, Greene 2008). Estimates are crude and several potential biases in the earlier studies are present, including net sampling efficiency, susceptibility of predators to capture, and estimation of predator populations within the study area. Recent evidence obtained using acoustic imaging equipment (DIDSON cameras) has shown that predators are quickly attracted to the discharge pipelines upon the startup of the priming water flow, indicating a learned response to the discharge of salvaged fish at the release sites.

In summary, the CHTR process has inherent risks to salvaged fish, including listed salmonids such as winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon. Fish are exposed to debris and turbulent flow during their movements through pipes, holding tanks, trucks and the discharge pipes. Such activities increase the stress level in the fish and elevate their corticosteroids and catecholamine levels, as previously described. Predation of disoriented and confined fish may occur by predators in the same holding tanks and during transport. There is a high probability that injury and stress will occur during the release phase back into the river and that post release morbidity or mortality will occur in the riverine environment (*e.g.*, infections, reduced swimming ability, or disorientation). Estimates of post release predation range from 10 to 30 percent of the salvaged fish released. Since salvage of listed fish primarily occurs to juveniles or smolt-sized fish, it is this life stage that is most affected by the CHTR process. Loss, including post release mortality, is approximately 12 to 32 percent of the fish salvaged.

NMFS estimates that the direct loss of fish associated with the screening and salvage process is 83.5 percent for the SWP and approximately 65 percent for the CVP for fish from the point they enter Clifton Court Forebay or encounter the trashracks at the CVP (table 6-28).

Table 6-28. Overall survival of fish entrained by the export pumping facilities at the Tracy Fish Collection Facilities and the John E. Skinner Fish Protection Facilities.

Estimate of Survival for Screening Process at the SWP and CVP[1]		
SWP	Percent survival	Running Percent
Pre-screen Survival[2]	25 percent[3] (75 percent loss)	25
Louver Efficiency	75 percent (25 percent loss)	18.75
CHTR Survival	98 percent (2 percent loss)	18.375
Post Release Survival (predation only)	90 percent (10 percent loss)[4]	16.54
CVP[5]	Percent survival	Running Percent
Pre-screen Survival[6]	85 percent (15 percent loss)	85
Louver Efficiency[7]	46.8 (53.2 percent loss)	39.78
CHTR Survival	98 percent (2 percent loss)	38.98
Post Release Survival (predation only)	90 percent (10 percent loss)	35.08

[1] These survival rates are those associated with the direct loss of fish at the State and Federal fish salvage facilities. Please see the text for a more thorough description.

[2] Prescreen loss for the SWP is considered to be those fish that enter Clifton Court Forebay that are lost due to predation or other sources between entering the gates and reaching the primary louvers at the Skinner Fish Protection Facility.

[3] Estimates have ranged from 63 to 99 percent (Gingras 1997). Recent steelhead studies indicate a loss rate of approximately 78 to 82 percent (DWR 2008).

[4] Predation following release of salvage fish ranges from less than 10 percent to 30 percent according to DWR (2009). NMFS uses the lower estimate to give a conservative estimate of loss. Actual loss may be greater, particularly in the winter when the density of salvage fish released is low, and predators can consume a greater fraction of the released fish (DWR 2009).

[5] These values do not incorporate the 45 percent of the operational time that the louvers are in noncompliance with the screening criteria. The actual values of the lover efficiency during this time are not available to NMFS. These values would determine the percentage of survival through the facility under real time circumstances.

[6] Prescreen survival in front of the trashracks and primary louvers at the TFCF have not been verified, but are assumed to be 15 percent.

[7] Overall efficiencies of the louver arrays at the TFCF have been shown to be 46.8 percent (59.3 percent primary, 80 percent secondary). Recent studies indicate overall efficiencies during low flow periods could be less than 35 percent (Reclamation 2008). This value does not include periods when the louvers are being cleaned, where overall efficiency drops towards zero.

6.6.2.4.1.5 Estimates of Direct Loss to Entrainment by the CVP and SWP Export Facilities under the Proposed Action

Individual winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon are entrained by the south Delta export facilities, with most dying or being "lost" to the population in the process. Because all of the different populations are migratory, entrainment is seasonal, based on their presence in the waters of the Delta. Juvenile sized winter-run are vulnerable from approximately December through April, with a peak in February and March. Spring-run juveniles and smolts are vulnerable from approximately November through March (as yearlings) and January through June as YOY. Wild (unclipped) CV steelhead have a longer period of vulnerability, based on their extended periods of emigration as 1 to 2 year old smolts. Wild juvenile steelhead are recovered in the USFWS Chipps Island trawls from October through July. There appears to be a difference in the emigration timing between wild and hatchery reared steelhead smolts, primarily due to the narrow window of hatchery steelhead smolt releases into the system versus the protracted emigration from natal streams by wild fish. Adipose fin-clipped hatchery fish are typically recovered at Chipps Island from January through March, with the peak in recoveries occurring in February and March. The timing of wild steelhead (unclipped) emigration is more spread out. Their emigration occurs over approximately six months, with peaks in February and March, based on salvage records at the CVP and SWP fish collection facilities.

To evaluate the effects of direct entrainment, Reclamation assembled the total CVP + SWP pumping projections (as "Jones" plus "Total Banks") in the CALSIM II output for the years between 1921 to 2003 and compared the current (Study 7.0), with the near future (Study 7.1), and future (Study 8.0) operations of the project and their anticipated effects on entrainment due to changes in pumping rates. For each comparison presented in table 6-29, the CALSIM II output for the monthly averages of the combined pumping levels of the Jones and Banks facilities are given for the different water year types. Utilization of salvage rates to express the effects of exports on the salmonid populations relies on the fish of interest actually reaching the point of enumeration, where they can be counted. Failure to reach the salvage facilities results in the perception that exports may not have an effect on those populations. Other factors in the Delta, such as predation, and at the salvage facilities (*e.g.*, low louver efficiency, or elevated pre-screen losses), can mask the effects of exports by removing the fish from the system prior to reaching the salvage facilities to be enumerated. Under such circumstances, even though the movement of water southwards towards the pumps due to exports was affecting the movement of fish, it cannot be determined by salvage alone, since the loss of fish prior to the salvage facilities prevents them from being enumerated in the salvage counts and showing any correlation with the exports. An alternative approach to estimating entrainment risk is the magnitude and direction of flows in Old and Middle Rivers under the different future modeling scenarios compared to the current levels. Table 6-30 gives the median net flows in Middle and Old Rivers under Studies 7.0, 7.1, and 8.0, as modeled for the years between 1922 and 2003 by the CALSIM model (CVP/SWP operations BA Appendix E). Both Reclamation and DWR, as well as the USFWS, have used this metric as a tool for evaluating entrainment risk to Delta smelt, and NMFS will incorporate the same tool as an additional ecological surrogate for evaluating the risk of entrainment to salmonids within the same water bodies. Although salmonids and green sturgeon are not water particles, they do use water movement (flow and direction) as cues for their behavioral movements. NMFS will use the movement of particles as a measure of the potential fate of water from the point of the particle injection through the channels of the central and southern Delta based on the eventual disposition of the particle at the end of the model run. In table 6-31, the monthly percentile differences between future CALSIM II Study cases (7.1 and 8.0) with the current Study (7.0) are presented, grouped by water year type and pumping facility.

The modeling runs indicate that export rates will increase over the current operations, as modeled by Study 7.0, through the late fall period and early winter period. Average export rates in November typically increase a modest 2 to 4 percent in most water year types. Under the near future and future operational models, average export rates increase about 10 percent in both December and January (range 5.84 to 15.12 percent increase). These increases can be expected to enhance the potential for fish entrainment (due to higher average export rates) at a time when winter-run juveniles and yearling spring-run are entering the Delta system. These increases in export are seen in all water year types, although the magnitude varies.

Table 6-29. Comparison of predicted monthly total export pumping from the CVP (Jones) and SWP (Banks) facilities for Studies 7.0 (current), 7.1 (near future) and 8.0 (future). The percentage difference is calculated for the percentage change from the near future and future conditions to the current operations. Highlighted cells are where future conditions have less pumping than current conditions.

October	Study 7.0	Study 7.1	% Difference 7.1 - 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	9054	8915	-1.54	9083	0.32
Above Normal	7982	7362	-7.77	7722	-3.26
Below Normal	8100	7717	-4.73	7729	-4.58
Dry	8111	7325	-9.69	7567	-6.71
Critically Dry	6799	6460	-4.99	6468	-4.87

November	Study 7.0	Study 7.1	% Difference 7.1 - 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	10503	10743	2.29	10699	1.87
Above Normal	8414	8581	1.98	8422	0.10
Below Normal	8851	8829	-0.25	8922	0.80
Dry	7416	7717	4.06	7748	4.48
Critically Dry	6278	6391	1.80	5801	-7.60

December	Study 7.0	Study 7.1	% Difference 7.1 – 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	10438	11515	10.32	11585	10.99
Above Normal	8870	10012	12.87	9662	8.93
Below Normal	8770	9829	12.08	9876	12.61
Dry	8924	9816	10.00	9817	10.01
Critically Dry	7107	7855	10.52	7522	5.84

January	Study 7.0	Study 7.1	% Difference 7.1 – 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	10686	11537	8.15	11425	7.10
Above Normal	10074	11433	13.49	11539	14.54
Below Normal	9908	10815	9.15	10960	10.62
Dry	8410	9584	13.96	9682	15.12
Critically Dry	7224	7646	5.84	7986	10.55

February	Study 7.0	Study 7.1	% Difference 7.1 – 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	10295	10507	2.06	10617	3.13
Above Normal	10143	10738	5.87	11062	9.06

Below Normal	9759	9625	-1.37	9171	-6.03
Dry	8322	7982	-4.09	8137	-2.22
Critically Dry	5154	6061	17.60	5853	13.56

March	Study 7.0	Study 7.1	% Difference 7.1 – 8.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	10099	9138	-9.52	9524	-5.69
Above Normal	10386	9660	-6.99	10138	-2.39
Below Normal	8692	8387	-3.51	8472	-2.53
Dry	7367	7270	-1.32	7188	-2.43
Critically Dry	3798	4316	13.64	4241	11.66

April	Study 7.0	Study 7.1	% Difference 7.1 – 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	6226	6944	11.53	6987	12.22
Above Normal	5488	6173	12.48	6226	13.45
Below Normal	4472	4737	5.93	4708	5.28
Dry	2716	3329	22.57	3339	22.94
Critically Dry	1780	2035	14.33	1893	6.35

May	Study 7.0	Study 7.1	% Difference 7.1 – 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	6114	6950	13.67	6924	13.25
Above Normal	4174	5193	54.41	5011	20.05
Below Normal	3069	4149	35.19	4051	32.00
Dry	2222	3259	46.67	3073	38.30
Critically Dry	1595	1751	9.78	1644	3.07

June	Study 7.0	Study 7.1	% Difference 7.1 – 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	8414	8635	2.63	8616	2.40
Above Normal	7344	7961	8.40	7802	6.24
Below Normal	6480	6988	7.84	6890	6.33
Dry	5621	6212	10.51	6118	8.84
Critically Dry	3540	2754	-22.20	2416	-31.75

July	Study 7.0	Study 7.1	% Difference 7.1 – 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	10154	10773	6.10	10875	7.10

Above Normal	8899	10037	12.79	9736	9.41
Below Normal	10476	11111	6.06	10641	1.58
Dry	10593	10539	-0.51	10123	-4.44
Critically Dry	5270	3675	-30.27	3359	-36.26

August	Study 7.0	Study 7.1	% Difference 7.1 – 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	11549	11491	-0.50	11627	0.68
Above Normal	11474	11082	-3.42	11168	-2.67
Below Normal	10514	9814	-6.66	9717	-7.58
Dry	7611	5720	-24.85	5277	-30.67
Critically Dry	4224	2020	-52.18	1880	-55.49

September	Study 7.0	Study 7.1	% Difference 7.1 – 7.0	Study 8.0	% Difference 8.0 – 7.0
WY Type	CFS	CFS		CFS	
Wet	11469	11249	-1.92	11315	-1.34
Above Normal	10498	10325	-1.65	10710	2.02
Below Normal	10128	9755	-3.68	9924	-2.01
Dry	8571	7024	-18.05	6838	-20.22
Critically Dry	5828	4922	-15.55	4777	-18.03

Table 6-30. Projected Average Old and Middle River Flows by Water Year Types and Months

Projected Average Old and Middle River Flows (in cfs) in Wet and Above Normal Water Years for the Months of December through March (CVP/SWP operations BA Appendix E CALSIM Output).

Study	December	January	February	March	Average
Study 7.0	-8350	-6391	-7322	-6858	-7230
Study 7.1	-8083	-6511	-7377	-7956	-7482
Study 8.0	-8230	-6276	-7203	-7890	-7400

Projected Average Old and Middle River Net Flows (in cfs) in Wet and Above Normal Water Years for the months of April through July.

Study	April	May	June	July	Average
Study 7.0	-5847	-4381	-4118	-643	-3747
Study 7.1	-6561	-4652	-3450	-1146	-3952
Study 8.0	-6611	-4941	-3792	-1193	-4134

Projected Average Old and Middle River Net Flows (in cfs) in Below Normal and Dry Water Years for the months of December through March.

Study	December	January	February	March	Average
Study 7.0	-7668	-6125	-6767	-7117	-6919
Study 7.1	-6687	-6098	-6504	-8063	-6838
Study 8.0	-6946	-6030	6435	-8004	-6854

Projected Average Old and Middle River Net Flows (in cfs) in Below Normal and Dry Water Years for the months of April through July.

Study	April	May	June	July	Average
Study 7.0	-6889	-6052	-5573	-1064	-4895
Study 7.1	-7889	-5897	-5440	-1442	-5167
Study 8.0	-8038	-5989	-5407	-1428	-5215

Projected Average Old and Middle River Net Flows (in cfs) in Critically Dry Water Years for the months of December through March.

Study	December	January	February	March	Average
Study 7.0	-4576	-5633	-5293	-6158	-5415
Study 7.1	-3375	-5399	-4892	-6389	-5014
Study 8.0	-3312	-5317	-4333	-6315	-4819

Projected Average Old and Middle River Net Flows (in cfs) in Critically Dry Water Years for the months of April through July.

Study	April	May	June	July	Average
Study 7.0	-5368	-4250	-2514	-797	-3232
Study 7.1	-5903	-4744	-2824	-842	-3578
Study 8.0	-5618	-4865	-3024	-870	-3594

February has mixed export patterns. In wet and above normal water years, exports increase modestly, compared to modest decreases in below normal and dry years. Critically dry years see a larger increase in average exports (17.6 percent in Study 7.1 and 13.56 in Study 8.0), which is anticipated to have negative impacts on emigrating fish during this month. The reductions in exports during the below normal and dry water years are expected to benefit outmigrating salmonids, including steelhead, which are entering the system in increasing numbers. Less pumping is believed to reduce the draw of water from the main channel of the San Joaquin River into the South Delta channels leading towards the pumps, and thereby reduce the effects of farfield entrainment of fish into these channels. In particular, fish from the Southern Sierra Diversity groups which include CV steelhead from the San Joaquin River basin, the Calaveras River basin, and wild CV steelhead from the Mokelumne River basin must pass several points of potential entrainment into the South Delta prior to reaching the western Delta. Conversely, increasing exports in the wet, above normal and critically dry water years will adversely affect emigrating salmonids.

Table 6-31. Average change in Banks and Jones pumping grouped by water year type. Highlighted cells indicate conditions where pumping is greater than the Study 7.0 current condition during the primary salmonid migration period (November through June).

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%

The average combined exports for March decrease in all water year types except critically dry years, when the export rate increases approximately 12 percent in the future compared to current operations (13.64 percent increase in Study 7.1 versus Study 7.0 and 11.66 percent increase in Study 8.0 compared to Study 7.0). Therefore, in critically dry years, based on the anticipated export rate increases, risk to winter-run and CV steelhead will increase, particularly since March is typically the peak of their outmigration through the Delta. On the other hand, risk of entrainment, as measured by salvage and export levels, declines during the month of March in the wet, above normal, below normal and dry hydrologic year types.

The months of April and May have significant increases in the export rates under the near future and future modeling runs when compared to the current operations model (Study 7.0). Export rates can increase by as much as 46.67 percent in the month of May during dry water year types, and are only moderately less than this in other water year types. Typically, the increases in exports range from approximately 10 percent to 40 percent during the April and May time period. These increases will likewise negatively affect emigrating salmonids, particularly spring-run and fall-run juveniles that are moving through the Delta during these months. San Joaquin River and Calaveras River basin fish, (*i.e.*, steelhead and fall-run Chinook salmon) are particularly vulnerable due to the proximity of their migration corridor to the location of the CVP and SWP pumping facilities and the multiple pathways leading from their migration corridor to the export facilities (*e.g.*, Head of Old River, Turner and Columbia Cuts, Middle River, and Old River).

The month of June has exports increasing approximately 2.5 percent to 10 percent over current conditions, except for critically dry years when exports are sharply reduced (-22 percent in Study 7.1 and -32 percent in Study 8.0). Overall, actual June export rates are increasing over the April and May levels, so that while the percentage of increases looks smaller than in the previous two months, the total volume of water diverted is actually increasing. This is expected to pull more water southwards through the central and southern Delta waterways towards the pumps. This, in turn, increases the risk of drawing any late emigrating fish present in the central and south Delta towards the pumps as well. This will adversely impact the migration rate of these late emigrating fish during a time when water quality, particularly water temperature, is becoming unfavorable to salmonids.

The month of July has exports that are increasing in the near future and future over the current model levels in wet, above normal, and below normal water year types. Similar to June, the drier water year types see a pattern of decreasing export levels between the future modeling runs and the current modeling run. For the remainder of the summer months, i.e., August and September, the future modeling studies indicate that combined export rates will be equivalent to or lower in than the current conditions as modeled in Study 7.0. Reductions are greatest in the drier water year types. Reductions in summer exports could reduce the vulnerability of green sturgeon juveniles in the central and south Delta from becoming entrained by the pumps.

In the analysis completed for Delta smelt, the CVP/SWP operations BA concluded that upstream flows, *i.e.*, flows that were negative, that were greater than -2000 cfs ± 500 cfs effectively prevented entrainment of Delta smelt that were north of the sampling stations in Old and Middle

River. A linear relationship between Delta smelt entrainment and flow exists at flows greater than -4000 cfs (more seaward flow). At flows less than -4000 cfs (more landward flow) the entrainment rate for Delta smelt begins to take on an exponential characteristic. Based on particle tracking modeling, the Delta smelt work group concluded that net river flows greater than -2000 ± 500 cfs in the Old River and Middle River complex reduced the zone of entrainment so that particles injected into the central Delta at Potato Slough would not be entrained towards the pumps (Kimmerer and Nobriga 2008 *op cit*. CVP/SWP operations BA). NMFS considers this information useful in analyzing the potential “zone of effects” for entraining emigrating juvenile and smolting salmonids. A similar pattern is observed in material (figures 6-65 and 6-66) provided to NMFS by DWR (Greene 2009). Loss of older juveniles at the CVP and SWP fish collection facilities increase sharply at Old and Middle River flows of approximately -5,000 cfs and depart from the initial slope at flows below this. Given the data derived from the CVP/SWP operations BA Appendix E, flows in Old and Middle River are consistently in excess of the -2000 ± 500 cfs threshold for entrainment (*i.e.*, more upstream flow). Assuming that in the normal (natural) flow patterns in the Delta, juvenile and smolting Chinook salmon and steelhead will use flow as a cue in their movements and will orient to the ambient flow conditions prevailing in the Delta waterways, then upstream flows will carry fish towards the pumps during current operations. General tendencies of the modeling results indicate that Old River and Middle River net flows trend towards greater upstream flow in the near future and future conditions, resulting in even more fish carried towards the pumps.

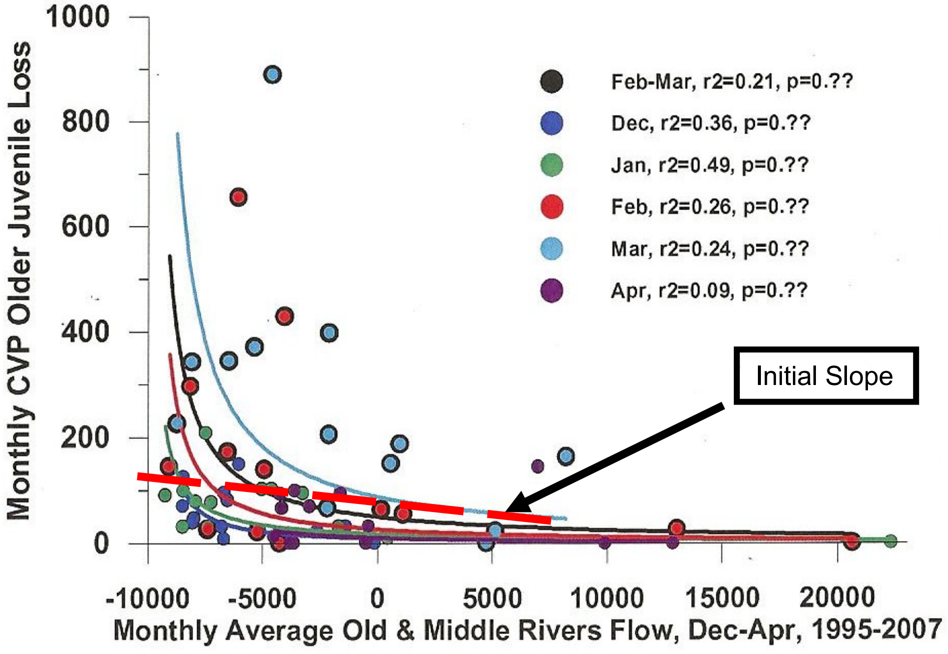


Figure 6-65. Relationship between OMR flows and entrainment at the CVP, 1995-2007 (DWR 2008).

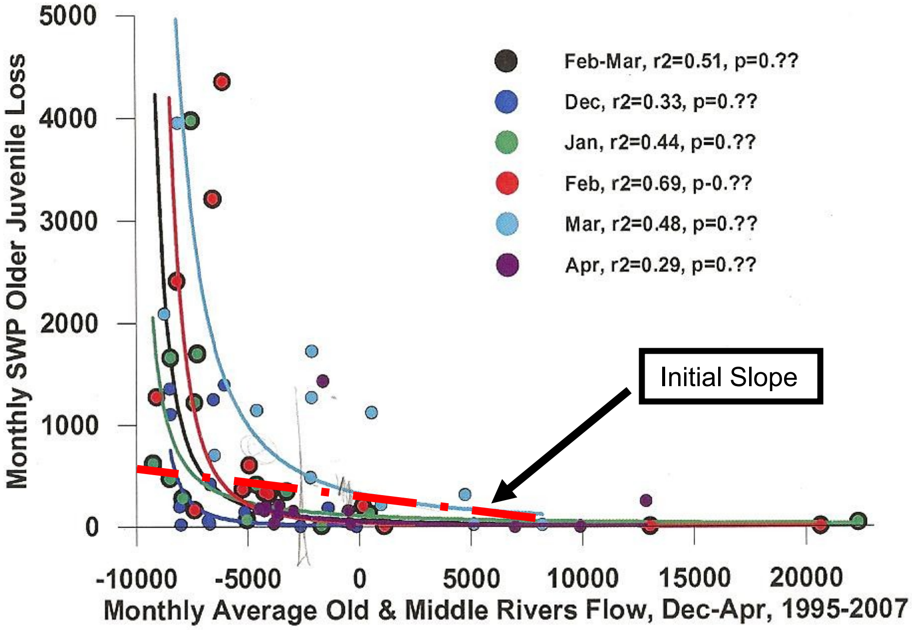


Figure 6-66. Relationship between OMR flows and entrainment at the SWP, 1995-2007 (DWR 2007).

During wet, above normal and critically dry water year types, the greatest level of negative net flows in Old and Middle rivers are seen during the months of December, January, and July. The months of December and January coincide with onset of movement of winter-run and yearling spring–run into the north Delta from the Sacramento River. NMFS believes that these elevated levels of net negative flow present a risk to emigrating fish that have entered the central Delta through Georgiana Slough or, when the DCC is open, the Mokelumne River system. In below normal and dry water year types, the Old and Middle River flows have high levels of net negative flow from December through March and again in June and July. This overlaps with a significant proportion of the salmonid emigration period through the Delta, particularly for winter-run Chinook salmon and Central Valley steelhead. In all water year types, the net negative flows in Old and Middle River are attenuated in April and May in response to the reduced pumping (export levels) required for the VAMP experiments.

The CALSIM II and DSM II modeling also indicates that the magnitude of the net negative flows in Old and Middle rivers generally get “larger” (*i.e.*, more negative, reverse landward flow) with the future conditions in wet, above normal, below normal and dry water year conditions. This corresponds with the trend in increased level of exports described earlier for these water year types. The enhancement of net negative flows in Old and Middle rivers in the near future and future conditions indicate an increasing level of vulnerability to the entrainment for emigrating fish located in the central and southern Delta regions.

Inspection of the salvage and loss records from the CVP and SWP fish collection facilities available through the Central Valley Operations web site (http://www.usbr.gov/mp/cvo/fishrpt.html) indicates that recovery of winter-run sized juvenile Chinook salmon begins in December and continues through approximately the end of March.

Roughly 50 percent of the total annual salvage of juvenile winter-run sized Chinook salmon occurs in March, with the previous 3 months (December, January, and February) accounting for the other 50 percent. Very few winter-run sized Chinook salmon juveniles are captured after the end of March. Likewise, the salvage of steelhead smolts at the fish collection facilities starts as early as November, but is primarily observed in the months of January, February, and March. The salvage of spring-run sized fish is primarily observed in the months of March, April, and May. Nearly two thirds of the spring-run sized Chinook salmon juveniles are collected during the month of April alone. This temporal pattern indicates that listed salmonids are within the waterways of the central and south Delta as early as November and December, but typically are most prevalent from January through May. Southern DPS of green sturgeon are also present during this time frame, as they occupy the waters of the Delta year round.

The presence of listed salmonids and green sturgeon in the salvage collections during the winter and spring months points out their vulnerability to negative flows in Old and Middle River during this time period. Particle tracking model simulations conducted for the Delta smelt consultation indicate that at flows more positive than -2,500 cfs, the probability of a neutrally buoyant particle injected at monitoring Station #815 eventually being entrained at the export facilities is less than 10 percent (see figures 6-67 and 6-68). Station #815 is on the San Joaquin River adjacent to the confluence of the Mokelumne River. This site is a valuable reference point as it is the location at which fish from the Sacramento River are likely to enter the Central Delta and the San Joaquin River system after traveling through Georgiana Slough or the Mokelumne River system. With increasing export pumping under a set of given conditions, the Old and Middle River flows become more negative, and a higher percentage of injected particles from Station #815 are entrained by the export pumps. Similarly, the closer a group of particles is injected to the export facilities, the higher the risk of eventual entrainment at the export facilities. The current profile of listed salmonid entrainment and the estimated Old and Middle River flows from the CALSIM II modeling indicate that fish entering the San Joaquin River from the Sacramento River at the confluence of the Mokelumne River are at an elevated risk of entrainment by the export facilities. Likewise, fish entering the Delta from the San Joaquin River basin, the Calaveras River or the Mokelumne River system are vulnerable to entrainment due to their proximity to the exports (station 912 and Mossdale), and the length of the migration corridor they must travel that is under the influence of the export actions (see figures 6-57c and 6-57d). Pumping rates predicted for the months of December through March create conditions in which the net flows in Old and Middle rivers average less than -4000 cfs (note: more negative values indicate higher export levels and the direction of flow is landwards), with drier years being more negative. The absolute magnitude of Old and Middle River negative flows generally increases (*i.e.*, more flow towards the pumps) under the near term and future modeling studies (see table 6-30).

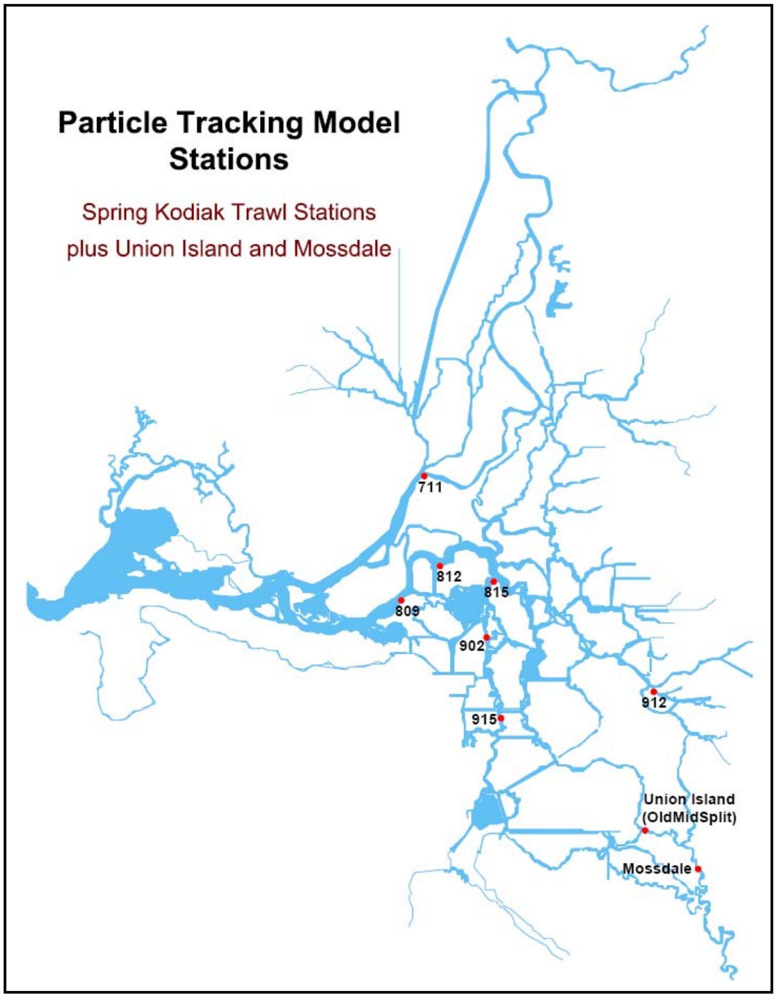
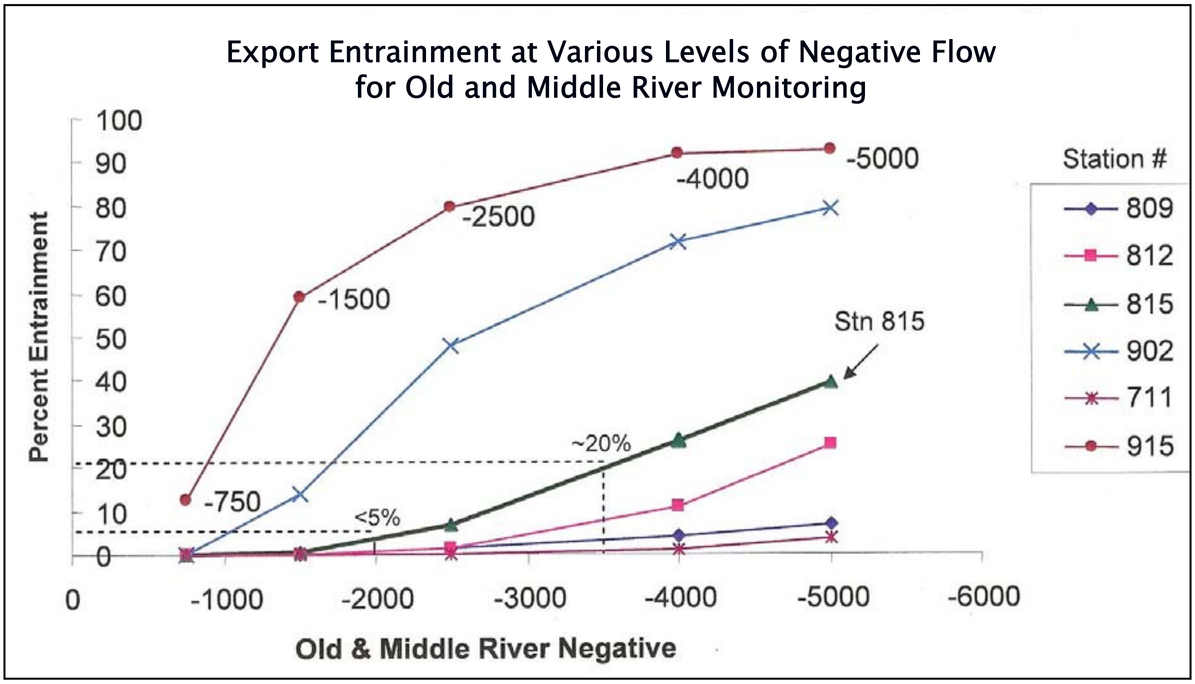


Figure 6-67. Location of particle injection points for the Particle Tracking Model simulations (Hinojosa 2009).



Station Key: Station 809 is located on the San Joaquin River (SJR) at Jersey Point, Station 812 is located on the SJR at Fisherman's Cut, Station 815 is located at the confluence of the Mokelumne River with the SJR, Station 915 is located on Old River at Orwood Tract, Station 902 is on Old River near Rhode Island/ Quimby Island, and Station 711 is on the Sacramento River near Rio Vista and Cache Slough.

Figure 6-68. Calculated percentages of entrainment at the CVP and SWP export facilities for different levels of flow in Old and Middle Rivers. Particles are injected at different locations in the Delta (USFWS 2008a).

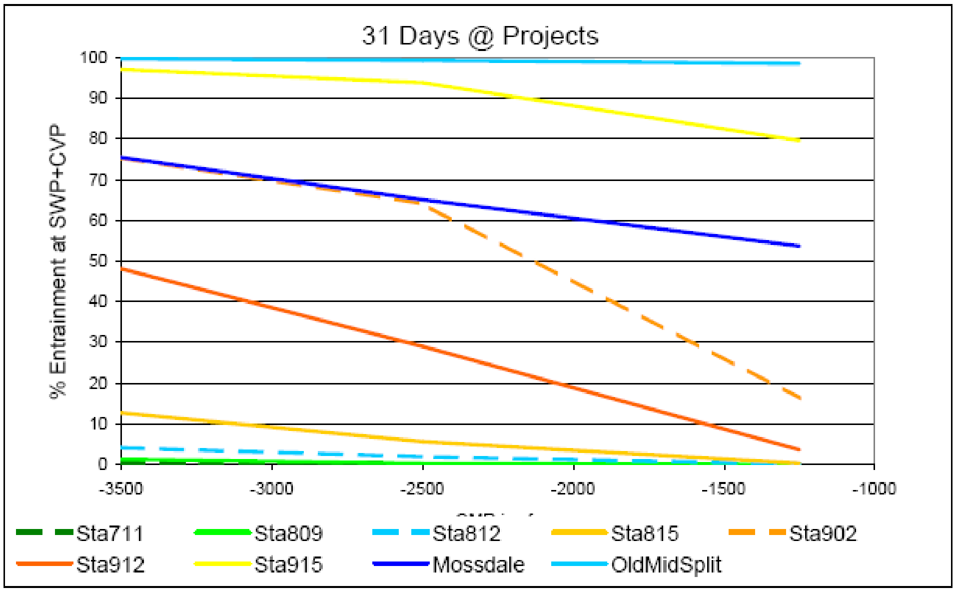


Figure 6-69. Calculated percentage of particles entrained by the CVP and SWP after 31 days at Old and Middle River flows of -3,500 cfs, -2,500 cfs, and -1,250 cfs. Particles were injected at various locations in the Delta. This figure was for March 2005, a "wet" year (Hinojosa 2009).

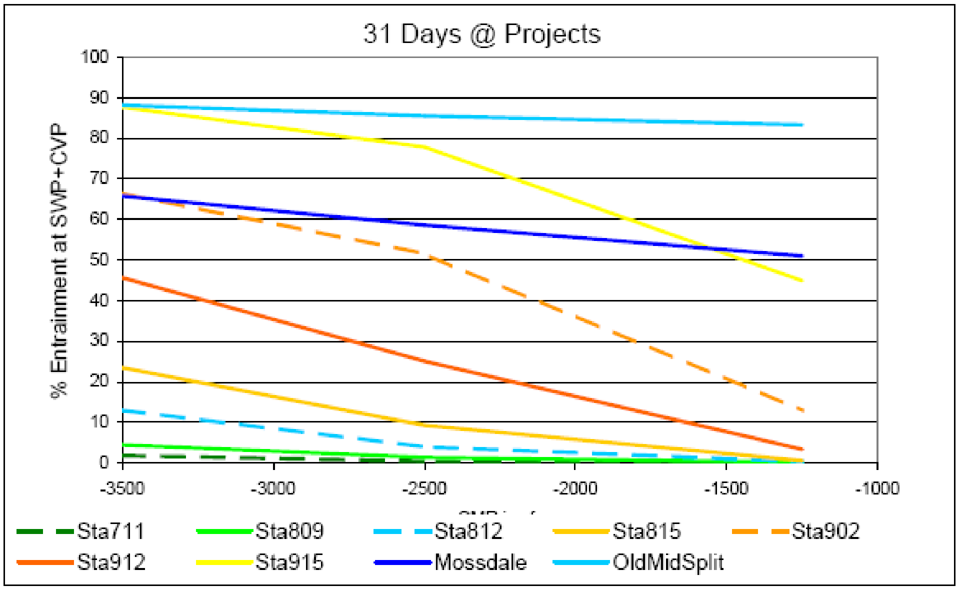


Figure 6-70. Calculated percentage of particles entrained by the CVP and SWP after 31 days at Old and Middle River flows of -3,500 cfs, -2,500 cfs, and -1,250 cfs. Particles were injected at various locations in the Delta. This figure was for March 2008, a "dry" year (Hinojosa 2009).

NMFS uses the findings of the PTM simulations to look at the eventual fate of objects in the river over a defined period of time from a given point of origin in the system. While salmonids and green sturgeon are not "neutrally buoyant particles", they can be represented to some degree by the PTM modeling results. The fish occupy a given body of water in the river and that body of water has eventual fates in the system, as represented by the dispersion of the injected particles. The salmonids have volitional movement within that body of water and react to environmental cues such as tides, water velocity vectors, and net water flow movement within the channel. The eventual fate of that body of water signifies the potential vulnerabilities of fish within that body of water to external physical factors such as export pumping or river inflows. For example, if exports increase, and the eventual fate of the water body indicates that it has a higher probability of entrainment compared to other conditions (*i.e.*, lower export pumping), then NMFS believes that salmonids within that same body of water will also experience a higher probability of entrainment by the export pumping. Conversely, under conditions where the eventual fate of injected particles indicate a high probability of successfully exiting the Delta at Chipps Island, NMFS believes salmonids traveling in the same body of water will have a higher probability of exiting the Delta successfully. Furthermore, conditions which delay movement of particles out of the Delta yet don't result in increased entrainment at the export facilities would indicate conditions that might delay migration through the Delta, which would increase vulnerabilities to predation or contaminant exposure. Finally, flow conditions at river channel splits indicate situations where migrating fish must make a "decision" as to which channel to follow. If water is flowing into a given channel, then fish closer to that channel bifurcation are more likely to be influenced by the flow conditions adjacent to the channel opening than fish located farther away from the channel mouth. Burau *et al.* (2007) describes the complexity of these temporal and spatial conditions and their potential influence on salmonid movement. PTM simulations currently do not give the necessary fine scale resolution both temporally (minutes to fractions of hours) and spatially (three dimensional on the scale of meters) to give clear results at these channel splits. Burau states that spatial distribution of fish across the river channel occurs upstream of the channel splits and is dependent "upon the interaction between local hydrodynamic processes (*e.g.*, secondary currents) and subtle behaviors that play out in a Lagrangian reference frame. These spatial structures evolve over fractions of hours to hours. Junction interactions, on the other hand, happen very rapidly, typically within minutes. Thus, route selection may only minimally depend on behavioral responses that occur in the junction, depending to a greater degree on spatial distributions that are created by subtle behavioral responses/interactions to geometry-mediated current structures that occur up-current of a given junction." This description illustrates the complexity of route selection. Based on Burau's explanation, fish upstream of the split are dispersed by the environmental conditions present in the channel into discrete locations across the channel's cross section. The proximity of these locations to the channel mouth is predictive of the risk of diversion into the channel itself. PTM data can be useful to indicate the magnitude of the net movement of water through the channel after the junction split (and the route selected by the fish), and thus can be used to infer the probable fate of salmonids that are advected into these channels during their migrations.

The comparison of study runs as represented by the percentile differences of monthly pumping rates from both the CVP and SWP facilities are grouped over water year types and compare the future study cases against the current modeled pumping rates (see table 6-29). This table gives better resolution regarding the details of the individual pumping operations of the two pumping plant facilities. The data from the modeling runs for the Banks pumping facility indicates that the comparison between the near term (Study 7.1) and the current pumping levels (Study 7.0) will have a higher rate of pumping increases over the different water year types then decreases during the period when salmonids are emigrating to the ocean (November through June). In particular, the months of April and May will have consistent increases in pumping levels, with rates in wet, above normal and below normal hydrologic years in the month of May showing the greatest relative increases (as high as 42 percent). This is a period of time when YOY spring-run are common in the Delta, as well as fall-run. Therefore increased pumping in April and May has the potential to entrain more individuals from these two runs in the near future and future cases than in the current operational regime. In general, pumping in the near future shows consistent increases at the Banks facility in the period between December and March. These increases place emigrating winter-run, CV steelhead and yearling spring-run at risk of entrainment. As described in the previous section regarding entrainment at the Clifton Court Forebay structure and the operations of the Skinner Fish Protection Facility, loss of entrained salmonids can be quite high for any fish entering this unit.

The pattern of operations for the Jones Pumping Plant facility is slightly different than that of the Banks Facility. In the near future (Study 7.1), pumping is increased over the current levels during the period between November and January. Pumping rates increase modestly in November in all water year types, ranging from 4.5 percent to 9 percent. The following two months, December and January, see pumping increase over 10 percent in almost all cases. This period corresponds to the time when winter-run Chinook salmon juveniles and spring-run Chinook salmon yearlings are entering the Delta from the Sacramento River system. Steelhead smolts are also beginning to enter the Delta waters from their upstream natal streams during this time period. Pumping at the Jones Facility generally decreases during the 3-month period between February and April in below normal, above normal and wet water year types. In dry and critically dry water years, the pumping rates at the Jones Facility tend to increase in the near-term future Study (7.1) over the current modeled conditions (Study 7.0). The reductions in pumping rates are considered to be beneficial to emigrating salmonid populations, particularly since March and April are peak months of movement through the Delta by listed salmonid species.

The modeled pumping rates at the state and Federal pumping plants for the future Study (8.0) are similar to those for the near-future conditions (Study 7.1), therefore the differences between the current operational conditions as modeled by Study 7.0 and the future conditions as modeled by Study 8.0 are not substantially different than those seen in the previous comparisons. The future pumping rates at the Banks pumping plant are still elevated for most of the period between December and May compared to the current operational conditions, and therefore present the same anticipated risk to emigrating salmonid stocks. As seen in the Study 7.1 modeling scenario, pumping rates, as determined by the percentage change from the current level, are substantially increased in the April and May period, which corresponds to the peak of outmigration for YOY spring-run and YOY fall-run. It also overlaps with the VAMP experiment on the San Joaquin River. The modeled pumping rates at the Jones facility under the future conditions in Study 8.0 show a similar pattern to those modeled under Study 7.1.

In summary, the overall pumping rates in the two future modeling scenarios elevate risk to emigrating salmonids in December, January, April, May, and June compared to the current conditions. However, entrainment risks in March are reduced due to pumping reductions taken by the facilities. There are mixed risks in the month of February due to differences in pumping strategy based on the type of water year modeled. In wet, above normal and critically dry water year types, overall pumping is increased. Conversely, pumping is reduced in below normal and dry conditions. The proposed actions also reduce pumping in the summer relative to the current modeling scenario. This benefits green sturgeon that may be rearing in the vicinity of the pumps during the summer, and reduces their risk of entrainment. The most obvious difference in pumping patterns between the current and future scenarios outside of the increases in December and January is the substantial increase in pumping that will occur in April and May at the SWP facilities. This increase in pumping corresponds to the period in which the majority of YOY fall-run and spring-run Chinook salmon are entering the Delta and moving towards the ocean, thus increasing their vulnerability to entrainment. In particular, San Joaquin River basin fish will be exposed to increased entrainment risks due to their migration route's proximity to the pump's entrainment field. This includes the basin's fall-run Chinook salmon population, as well as its severely limited steelhead population.

6.6.2.4.1.6 Discussion of Relationship of Exports to Salvage

There has been considerable debate over the relationship of salvage numbers and the export rate for many years. In addition, the survival rate of salmonid populations passing through the Delta towards the ocean, and the impact of the export facilities on those populations is also an area of controversy. The CVP/SWP operations BA presented data that regressed the loss of older juvenile Chinook salmon against exports (figure 6-71) and found that a significant relationship existed. The relationship was stronger for exports at the SWP (p = 0.000918) than for exports at the CVP (p = 0.0187). The months of December through April resulted in the most informative relationship based on the historical number of older juvenile Chinook salmon salvaged each month and the relationship of each month to salvage and exports. Conversely, regressions performed for monthly salvage of YOY Chinook salmon against exports did not result in a significant relationship at either the SWP or CVP facilities. Potential problems in this analysis may stem from the reduction of pumping for 30 days during the height of the YOY Chinook salmon emigration for the VAMP experiment, which may skew the data set. Likewise, as previously mentioned, loss of fish in the system prior to reaching the salvage facilities and their enumeration in the salvage will mute the response of the salvage numbers to any increase in exports until an apparent threshold level has been reached. It appears that pre-facility losses reach a saturation point, after which salvage numbers increase in accordance with increases in export rates. The shallow slope of the response curve is an indication of the relative insensitivity of the salvage numbers to the increases in exports. In order to see a large change in salvage numbers, a substantial increase in exports is required. The pattern of data points for larger juveniles indicates that at low export rates, very little increase in salvage is seen with increasing export rates. However, as exports increase further, the scatter in the salvage data points increases with both high and low salvage numbers occurring at the same export level. Interactions with predators may explain this pattern. Increased pumping moves fish past the predators faster within the affected channels, reducing their exposure time to the predators. Thus more fish show up to be counted at the salvage facilities once the threshold for predator success has been surpassed.

Regressions of monthly older Chinook salmon loss against export/inflow ratio between December and April did not result in significant relationships at either the SWP or CVP facilities. There is an inherent problem with using the E/I ratio exclusively in that significantly different pumping rates at the CVP and SWP can have the same E/I ratio when the inflow to the Delta is allowed to vary also. Better resolution of the relationship between the salvage to E/I ratio is achieved when at least one of the variables to the E/I ratio is held constant. In such instances, the relative importance of exports or inflow can be teased out of the relationship. Decisions as to which variable has more influence on the level of salvage can thus be made.

Reclamation also regressed data for steelhead salvage against exports in the CVP/SWP operations BA. The regressions resulted in significant relationships between exports and the salvage of steelhead at the facilities, more so for the SWP than the CVP (figure 6-72). The months of January through May produced the most informative relationships based on the historical number of steelhead salvaged each month and the relationship of each month between salvage and exports. Reclamation found that the months of December and June, due to the low number of salvaged steelhead in those months, had very poor and insignificant relationships to exports. Unlike the regressions performed for juvenile Chinook salmon, Reclamation found significant relationships between steelhead salvage and the E/I ratio for both the SWP and CVP (figure 6-73).

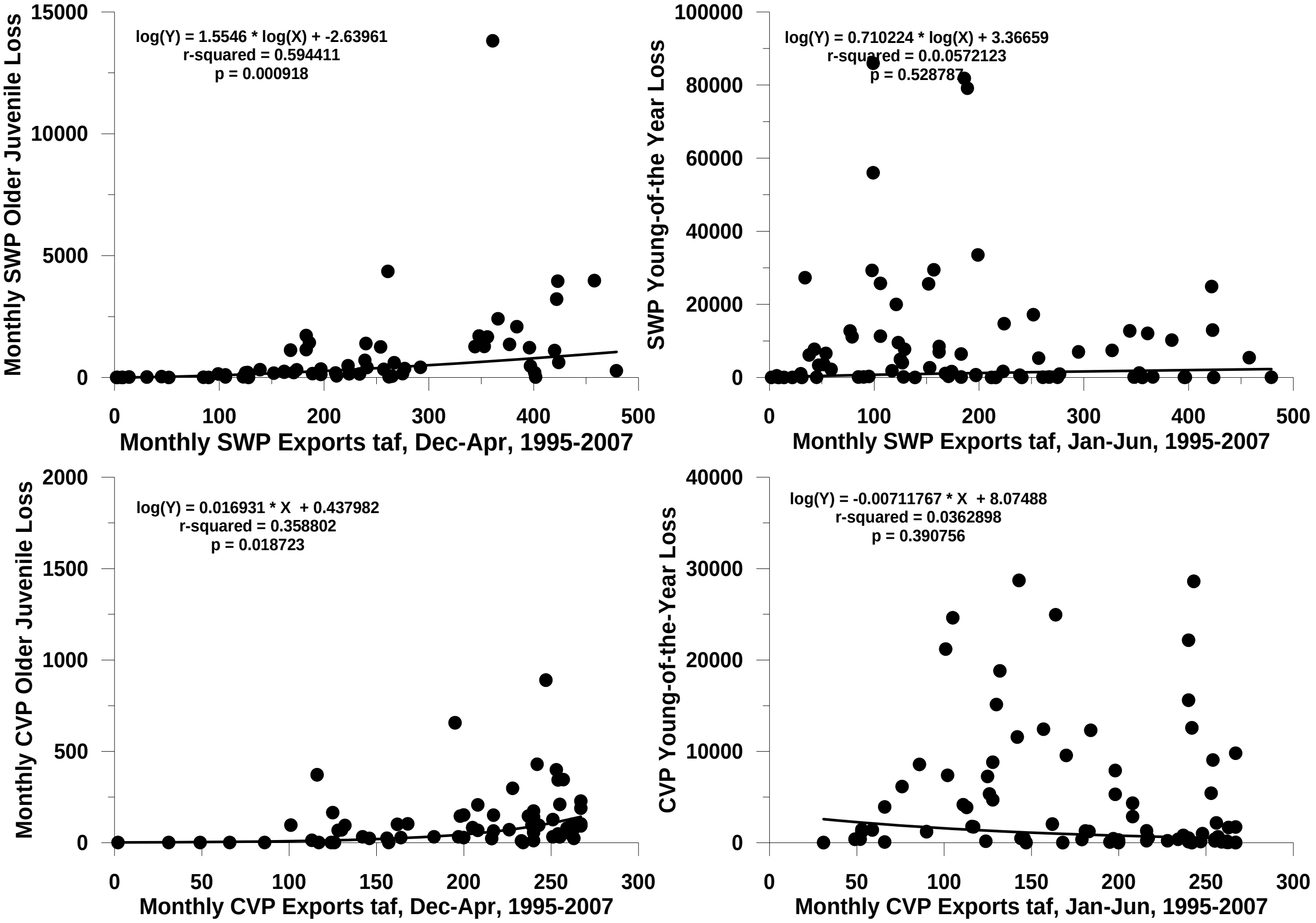


Figure 6-71. Monthly juvenile Chinook salmon loss versus average exports, December through June, 1993 through 2006, at each facility; SWP and CVP (CVP/SWP operations BA figure 13-40).

Recent analyses of the interaction of export rates and the salvage of salmonids at the CVP and SWP have arrived at differing conclusions based on past release and recapture studies conducted in the Delta. Newman (2008) analyzed the results of studies conducted in support of the DCC experiments, the Delta Interior experiments, the Delta Action 8 experiments, and the VAMP experiments. Newman used Bayesian hierarchical models (BHMs) to analyze the data collected from the multiple years of data generated by these four studies. The BHM framework explicitly defines probability models for the release and recovery data gathered and subsequently accounted for the unequal sampling variation and between release pair variation inherent in the raw data pool. Recoveries from multiple locations in the Delta were analyzed in combination rather than separately. According to Newman, the BHM framework is more statistically efficient and coherent than the previous methods of analysis used in these experiments. It is able to address deficiencies in the experimental designs and the high level of variability in the dependent data (*e.g.*, salvage and survival). Several levels of uncertainty can be accounted for using recoveries from multiple locations simultaneously to increase precision. Nevertheless, the original release and recovery data has several significant limitations, such as that fish can be captured only once, the low level of fish salvaged at the CVP and SWP from individual releases and the large variation between such releases under similar conditions, the low probability of capture in the recovery process (trawling), the relatively high level of environmental variation present in the data, and the lack of balance in the release strategy (VAMP experiments) all reduce the accuracy of the estimates of the desired endpoint, *i.e.*, survival of released fish. Newman explains that given the apparently high environmental variation present in these experiments, it could take many more replications of the temporally paired releases to provide a more accurate estimate of the effects of the DCC gate position, the effects of exports and river flow, and the placement of the HORB on the survival of released fish.

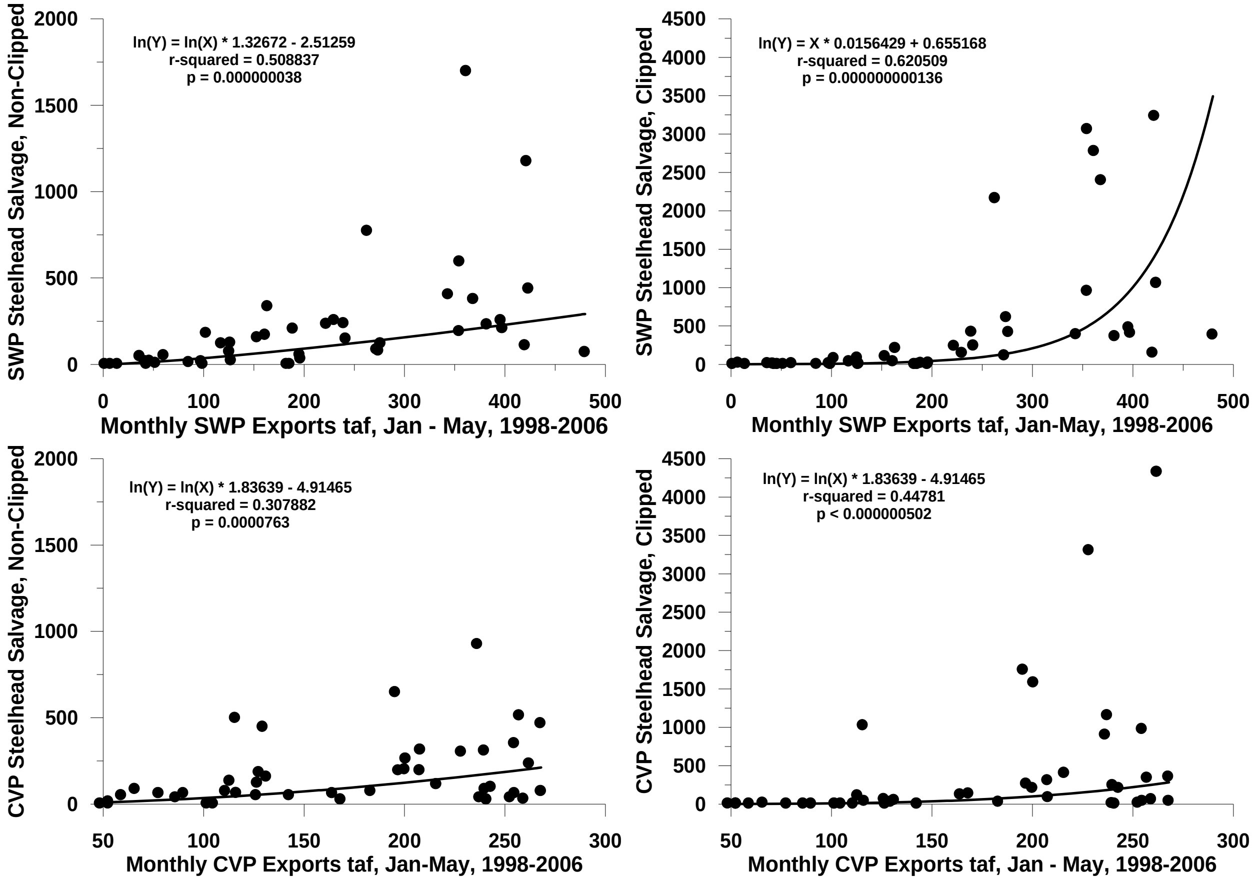


Figure 6-72. Monthly steelhead salvage versus average exports, January through May, 1998 through 2006, at each facility; SWP and CVP (CVP/SWP operations BA figure 13-45).

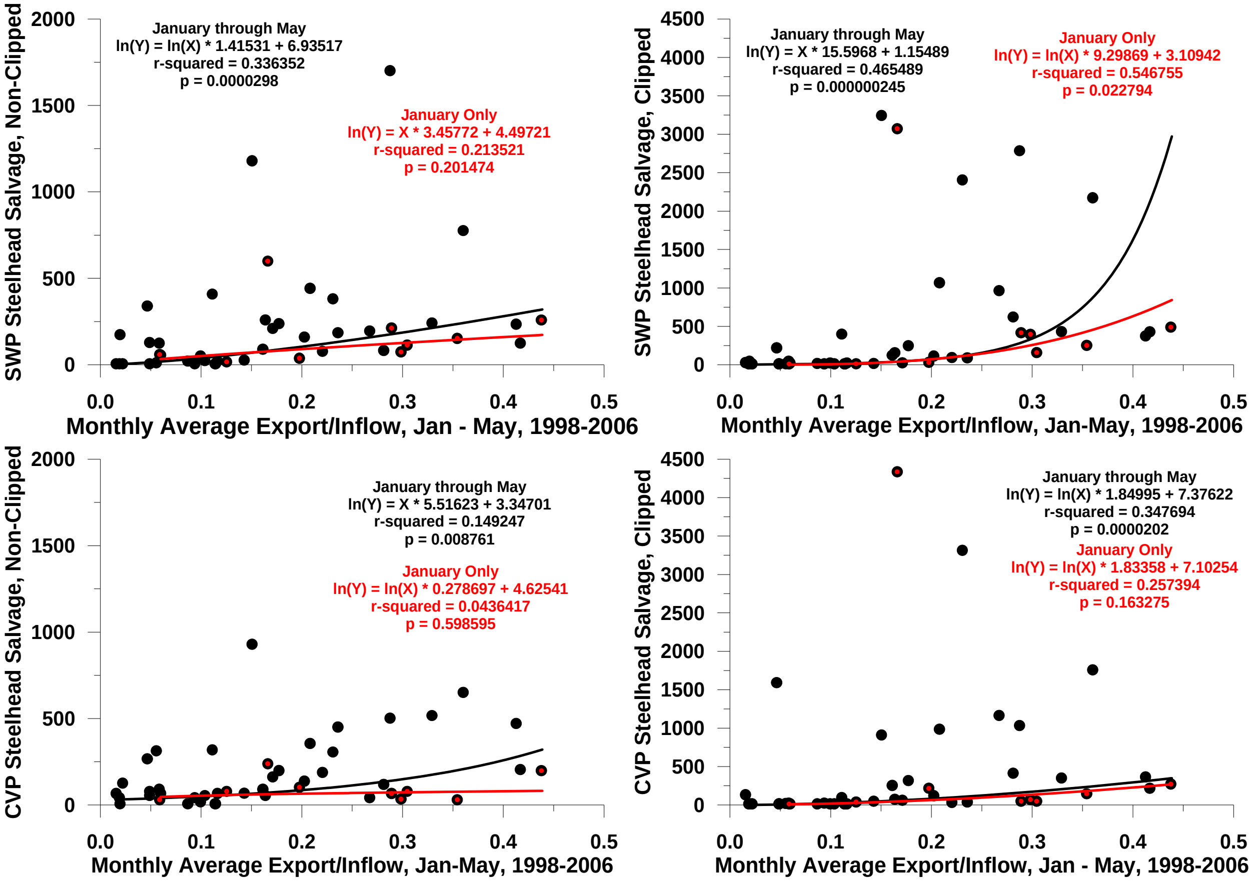


Figure 6-73. Monthly steelhead salvage versus average Export/Inflow ratio in TAF, January through May, and January alone, 1998 through 2006, at each facility; SWP and CVP (CVP/SWP operations BA figure 13-46).

Notwithstanding these limitations, Newman reached the following conclusions:

Delta Cross Channel Experiments: There was modest evidence (64 to 70 percent probability) that survival of fish released at Courtland (upstream of the DCC gates) to Chipps Island relative to the survival of releases made from Ryde (downstream of the DCC) increased when the DCC gates were closed.

Interior Studies: Although there was considerable variation between paired releases, the overall recovery fractions for Ryde releases remained higher than the Georgiana Slough releases in all cases. The means of the ratios for Ryde to Georgiana Slough recoveries were 0.26, 0.43, and 0.39 at Chipps Island, in the ocean, and inland sites, respectively, which is consistent evidence that fish released in Georgiana Slough had a lower probability of surviving than fish released in the Sacramento River at Ryde. Conversely, the relative fraction of fish that were salvaged at the CVP or SWP pumps was approximately 16 times greater for fish released in Georgiana Slough than for fish released in the Sacramento River at Ryde.

Delta Action 8 Experiments: There was a negative association between export volumes and the relative survival of released salmonids (*i.e.*, a 98 percent chance that as exports increased the relative survival of released Chinook salmon juveniles decreased). However, environmental variation in this set of experiments was very large and interfered with the results. There is also a positive association between exports and the fraction of Georgiana Slough releases that are eventually salvaged. With only one exception, (1995 release group), the fraction of fish salvaged from Ryde releases appear to be unrelated to the level of exports (Ryde is downstream of both the DCC and Georgiana Slough channel openings on the Sacramento River)

VAMP: The expected probability of surviving to Jersey Point was consistently greater for fish staying in the San Joaquin River (*i.e.*, passing Dos Reis) than fish entering Old River, but the magnitude of the difference varied between models somewhat. The placement of the HORB effectively keeps fish from entering Old River; therefore the survival of out-migrants should increase. There was a positive association between flow at Dos Reis and subsequent survival from Dos Reis and Jersey Point to Chipps Island. If data from 2003 and later were eliminated from data set, then the strength of the association with flow increased and a positive association between flow in Old River and survival in Old River also appeared. Finally, any associations between water export levels and survival probabilities were weak to negligible. This may have been due to the correlation between flow and export rates during the VAMP experiments. Given the complexity and number of potential models for the VAMP data, Newman recommends a more thorough model selection procedure using Reversible Jump MCM. An alternative analysis by Hanson (2008) did not find any significant relationship between exports and survival. Hanson also analyzed the relationship between exports and entrainment at the CVP and SWP as measured by salvage. Hanson (2008) referred to this fraction as direct losses. In Hanson's analysis, he examined the data from 118 studies involving approximately 14.2 million fish. Hanson found that on average, for fish released into the upper Sacramento River, direct losses due to the CVP and SWP pumps averaged 0.03 percent (sample size n = 118, 95 percent confidence interval (CI) = 0.0145) with a range of 0 to 0.53 percent. Hanson does not elaborate where these fish were released in the Sacramento River, what survival rates where prior to entering the Delta (losses may be as high as 80 percent in the Sacramento River prior to reaching the Delta, MacFarlane *et al*. 2008), whether these releases were paired in both spatial and temporal aspects to minimize environmental variance, the level of variance in pumping rates during his selected time frames of sampling, and how the inefficiency of the trawling recoveries and low recoveries rates at the fish collection facilities may have biased his results (see Newman 2008). Whereas Newman found increasing trends for fish in Georgiana Slough to be entrained with increases in exports (Delta Action 8 Studies), Hanson's analysis did not find this pattern. Likewise, the decrease in survival for fish in Georgiana Slough with increasing export rates found by Newman's analysis were not found in Hanson's analysis of the data. It is not apparent in Hanson's explanation of his analysis how he separated the different experimental studies into subgroups for statistical analysis with the goal of reducing bias and sampling variability, and thereby increasing the precision of his analysis.

Results from the different statistical analyses indicate that the data from the multiple releases-recapture studies are very "noisy" due to high levels of environmental variability. Finding clear cut results is a difficult task in which the various sources of error in the data, whether due to experimental design, sampling efficiency, hydrological conditions, temporal and spatial variability, or inability to maintain constant conditions during the duration of the experiment, all lead to a lack of resolution in determining the final result of interest. Future studies utilizing acoustic tagging are aimed at reducing these confounding factors. In particular, acoustic tagging gives fine scale temporal and spatial resolution to the movements and behavior of fish over an extended period of time. Unlike the release–recapture studies, individual fish can be "sampled" continuously without loss of the test subject (*i.e.*, captured in the trawl or salvage facility). They can be followed after flow splits into different channels and their final disposition determined by reach, if necessary, to calculate their survival without the uncertainty of the current recapture methods employed in studies to date.

6.6.2.5 Indirect Mortality Within the Delta

6.6.2.5.1 Overview of Mortality Sources

Survival of salmonids migrating through the Delta is affected by numerous variables, some related to the proposed action, others independent of the project. As fish move down the mainstem Sacramento River into the North Delta, the intersecting channels splitting off of the main river channel provide alternative routes for migration. For each of these routes, a different probability exists for taking that alternative channel or remaining in the main stem of the river. Within each channel, additional factors come into play that determines the ultimate survival of fish moving through that reach of water. Survival is affected by the degree of predation within each individual channel, which is itself a function of predator types and density. Some predators, such as striped bass, are highly efficient at feeding on various aquatic organisms and quite mobile, thus moving from location to location, opportunistically preying on emigrating salmonids when they encounter them. Others, such as centrarchids (*i.e.*, largemouth bass) are more localized and ambush prey as it moves past their location in a given channel. They are unlikely to follow a migrating school of prey any great distance from their home territory. The suitability of habitat for emigrating salmonids can affect whether sufficient food and cover is available to emigrating fish, which then influences the survival of fish moving through that waterway. For example, a heavily riprapped channel that has essentially a trapezoidal cross section is unlikely to provide suitable foraging habitat or habitat complexity necessary for migrating salmonids. This condition can be further exacerbated if the margins of the channel are vegetated with the non-native *Egeria densa* which provides excellent cover for ambush predators like largemouth bass. Likewise, residence time required for passage of the fish through the alternative channel determines the duration of exposure to the stressors present in that channel. For example, a short residence time in a channel with extreme predation may have the same effect on survival as a prolonged residence time in a channel with low predation.

The exposures to toxicants in these channels are also likely to vary substantially. Passage through a channel with outfalls from a domestic wastewater treatment facility (WWTF) is likely to have a very different profile of chemical exposure compared to a channel dominated by agricultural return water runoff. A further layer of complexity is created by precipitation events that create the "first flush" effects that discharges surface runoff from urbanized and agricultural areas into local streams and waterways through stormwater conveyance systems or irrigation return ditches. Fish swimming through these plumes are exposed to elevated levels of contaminants, as well as reduced water quality parameters (*e.g.*, lowered dissolved oxygen due to high organic matter loading) that have a high potential for compromising the physiological status of the exposed fish, and increasing the level of morbidity or mortality in those fish. In addition, regional effects such as river flows, tides, and export actions are superimposed on top of these localized effects. These large-scale factors can influence the route taken by the fish initially and subsequently determine its eventual disposition due to changes in local hydraulics and flow patterns.

6.6.2.5.2 Applicable Studies

Based on previous studies to date, it is assumed that fish remaining in the main channel of the Sacramento River have a higher survival rate than fish which move into other distributary channels splitting off from the main channel. Survival indices calculated for paired releases on the lower Sacramento River indicated that Chinook salmon smolts released into Georgiana Slough were between 1.5 times to 22 times more likely to be "lost"[15] to the system than fish released in the main stem of the Sacramento River below the head of Georgiana Slough at the town of Ryde, based on the recoveries of marked fish at Chipps Island (Brandes and McLain 2001, table 3). This is equivalent to a mortality rate of 33 to 95 percent. Statistical analysis by Newman (2008) found an average ratio of survival between the Georgiana Slough releases and the Ryde releases of 0.26, 0.43, and 0.39 for recoveries at Chipps Island, in the ocean harvest, and inland sites where adults were subsequently collected following spawning, respectively. Thus, survival in Georgiana Slough is less than one-half of that in the main stem Sacramento River, based on the Ryde releases. In comparison, Vogel (2004) found that approximately 23.5 percent of the radio tagged fish released in the mainstem Sacramento River during his radio telemetry tagging studies in the winter of 2002 were "lost," presumably to predation, leaving 76.5 percent of the fish reaching the Cache Slough Confluence near Rio Vista. Concurrent releases in Georgiana Slough during January and February of 2002 had mortality rates of 82.1 percent. In a similar study conducted in 2000 by Vogel, when ambient flows in the mainstem were higher (22,000 to 50,000 cfs compared to 14,000 to 23,000 cfs), the predicted predation rate on Chinook salmon smolts in the Sacramento River fell to 20 percent, while predicted predation in Georgiana Slough fell to 36 percent of the released fish. Vogel (2008a) conducted another study with acoustically tagged Chinook salmon smolts released on the Sacramento River near Old Town Sacramento in late 2006 and early 2007. While Vogel (2008a) presented preliminary general statistics, the full statistical analysis of this study will be reported by the U.S. Geological Survey (USGS). This study provided preliminary information on the behavior of fish as they passed side channels within the mainstem of the Sacramento River, and reach specific losses of tagged fish (assumed to be due to predation). Two releases were made, one on December 11-12, 2006 (n=96 fish in 4 groups of 24 fish) and one on January 22-23, 2007 (n=150 fish, released 8 groups). Although Vogel (2008a) presented only general summary statistics, he found that losses of fish that remained in the mainstem during the December study were approximately 20 to 22 percent, while those fish that moved into Georgiana Slough and the open DCC channels

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[15] For this discussion loss is equivalent to mortality, although the studies to date cannot determine whether loss is the result of mortality from predation or other sources, or the inability to detect and account for all released fish in the Chipps Island trawls or subsequent ocean recoveries.

experienced much higher levels of loss (55 percent in Georgiana Slough, 80 percent in the DCC). The January 2007 loss rates were slightly higher, approximately 35 percent of the mainstem fish were lost, while approximately 73 percent of the fish that entered Georgiana Slough were lost. A fairly large fraction of fish entered the Sutter Slough and Steamboat Slough reaches (37 percent of the fish in the mainstem) with loss rates of approximately 40 percent (see Vogel 2008a for more details). These data indicate that there are reach specific characteristics for loss rates due to intrinsic factors in those channels (*e.g.*, predation). The release of fish in December occurred approximately three days before the DCC was closed due to rising flows in the Sacramento River (DCC was closed on December 15, 2006 at 1000 hours). Sacramento River flows increased to approximately 26,000 cfs during December before receding. Therefore, fish released in West Sacramento had at most 3.5 days to travel downstream and encounter the open DCC gates and enter into the delta interior through this route. Fish traveling downstream during this release encountered a rising hydrograph on the Sacramento River. Conversely, the January 2007 release had closure of the DCC gates during the entire experimental period, with relatively stable flows below 12,000 cfs.

A more detailed report concerning fish releases in mid December 2006 and mid-January 2007 was provided by Burau *et al*. (2007), which statistically analyzed the distribution and survival of tagged salmon released during the same study as Vogel (2008a; December 11-12, 2006 and January 22-23, 2007). Burau *et al*. (2007) estimated that 22 percent (22.2 ±0.065) of released fish entered Sutter Slough and approximately 4 percent (3.7 ± 0.021 percent) entered Steamboat Slough during the December release, the same percentages as Vogel (2008a). Of the fish that reached the vicinity of the second junction point, approximately 18 percent (17.9 ± 0.057) went into the channel of the DCC, and an additional 20 percent (19.6 ± 0.053) went into the channel of Georgiana Slough. Approximately 62 percent (62.5 ± 0.065) continued downstream in the Sacramento River channel below the second junction point. Following the January releases, with the DCC gates closed for the entire experimental period, approximately 30 percent (29.9 ± 0.046) of the fish entered Sutter Slough and 7 percent (7.2 ± 0.026) entered Steamboat Slough. Of the fish that reached the vicinity of the second junction point, approximately 29 percent (28.9 ± 0.063) entered Georgiana Slough (DCC closed) with the remainder moving downstream in the Sacramento River channel (71.1 ±0.063 percent). The first release in December was made on a rising hydrograph with flows of approximately 19,600 cfs and 3 days before the DCC gates closed in response to the increasing flows. The January releases were made under conditions in which the flows in the Sacramento River were much lower, approximately 11,300 cfs at Freeport. The preliminary results from this study indicate that both route selection and reach specific-survival depend on Sacramento River discharge and DCC gate position. Burau *et al.* (2007) states that these data indicate that: (1) when the DCC gates are closed the probability that salmon are entrained in Sutter, Steamboat, and Georgiana sloughs increases, which is consistent with increases in discharge in each of these channels when the gates are closed; (2) survival in every channel was higher at the higher discharge: survival in the Sacramento River increased by approximately 20 percent between the City of Sacramento and Sutter Slough, by approximately 8 percent in the reach between Steamboat Slough and the DCC, and approximately 15 percent between Georgiana Slough and Cache Slough; (3) survival in Georgiana Slough is consistently lower than in any other channel when survivals were estimated (DCC channel and Mokelumne River survival were not estimated); and finally, (4) the precision in the survival estimates are progressively lower (increasing error bars) the farther into the system the measurements are made due to the reduction in fish passing through the lower reaches of these channels. The number of fish passing through the river sections farther from the release sites are reduced due to: (1) the total number of fish is progressively distributed into a greater number of pathways, and (2) mortality occurs as fish traverse the system, leaving fewer viable fish to traverse channels at a greater distance from the release site. The preliminary results from this study suggest that survival increased with increasing flows in the different river channels when comparisons could be made. The interpretation of the DCC gate position with survival was complicated by the very short duration of the "open" gate configuration (3 days) coupled with an increasing hydrograph during this period. Conversely, the "closed" gate condition occurred during lower river flows than the open gate configuration, and thus the comparison of the gate position is confounded by the flow variable between the two studies.

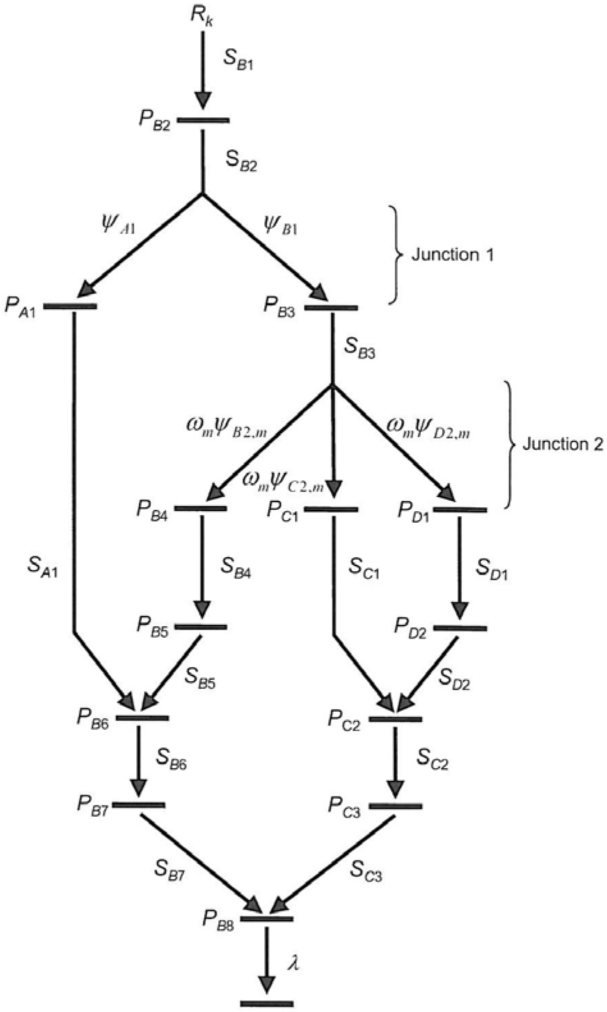
A study run by Perry and Skalski (2008) in the same region and general time frame produced similar results to the Vogel (2008a) and Burau *et al*. (2007) studies in some aspects, but different results in others. They developed a mark-recapture model that explicitly estimated the route-specific components of population-level survival in the Delta. The point estimate of survival through the Delta for the first release made on December 5, 2006 ($\hat{S}_{Delta} = 0.351$, SE = 0.101, n=66 fish), was lower than the subsequent release made on January 17, 2007 ($\hat{S}_{Delta} = 0.543$, SE = 0.070, n=80 fish). The authors attributed the observed difference in $\hat{S}_{Delta}$ between releases to (1) changes in the proportion of fish migrating through each distinct route through the Delta, and (2) differences in the survival for each given route traveled. Survival estimates for the routes through the interior of the Delta were lower than for the mainstem Sacramento River during both releases, however only 9 percent of the fish migrated through the interior of the Delta during the January release compared to 35 percent for the December release (table 6-32). The DCC gates closed on December 15, 2006 at 1000 hours, 10 days after the first release of fish on December 5, 2006. Passage data indicated that approximately 95 percent of the fish had passed through the second junction reach by the time the gates were closed. The first release was also made at Sacramento River flows of approximately 11,700 cfs at Freeport. Flows remained below 12,900 cfs until December 9, 2006, giving approximately 4 to 5 days of steady flow before increasing. Approximately 50 percent of the fish were detected arriving at the second junction prior to this date, and 75 percent of the fish had passed by approximately December 12, 2006. In comparison, the release of fish in January corresponded with steady flows of approximately 12,000 cfs for 10 days following the release and the gates in a closed position. Fish passage in January occurred much more quickly than in December, taking only 3 to 4 days to pass through the second junction. Perry and Skalski (2008) concluded that the operation of the DCC gates affected the route selection of fish during the study. The gates were closed on December 15, 2006, approximately half way through the first release study period and remained closed during the entire second study release period. The operation of the DCC affected both route selection and the distribution of flows within the channels of the north Delta. These effects were captured by the mark-recapture modeling of the study (figure 6-74).

Although the Vogel (2008a), Burau *et al*. (2007), and Perry and Skalski (2008) acoustic tagging studies have relatively small sample sizes, each fish provides valuable data concerning route selection, migration speed, and predation (loss) vulnerabilities. The two studies provide information that corresponds to the trends observed in previous CWT studies. These more recent studies verify that survival is lower within the channels of the interior delta and that higher flows benefit survival during fish movement downstream. Although the Vogel (2008a) and Burau *et al*. (2007) studies could not adequately address the effect of DCC gate position on survival due to confounding effects of increasing river flows and the short period between release of study fish and the gate closure, the results from the Perry and Skalski study indicate that population level survival can be increased by closing the gates. This results in reducing the fraction of the fish population entering the inerior of the Delta and increasing the fraction migrating through the northern system of channels, which include the Sacramento River, Sutter Slough and Steamboat Slough channels, where survival was higher relative to the interior Delta. If replications of the acoustic tag studies continue to provide similar outcomes, a more defined and accurate model of routing and predation vulnerabilities can be developed that is statistically robust and could provide a more thorough understanding of the system for ongoing management needs.

Table 6-32. Route-specific survival through the Sacramento-San Joaquin Delta ($\hat{S}_h$) and the probability of migrating through each route (Ψ_h) for acoustically tagged juvenile fall-run released on December 5, 2006, (R_1) and January 17, 2007, (R_2). Also shown is the population survival through the delta (S_{Delta}), which is the average of route specific survival weighted by the probability of migrating through each route (from Perry and Skalski 2008).

Migration Route	Survival $\hat{S}_h$ (SE)	95% Profile Likelihood Interval	Probability of Migratory Route Ψ_h (SE)	95% Profile Likelihood Interval
R_1 ; December 2006 (n=66)				
A) Steamboat & Sutter Sloughs	0.263 (0.112)	0.102, 0.607	0.296 (0.062)	0.186, 0.426
B) Sacramento River	0.443 (0.146)	0.222, 0.910	0.352 (0.066)	0.231, 0.487
C) Georgiana Sloughs	0.332 (0.179)	0.087, 0.848	0.117 (0.045)	0.048, 0.223
D) Delta Cross Channel	0.332 (0.152)	0.116, 0.783	0.235 (0.059)	0.133, 0.361
S_{Delta} (All Routes)	0.351 (0.101)	0.200, 0.692		
R_2: January 2007 (n=80)				
A) Steamboat & Sutter Sloughs	0.561 (0.092)	0.388, 0.747	0.414 (0.059)	0.303, 0.531
B) Sacramento River	0.564 (0.086)	0.403, 0.741	0.498 (0.060)	0.383, 0.614
C) Georgiana Sloughs	0.344 (0.200)	0.067, 0.753	0.088 (0.034)	0.036, 0.170
D) Delta Cross Channel	NA		0.0	NA
S_{Delta} (All Routes)	0.543 (0.070)	0.416, 0.691		

The mainstem Sacramento River channel has generally lower loss rates than the smaller distributary channels that diverge from it and loss rates appear to be affected by river flow levels. The subsequent total survival of fish leaving the Delta at Chipps Island is the sum of survival rates in each route multiplied by the probability of selecting that route multiplied by the "detection" probability for that group from all of the different potential routes that fish may take upon entering the north Delta from the Sacramento River, including the Yolo bypass in flood. This survival number is the fraction of total fish entering the Delta, which have avoided all of the potential sources of mortality to survive to Chipps Island. The number of fish entering the Delta from the Sacramento River is itself approximately 20 percent of the total number of fish that started migrating downstream in the Sacramento River from their natal rearing areas (MacFarlane *et al*. 2008a). This low survival number is due to the intrinsic losses in the migrating population of fish as they encounter the natural and anthropogenic sources of mortality along the migration route.



A1 = Steamboat Slough/Sutter Slough, B1 = West Sacramento, B2 = Freeport, B3 = Courtland, B4 = Walnut Grove/upstream of the DCC, B5 = Ryde, B6 = Rio Vista, B7 = Emmaton, B8 = Chipps Island, B9 = pooled survival from SF Bay stations (λ), C1 = Georgiana Slough, C2 = lower Mokelumne River system, C3 = Antioch/ lower San Joaquin River, D1 = DCC, D2 = Downstream of DCC, upper branches of Mokelumne River. Releases (R_k) are made into the Sacramento River at West Sacramento. Junction 1 is the reach which includes the Steamboat/Sutter Slough junction with the Sacramento River, Junction 2 is the river reach which contains the Sacramento River with the DCC and Georgiana Slough.

Figure 6-74. Schematic of the mark recapture model used by Perry and Skalski (2008) used to estimate survival (S_{hi}), detection (P_{hi}), and route entrainment (ψ_{hi}) probabilities of juvenile late-fall Chinook salmon migrating through the Sacramento-San Joaquin River Delta for releases made on December 5, 2006, and January 17, 2007.

Population level survival through the Delta was estimated from the individual components as:

$$S_{Delta} = \sum_{h=A}^{D} \psi_h S_h$$

where h = the four potential routes, A – D; A = Sutter/Steamboat Slough, B = Sacramento River, C = Georgiana Slough, and D = Delta Cross Channel.

Telemetry tagging also was instrumental in describing movement patterns in the channels of the Central Delta (Vogel 2004, radio telemetry) and the South Delta (SJRGA 2008, acoustic telemetry). Fish released in the mainstem San Joaquin River near Fourteenmile Slough in the spring of 2002 and 2003 showed distinct movement patterns based on the level of export pumping and tides. When the combined exports created negative flows in the channels feeding into the South Delta, (*i.e.*, Turner and Columbia Cuts), a significant proportion of the released fish moved into those channels and were followed in a southerly direction towards the pumps. Conversely, when the VAMP experiment reduced export levels and increased flows in the San Joaquin River, more fish stayed in the main channel of the San Joaquin River and headed downstream with the net flow towards San Francisco Bay. This study also determined that Chinook salmon smolts were not "holding" on the flood tide and then going downstream with the ebb tide (tidal surfing behavior). Fish were observed to move significant distances with the tidal oscillation, and their net movement downstream did not occur at obvious times of the tidal cycle. The data from this study and the North Delta study indicate that fish may be vulnerable to flow split selection several times depending on the magnitude and timing of the tidal oscillation, thus the probability of selecting one route over another is more complex than just a one time exposure to the channel split (see also Horn and Blake 2004). The acoustic tagging studies conducted during the VAMP experiments (SJRGA 2007) indicated that fish responded to flow and presumably export levels when moving downstream in the San Joaquin River past Turner and Columbia Cuts, and the mouths of Middle and Old River. The study also found that fish could pass through the culverts on the HORB and be subsequently detected downstream at the CVP and SWP facilities. Likewise, some fish that passed by the HORB and continued downstream into the Delta proper, were also detected moving southwards towards the pumps, presumably under the influence of the net negative flows in those channels. Preliminary predation hot spots, (*e.g.*, the scour hole in front of the HORB) were also detected, as well as areas with potential water quality concerns (City of Stockton WWTF outfall), which corresponded to increased losses of tagged fish passing through those reaches.

The tagging data and the results of theoretical particle tracking models (see Kimmerer and Nobriga 2008) support the position that movement of fish (or particles), at least in part, are influenced by the inflow of water into the Delta from the surrounding tributaries, and the volume of water being exported from the Delta by the CVP and SWP, thus affecting the flow patterns within the Delta channels. While the correlation of the survival rates of fish released in the Delta Action 8 and the Interior Delta CWT studies with the percentages of particles reaching Chipps Island is poor under most of the runs, Kimmerer and Nobriga (2008) offer potential causes for these differences. They opine that the lack of correlation may be merely due to the differences in the behavior between salmon and neutrally buoyant particles, or, on the other hand, that artifacts of the experiments such as the survival potential of fish traveling through the different waterways (*i.e.*, predation on the CWT fish) or the lack of efficiency in the trawl recapture rates for Chipps

Island biases the results of the CWT studies and results in lower numbers of fish reaching the terminal endpoints than suggested by the PTM results. They conclude that "despite all these differences, the PTM results suggests that river flow may be an important variable in determining which way the salmon go and their probability of survival, and should be included in the design and analysis of future studies" (Kimmerer and Nobriga 2008 page 19). Operations of the CVP and SWP, since they are supplied by the flow of water in the Sacramento and San Joaquin Rivers, set the hydraulic boundary conditions in conjunction with the two main sources of water flowing into the Delta. The boundary conditions, in part, dictate the flow percentage splits into distributary channels, in concert with the overlying tidal signal (see Horn and Blake, 2004). Operations of program infrastructures, such as the DCC radial gates and the South Delta temporary barriers, further influence the probability of entrainment into side channels leading off of the main river channel. The influence of the export pumps becomes more pronounced the closer to the pumps the fish or experimental particle gets, until entrainment is essentially certain.

DWR created a Delta Survival Model as part of their declarations to the court in September, 2008 (Greene 2008). The model provides estimates of survival through the Delta interior for a population of "fish" that enter the Delta from the Sacramento River. The model, using inputs for exports and Delta inflow, calculates percentage splits of the migrating fish population moving downstream in the Sacramento River into the interior of the Delta. The percentage splits are based on PTM simulations with injection points at Hood (upstream of the DCC and Georgiana Slough and indicating movement into the Delta interior) and in the South Mokelumne River (movement towards the export facilities in the South Delta and westwards towards Chipps Island). Interpolation of data provided in the Newman (2008) analysis estimated non-export and export related loss encountered in the Delta based on export levels. From the data output of the model, a final estimate of the survival through the Delta can be derived with losses calculated for export and non-export related mortality. The model is strongly driven by the export/inflow ratio which determines the PTM output and hence the particle fates (*i.e.*, fish) and by the export rate which determines relative survival rate between the Sacramento River and the Delta interior and the export related interior Delta survival rate. NMFS biologists used the summary output from the three studies (7.0, 7.1, and 8.0) simulated with the CALSIM II model over the different water year types for the months between December and June to estimate the different rates of mortality expected under the different CALSIM II scenarios for emigrating salmonids. Loss associated with exports ranged from 0.3 percent of the total population entering the Delta to slightly more than 15 percent of the population entering the Delta over the different simulation runs. The loss associated with non-export factors ranged from 3.3 percent to approximately 31.5 percent of the population. Total survival of the emigrating fish population was estimated to range between 41 and 77 percent. The data indicated that lower survival rates were predicted when E/I ratios were high, and more particles were moved into the Delta interior and thence southwards towards the export facilities. Losses were higher in drier years and during the early season of fish migration (December through February). The data also indicated that the near future and future studies would have higher levels of loss due to higher export levels and thus higher E/I ratios.

6.6.2.5.3 Environmental Factors

In addition to the "direct" effects of the CVP and SWP operations manifested by flows and exports, the modification of the Delta hydraulics for the conveyance of water has altered the suitability of the Delta for native species of fish, such as Chinook salmon, steelhead, and green sturgeon. Since the inception of the CVP and later the SWP, the natural variability in the hydrology of the Delta has been altered. As previously explained, the amount and timing of runoff from the Sacramento and San Joaquin Rivers has been altered and shifted to accommodate human needs. When large-scale exports of water were initiated in the South Delta, it became necessary to "freshen up" the Delta to guarantee high quality fresh water was available to export from the facilities on a reliable basis (*e.g.*, construction of the DCC). This necessitated an increase in the stability of the Delta's hydrology and the formation of a large freshwater "lake" for the reliable conveyance of water from the river sources to the export facilities. The enhanced stability of the freshwater pool in the Delta enabled non-native species, such as centrarchids and catfish, as well as invasive plants, such as *Egeria densa* and water hyacinth, to thrive in this "new" Delta hydrology (Brown and Michniuk 2007). In addition, the altered ecological characteristics of the Delta have been proposed as a contributing factor in the recent Pelagic Organism Decline (POD) observed in the Delta. The combination of these exotic species and altered ecological characteristics of the Delta interact to decrease the suitability of the Delta for native species of fish and have increased the potential for predation and loss (see 2008 CVP/SWP operations BA, Delta smelt sections for a more detailed explanation).

6.6.2.5.4 Summary

Many of the indirect mortality events are interrelated to the operations of the CVP and SWP. As previously discussed, the Delta has been operated as a freshwater conveyance instrument for the past half century. The necessity for the stable and reliable transfer of freshwater from the Sacramento River across this large expanse of waterways has required that natural hydrologies and circulation patterns be altered to maximize the efficiency of the water operations. This change has benefited non-native species to the detriment of native species, which evolved with a more dynamic habitat, which included variable hydrographs and seasonal fluxes of salinity into the western Delta. In light of the POD phenomenon that has become evident in the Delta in recent years, the aspect of a bottom to top reorganization of the ecosystem during the past decade indicates that the Delta is "unhealthy" and even the exotic, introduced species (*i.e.*, striped bass, thread fin shad, *etc*.) are in decline. Continued operations of the CVP and SWP are unlikely to benefit the health of the Delta, and increases of the facility operations are likely to degrade the system beyond their current conditions, rather than return the Delta to a more natural condition, with more functional hydraulics conducive to a healthy ecosystem.

6.6.2.6 Assess Risk to Individuals

This section summarizes the potential risks faced by individual fish of the winter-run population, the spring-run population, the CV steelhead population, and the Southern DPS of green sturgeon in the Delta region. The previous sections have described in detail, the effects of the proposed export operations on these fish.

Increased pumping, as proposed in the project description will increase the vulnerability of individual fish to entrainment at the TFCF and the SFPF in the South Delta. Salmonids entrained at the Federal facility, the TFCF, have a maximal survival estimate of approximately 35 percent under normal operating conditions. However this survival rate may decrease even further depending on louver cleaning frequency, pumping operations, and predation following CHTR releases. The survival rate of salmonids at the state's facility, the SFPF, is estimated to be approximately 16 percent under normal operating conditions. Unlike the Federal facility, where most of the salmonid loss is attributed to the louvers, the state's facility has relatively efficient louvers, but substantially greater predation risks. Predation loss within CCF is the main variable driving survival of entrained fish with little difference evident between the smaller salmon smolts and the larger steelhead smolts. It is estimated that only one out of every four to five fish entering the forebay survive their transit across this water body to be salvaged at the louvers. This predation risk is dependent on predator density and behavior in the forebay. Additional changes to the survival estimate can occur due to changes in export levels at the Banks Pumping Plant and predation risks following release back into the system at the CHTR release stations. It is unknown what percentages of juvenile and sub-adult green sturgeon are lost at the fish collection facilities. Based on the studies by Kynard and Horgan (2001), salvage rates should be almost 100 percent for green sturgeon based on the efficiencies for shortnose and pallid sturgeon. However, cleaning of the louvers where the louvers are lifted out of their guides and reductions in flow along the louver face during export reductions may degrade the louver efficiency for green sturgeon and loss of individual fish becomes greater under such conditions.

Salmonids are also subject to loss as they cross the Delta during their downstream migration towards the ocean. As shown by the Burau *et al*. (2007), Perry and Skalski (2008) and Vogel (2008a) studies, individual fish risk entrainment into the channels of Georgiana Slough under all conditions and into the Mokelumne River system when the DCC gates are open as they migrate downstream in the Sacramento River. Estimated average survival is only 33 percent with a range of approximately 10 percent to 80 percent survival. Most of this loss is believed to be associated with predation, but may also include prolonged exposure to adverse water quality conditions represented by temperature or contaminants. Several years of salmonid survival studies utilizing both CWT and acoustically tagged fish indicate that survival is low in the interior Delta waterways compared to the mainstem Sacramento River. Likewise, survival in the upper San Joaquin River between Durham Ferry and Jersey Point is substantially lower than survival from Jersey Point to Chipps Island (VAMP studies), indicating that transiting the Delta interior is a very risky undertaking for fish exiting from the San Joaquin River basin or the east side tributaries (Mokelumne and Calaveras River basins). The probability of ending up at the Delta export facilities or remaining in the interior delta waterways increases with increased export pumping, particularly for those fish in the San Joaquin River system.

NMFS estimates that loss associated with exports for fish emigrating downstream in the Sacramento River and entering the Delta ranged from 0.3 percent of the total population entering the Delta to slightly more than 15 percent of the population entering the Delta based on the different CALSIM II simulation runs for current (Study 7.0), near future (Study 7.1) and future conditions (Study 8.0) and the Delta Survival Model developed by DWR. The loss associated with non-export factors ranged from 3.3 percent to approximately 31.5 percent of the population.

Total survival of the emigrating fish population from the Sacramento River basin was estimated to range between 41 and 77 percent for fish entering the Delta and subsequently reaching Chipps Island in the western edge of the delta. These values most accurately represent losses to winter-run Chinook salmon and spring-run Chinook salmon since loss rates in the DWR model were constructed from studies of CWT tagged Chinook salmon. NMFS will also use these loss rates for CV steelhead migrating downstream in the Sacramento River for lack of species-specific studies for steelhead predation losses. Loss rates due to predation in the CCF were similar between the smaller Chinook salmon smolts and the larger steelhead smolts, and therefore provide a level of justification in making this assumption. The loss of juvenile and sub-adult green sturgeon in the delta due to exports is unknown. To date, NMFS is not aware of any studies designed to quantify the loss of these fish to export related actions. Only recently have acoustic tagging studies been undertaken to study the movement of fish through the delta and results are still being interpreted by the study investigators. The fact that some individual green sturgeon are collected at the export fish salvage facilities indicates that these fish are vulnerable to the exports and may incur population level effects. Loss rates for CV steelhead emigrating from the San Joaquin River basin and the east side tributaries of the Calaveras River and Mokelumne River systems are expected to be substantially higher than those experienced by the Sacramento River basin fish due to the proximity of the main migration corridor (the San Joaquin River) to the export facilities. Stronger flow effects from the pumps are observed on the San Joaquin River waterways and the nature of the south Delta channels provide multiple access points to the exports when water is being diverted.

Loss rates at the export facilities typically account for several hundred to several thousand individual wild fish per year from the different salmonid populations. As previously discussed, the importance of these wild fish to the population is potentially greater than their actual numbers. These fish represent individuals who have survived the numerous stressors present in the system between their natal streams and the Delta, and therefore represent behavioral and physiological traits that are necessary for survival in the natural environment. Loss of these individuals represents a loss of survival traits that would be beneficial to the population as a whole.

An historical assessment of estimated survival of fall-run smolts through the Delta by water year type at different levels of development in the Central Valley was calculated by Kjelson and Brandes (1989). They found that water development has adversely affected smolt survival over the period spanning 1920 to 1990. The authors reggressed smolt survival estimates on the Sacramento River with river flows at the City of Sacramento and applied this to monthly estimates of smolt migration through the Delta. These parameters were then used to calculate average survival rates using estimated historic flow patterens at Sacramento under four different water development scenarios. The results indicted that reduced inflow to the Delta caused by water development in the Sacramento Valley has reduced smolt survival substantially (table 6-33). The greatest differences in survival occurred in dry and critical years. The estimated maximum decrease in survival associated with the 1990 level of development occurred with the no development scenario. The authors estimated that between 1940 and 1990, survival of fall-run smolts decreased about 30 percent. These are considered minimal estimates of survival decline, since greater survival per unit flow would have occurred prior to the operations of the

DCC in the 1950s than was deduced form the current survival relationships. Survival is more than likely less now than the estimates for the 1990 level of development due to the increased demands in the Central Valley over the intervening 20 years.

Table 6-33. Average estimated Delta survival indices of fall-run Chinook salmon smolts by water year type at different levels of development: unimpaired (no development), and at 1920, 1940, and 1990 levels of development (Table 7 in Kjelson and Brandes 1989).

Water Year Type	Sample Size	Unimpaired No Development	1920 Level of Development	1940 Level of Development	1990 Level of Development
Wet	**19**	**0.97**	**0.92**	**0.91**	**0.83**
Above Normal	**10**	**0.91**	**0.85**	**0.83**	**0.61**
Below Normal	**10**	**0.84**	**0.69**	**0.66**	**0.41**
Dry	**10**	**0.76**	**0.57**	**0.55**	**0.33**
Critical	**8**	**0.33**	**0.17**	**0.21**	**0.12**
Mean		**0.76**	**0.64**	**0.63**	**0.46**

Annual survivals were estimated by weighting monthly survival indices by the average percent from 1978 to 1986 of total outmigrants going to sea (Table 6 in Kjelson and Brandes 1989). Monthly survival indices were estimated from monthly flows using linear relationships between salmon survival and flow at Sacramento where $y = 0.00005x - 0.465$ when y = survival and x = mean monthly Sacramneto River flow. Data from 1969-71 and 1978-81 were used to derive the equation. Monthly flows for the four different levels of developemnt were obtained from the California Department of Water Resources planning simulation Model studies.

6.6.2.7 Effects of the Action on Designated and Proposed Critical Habitat in the Delta Division

The proposed export actions represent an adverse impact to the PCEs of the designated and proposed critical habitats in the Delta region. As discussed in the preceding effects section, the exports divert a substantial amount of water (approximately 6 to 8 MAF annually) from the Delta environment. The hydraulic changes created by the export actions have altered the suitability of the delta as a rearing area and migratory corridor for juvenile salmonids, particularly for Central Valley steelhead which has designated critical habitat in the accessible waterways throughout the entire legal Delta. Likewise, the proposed critical habitat for the Southern DPS of green sturgeon encompasses the accessible waterways of the Delta, and overlaps the geographical area of the designated critical habitat for CV steelhead. Designated critical habitat for winter-run and spring-run is primarily confined to the north Delta region and the waterways associated with the main channel of the Sacramento River.

The effects of the CVP/SWP on the rearing qualities of the Delta are related to the removal or reduction of potential forage species from the Delta environment. Juvenile salmonids and green sturgeon rely on both benthic and pelagic microinvertebrates for their forage base. The actions of the exports directly remove the pelagic forms of these microinvertebrates (copepods, diatoms, cladocerans, *etc*.) through water diversion while also indirectly affecting the benthic forms.

These forage species rely on food webs in which phytoplankton and detritus serve as energy sources. Removal of the phytoplankton from the Delta due to water diversions by the CVP/SWP exports disrupts the flow of energy available to these other pelagic and benthic invertebrate communities, as well as reduces the creation of detrital matter from the decomposition of these organisms in the system along with other organic matter.

The actions of the CVP and SWP contribute to the degradation of the waterways in the Delta as migratory corridors. As described in the effects of the export actions above, emigrating juvenile salmonids are adversely affected by the withdrawal of water from the Delta by the export pumps. The flow of water southwards towards the pumps disrupts the natural flow cues used by emigrating salmonids to reach the lower estuary and the ocean beyond. The alteration in the hydrodynamics can entrain fish southwards from the Central Delta towards the pumps, delay migration by disrupting the normal flow cues associated with net downstream flow, and increase the vulnerability of fish to predation by lengthening their migratory route or directing them into new channels not normally used for emigration to the ocean. The effects on San Joaquin River basin steelhead are most pronounced as the conservation value of the migratory corridors in the south and central Delta are the most degraded. Under current conditions, few steelhead are expected to successfully reach the western Delta and the ocean beyond. Impacts to juvenile and sub-adult green sturgeon are less clear as these fish spend 1 to 3 years rearing in the Delta environment before transitioning to their marine life history stage. During this Delta rearing phase, fish are free to migrate throughout the Delta. Entrainment by the net negative export flows in the central and southern delta may cause fish to be pulled into the southern Delta waterways in an unnatural proportion to their normal movements. Ongoing acoustic tracking studies should provide more detailed information on the movements of this life stage in the Delta.

6.6.3 Clifton Court Aquatic Weed Control Program

6.6.3.1 Deconstruct the Action

The SWP has proposed treating the waters of Clifton Court Forebay with copper-based herbicides, including Komeen®, Nautique® and copper sulfate pentahydrate to reduce the standing crop of the invasive aquatic weeds or algal blooms growing in the water body. The dominant species of aquatic weed in the forebay is *Egeria densa*, however other native and invasive aquatic weeds are present. Excessive weeds fragment and clog the trashracks and fish screens of the Skinner Fish Protection Facility reducing operating efficiency and creating conditions in which the screens fail to comply with the appropriate flow and velocity criteria for the safe screening of listed fish. In addition, the weeds create sufficient blockage to the flow of water through the trashracks and louver array, that the pumps at the Banks Pumping Facility begin to reduce the water level downstream of the Skinner Facility and the loss of hydraulic head creates conditions that lead to cavitation of the impeller blades on the pumps if pumping rates are not quickly reduced. The algal blooms do not affect the pumps, but rather reduce the quality of the pumped water by imparting a noxious taste and odor to the water, rendering it unsuitable for drinking water.

DWR has applied herbicides in Clifton Court Forebay since 1995, typically during the spring or early summer when listed salmonids have been present in the forebay. Applications, however, have occurred as early as May 3rd and as late as September 10th during this time. Copper based herbicides present toxicity issues to salmonids and green sturgeon due to their high sensitivity to copper at both sublethal and lethal concentrations.

DWR, in response to NMFS' concern over the use of Komeen® during periods when listed salmonids may be present in the Clifton Court Forebay, has altered its operational procedure for application of copper-based herbicides from previous operations. DWR has proposed to apply copper sulfate or Komeen® between July 1 and August 31 of each year as needed. In addition, DWR will conduct the following actions:

1. Monitor the salvage of listed fish at the Skinner Facility prior to the application of the herbicides in Clifton Court Forebay.
2. Close the radial intake gates at the entrance to Clifton Court Forebay 24 hours prior to the application of herbicides to allow fish to move out of proposed treatment areas and towards the salvage facility.
3. The radial gates will remain closed for 24 hours after treatment to allow for at least 24 hours of contact time between the herbicide and the treated vegetation in the forebay. Gates will be reopened after a minimum of 48 hours.
4. Komeen® will be applied by boat, starting at the shore and moving sequentially farther offshore in its application. Applications will be made be a certified contractor under the supervision of a California Certified Pest Control Advisor.
5. Application of the herbicides will be to the smallest area possible that provides relief to the project.
6. Monitoring of the water column concentrations of copper is proposed during and after herbicide application. No monitoring of the copper concentration in the sediment or detritus is proposed.

6.6.3.2 Assess the Species Exposure

The timing of the application of the aquatic herbicide Komeen® to the waters of the forebay will occur during the summer months of July and August. The probability of exposing salmonids to the copper-based herbicide is very low due to the life history of Chinook salmon and steelhead in the Central Valley's Delta region. Migrations of juvenile winter-run and spring-run fish primarily occur outside of the summer period in the Delta. The presence of juvenile winter-run and spring-run in the Delta is described in *Section 5.5 Status of the Species and Critical Habitat in the Delta Division.* CV steelhead have a very low probability of being in the South Delta during the July through August period proposed for herbicide treatments. Historical salvage data indicates that in wet years, a few steelhead may be salvaged as late as early July, but this is uncommon and the numbers are based on a few individuals in the salvage collections. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. In contrast, juvenile and sub-adult green sturgeon are recovered year-round at the CVP/SWP facilities, and have higher levels of salvage during the months of July and August compared to the other months of the year. The reason for this distribution is unknown at present. Therefore, juvenile and sub-adult green sturgeons are likely to be present during the application of the copper-based herbicide Komeen®.

6.6.3.3 Assess Species Response to the Application of Herbicides for the Aquatic Weed Control Program in Clifton Court Forebay

Previous applications of Komeen® have followed the label directions of the product, which limits copper concentration in the water to 1,000 µg/L [1 part per million (ppm) or 1,000 parts per billion (ppb)]. Under the current proposal, DWR intends to apply Komeen® at a working concentration in the water column of 640 ppb as Cu^{2+} from the Komeen® formulation. The copper in Komeen® is chelated, meaning that it is sequestered within the Komeen® molecule and is not fully dissociated into the water upon application. Therefore, not all of the copper measured in the water column is biologically available at the time of application. Toxicity studies conducted by the California Department of Fish and Game (CDFG 2004a, b) measured the concentrations of Komeen® that killed 50 percent of the exposed population over 96 hours (96hr-LC_{50}) and 7 days (7d LC_{50}) as well as determining the maximum acceptable toxicant concentration level (MATC) to exposed organisms. CDFG found that the 96hr-LC_{50} for fathead minnows (*Pimephales promelas*) was 310 ppb (180 – 530 ppb 95 percent confidence limit) and the 7d- LC_{50} was 190 ppb. The MATC was calculated as 110 ppb Komeen® in the water column. Splittail (*Pogonichthys macrolepidotus*), a native cyprinid minnow, was also tested by CDFG. The 96hr-LC_{50} for splittail was 510 ppb.

NMFS did not find toxicity data for exposure of sturgeon to Komeen®, however exposure to other compounds including pesticides and copper were found in the literature (Dwyer *et al.* 2000, Dwyer *et al.* 2005a, b). From these studies, sturgeon species appeared to have sensitivities to contaminants comparable to salmonids and other highly sensitive fish species. Therefore, NMFS will assume that green sturgeon will respond to Komeen® in a fashion similar to that of salmonids and should have similar mortality and morbidity responses.

Pacific salmonids (*Oncorhynchus* spp.) are very susceptible to copper toxicity, having the lowest LC_{50} threshold of any group of freshwater fish species tested by the EPA in their Biotic Ligand Model (BLM; EPA 2003a) with a Genus Mean Acute Value (GMAV) of 29.11 µg/l of copper. In comparison, fathead minnows (*Pimephales promelas*), the standard EPA test fish for aquatic toxicity tests, have a GMAV of 72.07 µg/l of copper. Therefore, salmonids are approximately 3 times more sensitive to copper than fathead minnows, the standard test fish in EPA toxicity testing. NMFS assumes that sturgeon will have a similar level of sensitivity. Hansen *et al.* (2002) exposed rainbow trout to sub-chronic levels of copper in water with nominal water hardness of 100 mg/l (as $CaCO_3$). Growth, whole body copper concentrations, and mortality were measured over an 8-week trial period. Significant mortality occurred in fish exposed to 54.1 µg/l copper (47.8 percent mortality) and 35.7 µg/l copper (11.7 percent mortality). Growth and body burden of copper were also dose dependent with a 50 percent depression of growth occurring at 54.0 µg/l, but with significant depressions in growth still occurring at copper doses as low as 14.5 µg/l after the 8-week exposure.

In a separate series of studies, Hansen *et al.* (1999a, b) examined the effects of low dose copper exposure to the electrophysiological and histological responses of rainbow trout and Chinook salmon olfactory bulbs, and the two fish species behavioral avoidance response to low dose copper. Chinook salmon were shown to be more sensitive to dissolved copper than rainbow trout and avoided copper levels as low as 0.7 µg/l copper (water hardness of 25 mg/l), while the rainbow trout avoided copper at 1.6 µg/l. Diminished olfactory (*i.e.*, taste and smell) sensitivity reduces the ability of the exposed fish to detect predators and to respond to chemical cues from the environment, including the imprinting of smolts to their home waters, avoidance of chemical contaminants, and diminished foraging behavior (Hansen *et al.* 1999b). The olfactory bulb electroencephalogram (EEG) responses to the stimulant odor, L-serine (10^{-3} M), were completely eliminated in Chinook salmon exposed to ∃50 µg/l copper and in rainbow trout exposed to ∃200 µg/l copper within 1 hour of exposure. Following copper exposure, the EEG response recovery to the stimulus odor were slower in fish exposed to higher copper concentrations. Histological examination of Chinook salmon exposed to 25 µg/l copper for 1 and 4 hours indicated a substantial decrease in the number of receptors in the olfactory bulb due to cellular necrosis. Similar receptor declines were seen in rainbow trout at higher copper concentrations during the one-hour exposure, and were nearly identical after four hours of exposure. A more recent olfactory experiment (Baldwin *et al.* 2003) examined the effects of low dose copper exposure on coho salmon (*O. kisutch*) and their neurophysiological response to natural odorants. The inhibitory effects of copper (1.0 to 20.0 µg/l) were dose dependent and were not influenced by water hardness. Declines in sensitivity were apparent within 10 minutes of the initiation of copper exposure and maximal inhibition was reached in 30 minutes. The experimental results from the multiple odorants tested indicated that multiple olfactory pathways are inhibited and that the thresholds of sublethal toxicity were only 2.3 to 3.0 µg/l above the background dissolved copper concentration. The results of these experiments indicate that even when copper concentrations are below lethal levels, substantial adverse effects occur to salmonids exposed to these low levels. Reduction in olfactory response is expected to increase the likelihood of morbidity and mortality in exposed fish by impairing their homing ability and consequently migration success, as well as by impairing their ability to detect food and predators [Also see the technical white paper on copper toxicology issued by NMFS (Hecht *et al.* 2007)]. Given that sturgeon use their sense of smell and tactile stimulus to find food within the bottom substrate, degradation of their olfactory senses could diminish their effectiveness at foraging and compromise their physiological condition through decreases in caloric intake following copper exposure.

In addition to these physiological responses to copper in the water, Sloman *et al.* (2002) found that the adverse effect of copper exposure was also linked to the social interactions of salmonids. Subordinate rainbow trout in experimental systems had elevated accumulations of copper in both their gill and liver tissues, and the level of adverse physiological effects were related to their social rank in the hierarchy of the tank. The increased stress levels of subordinate fish, as indicated by stress hormone levels, is presumed to lead to increased copper uptake across the gills due to elevated ion transport rates in chloride cells. Furthermore, excretion rates of copper may also be inhibited, thus increasing the body burden of copper. Sloman *et al.* (2002) concluded that not all individuals within a given population will be affected equally by the presence of waterborne copper, and that the interaction between dominant and subordinate fish will determine, in part, the physiological response to the copper exposure. It is unknown how social interactions affect juvenile and sub-adult green sturgeon in the wild.

Current EPA National Recommended Water Quality Criteria and the California Toxics Rule standards promulgate a chronic maximum concentration (CMC) of 5.9 µg/l and a continuous concentration criteria of 4.3 µg/l for copper in its ionized form. The dissociation rate for the chelated copper molecule in the Komeen® formulation was unavailable at the time of this consultation, so that NMFS staff could not calculate the free ionic concentration of the copper constituent following exposure to water. However, the data from the CDFG toxicity studies indicates that a working concentration of 640 ppb Komeen® will be toxic to salmonids if they are present, either causing death or severe physiological degradation, and therefore green sturgeon would likely be similarly affected based on their similar sensitivities to copper toxicity.

6.6.3.4 Assess Risks to Individuals

The proposed modifications to the herbicide application program's period of application (July 1 through August 31) will substantially avoid the presence of listed salmonids in the Clifton Court Forebay due to the run timing of the juveniles through the Delta. As described earlier, Central Valley steelhead smolts may arrive during any month of the year in the delta, but their likelihood of occurrence is considered very low during the summer months of July and August. It also is highly unlikely that any winter-run or spring-run will be present during this time period in the South Delta. Unlike the salmonids, however, representatives of the Southern DPS of green sturgeon are routinely salvaged during the summer at both the CVP and SWP fish salvage facilities. This is related to their year round residency in the Delta during their first 3 years of life. The numbers salvaged typically increases during the summer (see figure 4-11). It is therefore likely that individuals from the Southern DPS of green sturgeon will be exposed to the copper herbicides, and based on the comparative sensitivities of sturgeon species with salmonids, some of these fish are likely to be killed or otherwise negatively affected. The exact number of fish exposed is impossible to quantify, since the density of green sturgeon residing or present in the forebay at any given time is unknown. The short duration of treatment and rapid flushing of the system will help to ameliorate the adverse conditions created by the herbicide treatment.

The application of Komeen® to Clifton Court Forebay under the Aquatic Weed Control Program will not affect the populations of winter-run or spring-run. These populations of salmonids do not occur in the South Delta during the proposed period of herbicide applications and thus exposure to individuals is very unlikely. Since no individual fish are exposed, population level effects are absent. Exposure of CV steelhead is also very unlikely; however some individual fish may be present during July as indicated by the historical salvage record and thus occurrence of fish in the forebay during the Komeen® treatment is not impossible. The numbers of steelhead that may be potentially exposed to the copper-based herbicide is believed to be very small, and therefore demonstrable effects at the population level resulting from Komeen® exposure are unlikely.

The effects to the green sturgeon population are much more ambiguous due to the lack of information regarding the status of the population in general. Although NMFS estimates that few green sturgeons will be exposed during the 2 to 3 days of herbicide treatment; the relative percentage of the population this represents is unknown. Likewise, the number of green sturgeon that reside in the forebay at any given time and their susceptibility to entrainment is also unknown. This uncertainty complicates the assessment of both population and individual exposure risks. This area of green sturgeon life history needs further resolution to make an accurate assessment of the impacts to the overall status of the population.

6.6.3.5 Effects of the Action on Designated and Proposed Critical Habitat in the Delta Division

Clifton Court Forebay is not part of the designated critical habitat for CV steelhead and thus actions taken within the forebay itself do not affect PCEs in the Delta for rearing habitat or migratory corridors. The design of the herbicide application protocol prevents movement of the copper-based herbicide from the forebay into the waters of the Delta outside of the forebay through the closure of the radial gates. After the exposure period, residual herbicide is pulled into the California Aqueduct via the pumps when the radial gates are opened to let in fresh water from the Delta. The flushing of the forebay with external Delta water should reduce any remaining Komeen® to insignificant levels and move the treated water volume into the aqueduct system of the SWP. There should be no discernable effects on designated critical habitat outside of the forebay. The proposed critical habitat for the Southern DPS of green sturgeon also does not include the forebay. As previously discussed above, measures to prevent movement of the copper-based herbicide outside of the forebay treatment area should preclude any discernable effects on proposed critical habitat for green sturgeon.

6.6.4 South Delta Improvement Program – Stage 1

6.6.4.1 Deconstruct the Action

The South Delta Improvement Program (SDIP) Stage 1 involves the placement of four permanent gates in the channels of the South Delta already affected by the temporary rock barriers installed under the TBP action. Three of the location, Old River at Tracy, Middle River near Victoria Canal, and the Head of Old River are essentially the same as the locations for the temporary barriers previously discussed in section 5.6.3. The fourth location, the channel formed by Fabian - Bell and Grant Line Canals will have the permanent structure located several miles to the west of the temporary barrier location. The permanent operable gate will be near the confluence of the Fabian - Bell and Grant Line Canal channel with Old River. This location is between the CVP and SWP facilities on Old River just south of Coney Island. For a short period, during the construction of the permanent gates, the rock barriers will continue to be installed and operated and there will be an overlap between the two actions. NMFS expects that the operation of the permanent gates proposed for the SDIP will have many of the same effects as described for the TBP in regards to changes in the regional hydrodynamics and the increase in predation levels associated with the physical structures and near-field flow aspects of the barriers. The effects of the temporary barriers have been described in NMFS (2009). The CALSIM II and DSM 2 modeling conducted for this consultation incorporated the permanent barriers into the modeling assumptions for Studies 7.1 and 8.0 while including the temporary barriers as part of the current conditions under the assumptions for Study 7.0. Therefore, individual effects of the barriers on the future conditions must be inferred from the modeling output, or derived from other sources of information. The future baseline conditions include the ongoing natural and anthropogenic activities in the Delta not associated with the project (levees, dredging, contaminants, urban development, non-native species, predation, *etc*.). NMFS considers the 4-month winter "no barrier" situation to be the most conservative future baseline condition with regard to the TBP. It represents a "no action" condition for the barrier operations. In winter, the HORB is completely removed while the majority of the three agricultural rock barriers are removed, leaving only portions of the the side abutments containing the culverts remaining in the river channel. The channels are open to river flow and tidal circulation with a minimum of channel obstruction. The projects would be operated to Study 7.0, the purported baseline condition present under current operations in the simulation modeling. Addition of the barriers in spring is in response to the ongoing export actions of the project and the requirement to provide suitable water surface elevations in the south Delta for agricultural diversions.

As described in previous sections, future pumping rates are expected to increase during the April and May time frame over the current conditions due to the reduction in "environmental" water available to make export curtailments. Although the reduction in "environmental water" is not related to the proposed SDIP action, it does coincide with the proposed operations of the permanent gates in April and May, and therefore has bearing on the effects of the gates on fish drawn into the South Delta by the export actions. Based on the description and analysis for the SDIP in the draft EIR/EIS (DWR 2005) and the SDIP Action Specific Implementation Plan (DWR 2006), the stated purposes for the permanent gates, includes maintaining surface water elevations for South Delta agricultural diverters and enhancing the flexibility to operate the CVP and SWP exports without impacting the South Delta diverters. Operations of the inflatable gates from June through November likewise enable the projects to more frequently sustain higher levels of pumping within regulatory and operational parameters by avoiding impacting South Delta water elevations and reducing the electrical conductivity levels in the South Delta waterways. It does this by "trapping" high quality Sacramento River water upstream of the permanent operable gates and redirecting its flow within the channels to improve water quality and circulation between the three agricultural gates. During the flood tide, higher quality water with Sacramento River origins flows upstream past the position of the gates and provides the desired water quality conditions within the South Delta channels. Without the gates, this higher quality water would flow back downstream on the ebb tide and not provide the desired water quality improvements upstream of the gate positions during all phases of the tidal cycle.

6.6.4.2 Assess Species Exposure

The permanent operable gates proposed under the SDIP action will be present year round in the four locations in the South Delta identified for the operable gates. Winter-run juveniles will be exposed to the effects of the gates from December through June when they have been documented to occur in the channels of the South Delta based on the salvage records of the projects. Predation associated with the physical structures of the operable gates will occur year round and effect juvenile winter-run when they are present in the vicinity of the gates. Operations of the gates will occur from April through November and affect juvenile winter-run when they are present during this time period (April through June). In addition to predation, delays in migration and hydraulic effects linked to the operation of the inflatable gates will affect winter-run juveniles during this period. No adult winter-run are expected to be present at any time in the channels influenced by the operable gates.

Juvenile spring-run are expected to be present from January through June based on historical salvage records. Predation associated with the physical structures of the operable gates will occur year round and effect juvenile spring-run when they are present in the vicinity of the gates. Operations of the gates will occur from April through November and affect juvenile spring-run from approximately April through June. In addition to predation, delays in migration and hydraulic effects linked to the operation of the inflatable gates will affect juvenile spring-run during this period. No adult spring-run are expected to be present at any time in the channels influenced by the operable gates.

CV steelhead smolts may be present from approximately November through the end of June based on historical salvage records. Predation associated with the physical structures of the operable gates will occur year round and affect steelhead smolts when they are present in the vicinity of the gates. Operations of the gates will occur from April through November and affect juvenile spring-run from approximately April through June and late fall (November). In addition to predation, delays in migration and hydraulic effects linked to the operation of the inflatable gates will affect steelhead smolts during this period. Adult steelhead from the San Joaquin River basin are expected to be present in the channels influenced by the operable gates during their upstream spawning run. This is typically the fall through the winter period (September through approximately March) with the highest numbers occurring in December.

Green sturgeon have the potential to be present year round in the areas affected by the operable gates. Historical salvage records indicate that juveniles (≈130 mm to 750 mm) have been salvaged in every month of the year at the CVP and SWP fish collection facilities. Fishing records (CDFG 2008) provided by the new sturgeon report card for sport fishermen indicate that adults and sub-adults are caught by fisherman year round in the San Joaquin River.

6.6.4.3 Assess Species Response to the Proposed Action

The operation of the permanent agricultural gates allows the manipulation of water circulation in the channels of the South Delta by redirecting flows “upstream” in Old and Middle rivers and downstream through Grant Line and Fabian/Bell canals. This redirection of flows in the channels of the South Delta is accomplished through the operation of the inflatable gates (“Obermeyer” style dams). Gates are fully deflated when the downstream tidal elevations match the upstream water elevations. At this time, flooding tides are allowed to flow over the fully lowered dam and into the channels upstream of the gate structures. Estimates of the volume of flood tide allowed to pass over the gates are approximately 80 percent of the unimpeded flow without the barriers (or their operations). The current temporary rock barriers allow significantly less, water to flow over them, passing approximately 50 percent of the unimpeded tidal flow upstream of the barriers. The current temporary barriers present a greater physical barrier to tidal upstream flows, allowing water to pass through the culverts or over the top of the weir when tidal elevations are sufficient, while blocking a large fraction of the tidal volume with the rock weir structure.

After the flood tide has reached its peak, the gates are inflated and their crest elevations manipulated to retain the water pushed upstream by the flood tides before it starts to recede on the ebbing tide. By manipulating the elevations of the three agricultural dams (Old River at Tracy, Grant Line/ Fabian–Bell, and Middle River), water circulation can be "forced" to move through the channels in whichever direction deemed necessary for circulation needs. Under proposed operations, the crests of the Obermeyer dams at Old River at Tracy and Middle River will be retained at slightly higher elevations than the dam crest on Grant Line/ Fabian-Bell Canal. Typically, flow will not be allowed to move back over these two dam crests on the falling tide, since the crests of the two dams will be maintained above the high tide elevation (Appendix 1 to this Opinion, pages 133-134). The remaining dam on Grant Line/ Fabian–Bell Canal will be operated to maintain a minimum water surface elevation of 0.00 feet msl in the channels of the South Delta. This method of gate operations results in a larger volume of water past the locations of the inflatable gates on each flood tide (80 percent of normal tidal volume). This "cell" of water will then essentially become trapped behind the inflated gates and forced to flow progressively "upstream" in the direction of the lowest dam crest elevation between the three agricultural barriers. Frequently this means the net flow is negative to the normal flow of water in the channel, such as in Old River and Middle River. The larger volume of water will carry any fish within that body of water with it above the barrier. It is expected that these fish will then be exposed to predation pressures above the barriers, changes in water quality conditions that may occur, and irrigation diversions associated with South Delta agriculture.

Under the current temporary barriers operational conditions, fish (*i.e.*, juvenile salmon, steelhead) that have not been entrained by the SWP at Clifton Court Forebay, or the CVP pumps have the potential to move upstream on the incoming flood tide into the channels of Old River or Grant Line/Fabian-Bell Canal. These fish are currently blocked by the rock barriers upstream of the project facilities. Fish are also likely to enter Middle River before encountering the project facilities farther south in the Delta and likewise encounter the rock weir on Middle River upstream of its confluence with Victoria Canal. These conditions are also encountered on the rising tide in future operations by the upright Obermeyer dams located on these channels. In the current conditions, some fish pass upstream through the tied open culverts (typical spring operations for Delta smelt protection), prior to the tide overtopping the crest of the rock weir. Under future conditions, no fish will pass upstream until the dam is deflated. Once the dam is deflated however, a greater proportion of the fish congregating below the barrier will be entrained upstream of the gate, and thus more will be "trapped" by the raised gate on the falling tide due to the greater volume of water passed through the position of the gate. The differences in the level of predation associated with the alternative operations protocols between barriers and gates are difficult to determine without empirical data. Both scenarios are likely to have high levels of predation associated with their implementation. In both cases, fish are blocked, at least initially, in their movement upstream on the flooding tide by the structures. In the current operations, some fish are passed through culverts, and predation is expected to be high following their discharge from the culverts on the down current side of the culvert where predators are expected to be waiting to prey on the disoriented fish [detailed analysis provided in NMFS

(2009)]. In both the current and future operations, fish are expected to be carried past the main portion of the barriers when tidal levels reach their peak. In the current operations, fish would be carried over the top of the weir through a turbulent flow field. It is expected that predators will be located on either side of the weir and that some of those predators down current of the barrier will follow the prey fish upstream over the weir. Some prey fish may remain below the barrier and attempt to flee to the margins of the channel or into the deeper water at the foot of the barrier. In the future operational conditions, the Obermeyer dam will drop to its fully open position on the channel floor once downstream water elevations are equal to the upstream water elevations. This creates an essentially unimpeded channel cross section at the barrier location which allows for almost total unobstructed flow upstream. This design is intended to have flows always moving upstream with the flooding tide, thus fish will move with the current upstream. Predators will likely follow the prey species upstream above the barrier location, and will be "trapped" with them following the inflation of the dam on the ebbing tide. Predation rates will be dependent on predator density and occurrence of prey species in the channels, as well as length of exposure to the predators in these channels.

The physical structures of the permanent barriers also create predator habitat within the channels of the South Delta. The designs of the four barriers include substantial amounts of riprapped levee facing coupled with sheet pile walls. The sheet pile walls have large indentations created by the corrugated nature of the metal sections, with each section having an approximately 36-inch long by 18-inch deep depression associated with it (DWR 2006). At each barrier location, the foundation for the multiple Obermeyer dam sections comprising the barrier will span the entire width of the channel (several hundred feet). The width of the foundation for each Obermeyer dam section is approximately 10 to 15 meters and is not completely flat to the channel bottom, but rises slightly due to the curved hydrofoil shape of the dam structure itself. Preliminary design drawings indicate that at low tide, water elevations over the dam will only be a few feet (approximately 1 to 1.5 meters at the Middle River and Old River at Tracy sites, slightly deeper, approximately 2 meters, at the Head of Old River) except for the Grant Line/ Fabian–Bell location which will be installed in deep water (6 m deep). This condition is expected to create localized turbulent flow over the structure on a fine spatial scale. Fine scale flow disruption creates microhabitats by increasing the complexity of the boundary layer along the channel bottom or margins. Predators can utilize these microhabitats to hold station in while waiting for prey to pass by. This disruption of the flow field is on the order of a few meters or less and would not be captured by the hydraulic modeling previously done for the project. An example of such microhabitat would be a boulder or ledge in a stream, which provides relief from the stream flow to a fish, such as a trout, holding below it. The placement of the four gates will ensure that any fish entering the channels of the South Delta, whether from the San Joaquin River side via the Head of Old River or from the western side via one of the three channels with gates, will have to negotiate at least two gates to move through the system. The argument that the gates only occupy a small footprint in the South Delta and therefore do not create an additional risk of predation is false. The physical structures of the gates create a point where predation pressure is increased and which migrating fish must negotiate to complete their downstream journey if they enter the South Delta channels. The environmental stressors created by the implementation of the SDIP will add to the already existing stressors present in the San Joaquin River basin.

The analysis of the SDIP presented in the draft EIR/EIS (DWR 2005 Appendix J) also included numerous PTM runs which analyzed various combinations of flow, export pumping levels, and gate operations (and by reference SDIP gate operations at the Head of Old River). The particle tracking simulations conducted for the SDIP proposal indicated that entrainment in the lower San Joaquin River watershed is of great concern to fisheries management. In the simulations without the HORB installed, nearly 100 percent of the particles injected above the Head of Old River split at Mossdale are entrained by the CVP and SWP pumps after 30 days, regardless of the level of pumping at the two facilities. This situation is greatly exacerbated when flows on the San Joaquin River flow are less than or equal to the level of exports. Entrainment of particles injected at other points in the South Delta, along the San Joaquin River as far west as Jersey Point, and in the Mokelumne River/ Georgiana Slough system are also subject to entrainment. The PTM results indicate that the rates of entrainment increase in concert with increasing pumping rates when the flows on the San Joaquin River are low. The conclusions drawn from these findings are that even with a 30-day reduction in pumping (*i.e.*, a VAMP-like scenario or an EWA style export curtailment) significant levels of particle entrainment still occurs in the channels of the South Delta and Central Delta and that 30 days of pumping reduction may not be sufficient to reduce overall entrainment. This situation is exacerbated by low inflows from the San Joaquin River basin, even if delta outflow is increasing due to higher Sacramento River flows occurring simultaneously.

Entrainment of particles from the North Delta region and the Sacramento River also can be significant under the baseline operational conditions tested in the SDIP proposal. Particle injections made at Freeport with the DCC open, exports at the CVP equal to 4,600 cfs and the SWP equal to 6,680 cfs, had project entrainment levels of 50 to 60 percent depending on the Delta outflow level (5,000; 7,000; and 12,000 cfs). Even with the higher Delta outflow levels, approximately 15 percent of the particles "lingered" within the Delta after the 30-day period of the simulation run. This scenario represents the type of conditions expected in the late fall and early winter before the DCC is closed (October through January) and represented by the CALSIM II modeling for the CVP/SWP operations consultation.

Therefore, the simulations completed for the SDIP (DWR 2005) indicate that under typical conditions found in the South Delta with low San Joaquin River inflows, nearly all the particles entering the South Delta from the San Joaquin River basin will be entrained by the project exports. The "zone of entrainment" extends into the central and northern regions of the Delta, with particles either being entrained directly by the project exports or "lingering" in the south Delta after 30-days of simulation. This "baseline" operational condition is further degraded by the future export increases modeled in Studies 7.1 and 8.0 as modeled in the CVP/SWP operations BA, which have extended periods of elevated pumping levels over the current conditions.

The PTM simulations for the SDIP proposal also addressed the gate operations at the Head of Old River during VAMP conditions. Results indicated that when the gate was in, the level of entrainment for the Mossdale injections was still exceptionally high and nearly all of the particles were either captured by the project exports at the CVP and SWP or other diversions in the South

Delta (approximately 30 to 50 percent) or otherwise retained within the waterways of the South and Central Delta. With the Head of Old River gate closed, particles travelled downstream in the San Joaquin River past Stockton, but were subsequently entrained into the channels of Turner and Columbia Cuts, Middle River, and Old River. The radio and acoustic telemetry work done by Vogel (2004) and SJRGA (2007) support this aspect of the modeling results. Another characteristic of the closed Head of Old River gate condition is the increase in entrainment of particles released farther downstream in the San Joaquin River system at Prisoners Point and Jersey Point as well as in the Mokelumne River system. Since exports could not divert water from the San Joaquin River entering through the Head of Old River, the additional water was pulled from the lower San Joaquin River reaches, thus increasing the risk of entrainment in these lower segments. This characteristic of the hydraulic environment created by the Head of Old River gate places fish entering the Central Delta from the Sacramento River at greater risk of entrainment. The simulated fraction of particles escaping the Delta and reaching Chipps Island was consistently low under all of the tested parameters for passive particles, never exceeding 15 percent of the Mossdale injections. The highest San Joaquin River flow to export pumping ratio tested was 2:1 with 3,000 cfs combined pumping coupled with 7,000 cfs San Joaquin River outflow (reduced pumping scenario). This resulted in 14.9 percent of the particles reaching Chipps Island after 30 days. In simulations where the Head of Old River gate was not installed, a lower percentage of the particles reached Chipps Island then under the gate installed situation, having been quickly entrained into Old River and subsequently captured at the CVP.

Based on the PTM simulations and the initial results of radio and acoustic telemetry studies, the proposed SDIP still has significant effects on San Joaquin River basin fish. The eventual entrainment of San Joaquin River fish by the SWP and CVP after they have passed the head of Old River through the channels lower down on the San Joaquin River (*e.g.*, Turner and Columbia Cuts) is contradictory to the stated purpose of the fish barrier portion of the SDIP proposal. The agricultural gates component of the proposal benefits agricultural interests without apparent detriment to those interests and allows the CVP and SWP to enhance their water diversion opportunities by providing greater flexibility to their operations within the constraints of existing regulatory criteria. As described previously, the agricultural gates and the enhanced pumping regimen under studies 7.1 and 8.0 are detrimental to listed fish occurring in the South Delta, regardless of their origins (*i.e.*, spring-run from the Sacramento River or CV steelhead from the San Joaquin River basin) and the proposed action (which include the enhanced pumping schedule under studies 7.1 and 8.0) will increase the loss of fish over the current conditions. The purported benefit of the SDIP proposal to fisheries management was the Head of Old River gate, which was supposed to reduce the entrainment of fall-run originating from the San Joaquin River basin during their spring out migration period. CV steelhead migrating from the San Joaquin Basin during the Head of Old River gate operations were also believed to have been protected by the gate. Based on the PTM simulation results and the telemetry findings, this protective aspect of the Head of Old River operable gate appears to be overstated, and in fact the operation of the gate may place fish entering the system from other tributaries such as the Calaveras River, Mokelumne River, and Sacramento River at greater risk of entrainment when it is in operation. In order to achieve the proposed benefits of the operable gate at the Head of Old River, reductions in exports, coupled with increases in San Joaquin River flows to move fish through the system are needed. Without these concurrent actions, the full benefit of the operable gate cannot be realized. The proposed SDIP action did not make this linkage part of the operations.

6.6.4.4 Assess Risks to Individuals

Many of the effects described in NMFS (2009) for the TBP apply to the proposed SDIP action. The significant difference is the additional predation impacts that can occur during the December through March period. Under the SDIP action, physical structure remains in the channel year round and thus provides habitat and hydraulic conditions that are beneficial to predators in the area. NMFS expects that this will increase the predation potential for listed salmonids present in the South Delta channels during this period. Migratory delays are not anticipated to occur during this period due to the gates lowered condition. Passage past the locations of the gates during the winter period should not be affected except for the previously mentioned predation issues.

NMFS does not anticipate that the permanent gates will increase predation on green sturgeon during the winter period. As described in NMFS (2009), any green sturgeon present in the South Delta channels are typically large enough to be at low risk of predation by predators such as largemouth bass or striped bass. The operations of the gates in the period between April and November may impede passage during the gates up condition, but passage should be available when the gates are lowered during the flood tide.

Spring-run Chinook salmon - The affects to the spring-run population under the SDIP actions are expected to be comparable to the effects already described for the temporary barriers discussion in NMFS (2009). Since approximately 80 percent of the spring-run population presence occurred during the April through June period, the predation effects and migrational delays should be similar in magnitude between the two projects. The difference between the two actions is the additional predation risk to early migrating spring-run prior to April. These fish would encounter the permanent physical structures of the SDIP gates and the predator issues associated with them. NMFS does not expect more than approximately 3 percent of the total annual spring-run population in the Central Valley to be present in the South Delta waters within the vicinity of the permanent gates.

Winter-run Chinook salmon – Since the permanent gates are in place year round, the entire population of winter-run that enter the waters of the South Delta has the potential to encounter the predation effects associated with the SDIP gates. This is in contrast to the temporary barriers, in which only 3 percent of the winter-run population in the South Delta was exposed to the rock barriers during the April through June period of their operations. Migrational delays should be similar to those described for the temporary barriers in NMFS (2009). The period of gate operations during winter-run presence is the same as previously described for the operations of the rock barriers. NMFS anticipates that approximately 3 percent of the winter-run population is present in the waters of the South Delta within the vicinity of the permanent gates and the export facilities when the permanent gates will be operated for water surface elevation control.

Central Valley steelhead – The permanent gates have the potential to affect all of the CV steelhead that move through the South Delta. Previously, only about 9 percent of the annual presence of steelhead in the South Delta was affected by the temporary barriers and their operations. Due to the year round presence of the physical structures in the channels of the South Delta related to the permanent gates, steelhead smolts are exposed to the predation issues whenever they are present in the waters adjacent to the gate locations. Delays in migration should remain comparable to the temporary barriers, affecting only 9 percent of the annual steelhead presence in the South Delta, since the operations of the permanent gates occur during the same months as the temporary barriers' operations. However, San Joaquin River basin steelhead are disproportionately affected due to their close proximity to the project and the overlap of their migratory corridor with the action's location. Adult effects should also be comparable between the two actions. This should primarily be delays in migration due to gate operations, rather than blockage of migration since the gates are operated in concert with the tidal stages in the south Delta.

Green Sturgeon – The proposed SDIP permanent barriers will be operated during the same seasonal periods as has been done previously for the TBP (April through November). Therefore, effects to the green sturgeon population are expected to generally be comparable between the two programs. The operations of the permanent gates may expose more fish during the operational season to migrational delays due to the tidal operation of the gates allowing passage upstream of the gates; however, the length of delay should be considerably shorter than the temporary barriers due to the same tidal operations which allow the gates to be opened on each tidal cycle, thereby allowing the opportunity for sturgeon to pass downstream of the gates. Nevertheless, the permanent gates do represent a barrier to free movement of fish in the waterways of the South Delta even if it is only for a short time.

Little is known about the population size or the movements of green sturgeon within the Delta, therefore assessments of population effects are difficult at best to make. In order to make any reasonable assessment, the number of green sturgeon present in the population, as well as the frequency of occurrence in the South Delta would need to be known. NMFS does not have this information. Monitoring studies using acoustic tags aimed at assessing the behavior of green sturgeon in relation to the barriers and the movements of green sturgeon within the channels of the South Delta are planned for the near future but have not been implemented to date.

6.6.4.5 Effects of the Action on Designated and Proposed Critical Habitat in the Delta Division

The conservation value of CV steelhead designated critical habitat in the South Delta will be degraded as a result of the SDIP impacts. Part of the intrinsic values of the PCEs listed for critical habitat in the South Delta is unobstructed passage of emigrating fish through the region. This characteristic of the PCE's will be permanently modified by the construction and operation of the proposed barriers as well as additional risks of entrainment and predation presented by the modified pumping environment fostered by the SDIP proposal. As described above, listed steelhead will be prevented from using portions of the Delta by the Head of Old River permanent gate. Migration will be restricted to one channel initially until the fish pass the Port of Stockton. The risk of entrainment by the export facilities appears to have been delayed until the fish pass into the lower sections of the river, rather than prevented as proposed. Furthermore, delays in migration appear to be a distinct possibility following the movement of steelhead into the lower San Joaquin River below the Port of Stockton. The functioning of the lower San Joaquin River as a migratory corridor has not been improved by the action; rather migration has been redirected into only one possible route to avoid adverse impacts in another migratory route. Although the selected mainstem San Joaquin River route apparently has better overall survival than the southern Delta waterways, it does place the San Joaquin River basin at increased risk for catastrophic events that could impact the one selected migratory route, particularly since the selected route passes a major waste water treatment plant in the City of Stockton and the industrialized Port of Stockton. Accidental chemical spills are potential catastrophes that could severely impact a given year class or more depending on its severity.

In addition to the installation of the gates, the SDIP proposes to dredge certain channels of the South Delta to enhance conveyance of water for agricultural diversion and circulation flow patterns (portions of Old and Middle River), reduce scouring (West Canal), and increase water depth for private water diversions located upstream of the proposed agricultural gates. This will, at the minimum, reduce the benthic communities in the affected channels for a short period of time until the substrate is recolonized. It is also likely that the profile of the new benthic community will be different than surrounding areas for a considerable period of time (climax community versus disturbed community effect) as well as whether native or exotic species are better situated to take advantage of the newly disturbed substrate. These newly created channels with greater depth will also alter the community complexity and species profiles of organisms that will inhabit them. For instance, greater depth may alter the species profiles of predatory fish inhabiting these channels by providing additional cover in the form of deeper waters in the dredged channels thus allowing larger predatory fish or greater numbers of fish to inhabit them. Listed fish will more than likely pass through these channels when the Head of Old River permanent gate is not in operation, and the altered habitat will become part of their migrational corridor. It is likely that the value of the future aquatic habitat within the boundaries of the proposed SDIP project will reflect a more degraded value to migrating San Joaquin River basin CV steelhead compared to the current situation. The proposed action does not incorporate any actions to enhance the aquatic environment beyond its current standing nor does it reverse any of the anticipated adverse alterations to the aquatic habitat considered above. Therefore, NMFS believes that the future habitat condition will be adversely modified and provide a less suitable suite of PCEs to listed steelhead that will diminish their likelihood of survival through the South Delta. Likewise, the value of the aquatic habitat to fall-run will be diminished by the SDIP proposal. Although fall-run are unlisted, they share similar habitat requirements with CV steelhead for migration and rearing and their future use of the habitat will be adversely modified by the proposed actions. Therefore the value of the South Delta waterways as essential fish habitat also will be diminished.

The waterways of the South Delta have also been proposed as critical habitat for the Southern DPS of green sturgeon (September 8, 2008, 73 FR 52084). Like the CV steelhead, green sturgeon critical habitat in the South Delta requires unobstructed passage through the channels of the South Delta during their rearing and migratory life stages. The operation of the barriers as proposed will create obstructions to their free passage when the gates are in their upright positions. It is unknown whether sturgeon will volitionally move against the current of an incoming tide to pass back downstream over the barriers when they are lowered on the incoming flood tide. Furthermore, the duration of time in which the gates are lowered compared to the periods in which they are raised is unequal. The gates are predominately in the raised position throughout the tidal cycle, except for the few hours they are lowered on the incoming tides. DWR and Reclamation believe that theoretically sturgeon may pass through the boat locks associated with the barriers during their operations and thus not be obstructed in their passage. This theory has not been proven satisfactorily by the information provided in their analysis. It is based on the belief that the boat locks will be used frequently enough to allow fish to move through the structures without undue delays. Unlike the Suisun Marsh Salinity Control Gates, the boat locks will not be left open the majority of the time, but will remain closed to retain stage elevations until needed for boat passage.

6.6.5 Delta Cross Channel

6.6.5.1 Deconstruct the Action

The DCC was constructed by Reclamation in the early 1950s to redirect high quality Sacramento River water southwards through the channels of the Mokelumne River system towards the South Delta and the CVP pumps at Tracy. This modification of the Delta's hydraulics prevented the mixing of the Sacramento River water with water in the western Delta, with its higher salinity load, prior to diverting it to the CVP pumps. Originally the gates remained open except during periods of high Sacramento River flow (> 20,000 to 25,000 cfs) when scouring of the channel or flooding risks downstream of the gates warranted closure. Currently, 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 saltwater intrusion rates in the western Delta.

The conditions for closing the DCC gates to protect fishery resources were first instituted in the State Water Resource Control Board's D-1485 decision in 1978. In 1995, the Water Quality Control Plan (WQCP) for the Bay Delta (95-1) instituted additional operations of the DCC for fisheries protection (SWRCB 1995). These criteria were reaffirmed in the SWRCB's D-1641 decision. The DCC gates may be closed for up to 45 days between November 1 and January 31 for fishery protection purposes. From February 1 through May 20, the gates are to remain closed for the protection of migrating fish in the Sacramento River. From May 21 through June 15, the gates may be closed for up to 14 days for fishery protection purposes. Reclamation determines the timing and duration of the closures after discussion with USFWS, CDFG, and NMFS. These discussions will occur through the water operations management team (WOMT) as part of the weekly review of CVP/SWP operations. WOMT uses input from the Salmon Decision Process to make its gate closure recommendations to Reclamation.

The Salmon Decision Process (CVP/SWP operations BA 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 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 life stage 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 primary avenue for juvenile salmonids emigrating down the Sacramento River to enter the interior Delta, and hence becoming vulnerable to entrainment by the export facilities, is by diversion into the DCC and Georgiana Slough. Therefore, the operation of the DCC gates may significantly affect the survival of juvenile salmonids emigrating from the Sacramento River basin towards the ocean. Survival in the Delta interior is considerably lower than the mainstem Sacramento River. This has previously been discussed in section 6.6.2.5 *Indirect Mortality Within the Delta*.

6.6.5.2 Assess the Species Exposure

The proportion of juvenile Chinook salmon that enter the Delta from the Sacramento River is given in table 6-34. Salvage and loss across months (http://www.usbr.gov/mp/cvo/fishrpt.html) represents fish presence in the South Delta (table 6-27). The closure of the DCC gate under the current schedule protects 100 percent of the migrating fish from February 1 through May 20 from entering the DCC channel and entering the Mokelumne River system through Snodgrass Slough. Prior to February 1, the gates can be closed for up to 45 days between November 1 and January 31 (maximum 50 percent). After May 20, the gates can be closed for up to 14 days through June 15.

Table 6-34. The proportion of juvenile Chinook salmon and steelhead production entering the Delta from the Sacramento River by month.

Month	Sacramento River Total[1,2]	Fall-Run[3]	Spring-Run[3]	Winter-Run[3]	Sacramento Steelhead[4]
January	12	14	3	17	5
February	9	13	0	19	32
March	26	23	53	37	60
April	9	6	43	1	0
May	12	26	1	0	0
June	0	0	0	0	0
July	0	0	0	0	0
August	4	1	0	0	0
September	4	0	0	0	1
October	6	9	0	0	0
November	9	8	0	03	1
December	11	0	0	24	1
Total	100	100	100	100	100

Notes:

[1] Mid Water trawl data

[2] All runs combined

[3] Runs from Sacramento River basin only
[4] Rotary screw trap data from Knights Landing
Source: DWR and Reclamation (2005 Tables J-23 and J-24, Appendix J).

Winter-run Chinook salmon - Prior to the DCC gate closures in February, approximately 44 percent of the annual winter-run juvenile population is vulnerable to entrainment into the DCC. Emigration of winter-run juveniles during December and January accounts for nearly all of this entrainment. Loss records from the CVP and SWP fish collection facilities (http://www.usbr.gov/mp/cvo/fishrpt.html) have a slightly lower fraction of the winter-run juvenile population present in the Delta during December and January (≈21 percent of the annual total), which may represent the lag in movement across the delta or potentially holding and rearing behavior. The majority of adult winter-run will migrate upstream through the Delta during the period when the DCC gates are closed.

Spring-run Chinook salmon – Only 3 percent of the annual juvenile spring-run emigration occurs prior to February in the Sacramento River basin. However, this fraction represents the yearling spring-run life history stage, an important alternative to the more common YOY life history stage where fish emigrate during their first spring after hatching. Spring-run juveniles are not represented in the salvage and loss records at the CVP/SWP facilities until March and April. Adult spring-run migrating through the Delta will encounter the DCC gates in both the closed position prior to May 15 and the open gate configuration after May 15.

Central Valley steelhead – Approximately 7 percent of the steelhead form the Sacramento River basin emigrate prior to February in any given year and thus would be vulnerable to open DCC gates and diversion into the Delta interior. Steelhead begin showing up in the salvage at the CVP and SWP fish collection facilities in January and February and most likely represent the steelhead moving out of the Mokelumne system during December and January. Adult steelhead are likely to encounter the DCC gates in both an open and closed configuration through out their extended spawning migration. Most steelhead have entered the Sacramento system prior to February and therefore would have been exposed to open gates.

Green sturgeon – Little is known about the migratory behavior of juvenile green sturgeon in the Sacramento River basin. It is likely that juvenile green sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta. More information is required to accurately assess the migratory movements of juvenile sturgeon in the river system, as well as their movements within the Delta during their rearing phase in estuarine/Delta waters. Adult green sturgeon are likely to encounter closed DCC gates during their upstream spawning migration in winter and early spring, but encounter open gates during their downstream migration in summer and fall following spawning.

6.6.5.3 Assess Species Response to the Proposed Action

The DCC can divert a significant proportion of the Sacramento River's water into the interior of the Delta. The DCC is a controlled diversion channel with two operable radial gates. When fully open, the DCC can allow up to 6,000 cfs of water to pass down the channel into the North and South Forks of the Mokelumne River in the central Delta (Low *et al*. 2006, CVP/SWP operations BA Appendix E). During the periods of winter-run emigration (*i.e*., September to June) through the lower Sacramento River, approximately 45 percent of the Sacramento River flow (as measured at Freeport) can be diverted into the interior of the Delta through the DCC and Georgiana Slough when both gates are open. When the gates are closed, approximately 15 to 20 percent (as measured at Freeport) of the Sacramento River flow is diverted down the Georgiana Slough channel[16] (CVP/SWP operations BA Appendix E). Peak flows through Georgiana Slough can be almost 30 percent of the Sacramento River flows. Together, the DCC and Georgiana Slough can divert nearly half of the Sacramento River's flow into the Delta interior.

In most years, the peak of winter-run emigration past the DCC occurs from late November through February, based on USFWS trawl and seining data (USFWS 2001, 2003, 2006; Low *et al.* 2006, DWR 2005); when 10 to 25 percent of the Sacramento River flow can be diverted through the DCC and an additional 17 to 20 percent is diverted down Georgiana Slough. There is little change between the current and future conditions (Study 7.0 compared to Studies 7.1 and 8.0). Kjelson and Brandes (1989) found that survival of tagged Chinook salmon smolts was negatively correlated (r= -0.63) with the percentage of water diverted through the DCC from the Sacramento River. When diversion rates were high (> 60 percent) with the DCC gates open, the survival of smolts released above the DCC was about 50 percent less than those releases which occurred below the DCC. When the gates were closed, there was no difference between the two release points under high flow conditions, however, under low flow conditions, the survival of the upper release point was about 25 percent less than the downstream release point. Kjelson and Brandes (1989) attributed this lower survival rate to the effect of the fish being diverted into Georgiana Slough. Low *et al.* (2006) found significant linear relationships between the proportion of Sacramento River flow diverted into the interior of the Delta in December and January and the proportion of the juvenile winter-run lost at the CVP/SWP export facilities. Analysis of 2-week intervals found highly significant relationships between these proportions in late December (December 15 to 31) and early January (January 1 to 15) periods before the DCC gates are closed. A series of studies conducted by Reclamation and USGS (Horn and Blake 2004) supports the previous report's conclusion of the importance of the DCC as an avenue for entraining juvenile salmonids into the central Delta. These studies used acoustic tracking of released juvenile Chinook salmon to follow their movements in the vicinity of the DCC under different flows and tidal conditions. The study results indicate that the behavior of the Chinook salmon juveniles increased their exposure to entrainment through both the DCC and Georgiana Slough. Horizontal positioning along the east bank of the river during both the flood and ebb tidal conditions enhanced the probability of entrainment into the two channels. Upstream movement of fish with the flood tide demonstrated that fish could pass the channel mouths on an ebb tide and still be entrained on the subsequent flood tide cycle. In addition, diel movement of fish vertically in the water column exposed more fish at night to entrainment into the DCC than during the day, due to their higher position in the water column and the depth of the lip to the DCC channel mouth (-2.4 meters). The study concluded that juvenile Chinook salmon entrainment at a channel branch will not always be proportional to the average amount of flow

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[16] Instantaneous percentages can be much higher depending on the interaction of river flow and tidal flow as describe in Horn and Blake (2004).

entering that branch, and can vary considerably throughout the tidal cycle. Furthermore, secondary circulation patterns can skew juveniles into the entrainment zones surrounding a given branch, thus resulting in a disproportionately high entrainment rates. This characteristic was observed in the recent acoustic tagging studies (Burau *et al*. 2007, Perry and Skalski 2008, Vogel 2008a) experiments at the mouth of Sutter and Steamboat sloughs. The percentage of fish selecting the alternative routes from the mainstem Sacramento River was different than the percentage of water entering the channel, indicating spatial distribution in the channel may play an important role in entrainment rates.

Fish that are diverted into the Delta interior and survive the high loss rates migrating through Georgiana Slough and the lower Mokelumne River system are eventually discharged into the San Joaquin River system near RM 22. As presented previously in the Delta Division discussion, changes in Delta hydrodynamic conditions associated with CVP and SWP export pumping inhibit the function of Delta waterways as migration corridors. When pumping is elevated, the flows in the river reaches surrounding this confluence are directed towards the export facilities, indicated by negative flows in Old and Middle River. Additional loss is experienced during this movement of fish towards the CVP/SWP facilities and throughout the salvage process. With mandatory closure of the DCC gates from February 1 through May 20 (pursuant to current criteria in SWRCB D-1641), approximately 50 percent of juvenile winter-run outmigration and 70 to 90 percent of the steelhead and spring-run juveniles migrating downstream in the Sacramento River are not exposed to the open DCC gate configuration and are therefore expected to have a greater likelihood of remaining in the Sacramento River (including Sutter and Steamboat sloughs) and surviving to Chipps Island. These fish will be less vulnerable to decreased survival rates through the Delta interior and any subsequent losses related to the effects of CVP and SWP Delta export pumping from the San Joaquin River confluence southwards. That segment of the respective salmonid populations which migrates earlier than the mandatory closures will be exposed to the effects of the DCC gates when they are in the open configuration. All fish will be exposed to entrainment into Georgiana Slough, which has the potential to capture approximately 15 to 20 percent of the downstream migrants moving past it.

Several years of USFWS fisheries data indicate that the survival of salmon smolts in Georgiana Slough and the central Delta is significantly reduced when compared to the survival rate for fish that remain in the Sacramento River (Kjelson and Brandes 1989, Brandes and McLain 2001). Data from investigations conducted since 1993 with late fall-run during December and January are probably the most applicable to emigrating steelhead and spring-run yearlings due to their comparable sizes. These survival studies were conducted by releasing one group of marked (*i.e.*, CWT and adipose fin clipped) hatchery-produced salmon juveniles into Georgiana Slough, while a second group was released into the lower Sacramento River. Results have repeatedly shown that survival of juvenile salmon released directly into the Sacramento River while the DCC gates are closed are, on average, two to eight times greater than survival of those released into the central Delta via Georgiana Slough (CDFG 1998, Newman 2008). More recent acoustic tagging studies support these earlier findings (Perry and Skalski 2008) indicating that when the DCC is closed, survival through the delta can increase approximately 50 percent compared to open DCC conditions (35.1 percent survival with the DCC open versus 54.3 percent survival with the DCC closed; data from Perry and Skalski 2008). In comparison, Burau *et al*. (2007) found that increasing flows influenced survival in the Sacramento River, *e.g.*, higher flows correlated to higher survival in the different channels. These results were described previously in the Delta Division section assessing indirect mortality within the Delta.

The results of these studies demonstrate that the likelihood of survival of juvenile salmon, and probably steelhead, is reduced by deleterious factors encountered in the central Delta. In addition to predation, water quality parameters such as temperature can have significant effects on survival. Baker *et al.* (1995) showed that the direct effects of high water temperatures are sufficient to explain a large part (*i.e.*, 50 percent) of the smolt mortality actually observed in the Delta. The CVP and SWP export operations are expected to contribute to these deleterious factors through altered flow patterns in the Central and South Delta channels. In dry years, flow patterns are altered to a greater degree than in the wet years and are expected to result in a higher level of impact to emigrating steelhead and winter-run and spring-run smolts (Kjelson and Brandes 1989). If the DCC gates are opened for water quality improvements or other purposes, a significantly greater proportion of Sacramento River flow and juvenile fish will be diverted into the central Delta.

False Attraction and Delayed Migration - From November through May, adult winter-run and spring-run and steelhead migrate through the Delta for access to upstream spawning areas in the Sacramento and San Joaquin basins. Changes in Delta hydrodynamics from CVP and SWP export pumping in the South Delta may affect the ability of adult salmon and steelhead to successfully home in on their natal streams. Radio tagging studies on adult fall-run indicate that these fish frequently mill about in the Delta, often initially choosing the wrong channel for migration (CALFED 2001). CVP and SWP export pumping alters Delta hydrodynamics by reducing total Delta outflows by as much as 14,000 cfs and reversing net flows in several central and south Delta channels. Adults destined for the Sacramento Basin may experience some minor delays during passage through the Delta by straying temporarily off-course in northern and central Delta waterways. Closure of the DCC gates from November 1 through May 20 may block or delay adult salmonids that enter the Mokelumne River system and enter through the downstream side of the DCC. However, it is anticipated that closure of the DCC gates during this period will reduce diversion of Sacramento River water into the Central Delta, thereby improving attraction flows for adults in the mainstem Sacramento River. Intermittent openings to meet water quality standards or tidal operations are not expected to cause significant delays to adults because of their temporary nature and the ability of adults to drop back and swim around the DCC gates. Acoustic tracking studies by Odenweller of CDFG (CALFED 2001) indicated that adult fall-run may make extensive circuitous migrations through the Delta before finally ascending either the Sacramento or San Joaquin Rivers to spawn. These movements included "false" runs up the mainstems with subsequent returns downstream into the Delta before their final upriver ascent.

Within the south Delta, several studies have indicated that adult fall-run may be negatively impacted by the operations of the export facilities during their upstream spawning migration (Hallock *et al.* 1970, Mesick 2001). The reduced fall flows within the San Joaquin system, coupled with the elevated pumping actions by the SWP and CVP during the fall to "make up" for reductions in pumping the previous spring, curtails the amount of San Joaquin River basin water that eventually reaches the San Francisco Bay estuary. It is necessary for the scent of the San Joaquin basin watershed to enter the Bay in order for adult salmonids to find their way back to their natal river. Reductions, or even the elimination, of this scent trail has been postulated by Mesick (2001) to increase the propensity for fall-run to stray from their natal San Joaquin River basin and into the adjacent Mokelumne River or Sacramento River basins. This problem may exist for CV steelhead that utilize the San Joaquin River basin or the Calaveras River for their olfactory cues during their upstream spawning migrations back to their natal stream. The increased time spent by adults searching for the correct olfactory cues in the Delta could lead to a decrease in the fish's overall health, as well as a reduction in the viability of its gametes. Increased exposure to elevated water temperatures, chemical compounds and bacterial or viral infections present in the Delta increases the likelihood that adult Chinook salmon and their eggs may experience negative effects on the behavior, health, or reproductive success of the fish (Meehan and Bjornn 1991, Rand *et. al.* 1995).

In addition, the existence of the chronic DO sag in the San Joaquin River between the Port of Stockton and Turner Cut can delay the upstream migration of adult salmonids. The ambient DO levels in this portion of the San Joaquin can drop below 4 mg/L during the fall and early winter periods. Hallock *et al.* (1970) found that most adult fall-run would not migrate through water with less than 5 mg/L DO. Laboratory data for juvenile Chinook salmon (Whitmore *et al.* 1960) supports this finding as the juvenile Chinook salmon avoided water with less than 4.5 mg/L under controlled laboratory conditions. Flow levels in the mainstem San Joaquin below the head of Old River are inherently dependent on the status of the HORB, reservoir releases, and the operation of the CVP pumps. When flow rates are high, the DO sag does not set up. Conversely, when flows drop below approximately 1,500 cfs, the conditions in the deep-water ship channel become conducive to creating the low DO situation.

6.6.5.4 Assess Risks to Individuals

As previously described earlier in the Delta division analysis, individual juvenile fish that move into the Delta interior through the DCC or Georgiana Slough are at a much higher risk of mortality from predation or other stressors in the environment. These other stressors can take the form of delayed migration; water quality issues such as temperature and low DO, and prolonged exposure to contaminants in the system. Individual winter-run juveniles and spring-run juveniles are at an increased risk of entrainment if they move downstream earlier in the season than later, or respond to increases in river flows upstream of the Delta in the Sacramento River or reductions in river temperature. These environmental cues typically induce winter-run juveniles and yearling spring-run to initiate downstream movement towards the Delta and the ocean. Individuals that display this sensitivity to early triggers are at a higher risk of mortality due to the open configuration of the DCC gates. Fish that are successful in surviving the Delta interior by passing through Georgiana Slough or the Mokelumne River system still must negotiate the effects of the export pumps and the altered hydraulics in the San Joaquin River main stem. If exports are high, individual fish face a greater probability of being entrained towards the export facilities. Such increased exports are modeled for the current, near future, and future conditions of the CVP/SWP operations action. Survival from the San Joaquin River southwards towards the pumps is considered to be low for salmonids. It is thought that this is primarily a result of intense predation pressure within the waterways leading to the facilities. Fish that ultimately reach the salvage facilities still face a high probability of mortality from that encounter. Calculated losses (mortalities) at the CVP are approximately 2 out of every 3 fish that enter the salvage operation. Fish survival is far worse at the SWP facility where 1 out of 6 fish survive the salvage operation, primarily due to high predation losses in the forebay. Steelhead smolts, although larger than spring-run or winter-run emigrants, are also likely to have low survival rates if they are diverted into the Delta interior. Recent studies in Clifton Court Forebay verified that 200- to 250-mm long steelhead smolts were just as likely to be eaten by predators as the smaller Chinook salmon smolts.

Little information is available regarding juvenile green sturgeon movements in the lower Sacramento River and Delta waterways. It is unknown how vulnerable these juvenile sturgeons are to diversion into the DCC or Georgiana Slough or their risk to predation by the larger predators such as striped bass and largemouth bass that inhabit the Delta system. Additional research is required to answer these questions before a thorough assessment can be made.

Winter-run Chinook salmon – Nearly half of the annual winter-run population emigrates during the gates open period in late fall and early winter. These early emigrating winter-run are vulnerable to the effects of the open DCC gates as previously explained. The loss of individuals from this segment of the winter-run population may decrease the population's future expression of varied life history strategies, such as early migrational behavior. Having a broad representation of different life history strategies enables the population to spread its survival risk over time, rather than having one monotypic life history. By varying the time that individuals emigrate to the Delta and the ocean, the population can take advantage of potentially better environmental conditions outside of the normal migration period. In the case where environmental conditions may be poor for most of the run during the "normal" migration period due to stochastic variation in the environment (*e.g.*, poor upwelling conditions in the coastal ocean), those segments of the population that migrated at different times may find more suitable conditions and thus perpetuate the population. Maintaining those segments of the winter-run population that exhibit different life history behavioral traits is central to the long-term viability of the population. Based on the data generated from the acoustic tracking studies of Perry and Skalski (2008) and Burau *et al.* (2007), NMFS has estimated that losses to the winter-run population associated with the operations of the DCC range from 6 to 20 percent of the winter-run population entering the Delta. These estimates used the percentage of fish entering the Delta interior through either the DCC or Georgiana Slough channels (based on acoustic tracking data of Chinook salmon smolts: 28 percent when DCC open, 18 percent when closed), the survival estimates within those channels (35 percent survival base case, 10 percent survival when high losses occur, 75 percent survival when losses are low), the monthly position of the DCC gates, and the percentage of the winter-run population entering the Delta from the Sacramento River each month from table 6-26.

Spring-run Chinook salmon – The DCC gates are open during the period when yearling spring-run are emigrating into the Delta from their upstream natal tributaries. Like the early migrating winter-run juveniles, the yearling spring-run life history strategy represents an important component of the overall spring-run life history. Yearling fish are larger than young of the year emigrants, having spent additional time growing in their natal streams over the summer before emigrating downstream. They have a higher success rate at transitioning to the ocean environment than the smaller YOY. They also represent a mechanism to spread out the risk to an individual brood year's population by going out later than the more common first spring emigration life history strategy expressed by the young of the year emigrants. By having more opportunities to enter the ocean at different times, the probability of finding suitable conditions increases. This in turn increases the likelihood that the population will endure. Maintaining those segments of the spring-run population that exhibit different life history behavioral traits is central to the long-term viability of the population. Based on the data generated from the acoustic tracking studies of Perry and Skalski (2008) and Burau *et al.* (2007), NMFS has estimated that losses to the spring-run population associated with the operations of the DCC and fish entering the Delta interior range from approximately 5 to 17 percent of the spring-run population entering the Delta. These estimates used the percentage of fish entering the Delta interior through either the DCC or Georgiana Slough channels (based on acoustic tracking data of Chinook salmon smolts: 28 percent when DCC open, 18 percent when closed), the survival estimates within those channels (35 percent survival base case, 10 percent survival when high losses occur, 75 percent survival when losses are low), the monthly position of the DCC gates, and the percentage of the spring-run population entering the Delta from the Sacramento River each month from table 6-26.

Central Valley steelhead – As discussed for the winter-run and spring-run populations, diversity of life history strategies represents a mechanism by which the population can take advantage of variability in the natural environment and spread its risks across a larger temporal period. By encountering many different environmental conditions, the probability of finding an environment with suitable conditions increases. Although only a small proportion of the Sacramento Valley steelhead are emigrating during the period when the gates are open in late fall and early winter, they represent an important component of the life history strategy of the CV steelhead. These early migrants are vulnerable to the open gates and the expected high loss rate in the Delta interior would remove an important component of the steelhead life history strategy from the population. Based on the data generated from the acoustic tracking studies of Perry and Skalski (2008) and Burau *et al.* (2007), NMFS has estimated that losses to the CV steelhead population associated with the operations of the DCC ranage from approximately 5 to 17 percent of the CV steelhead population entering the Delta from the Sacramento River basin. These estimates used the percentage of fish entering the Delta interior through either the DCC or Georgiana Slough channels (based on acoustic tracking data of Chinook salmon smolts: 28 percent when DCC open, 18 percent when closed), the survival estimates within those channels (35 percent survival base case, 10 percent survival when high losses occur, 75 percent survival when losses are low), the monthly position of the DCC gates, and the percentage of the winter-run population entering the Delta from the Sacramento River each month from table 6-26.

Green sturgeon – It is unknown what population effects the DCC gate operations will have on the green sturgeon population in the Delta. The behavior of green sturgeon juveniles in relation to the gate operations is unknown. The situation is further complicated by the lack of knowledge of migrational timing for juvenile green sturgeon entering the Delta from the Sacramento River and thus the timing of their exposure to the gate operations. Adult green sturgeon may be impacted by the potential for delay behind the closed gates during their upstream migration. However, acoustic tagging efforts to date indicate that tagged fish move upriver through the mainstem of the Sacramento River in the Delta and not within the interior delta waters adjacent to the downstream channel of the DCC. Only those fish that entered the downstream sections of the Mokelumne River system and continued upstream in this system would be subject to migrational delays below the DCC gates during their spawning runs. This may change as more fish are tagged and a greater knowledge of adult fish movement is gained.

6.6.5.5 Effects of the Action on Designated and Proposed Critical Habitat in the Delta Division

For both the winter-run and spring-run, designated critical habitat lies adjacent to the location of the DCC gates. In the case of designated critical habitat for the winter-run (58 FR 33212) the DCC is specifically not included because the biological opinions issued by NMFS in 1992 and 1993 concerning winter-run included measures on the operations of the gates that were designed to exclude winter-run from the channel and the waters of the Central Delta. For the spring-run, designated critical habitat (70 FR 52488) includes the DCC from its point of origin on the Sacramento River to its terminus at Snodgrass Slough, including the location of the gates. Designated critical habitat for CV steelhead includes most of the Delta and its waterways; however, the DCC waterway was not included in the text or maps of the Federal Register notice as being part of the Delta waters designated as critical habitat. Nevertheless, actions of the DCC gates affect the critical habitat PCEs designated for the spring-run and CV steelhead populations as well as the essential fish habitat functions for winter-run Chinook salmon. Primarily, DCC gate operations interfere with the performance of the Sacramento River as a migratory corridor for spring-run and CV steelhead and as essential habitat for winter-run by preventing access downstream from the spawning grounds to San Francisco Bay and the Pacific Ocean. Fish entrained into the DCC and the Mokelumne River systems are at a greater risk of mortality than their counterparts who have remained in the mainstem of the Sacramento River. The operations of the gates permit fish to enter habitat and waterways they would not normally have access to with substantially higher predation risks than the migratory corridor available in the Sacramento River channel. Operations of the gates have a direct effect on the entrainment rate and hence the functioning of the Sacramento River as a migratory corridor.

6.6.6 Contra Costa Water District Diversions

6.6.6.1 Deconstruct the Action

CCWD currently operates three facilities to divert water from the Delta for irrigation and Municipal and Industrial (M&I) uses. These are the facilities at Mallard Slough on the lower San Joaquin River near Chipps Island, on Rock Slough near Oakley, and on Old River near the Highway 4 Bridge. The fourth diversion to be added to those facilities operated by CCWD is the “Alternative Intake Project” on Victoria Slough in the South Delta. Reclamation owns the Contra Costa Canal and shortcut pipeline, as well as the Rock Slough Intake and pumps. The CCWD operates and maintains these facilities under contract to Reclamation. CCWD owns

Mallard Intake, Old River Intake and Los Vaqueros Reservoir, and the proposed Alternative Intake on Victoria Canal. Separate Opinions have been issued for these structures.

The Rock Slough Intake is an unscreened diversion owned by Reclamation and one of three operated in the Delta by CCWD. Pumping Plant 1, located several miles downstream from the canal's headworks on Rock Slough, has the capacity to pump 350 cfs into the concrete lined portion of the Contra Costa Canal. The Rock Slough intake currently accounts for approximately 17 percent of the total water diverted by the CCWD in the Delta. Pursuant to the USFWS' (1993) Opinion for the Los Vaqueros Project, the positively screened Old River Facility is now the primary diversion point for CCWD, accounting for approximately 80 percent of the annual water supply diverted by CCWD. In the future, when the positively screened Alternative Intake comes on line, the share of CCWD water diverted from the Old River and Victoria Canal intakes will account for approximately 88 percent of the annual water diversions for the CCWD, while the Rock Slough intake will be reduced to approximately 10 percent of the annual diversions. All three current intakes are operated as an integrated system to minimize impacts to listed fish species. 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 CDFG, 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.

6.6.6.2 Assess Species Exposure

At least one of the listed species are present in the south Delta waterways adjacent to the CCWD diversion intakes in all months of the year. Winter-run are present from approximately December through June based on salvage records from the CVP/SWP fish collection facilities. The peak occurrence of winter-run in the south Delta is from January through March. Juvenile spring-run are present in the South Delta in the vicinity of the CCWD diversions from January through June with peak occurrence from March through May. Central Valley steelhead may be present in the waters of the South Delta from October through July, but have peak occurrence from January through March. Both juvenile and sub-adult green sturgeon are expected to be present year round in the South Delta as indicated by the salvage record. Adult green sturgeon have been caught by sport fisherman in the mainstem of the San Joaquin River from Sherman Island to the Port of Stockton in most months of the year based on the draft 2007 sturgeon report card (CDFG 2008). Presence in the South Delta is assumed for the same period. During the 75 day pumping reduction from March 15 to May 31 and the 30 day no pumping period (April 1 to April 30), the effects of the CCWD action is significantly reduced or eliminated.

6.6.6.3 Assess Species Response to the Proposed Action

In the 1993 winter-run Opinion, NMFS required monitoring for winter-run. Based on the CDFG sampling during the period from 1994 through 1996, mortality from entrainment in the Rock Slough Intake occurred from January to June. Annual numbers captured in a sieve-net downstream of the pump plant for the years 1994-1996 were 2 to 6 winter-run, 25 to 54 spring-run, and 10 to 14 steelhead (Morinaka 2003). Additional losses (8 to 30 percent) due to predation in the canal and fish being killed passing through the intake also were determined to occur. Extrapolated numbers of juvenile Chinook salmon (all races) entrained at Rock Slough between 1994 and 1996 ranged from 262 to 646 fish per year.

Since that time, most of CCWD water diversions have shifted to newer, screened facilities on Old River near Highway 4. These screens are designed to exceed NMFS' juvenile salmon screening criteria since they also must be protective of juvenile and larval delta smelt which co-occur in the same waters. In addition, the current pumping rates at Rock Slough have been reduced in the winter months compared to the historical conditions (CVP/SWP operations BA Appendix E). 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 winter-run is collected at the CVP and SWP (generally January or February) through June. Since 1998, the expanded fish monitoring has only recovered 1 winter-run sized Chinook salmon, 14 spring-run sized Chinook salmon, 6 unclipped steelhead, 8 clipped steelhead, and one steelhead of indeterminate origin. During the same period of time, 19 wild fall-run and 2 clipped fall-run have been recovered (table 6-35) at the Rock Slough Headworks and Pumping Plant 1. NMFS previously estimated that annual take of listed fish at the Rock Slough Intake will be 50 spring-run, 50 winter-run, and 20 steelhead. In all of the years of fish monitoring, no green sturgeon has ever been recovered in the seines or plankton nets.

Table 6-35. 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**

Future entrainment is expected to be reduced with the addition of CCWD's Alternative Intake Project. As previously stated, the percentage of water diverted from the Delta via the Rock Slough Intake will fall from 17 percent to approximately 10 percent of the annual CCWD diversions when the Alternative Intake Project comes on line. Furthermore, the use of the Rock Slough Intake will move into the summer months, when listed salmonids will be less likely to be present in the waters adjacent to the intake. The two other intakes on Old River and Victoria Canal will both be positively screened. Approach velocities and sweeping velocities for these two facilities will exceed NMFS' criteria for screening since they are designed to also meet Delta smelt criteria (see NMFS 2007). Estimates of future losses of spring-run and winter-run 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.

6.6.6.4 Assess Risk to Individuals

Individual salmonids are likely to be present in the waters of the South Delta near the Old River Intake and the future Alternative Intake site on Victoria Canal during the winter and spring periods. Since the fish screens of the Old River Intake and the future Alternative Intake have been designed to meet Delta smelt standards, NMFS does not expect any salmonids to be entrained by these facilities, as the Delta smelt screening criteria are more stringent than those required for the protection of salmon fry or juveniles. The past several years of monitoring at the Old River Intake Facility has not recovered any listed fish from behind the screens, indicating that they are effective for salmonids. Individual fish may become impinged on the outside of the screens and incur some level of injury from the contact with the screens or become susceptible to localized predation adjacent to the screens while holding position in front of the screens. Experiments by Swanson *et al.* (2004) exposed juvenile Chinook salmon to a simulated fish screen in a large annular flume. Juvenile Chinook salmon tended to exhibit positive rheotaxis, swimming against the resultant current at all times. The incidence of impingement was very low (< 1 percent) in experimental fish. However, juvenile Chinook salmon experienced frequent temporary contacts with the screen surface, particularly with their tails (80 percent of contacts). The rate of morbidity was very low following the incidental contacts with the screen in these experiments. However, this could be a reflection of the benign environmental conditions under which the experiments took place. There were no predators, and the post-experiment observation period only lasted 48 hours. In the field, screens may have debris and other anomalies on their surface, which could produce abrasions to the skin of the fish. These wounds to the skin of the juvenile salmonid would create an opening for pathogens to colonize, and possibly cause morbidity or mortality in the affected fish later on. In addition, predators may seize the opportunity to mount attacks on juvenile salmonids that are dazed by the contact with the screen, or otherwise concentrated around the surface of the screen while holding position against the current. NMFS assumes a 5 percent loss for fish exposed to the screens (95 percent effective) due to these various effects.

NMFS does not anticipate that the screens will have any demonstrable effect on green sturgeon juvenile and sub-adults. The size of the sturgeon present in the south Delta would preclude them from being entrained through the small perforations in the screen. Green sturgeon rearing in the south Delta are considerably larger than the small perforations in the screen. Salvaged green sturgeons are bigger than 125 mm and average 330 mm. Studies with pallid and shortnose sturgeon (Kynard and Horgan 2001) previously mentioned had nearly 100 percent efficiency with louver arrays with considerably larger gaps in the screen than present at the CCWD's intake facilities. NMFS does not anticipate that there will be any significant loss of green sturgeon related to the operation of the positive barrier screens.

Entrainment at the Rock Slough diversion is expected to be minimal based on the past several years of monitoring data at this facility. Although the diversion is not screened, current operations which minimize water diversions from this facility have substantially reduced the number of listed salmonids entrained. Future plans to further reduce exports to only the summer months will have additional benefits as listed salmonids will be less likely to be present in the regional waters. Risk to individual fish will remain, but overall risk will be reduced since pumping is minimized during periods when fish are present in the system, and the likelihood of entrainment within the flow to the Rock Slough intake is reduced due to its lower volume. No green sturgeon have ever been recovered during the 10 years of monitoring the Rock Slough canal and NMFS does not expect this to change. Risk to individual sturgeon is considered to be very low to nonexistent.

Increased flows in the future could affect OMR flows in the region. This could lead to increased impacts on individual fish moving in the region's waterways by increasing their vulnerability to the CVP/SWP export facilities.

Based on the efficiency of the positive barrier screens in the Old River and Alternative Intake facilities, the risks to the populations of winter-run and spring-run, CV steelhead, and green sturgeon present in the South Delta during the year are believed to be minimal. As mentioned in the above section, NMFS assumes that the screens are 95 percent efficient and are likely much better than this in reality. Although individual fish my suffer mortality or morbidity, it is not anticipated that this will occur at a scale that would have population level ramifications. Likewise, given the very low numbers of listed salmonids and the complete absence of green sturgeon from the monitoring records over the past 10 years at the Rock Slough facility, its operation is believed to have negligible effects on the populations of listed salmonids or green sturgeon present in the South Delta. The combined diversions from all three intakes however, may affect the OMR flows in the region and could make them more negative. This would create additional stresses on the hydrodynamics in the South Delta, which can translate into greater impacts on fish movements in the region and a greater likelihood of encountering the flow fields around the CVP/SWP export facilities.

6.6.6.5 Effects of the Action on Designated and Proposed Critical Habitat in the Delta Division

The effects of the CCWD on the designated critical habitat of CV steelhead and proposed critical habitat for Southern DPS green sturgeon in the South Delta is anticipated to be minimal by themselves. The current and future levels of exports are substantially below those envisioned for the CVP and SWP facilities. Nevertheless, the exports from the CCWD intakes do contribute to the additive net negative flow in Old and Middle Rivers and thus, in combination with the much larger CVP and SWP exports, negatively impact the hydrodynamics of the South Delta. This affects the value of the South Delta waterways as migratory corridors for steelhead and green sturgeon.

6.6.7 North Bay Aqueduct at Barker Slough Intake

6.6.7.1 Deconstruct the Action

DWR operates the North Bay Aqueduct (NBA) intake in the North Delta through the operation of the Barker Slough Pumping Plant. The NBA delivers water to Solano and Napa Counties. The plant's exports currently range from 30 to 140 cfs. Current pumping capacity is limited to 140 cfs due to capacity of the existing pumps at the facility. An additional pump is required to reach the pipeline design capacity of 175 cfs. The Barker Slough Pumping Plant facility is equipped with a positive barrier fish screen designed and constructed to meet NMFS' fish screening criteria. The Barker Slough Pumping facility entrains water from Barker Slough and surrounding waterbodies including Campbell Lake, Calhoun Cut, and Lindsey Slough. It is approximately 7 to 10 miles upstream of the confluence of Lindsey Slough with Cache Slough. Due to the entrainment of water from the surrounding sloughs, the intake has the potential to entrain migrating salmonids and green sturgeon that may be present in the Cache Slough complex of channels, including waters from the Yolo Bypass and Miners Slough.

6.6.7.2 Assess Species Exposure

Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant, however several years of monitoring have failed to consistently capture any salmonids during the winter Delta smelt surveys (1996 to 2004) in Lindsey Slough or Barker Slough. Captures of Chinook salmon have usually occurred in the months of February and March and typically are only a single fish per net haul (http://www.delta.dfg.ca.goc/data/nba). Most Chinook salmon captured have come from Miners Slough, which is a direct distributary from the Sacramento River via Steamboat and Sutter Sloughs. No steelhead have been captured in the monitoring surveys between 1996 to 2004, the dates available on the DFG website. Green sturgeon are assumed to occur in the waters of Cache Slough and the Sacramento ship channel as green sturgeon have been caught in these waters by sport fisherman.

6.6.7.3 Assess Species Response to the Proposed Action

Seasonal pumping rates during the years 2005 to 2007 were 109 cfs in summer (June to August), 94 cfs in fall (September through November), 39 cfs in winter (December through February), and 36 cfs in spring (March through May). The recent historical data indicates that actual pumping levels are substantially less than those predicted in the CALSIM II current conditions scenario (Study 7.0) during the winter and spring months. For instance, the month of December has an average historical export rate of 52 cfs for the years 2005 through 2007. The estimated export rate for December from Study 7.0 is 116 cfs. The historical rate is only 44 percent of the modeled export rate. Similarly, the historical export rate for the month of April (2005 through 2007) is 31 cfs, while the estimate from Study 7.0 is 133 cfs. The historical export rate is only 23 percent of the modeled export rate. Therefore under the current historical conditions, relatively little exports are diverted from the Barker Slough Pumping Plant. In the modeled export scenario representing current conditions (Study 7.0), pumping is increased nearly two fold over historical conditions and increases even more during the near future and future conditions modeled for the action. This would increase the potential for entrainment over the current historical conditions observed at the pumping plant.

During the summer, seasonal pumping rates for the modeled studies 7.0 and 7.1 are not substantially different from each other (average rates were 115 cfs and 107 cfs, respectively) but both were lower than the future condition modeled in Study 8.0 (135 cfs), a difference of 15 to 20 percent. The historical value for the summer season (2005 to 2007) is 109 cfs, relatively similar to the modeled current conditions. NBA diversions are lower in fall, averaging 101 cfs in study 7.0, 99 cfs in study 7.1, and 123 cfs in study 8.0. The historical pumping rate during the fall (2005 to 2007) was 94 cfs, which is similar to Study 7.0 which modeled the current conditions. Modeled NBA diversions are highest during the winter months. There was very little difference between Studies 7.0 and 7.1 during the winter. However, study 8.0 differed from the other two studies, being greater in December (142 cfs versus 116cfs and 112 cfs) and lower in January (112 cfs versus 157 cfs and 155 cfs) and February (126 cfs versus 155 cfs and 154 cfs). All of the modeled pumping estimates are significantly greater than the historical average of 39 cfs for the period between December and February (2005 to 2007). This represents a substantial increase between historical conditions and the modeled conditions. Modeling estimates for the spring period also were substantially greater than the historical values from 2005 to 2007. The estimates for Study 8.0 export rates also were also greater than those for Studies 7.0 and 7.1. For April, Study 8.0 had a diversion rate of 145 cfs while study 7.0 (133 cfs) and Study 7.1 (128 cfs), a difference of approximately 10 percent. For May, Study 8.0 also had a diversion rate of 145 cfs, which is approximately 25 percent higher than the estimated rates for Studies 7.0 and 7.1 (both 116 cfs). Study 8.0 estimated an export rate of 148 cfs for June, approximately 18 percent higher than the estimates for Study 7.0 (126 cfs), and Study 7.1 (123 cfs). The historical export rate for the spring period between 2005 and 2007 was 36 cfs. Again the modeled rates are substantially greater than the historical pumping rates.

Overall, the modeled exports represent a significant increase in export levels and thus a greater risk to salmonids and green sturgeon in the waters adjacent to the pumping facility compared to their historical vulnerability. The increased export rates increase the potential exposure of fish to the fish screen over the historical conditions. However, the screens, which were designed to protect juvenile salmonids per NMFS criteria, should prevent entrainment and greatly minimize any impingement of fish against the screen itself. Furthermore, the location of the pumping plant on Barker Slough is substantially removed from the expected migrational corridors utilized by emigrating Chinook salmon and steelhead smolts in the North Delta system. Green sturgeon may be present in the waters of Lindsey and Barker sloughs since they are present in Cache Slough and the Sacramento Ship Channel. Green sturgeon are expected to be fully screened by the positive barrier fish screen in place at the pumping facility.

6.6.7.4 Assess Risks to Individuals

Based on the increases in modeled pumping rates over the historical export rates between 2005 and 2007, individual fish would be at a greater risk of exposure to the screens in response to the proposed action's greater export rates. However, the presence of salmonids in the waters of Barker Slough does not appear to be likely based on the monitoring data available. If the fish are not present in the vicinity of the export pumps, then there is no increase in the encounter rates with the screens. NMFS does not expect to see a demonstrable increase in the take of salmonids from the increased exports of the Barker Slough pumps for this reason.

The presence of green sturgeon is possible at the Barker Slough Pumping facility, but the entrainment risks presented by the pumps are minimized by the design of the screens. NMFS does not expect that individual green sturgeon will be harmed by the screens.

There is no discernable effect to the populations of winter-run or spring-run due to the operations of the Barker Slough Pumping Facility. The infrequent presence of Chinook salmon in the monitoring surveys indicates that Chinook salmon are at low risk of entrainment. Density appears to be quite low, and those Chinook salmon that have been captured in the monitoring surveys have tended to be in Miners Slough, a waterway to the east of Barker Slough. If Chinook salmon were to be pulled into the vicinity of the screened pumps by the increased exports, the screens are designed to effectively prevent the entrainment of these fish.

No steelhead have been recovered during the monitoring surveys conducted for the NBA at any of the monitoring sites sampled in the region. Therefore, it would appear that steelhead are rare in these waters and very few would have the potential to be affected by the screened export pumps. The take of very few fish would not be sufficient to have a population effect on Central Valley steelhead.

6.6.7.5 Effects of the Action on Designated and Proposed Critical Habitat in the Delta Division

The location of the Barker Slough Pumping Plant lies within the regional waterways designated as critical habitat for both spring-run and CV steelhead. The Federal Register (September 2, 2005, 70 FR 52488) identifies the upstream tidal limits of Cache Slough and Prospect Slough, as well as Miners Slough and the Yolo Bypass within the Sacramento Delta Hydrologic Unit 5510 as critical habitat. Barker Slough and Lindsey Slough are interconnected with the Cache Slough complex of waterways and were not specifically excluded as critical habitat as was the Sacramento DWSC. The proposed critical habitat for Southern DPS of green sturgeon includes the Yolo bypass as well as waters of the legal Delta. Designated critical habitat for winter-run is more ambiguous, as only the Sacramento River was named as critical habitat (58 FR 33212) and not any of the tributaries or side channels and sloughs associated with the north Delta system.

The footprint of the Barker Slough Pumping Plant is relatively small and located approximately 7 to 10 miles upstream from Cache Slough on Barker Slough. Barker Slough is a dead-end Slough without any significant sources of inflow. It does not physically block a migratory corridor, nor does it occur in habitat that appears to be utilized extensively by Chinook salmon, steelhead, or green sturgeon based on the monitoring surveys mentioned previously. The primary effects of the NBA and the Barker Slough Pumping Plant are related to the entrainment of water from the Cache Slough complex of waterways. The entrainment of water from these waterways can redirect or delay listed salmonids present in those waterways. This can affect the PCE concerned with the preservation of the functionality of the migratory corridors for listed salmonids or green sturgeon. However the effect the Barker Slough Pumping on this PCE is believed to be negligible due to the relatively small magnitude of the diversion, even with the predicted increases in exports in the near future and future conditions.

6.6.8 Vernalis Adaptive Management Plan

6.6.8.1 Deconstruct the Action

The VAMP is an experimental study that provides for a steady 31-day pulse flow of water (target flow) at the Vernalis gage on the San Joaquin River during the months of April and May. The target flow is calculated from a formula which takes into account the existing flows in the San Joaquin River and the current and past 2 year's hydrology, based on the San Joaquin River Basin 60-20-20[17] water year classification scheme. In addition to the target flow, there are corresponding restrictions in the export levels of the CVP and SWP pumping facilities as well as the installation of the fish barrier at the Head of Old River. Both Reclamation and DWR are signatories to the SJRA and have agreed to pay 4 million dollars per year ($4,000,000) to the SJRGA to cover the authorities' contribution of water to the plan from their respective water supplies. Reclamation's share of this payment is $3,000,000 per year, and DWR, as part of its CVPIA cost share obligations, will furnish the remaining $1,000,000. This funding agreement is set to terminate on December 31, 2009, while the SJRA sunsets in 2012 unless it is extended.

During the early discussions regarding modeling assumptions, Reclamation and DWR committed to providing a VAMP-like river flow in the San Joaquin River and export reductions during the VAMP operational period, should the agreement not be extended into the future (project description, pages 76-77). The VAMP target flows and export rates are contained in table 6-36, below. For the purposes of the combined CVP/SWP operations forecasts, the VAMP target flows are simply assumed to exist at the Vernalis gage compliance point. Currently, supplemental volumes of water needed to reach the annual target flow are released on each of the three east side tributaries, *i.e.* the Stanislaus River, the Tuolumne River, and the Merced River, in a coordinated fashion to provide pulse flows down each river channel while maintaining the target flow at the Vernalis gage. These pulse flows are believed to stimulate outmigration of fall-run (the target species for the VAMP experiments) downstream towards the Delta. However, it also is acknowledged that other species of fish, including the CV steelhead, benefit from these pulses. NMFS believes that these pulse flows are critical cues for the listed steelhead in these tributaries to initiate their downstream emigration to the ocean (see SJRGA annual reports 2001-2008).

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[17] 60-20-20, also known as the San Joaquin Valley's water year type index, equals 0.6 * Current Apr-Jul Runoff + 0.2 * Current Oct-Mar Runoff + 0.2 * Previous Year's Index, where runoff is the sum of unimpaired flow in MAF at: Stanislaus River below Goodwin Reservoir (aka inflow to New Melones Res.), Tuolumne River below La Grange (aka inflow to New Don Pedro Reservoir), Merced River below Merced Falls (aka inflow to Lake McClure), and San Joaquin River inflow to Millerton Lake, and the previous year's index is a maximum of 4.5 (http://cdec.water.ca.gov/cgi-progs/iodir/wsi).

Table 6-36. Scheduled VAMP target flows and export reductions required under the San Joaquin River Agreement.

VAMP Vernalis Flow and Delta Export Targets		
Forecasted Existing Flow (cfs)	Vamp Target Flow (cfs)	Delta Export Target Rates (cfs)
0 to 1,999	2,000	
2,00 to 3,199	3,200	1,500
3,200 to 4,449	4,450	1,500
4,450 to 5,699	5,700	2,250
5,700 to 7,000	7,000	1,500 or 3,000
Greater than 7,000	Provide stable flow to extent possible	1,500, 2,250, or 3,000

Reclamation and DWR did not provide further resolution of their future operations other than to provide VAMP-like flows at Vernalis. NMFS has considerable interest in how the flows in the two other tributaries, besides the Stanislaus River, will be affected by the future CVP/SWP operations. As mentioned above, the Tuolumne River and Merced River release a portion of the total supplemental water required to meet the targeted flows required under the VAMP experiment each year. These flows are integral to stimulating outmigration of both the threatened CV steelhead, and fall-run, a species of concern under the ESA, from the Tuolumne River and Merced River. Furthermore, decreases in the pulse flows on these rivers would be an adverse modification of critical habitat designated for CV steelhead in regards to flow related decreases in rearing area suitability and physical and flow related obstructions in the migration corridors from the rearing areas below the dams, downstream to Vernalis on the San Joaquin River where the Stanislaus River enters.

6.6.8.2 Assess Species Exposure

VAMP actions will primarily affect CV steelhead originating in the San Joaquin River basin. Under historical and current conditions, pulse flows in the tributaries will affect steelhead originating in the Stanislaus, Tuolumne, and Merced rivers. These pulse flows are typically staggered among the tributaries to maintain the desired target flows at Vernalis, with the Stanislaus River generally contributing the greatest volume. San Joaquin River basin steelhead within the mainstem San Joaquin River from the Merced River confluence through the Delta benefit from the VAMP pulse flows.

Within the Delta proper, other runs of listed salmonids and the Southern DPS of green sturgeon may benefit from the additional water flowing downstream and the export reductions taken as part of the experiment. During the 31 day pulse flow (typically April 15 through May 16), spring-run from the Sacramento River basin, steelhead from several watersheds outside of the San Joaquin River basin (*i.e.*, the Sacramento River basin, Feather River, American River, Mokelumne River and Calaveras River), the tail end of the winter-run outmigration, and rearing green sturgeon in the Delta all may benefit from the VAMP operations due to their potential presence in the Delta during this time period.

6.6.8.3 Assess Species Response to the Proposed Action

The VAMP experiments were designed to examine the relationships between upstream flows as measured at Vernalis, the role of exports, and the eventual survival of fall-run migrating through the Delta. The experiments provided sufficient in-river flows to provide migratory cues in the three San Joaquin River tributaries to fall-run and subsequently to test the relationship of flows with survival through the lower river reaches of the mainstem San Joaquin River and subsequently through the Delta. CV steelhead co-occurring with fall-run in these tributaries were also expected to benefit from these flow manipulations.

Under the future proposed VAMP-like operations, spring pulse flows are only linked to the Vernalis standard. Reclamation and DWR have not elaborated the details of this plan, particularly if pulse flows will continue on the Merced and Tuolumne rivers as has occurred historically in the VAMP experiment. Decreased flows on these rivers would create a situation in which the downstream water temperatures on the valley floor would become warmer with the progressively increasing air temperatures experienced during a typical spring in the Central Valley. As spring progressed, the increasing air temperature would continue to warm the river water and create thermal barriers within the downstream reaches of the river channel. Without a suitable pulse of cooler water moving downstream from increased dam releases to breakdown this thermal barrier, juvenile salmonids would be unlikely to survive their migration downstream to the Delta, dying from excessive thermal exposure en route. The only recourse is to remain within the reaches immediately below the terminal dams and reside in the cool tailwater reaches of the river over the summer and emigrate the following fall or winter when air temperatures decrease with the onset of winter. Unfortunately, due to the restricted habitat available below the dams with sufficient cool water to maintain suitable habitat requirements for either steelhead or fall-run Chinook salmon, density dependent mortality is anticipated to occur. There is currently insufficient space in the tailwater sections of these tributaries to support a large population of over summering salmonids under current summertime releases, and this is itself identified by NMFS as a limiting factor in steelhead recovery in the San Joaquin River basin. Forcing increased numbers of Chinook salmon and steelhead to compete for the limited over summering habitat and their resources (food, holding areas, cover, *etc*.) due to lack of sufficient outmigration spring pulse flows, would place additional stressors on the remaining populations of CV steelhead that would “normally” be present in these areas over the summer.

NMFS reviewed several reports in assessing the effects of flow in the San Joaquin River basin on the salmonid populations residing in the basin. Skinner (1958) reported that Central Valley populations of Chinook salmon exhibited wide fluctuations in abundance from 1870 onward by examining landings of Chinook salmon in California. The overall trend in abundance was negative, but every 30 years or so, particularly large landings occurred. Skinner (1958) opined that the declines in the Chinook salmon fisheries appear to be chronologically associated with water development projects in California, and the increase in the ocean troll fishery. Skinner (1958) describes the effects of the construction of Friant Dam on the upper San Joaquin River on the extirpated the spring-run population that formerly inhabited that watershed. Skinner (1958) stated:

> "Friant Dam on the San Joaquin River has had multiple effects on the spring fishery. In the first place the dam has cut off a third or more of the spawning area. Secondly, flows below the dam were inadequate during normal migration periods to assure passage of the fish either up or down the river. Only enough water is permitted to flow down the river to fulfill irrigation commitments. The released water flows to the delta Mendota Pool and a small amount reaches the 'Sack Dam' at Temple Slough where it is diverted for agricultural purposes. Below this point, the river goes dry except for small amounts of water received from its downstream tributaries. Because of these conditions, salmon obviously cannot ascend to the spawning area in the vicinity of Friant Dam."

Skinner (1958) also makes the observation that with the extirpation of the San Joaquin River spring run population that the commercial catches of spring run plummeted from 2,290,000 pounds in the 1946 season to 14,900 pounds in 1953. Functional extirpation of the San Joaquin River spring-run population occurred following the completion of the Madera Canal in 1944, and the completion of the Friant-Kern canal in 1949, allowing full use of the distributional system under Reclamation's operational plan. Skinner (1958) concluded that the last successful spawn of spring run in the San Joaquin River has not occurred "since the spring of 1946." This is an example of the direct consequences resulting from the alteration and loss of necessary in-stream flows to support salmonid populations below dams in the San Joaquin River basin.

Kjelson *et al.* (1981) described the effects of freshwater inflow on survival, abundance, migration, and rearing of Chinook salmon in the upstream (Delta) portions of the Sacramento-San Joaquin Estuary. Kjelson *et al*. (1981) pointed out that additional inflows of freshwater at the appropriate time during the winter and spring will increase the numbers of fry and juvenile salmon utilizing the estuary and the survival of juveniles in the estuary. Flow-related concerns for salmon in the estuary stem from water development activities in the Central Valley that have altered the distribution of flow resulting in impacts on juvenile and adult salmon migrations, as well as the lack of comprehensive flow standards on the tributaries and mainstem river reaches that are protective of salmon. The authors further explain that water development projects have caused major changes in the flow patterns within the estuary and the amount of flow entering the ocean from upstream sources. The San Joaquin River system has been particularly altered as most of the upstream inflow to the basin has been captured and utilized in regions upstream of the Delta. Typical export rates substantially exceed the flow of the San Joaquin River; hence most of the San Joaquin River flow goes to the export pumps rather than to the ocean. The authors concluded that the distribution and flow of water through the Delta waterways are heavily influenced by the design and operation of the state and federal water projects. Kjelson *et al.* (1981) report that analysis of data gathered between 1957 and 1973 indicates that the numbers of adult Chinook salmon spawners returning to the San Joaquin River system are influenced by flows 2.5 years earlier during their rearing and downstream emigration life history phases. In general, higher flows resulted in greater numbers of adults returning to spawn. Kjelson *et al.* (1981) also implicate the potential adverse effects of the pumps in the reduced survival of fish emigrating through the Delta, indicating that as export rates are increased, more downstream migrating salmon are drawn to the fish screens. Kjelson *et al.* (1981) estimate that the number of fish observed at the fish screens is probably only 5 percent of the total downstream migration in the system, but that a "much larger fraction probably is drawn out of their normal migration path" by the effects of the pumps on water flow in the Delta's channels. Kjelson *et al*. (1981)

state that the "alteration in flow distribution caused by drafting increased volumes of water across the Delta to the pumps apparently increases the mortality of salmon that do not ever reach the fish screens." In support of this statement, Kjelson *et al*. (1981) point out those mark-recapture studies in which fish that migrate downstream in waterways that are far removed from the effects of the pumps had higher relative survival rates than those released in waterways under the influence of the pumps.

Kjelson *et al.* (1982) reiterate the reduced survival of salmon in the delta due to influences of natural and anthropogenic sources. They found that Chinook salmon smolt survival decreased as flow rates decreased and water temperatures increased, particularly in the later portions of the outmigration period. Furthermore, they restated their belief that the influence of the state and federal exports negatively impacted the survival of emigrating smolts through the Delta.

In a study assessing the influence of San Joaquin River inflows, state and Federal exports, and migration routes, Kjelson *et al.* (1990) released experimental fish (coded wire tagged hatchery Chinook salmon) during the spring of 1989 at Dos Reis on the San Joaquin River below the head of Old River, and in Old River itself downstream of the head under conditions with low San Joaquin River flow (≈ 2,000 cfs) and high/low export conditions (10,000 cfs and 1,800 cfs). The results of the study were unexpected as the rate of survival was not greater for the low export conditions compared to the higher export conditions. Upon further examination of the data, Kjelson *et al*. (1990) found that survival was comparatively lower for all upstream release groups that year compared to other studies conducted in previous years. In addition, Kjelson *et al.* (1990) surmised that the short period of reduced exports (7 days) was not long enough to allow fish to exit the system and move beyond the influence of the exports when higher pumping resumed. Based on the times to recovery at Chipps Island, it was concluded that a sizeable proportion of the released fish were still in the Delta when the higher export levels resumed. This conclusion is further reinforced by the salvage of fish released at Jersey Point, indicating that fish were drawn upstream into the interior of the Delta and towards the pumps from their release points in the western Delta. The study, although having several significant flaws, did conclude that survival was higher in the mainstem San Joaquin River compared to Old River and that survival in the Delta interior was lower compared to the western Delta (*i.e.,* Jersey Point releases). Kjelson *et al*. (1990) cautioned about drawing conclusions about export rates and survival from the data due to its obvious flaws.

Kjelson and Brandes (1989) reports on the results of ongoing mark-recapture studies conducted in the Sacramento-San Joaquin Delta and the effects of river flows, percent diversion of Sacramento River water through the DCC, and river temperatures. The findings of that paper also conclude that elevated flows, as measured at Rio Vista on the Sacramento River, increase survival of Chinook salmon smolts from the Sacramento River basin through the Delta as measured by both ocean recoveries of adults and recaptures of tagged smolts at Chipps Island in the mid-water trawls. Similarly, adult escapement in the San Joaquin River basin also increases with spring time flows at Vernalis 2.5 years earlier. Increasing water temperature was also shown to decrease smolt survival through the Delta during the critical April through June outmigration period of fall-run.

In a more recent report, Mesick *et al.* (2007) assessed the limiting factors affecting populations of fall run and steelhead in the Tuolumne River. The paper describes potential limiting factors which may affect the abundance of fall-run and both resident and anadromous (steelhead) forms of rainbow trout in the Tuolumne River. This information was then synthesized into conceptual models to help guide management decisions in regards to steelhead and fall-run. In general, Mesick *et al.* (2007) found that river flows were the limiting factor with the greatest influence on the salmonid populations in the Tuolumne River. As found in previous studies, there is a strong relationship between adult escapement and spring-time river flows during the juvenile/smolt outmigration stage. Flows measured over the period between March 1 and June 15 explained over 90 percent of the variation in the escapement data. However, Mesick *et al*. (2007) identified two critical flow periods for salmon smolts on the Tuolumne River: winter flows which affect fry survival to smolt stage, and spring flows which affect the survival of smolts migrating from the river through the delta. Based on results from ongoing VAMP studies, Mesick *et al*. (1990) also noted that increased flows at Vernalis also increased survival of smolts emigrating through the Delta. Water temperature in the river was also identified as a potential limiting factor for salmonid survival within the emigration time period. Flows have a substantial role in maintaining suitable water temperatures within the river system, with higher flows prolonging and extending the cool water migratory corridor downstream than low flow conditions. Mesick *et al.* (1990) found that for Tuolumne River fall-run escapement data, that exports had little effect on adult production compared to winter and spring flows. Flows were the primary factor, beyond all other factors, in determining adult production from smolts.

NMFS also reviewed the restoration reports for the CVPIA, including the three volumes of "Working Paper on Restoration Needs" for the AFRP (USFWS 1995) and the Final Restoration Plan for the AFRP (USFWS 2001). The plan identified the Delta as the highest priority for restoration actions (USFWS 2001 page 17), given that it was highly degraded, due in part to CVP (and SWP) operations, and that all anadromous fish must pass through the delta as juveniles and adults. In addition, the San Joaquin River mainstem and its tributaries below Mendota Pool were assigned a high priority (but lower than the Delta) due to its highly degraded habitat and substantially reduced production of fall-run. Specific actions in each watershed and the Delta were identified to address the limiting factors present in those areas and were prioritized as to their ability to implement the "doubling goal" for affected fish populations. In general, actions scored a high priority if they promote natural channel and riparian habitat values and natural processes, such as those affecting stream flow, water temperature, water quality, and riparian areas. Actions are assigned medium priority if the affect emigration or access to streams, such as sites of entrainment into diversions and migration barriers. Like the previous reports, the AFRP Restoration Plan recommended increasing flows within the tributaries and mainstem San Joaquin River as a high priority action to increase salmonid production. Within the Delta, actions which would provide protection to juvenile salmonids migrating through the Delta from November 1 through June 30, equivalent to the protection provided by restricting exports to minimal levels, were given high priority. The specific increases in flow were developed to achieve the targeted doubling of fish populations as required under the CVPIA, and are not necessarily the flows needed to sustain or protect populations from further decline or achieve population stability. Targeted flows are typically much greater than the average or median flows observed in the rivers under current conditions. In addition to flows, maintaining appropriate water temperatures in the tributaries for salmonid life history stages were also given a high priority. The AFRP restoration plan recommended that actions be implemented "to maintain suitable water temperatures or minimize length of exposure to unsuitable water temperatures for all life stages of Chinook salmon in the San Joaquin River and Delta." Targeted water temperatures are 56°F between October 15 and February 15 and 65°F between April 1 and May 31 for Chinook salmon in the mainstem San Joaquin River. Furthermore, the construction and operation of a barrier at the head of Old River to improve conditions for Chinook salmon migration and survival was given a high priority so long as its operation had minimal adverse effects on other delta fish species.

An additional reference used by NMFS during the evaluation of flow impacts in the San Joaquin River Basin is CDFG's "Final Draft 11-28-05 San Joaquin River Fall-run Chinook salmon Population Model," which evaluated various parameters that have been identified as influencing abundance of escapement of fall-run into the San Joaquin River. These parameters included such variables as ocean harvest, Delta exports and survival, abundance of spawners, and spring flow magnitude, duration, and frequency. The model was developed in response to the SWRCB call for comments and recommendations to the 1995 WQCP San Joaquin River spring Vernalis flow objectives in 2005. CDFG determined that the Vernalis spring flow objectives were not adequate for the long-term protection of fall-run beneficial uses in the San Joaquin River basin because: (1) the San Joaquin River salmon population trend continues to be below the 1967 - 1991 historic average upon which the narrative Doubling Goal was established (CVPIA Restoration Plan goals); (2) salmon smolts are not afforded the level of protection as envisioned by the 1995 WQCP; (3) the VAMP experiment is not working because it has not been implemented as designed; and (4) spring outflow is the primary factor controlling fall-run population in the San Joaquin River basin. CDFG summarized the shortfalls of the 1995 WQCP Vernalis flow objectives as being due to: (1) the diminished magnitude of the Vernalis flow objective; (2) the narrowness of the pulse flow protection window; (3) the infrequent occurrence of elevated flow objective levels; and (4) the frequent occurrence of reduced flow objective levels. CDFG found in the development of their spreadsheet model that non-flow parameters had little or no relationship to fall-run population abundance and that spring-time flow magnitude, duration, and frequency were the dominant factors influencing Chinook salmon abundance in the basin. In their analysis of the influence of exports and flow on salmon production, CDFG could not find a statistically significant role for exports compared to the influence of the spring time flows. The role of flow always dominated the interaction of exports and flow on salmon abundance. However, it should be noted that exports typically increase when San Joaquin River flows increase, thereby making exact relationships difficult to determine and that only a narrow range of river flows and exports were tested in the VAMP experiments to date. CDFG summarized the relationship between export, flow, and salmon production to be that when the ratio of exports to Vernalis flow decreases both escapement and cohort production increases. The relationships that suggest flow is the dominant factor influencing salmon production, rather than exports, are: (1) when the ratio of spring exports to spring Vernalis flows decreases, Vernalis flow greatly increases and San Joaquin River basin production greatly increases; (2) when the ratio of spring exports to spring Vernalis flows increases, Vernalis flow greatly decreases and San Joaquin River basin salmon production substantially decreases; (3) juvenile salmon survival increases when spring Vernalis flows increase; (4) spring export to spring Vernalis flow ratio has little influence upon juvenile salmon survival; and (5) as the difference between spring Vernalis flow level and spring export flow level increases, escapement increases. Nevertheless, CDFG recognized that the influence of delta exports upon San Joaquin River salmon production was not totally clear but that its influence was not as negative, at least compared to flows, as it had previously been thought to be. Its analysis indicated that comparatively, flows were the much more influential variable in determining production levels in the basin compared to exports.

The model results indicated that in all scenarios tested, increasing the magnitude of spring outflow resulted in increased salmon production for all water year types. Likewise, in all scenarios tested, expanding the window of protection resulted in increased salmon production. The greatest increment in salmon production associated with increasing the window of protection was from 30 days to 60 days. Further increases in the window of protection beyond 60 days produced smaller incremental gains in salmon production. The 60-day period roughly encompasses the majority of the salmon outmigration window. When both flow magnitude and the window of protection are increased together, the salmon production in the basin increases substantially. Based on the model results, CDFG concluded that the optimal mix of flows and window of protection was: (1) wet years=20,000 cfs for 90 days; (2) above normal years=15,000 cfs and a 75-day window; (3) below normal years = 10,000 cfs for 60 days; (4) dry years = 7,000 cfs for 45 days; and (5) critical years = 5,000 cfs for 30 days. The model suggests that these flow objectives at Vernalis would accomplish the Doubling Goals of the CVPIA-AFRP, improve the fall-run replacement ratio, and would, as compared to other possible flow objective windows simulated with the model which met the Doubling Goals; result in the lowest water demand. This mixture of flows and protective windows, however, still used approximately 1 million additional acre feet of water from the reservoirs, on average, to meet its needs.

Recent papers examining the effects of exports on salmon survival have been unable to prove a statistically significant reduction in survival related to exports (Newman 2008). However Newman also caveats these findings by indicating that the data used in his analysis had a very low signal to noise ratio and that substantially greater numbers of observations were needed to more precisely estimate the effects of exports on salmon survival (Newman and Brandes in review). The final resolution of the impacts of exports on survival is still being assessed and the inability of the statistical analysis to detect true impacts is not surprising given the high level of environmental variation in the data sets analyzed. The inability to find a significant relationship between exports and salmon survival in a data set with a high noise to signal ratio does not mean that a relationship does not exist, but that further work is warranted to reduce the level of noise and clarify the relationship between these two factors.

6.6.8.4 Assess Risk to Individuals

The alterations of flow in the future VAMP-like action will affect individual steelhead residing in the Tuolumne and Merced rivers, based on the assumption that Reclamation and DWR will provide the water necessary for the Vernalis flow standards solely from the Stanislaus River. Reduced flows on the Tuolumne and Merced rivers will lead to declines in the suitability of the riverine habitats for steelhead, increased intra- and interspecies competition for resources and space in the remaining cold water reaches below the terminal dams, and a diminishment in the opportunity to emigrate successfully from these basins in the spring. This may cause individual steelhead to residualize in the tailwater sections of the rivers and forego their steelhead life history expression. Steelhead that are successful in leaving the Tuolumne and Merced River basins will encounter conditions similar to the current VAMP operations once they pass Vernalis, as the flows are required to be comparable to the historical VAMP conditions at this point. Conditions through the Delta should also be comparable to current conditions, as a commitment to continue export reductions has been made by Reclamation and DWR as part of the project description. In light of the results from the recent years of the VAMP experiment, steelhead survival through the Delta is expected to be low. The loss of individually marked Chinook salmon between the upstream release points and downstream recapture locations remains high, and the survival of steelhead smolts is expected to be similar to these experimental fish since they travel through the same migratory corridor at the same time.

The expected changes in the VAMP water releases among the three tributaries is expected to decrease the viability of the San Joaquin River basin steelhead population. The diminishment of the steelhead habitat in the Tuolumne and Merced River tailwaters essentially reduces the available functioning habitat to only the Stanislaus River. This increases the risk to the population as only the Stanislaus River can be operated to support the basin's remaining population with any certainty. Risks associated with catastrophic events increase dramatically when the population is reduced to only one stream for its survival in the basin and the viability of the Southern Sierra steelhead diversity group becomes more tenuous as a result. This decreases the overall viability of the CV steelhead DPS by reducing the survival capacity of one of its original diversity groups.

6.6.8.5 Effects of the Action on Designated and Proposed Critical Habitat in the Delta Division

The potential changes in the VAMP springtime pulses have the potential to substantially reduce the function of the designated critical habitat on the Tuolumne and Merced River for steelhead. The reductions in springtime pulses on these tributaries reduce the values of PCEs associated with freshwater rearing and freshwater migratory corridors. As previously explained in the effects section for this action, reductions in springtime pulses reduce the cues for steelhead to initiate their downstream emigration at an appropriate time. The pulses help to connect the upper tailwater sections of the rivers with the lower valley floor reaches. Temperatures during spring increase on the valley floor and the altered hydrology of the tributaries due to dams prevents runoff from spring snowmelt from providing a continuous corridor of appropriately cool water between the rearing areas (now below the dams) with the lower valley floor reaches running down the middle of the San Joaquin Valley. This connection must now be made from controlled releases from the terminal dams. Without the releases, the downstream sections of the tributaries and valley floor sections of the San Joaquin River are too warm to provide appropriate thermal conditions for emigrating steelhead. Warmer temperatures may prove to be fatal in their own right, but are also expected to reduce the condition of the emigrating steelhead and make them more susceptible to predators and disease. Reduced flows are also likely to increase the population density of steelhead in the shrinking habitat below the dams as the weather warms. The outcomes of this truncated rearing habitat were previously explained in the effects section for this action. Overall survival is expected to decrease with the reduction in the value of the freshwater rearing habitat available to the steelhead.

6.6.9 Climate Change

The results from Reclamation's climate modeling show that climate change typically had more effect on Delta flows during wetter years than during drier years. This result seems related to how CVP and SWP operations occur with more flexibility during wet years, within the constraints of flood control requirements, compared to drier years when the CVP and SWP operations may be more frequently constrained to maintain in-stream flows and other environmental objectives.

- Head of Old River Flows
  - Remained positive (oceanward) for all scenarios
  - Decreased in winter and spring of wetter years for the drier climate change scenarios (studies 9.4 and 9.5)
  - Increased in winter of wetter years for the wetter climate change scenarios (studies 9.2 and 9.3)
  - Changes were minor during drier years for all climate change scenarios
- Old and Middle River Flows
  - Flows were typically negative (landward) except for a flow reversal in winter of wetter years for the wetter, less warming scenario (study 9.2)
  - Fall and winter flows are the most sensitive to climate change
  - Negative winter flows decreased for the wetter scenarios and increased for the drier scenarios
  - Negative fall flows increased for the wetter scenarios and decreased for the drier scenarios
- QWEST Flows (westward flows from the Delta towards the ocean)
  - Magnitude and direction of QWEST is affected by climate change scenario and season.
  - Flow direction is
    - typically positive during wetter water years except for summer for the drier climate change scenarios
    - always positive in the spring
    - typically negative in the summer of drier years except for the drier, more warming scenario
    - positive in the fall of drier years for the drier climate change scenarios and negative in fall of drier years for the wetter climate change scenarios
  - Winter flows are the most sensitive to climate change and response varies by scenario
- Cross Delta Flows
  - Winter flows were the most sensitive to climate change, flows decreased for the drier climate scenarios and increased for the wetter climate scenarios

Results show that climate change typically had more effect on Delta velocities during wetter years than during drier years. This result is consistent with the Delta flow results

- Head of Old River Velocities

  - Are positive (oceanward) for all scenarios
  - Increased in winter and spring of wet years for the wetter climate change scenarios
  - Decreased in winter and spring of wet years for the drier climate change scenarios
  - Changes were typically less than 0.05ft/s during drier years for all climate change scenarios

- Middle River at Middle River Velocities
  - Are negative (landward) for all scenarios except for a slight reverse flow in winter of the wetter, less warming scenario
  - During wetter years, negative winter velocities decreased for the wetter climate change scenarios and increased for the drier climate change scenarios
  - Changes were typically less than 0.05ft/s for drier climate change scenarios

- San Joaquin River at Blind Point Velocities
  - Are positive (oceanward) for all scenarios
  - Changes were typically less than 0.05ft/s

- Cross Delta Velocities (Georgiana Slough)
  - Are positive (oceanward) for all sceanarios
  - Increased in winter for the wetter climate change scenarios and decreased in winter for the drier climate change scenarios

The fall and winter periods appear to have the most sensitivity to climate changes. In general, the pattern of study 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 compared to the other scenarios. In other words, in the drier climate change scenarios it is expected that fish in the channels surrounding the CVP and SWP projects will be exposed to higher entrainment risks during the January through June time frame than under projected future conditions without climate change. Wetter climate patterns appear to present less entrainment risk during the January through June period in wet and above normal water year types, but elevated risks during the below normal, dry and critically dry water year types. The late fall period (October through December) also had consistently higher risks of entrainment in the wetter climate scenarios than the base case modeled in Study 9.0 for the future climate change models (see tables 6-37 and 6-38).

Table 6-37. Trends for Average Changes in Flow for Climate Change Scenarios Relative to the Base Case. Trends and flow directions are based on 50 percent values. Trends are rounded to nearest 250 cfs. No shading (white) indicates locations with positive (oceanward) flows. Dark shading (blue) indicates locations with negative (landward) flows. Light shading (yellow) indicates locations with mixed flow regimes (sometimes positive and sometimes negative). Seasons are defined as winter is Jan-Mar, spring is Apr-Jun, summer is Jul-Sep, and fall is Oct-Dec. Wetter year types are those classified as wet or above normal. Drier year types are those classified as below normal, dry or critically dry.

Name	Year Type	Wetter, Less Warming Flow	Wetter, More Warming Flow	Drier, Less Warming Flow	Drier, More Warming Flow
Head of Old River	Wetter	Increased by 1750cfs in spring, 1000cfs in summer, 250cfs in fall, and 750cfs in winter	Increased by 500cfs in winter, decreased by 1500cfs in spring, decreases were less than 250cfs in summer and fall	Decreased by 3500cfs in winter and spring, and decreased by 250cfs in summer and fall	Decreased by 2750cfs in winter and 3000cfs in spring, decreases were less than 250cfs in summer and fall
	Drier	Changes were less than 250cfs	Changes were less than 250cfs	Changes were less than 250cfs	Changes were less than 250cfs
Old and Middle River	Wetter	In winter flows changed from negative 3200cfs (landward) to positive 100cfs (oceanward). The rest of the year, negative (landward) flows decreased by 750cfs in spring, 250cfs in summer, and increased by 500cfs in fall	Negative (landward) flows decreased by 2500cfs in winter, 750cfs in spring, and 250cfs in summer. Negative flows increased by 750cfs in fall.	Negative (landward) flows increased by 3250cfs in winter, 500cfs in spring and 1000cfs in summer. Negative flows decreased by 500cfs in fall.	Negative (landward) flows increased by 1250cfs in winter. Negative flows decreased by 250cfs in spring and by 1750cfs in fall. Summer flow changes were less than 250cfs.
	Drier	Negative (landward) flows increased by less than 250cfs in winter, 750cfs in spring, 1000cfs in summer and 1750cfs in fall.	Negative (landward) flows increased by 500cfs in winter, spring, fall, and 750cfs in summer.	Changes were less than 250cfs in spring and fall. Negative (landward) flows decreased by 750cfs in summer and increased by 500cfs in winter.	Negative (landward) flows decreased by 250cfs in winter, 500cfs in spring, 1000cfs in summer and 750cfs in fall
QWEST	Wetter	Increased by 4000cfs in winter, 3000cfs in spring, 1500cfs in summer and 500cfs in fall	Increased by 3750cfs in winter, changes were less than 250cfs in spring, increased by 250cfs in summer, and decreased by 500cfs in fall	Positive (oceanward) flows decreased by 6500cfs in winter, 1750cfs in spring, 750cfs in summer, and 250cfs in winter.	Positive (oceanward) flows decreased by 4250cfs in winter and 1250cfs in spring, 250cfs in summer. Positive fall flows increased by 250cfs.
	Drier	Negative (landward) winter flows of 0cfs changed to positive (oceanward) flows of 400cfs. Positive spring flows increased by 250cfs. Summer flow changes were less than 250cfs. Positive flows of 200 fall flows changed to negative flow of 300cfs.	Changes were less than 250cfs	Flow changes were less than 250cfs in winter. Positive flows increased by 250cfs in spring and fall, 750cfs in summer.	Flow changes were less than 250cfs in winter. Positive (oceanward) flows increased by 750cfs in spring, summer, and fall.
Cross Delta	Wetter	Increased by 1000cfs in winter, decreased by 250cfs in spring and summer, changes were less than 250cfs in fall	Increased by 2000cfs in winter, 750cfs in spring, and decreased by 750cfs in summer and 500cfs in fall	Decreased by 1250cfs in winter, 500cfs spring and fall, increased by 250cfs in summer	Decreased by 2250cfs in winter, 500cfs in spring, 250cfs in summer and 1000cfs in fall
	Drier	Increased by 250cfs in winter and summer, 750cfs in fall, changes were less than 250cfs in spring	Increased by 500cfs in winter, 250cfs in fall, changes were less than 250cfs in spring and summer	Decreased by 250cfs in winter, summer and fall, decreased by 500cf in spring	Decreased by less than 500cfs in winter, spring and fall, decreased by 750cfs in summer

Table 6-38. Trends for Average Changes in Delta Velocities for Climate Change Scenarios Relative to the Base Case.

Trends and velocity directions are based on 50 percent values. Trends are rounded to nearest 0.05ft/s. No shading (white) indicates locations with positive (oceanward) velocities. Solid shading (blue) indicates locations with negative (landward) velocities. Lighter shading (yellow) indicates locations with mixed velocity regimes (sometimes positive and sometimes negative). Seasons are defined as winter is Jan-Mar, spring is Apr-Jun, summer is Jul-Sep, and fall is Oct-Dec. Wetter year types are those classified as wet or above normal. Drier year types are those classified as below normal, dry or critically dry.

Name	Year Type	Wetter, Less Warming	Wetter, More Warming	Drier, Less Warming	Drier, More Warming
		Velocity	Velocity	Velocity	Velocity
Head of Old River	Wetter	Increased by 0.05ft/s in winter, 0.25-0.50ft/s in spring and summer, and 0.15ft/s in fall	Increased by 0.05ft/f in winter, increased by 0.35ft/s in spring, and changes were less than 0.05ft/s in summer and fall	Decreased by 0.70ft/s in winter, 0.9ft/s in spring, 0.1ft/s in summer and less than 0.15ft/s in fall	Decreased by 0.5ft/s in winter, 0.75ft/s in spring, 0.05ft/s in summer and fall
	Drier	Increased by 0.05ft/s in spring, changes were less than 0.05ft/s in summer, fall and winter	Changes were less than 0.05ft/s	Decreased by 0.05ft/s in winter, spring and summer, decreased by less than 0.05ft/s in fall	Decreased by 0.05ft/s in winter and changes were less than 0.05ft/s in spring, summer and fall
Middle River at Middle River	Wetter	Winter velocities changed negative (landward) 0.1ft/s to nearly 0ft/s. Negative velocity changes were less than 0.05ft/s in spring and summer. Changes were less than 0.05ft/s in fall	Negative (landward) velocities decreased by 0.05ft/s in winter, changes were less than 0.05ft/s in spring, summer and fall	Negative (landward) velocities increased by by 0.1ft/s in winter. Velocity changes were less than 0.05ft/s in spring, summer and fall.	Negative (landward) velocities increased by 0.05ft/s in winter and decreased by 0.05ft/s in fall. Velocity changes were less than 0.05ft/s in spring and summer.
	Drier	Negative (landward) velocities decreased by 0.05ft/s in fall, changes were less than 0.05ft/s in winter, spring and summer	Changes were less than 0.05ft/s	Changes were less than 0.05ft/s	Changes were less than 0.05ft/s
San Joaquin River at Blind Pt.	Wetter	Increased by 0.05ft/s in winter and spring, changes were less than 0.05ft/s in summer and fall	Increased by 0.05ft/s in winter, changes were less than 0.05ft/s in spring, summer and fall	Decreased by 0.05ft/s in winter, changes were less than 0.05ft/s in spring, summer and fall	Decreased by 0.05ft/s in winter, changes were less than 0.05ft/s in spring, summer and fall
	Drier	Changes were less than 0.05ft/s	Changes were less than 0.05ft/s	Changes were less than 0.05ft/s	Changes were less than 0.05ft/s
Georgiana Slough	Wetter	Increased by 0.10ft/s in winter, 0.05ft/s in spring, 0.25ft/s in fall, and changes were less than 0.05ft/s in summer	Increased by 0.15ft/s in winter, changes were less than 0.05ft/s in spring, summer and fall	Decreased by 0.1ft/s in winter and fall, increased by 0.05ft/s in summer and changed less than 0.05ft/s in spring	Decreased by 0.15ft/s in winter, 0.10ft/s in spring, 0.05ft/s in summer and fall
	Drier	Changes were less than 0.05ft/s	Increased by 0.05ft/s in winter, spring and fall, and changes were less than 0.05ft/s in summer	Decreased by 0.05ft/s in winter, spring and summer, changes were less than 0.05ft/s in fall	Decreased by 0.05ft/s in winter, summer and fall, and 0.1 ft/s in spring

6.6.10 Summary of the Delta Effects

The quality of the Delta has been diminished over the past hundred years. Human activities in the surrounding watershed during this period have led to the removal of vast stands of riparian forests and severe reductions in the fringing marshland habitat surrounding the Delta waterways, creation of armored levees throughout the valley floor watershed, channelization of waterways and construction of new channels to aid water conveyance in the interior of the delta (*e.g.*, Victoria Canal, Grant Line Canal) and commercial shipping traffic (The Bay Institute 1998, Conomos *et al.* 1985, Nichols *et al.* 1986, Wright and Phillips 1988, Monroe *et al.* 1992, Goals Project 1999). Over the past half century, substantial increases in the volume and frequency of water diversions by the CVP and SWP have occurred. The value of the Delta as a rearing habitat for juvenile salmonids has been incrementally diminished with each modification to the system. Current data indicating that survival is substantially better for those fish that remain in the main channel of the Sacramento River rather than dispersing into the side channels and interconnected waterways (Brandes and McLain 2001; Vogel 2004, 2008a) indicate that the Delta has lost its ecological function for these fish and that human induced conditions, such as exotic introduced predators, pollution, and water diversion operations have negated the benefits of these habitats for rearing fish during their outmigration to the ocean. Likewise, fish emigrating from the San Joaquin River basin are very unlikely to survive their passage through the Delta to enter the San Francisco Bay estuary at Chipps Islands (SJRGA 2001-2008) for many of the same reasons. As described above, substantial reductions in the basin's salmonid population have occurred as a direct result of these anthropogenic actions as well as those occurring upstream in the tributaries. Population impacts can be so severe that they may lead to the extirpation of a population as seen in the loss of the sizeable spring-run population that once inhabited the San Joaquin River Basin (Skinner 1958). Currently, the San Joaquin River basin's population of fall-run is decline, and the CV steelhead population is comprised of very limited number of fish.

The current suite of projects under consultation for the CVP/SWP operations in the Delta includes continued water diversions at the CVP and SWP facilities in the South Delta, which will increase under the near term and future conditions over the already substantial level of diversions. Increased water diversions during the periods of listed salmonid outmigrations will unquestionably lead to increased loss of listed salmonids from both the Sacramento River and San Joaquin River basins at the water diversion facilities, either through direct or indirect means. The magnitude of these increases remains uncertain. For example, the estimates of loss and salvage at the fish collection facilities have inherent assumptions that can lead to errors in the final calculation of these values. For instance, the assumption that fish are passed through the facility at a consistent level; thereby allowing subsamples to be taken at timed intervals to determine overall salvage and loss estimates is likely an inaccurate assumption. Fish are more than likely to come through the facilities in an episodic pattern, with pulses of high numbers of fish followed by periods of low to no fish in the samples. This would be particularly relevant for fish that are rare or low in numbers to begin with. The assumption that a 10 minute or 20 minute count every 2 hours would always capture these events needs to be more thoroughly evaluated. Furthermore, the variations in louver efficiencies related to bypass flows and the impacts of operations such as louver cleaning need to be more adequately addressed in calculating the loss and salvage numbers. Likewise, the uncertainty of the extent of the contribution of indirect or interrelated losses related to fish moving across the Delta towards the pumps under the influence of the water withdrawals (*i.e.*, net negative flows) to the overall loss estimate continues to remain a significant area of concern. As described earlier in the Delta effects analysis, many of the sources of loss associated with moving fish through the Delta, such as predator populations and the increased prevalence of non-native aquatic weeds such as *Egeria densa*, have their own interconnections with the operations of the CVP and SWP, and their continued presence is linked to maintaining an artificially stable Delta environment conducive to moving freshwater towards the pumps.

Given the current fragility of the winter-run, spring-run, and CV steelhead populations, additional levels of take will create a disproportionate level of adverse effects upon these groups of fish[18]. The low numbers of individuals in these populations and the current and future disability of their habitats to support spawning and rearing reduce the ability of the fish populations to recover from chronic take issues as current reproductive success likely cannot compensate for additional losses of individuals. Historical data indicate that entrainment of fish at the CVP and SWP is likely to occur in a more episodic fashion, when pulses of fish move through the system under the influence of environmental factors that are not easily captured in averaged data. The proposed Delta operations of the CVP and SWP under CVP/SWP operations not only maintain the current trajectory of loss seen today, but increase that trajectory through increased pumping rates and greater amounts of water diverted annually. Therefore, it is unlikely that the listed fish populations will experience any form of recovery and/or reduced vulnerability to loss resulting from these operations as described.

In addition to these core environmental conditions in the Delta, the future project actions will continue to expose fish to the salvage facilities as a consequence of the pumping operations resulting in continued losses into the future. Furthermore, operation of the permanent gates will lead to losses associated with predation at the physical structures and the local and farfield hydraulic conditions created by the barriers. Due to the geometry and hydraulic conditions in the South Delta, the interactions of the CVP and SWP with populations of salmonids in the San Joaquin River basin are exceptionally adverse. Under current operating conditions, significant reductions in the abundance of CV steelhead and fall-run originating in the San Joaquin River basin, (as well as the Calaveras River and Mokelumne River basins) are likely to continue to occur. This not only decreases the abundance of the San Joaquin River basin populations as they emigrate to the sea, but also reduces the genetic diversity and spatial distribution of the Central Valley salmonid populations by placing an inordinate amount of risk in this region of the ESU. This violates the "representation and redundancy rule" of having viable populations represented in each of the historic geographical regions in which the different populations originally occurred.

6.7 Suisun Marsh Facilities

DWR operates several facilities within Suisun Marsh that may affect listed anadromous salmonids and threatened green sturgeon. The SMSCG are operated seasonally to improve water quality in Suisun Marsh. At Roaring River and Morrow Island, DWR operates water distribution

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[18] The resilience of the Southern DPS of green sturgeon is unknown. Currently, there are no accurate estimates of the standing population of green sturgeon (*i.e.*, abundance) comprising the Southern DPS and therefore estimates of the different population parameters are unavailable.

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NOV 15 2010

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Subject: Comment on the State Water Resources Control Board's "Do Not List either the San Joaquin River or its tributaries, the Merced, the Tuolumne, and the Stanislaus for Temperature"

Dear Ms. Strauss:

NOAA's National Marine Fisheries Service (NMFS) submits these comments on the "Do Not List either the San Joaquin River or its tributaries, the Merced, the Tuolumne, and the Stanislaus for Temperature" as stated in the State Water Resources Control Board (SWRCB) Resolution No. 2010-0040 – Revised. NMFS understands that the revised 2010 303(d) list has been transmitted by SWRCB to the United States Environmental Protection Agency (US EPA) for approval or disapproval. NMFS is concerned about the removal of the water temperature impaired water bodies from the 303(d) list. We urge you to restore the 303(d) listing of water temperature impaired water bodies in the Merced, Tuolumne, Stanislaus, and San Joaquin rivers and reduce the adverse impacts of elevated water temperature on the Endangered Species Act (ESA)-listed species in these water bodies. We are providing you with information in this letter that we think will help you make a final decision with the goal of protecting and recovering the listed species.

1. NMFS is obligated to protect and recover endangered and threatened species in the Central Valley.

Under the ESA, NMFS is responsible for developing regulations and management measures to protect, conserve, and recover endangered and threatened anadromous fish species and their habitats. It conducts consultations under Section 7 of the ESA to insure that Federal actions do not jeopardize the continued existence of the listed species, or destroy or adversely modify their designated critical habitats. Federally listed species in the Central Valley include the endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), the threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*), and the threatened Central Valley steelhead (*O. mykiss*) (NMFS 2009a).

These species were once widely distributed and abundant throughout the Central Valley and supported important commercial and recreational fisheries for over 100 years. The populations of these species generally show a continuing decline, an overall low abundance, and fluctuating return rates. The major factors contributing to the decline of the listed species include dams that block fish passage, water withdrawals, impaired river flows, and warm water temperatures below dams (NMFS 2009b).

Historically, the San Joaquin River Basin supported steelhead and four runs of Chinook salmon populations including spring-run, late summer-run, fall-run, and winter-run. Today, three of the four runs have been extirpated in the basin and only the fall-run salmon and steelhead trout remain in the Merced, Tuolumne, and Stanislaus Rivers.

Steelhead trout are currently extant populations in the Stanislaus, Tuolumne, and Merced rivers (NMFS 2009a, b). Since no viable independent steelhead populations have been identified in the San Joaquin River Basin, one of the NMFS' recovery goals is to secure and/or improve all extant populations, including the maintenance and/or establishment of spawning steelhead populations in the Stanislaus, Tuolumne, and Merced rivers (NMFS 2009b).

Spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin, which represented a large portion of the historic range and abundance. They will be reintroduced into the San Joaquin River in 2012 as part of the San Joaquin River Restoration Program. This reintroduction has been identified as an important element of recovery for the spring-run evolutionarily significant unit to establish a population in the Southern Sierra Diversity Group.

Fall-run are currently the most abundant of Chinook in the Central Valley, contributing to large commercial and recreational fisheries in the ocean and popular sport fisheries in the freshwater streams. Fall-run Chinook are raised at five major Central Valley hatcheries that release more than 32 million smolts each year. Due to concerns about population size and hatchery influence, Central Valley fall/late fall-run Chinook salmon are a Species of Concern under the ESA.

2. Inadequate water temperature has been identified as one of the human-caused stressors that contribute to the decline of the listed salmonid species.

Water temperature influences the survival of salmonids at all life stages of the life cycle, including growth and feeding rates, metabolism, development of embryos and alevins, timing of life history events such as upstream migration, spawning, freshwater rearing, and seaward migration, and the availability of food (CDFG 2010, McCullough 1999, Myrick and Cech 2001, US EPA 2003). Further, the stressful impacts of water temperatures on salmonids are cumulative and positively correlated to the duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival (Carter 2008, US EPA 2001). It may be possible for healthy fish populations to endure some of these chronic impacts with little appreciable loss in population size. However, for vulnerable fish populations such as the endangered or threatened salmonids of the Central Valley, these sub-lethal effects can reduce the overall health and size of the population, making the survival and eventual recovery of these listed species more uncertain.

The general response of salmonids to temperature is that growth increases as temperature increases to an optimum, at which growth is maximized, followed by a rapid decline in growth as temperatures increase further (Figure 1). The optimum temperature for growth is dependent to some degree on the availability of food. At ration levels lower than the maximum (Rmax), the optimal temperature for growth is reduced because of the effects of temperature on metabolic rates and the subsequent maintenance metabolic demands for energy inputs (Brett *et al.* 1982 as cited in US EPA 2001).

While considering salmonids' responses, water temperatures may be described as optimal, sublethal, and lethal (Figure 1). Physiologically optimal temperatures are those where physiological functions (*e.g.*, growth, swimming, heart performance) are optimized. At optimal temperatures, growth rates, expressed as weight gain per unit of time, are maximal for a life stage. These temperatures are generally determined in laboratory experiments. Ecologically optimal temperatures are those where fish do best in the natural environment, considering food availability, competition, predation, and fluctuating temperatures (US EPA 2003).

Exposure to water temperatures above the optimal range results in increased severity of harmful effects, often referred to as sublethal or chronic effects such as decreasing juvenile growth that results in smaller, more vulnerable fish; increasing susceptibility to disease that can lead to mortality, affecting reproduction, inhibiting smoltification, and decreasing ability to compete and avoid predation (McCullough *et al.* 2009, US EPA 2003). All of these responses, even those not resulting in immediate death, can lead to mortality prior to reproduction or reduced fecundity. These factors result in reduced productivity of a stock and reduced population size. In addition to the seasonal probability of consecutive days of critical maxima, consecutive years with serious cumulative thermal effects over significant portions of a species' range for one or more life stages can lead to dramatic reduction in stock viability (McCullough 1999).

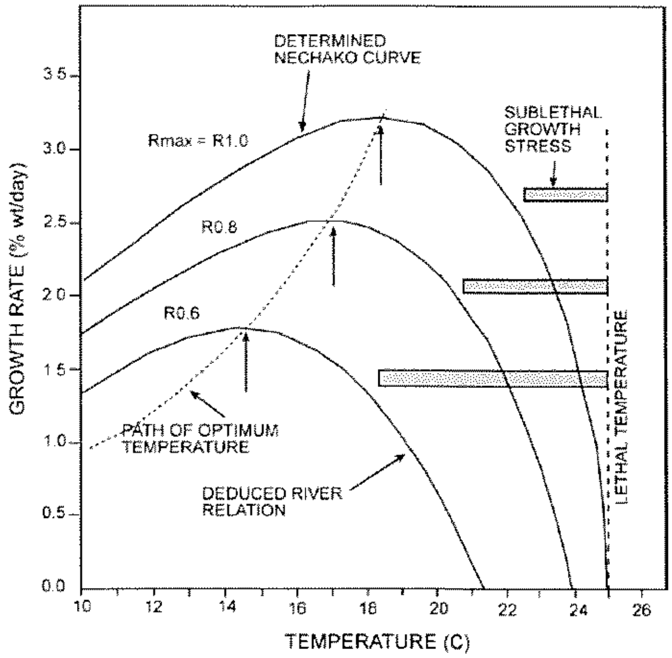

Figure 1. Water temperature vs. growth rate of spring-run Chinook (US EPA 2001). R0.8 = 80% satiation feeding. Rmax = R1.0 = unlimited rations

Growth rates at temperatures above the optimum plummet with increasing temperature and rapidly reach zero. As temperatures rise to some point, they become lethal. Lethal temperatures are those that cause direct mortality within an exposure period of less than one week. One of the measures for lethal temperatures is the upper incipient lethal temperature (UILT), at which 50% mortality occurs (McCullough 1999, US EPA 2001).

3. Water temperatures in the San Joaquin, Stanislaus, Tuolumne, and Merced rivers exceeded water temperature criteria for salmonid species.

The CDFD conducted a long-term study on monitoring water temperatures in the San Joaquin River basin. The CDFG collected and analyzed water temperature data from the San Joaquin River (1971 through 2006), Stanislaus River (1999 through 2005), Tuolumne River (1998 through 2006), and Merced River (1997 through 2005) (CDFG 2006, CDFG 2010). The results of the data analysis by CDFG indicated that segments of the rivers mentioned above do not meet the water temperature criteria recommended by the US EPA to protect designated uses for anadromous fish, including listed species.

The CDFG finds that water temperatures in the Tuolumne and Merced rivers exceeded the steelhead rearing criterion (18°C) throughout 100% of the rearing season for three and five, respectively, of the 6-year study period. Water temperatures in the Stanislaus River exceeded the steelhead rearing criterion at 50% of the rearing season. Water temperatures in all four river systems exceeded the adult Chinook migration criterion (18°C) for 33% to 75% of the migration season. Water temperatures in the three tributaries exceeded the Chinook salmon spawning and egg incubation criterion (13°C) at 70% to 100% of the spawning/incubation season. Water temperatures in the Stanislaus and Merced Rivers exceeded the Chinook smoltification criterion (15°C) at 100% of the season during most years. Water temperatures exceeded the Chinook juvenile migration criterion (18°C) for more than 50% of the season.

4. The 303(d) listing of the water temperature impaired water bodies in the San Joaquin, Merced, Tuolumne, and Stanislaus rivers is based on the best available data and water quality standards and is scientifically justified.

The Federal Clean Water Act (CWA) section 303(d) requires states to identify waters that do not meet, or are not expected to meet by applicable water quality standards [40 CFR 130.7(c)]. The Listing Policy of California (SWRCB 2004) requires that all waters that do not meet water quality standards be placed on the 303(d) list. Water quality standards include designated uses (*i.e.*, beneficial uses in California) and water quality criteria to protect those uses.

Designated uses are the statement of management objectives and expectations for each of the individual surface waters under state jurisdiction. The water quality standard regulations [40 CFR Part 131] establish a rebuttable presumption that the CWA 101(a)(2) uses are attainable. This means that, unless a state can demonstrate otherwise, there is a presumption that all water bodies in a state can attain "protection and propagation of fish, shellfish, and wildlife and recreation in/on water." As described in the Central Valley's Basin Plan, the designated uses in the San Joaquin, Merced, Tuolumne, and Stanislaus rivers include migration and spawning of anadromous fish (CVRWQCB 2007).

Water quality criteria are either numeric limits or narrative statements established to protect and support a designated use. The CVRWQCB established a narrative temperature objective for aquatic life species: "[t]he natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses" (CVRWQCB 2007). In the absence of numeric water temperature criteria, the Listing Policy of California (SWRCB 2004) specifically states that (1) recent temperature monitoring data shall be compared to the temperature requirements of aquatic life in the water segment, (2) determination of life stage temperature requirements of sensitive aquatic life species shall be based on peer-reviewed literature, and (3) evaluation of temperature data shall be based on temperature metrics reflective of the temperature requirements for the sensitive aquatic life species.

By following the above guidance, the CDFG and CVQWQCB used the US EPA Region 10 water temperature guidance that established numeric water temperature criteria recommendations to protect salmon and trout. The US EPA water temperature criteria have been adopted by the states of Oregon and Washington. The criteria have been used to develop the 303(d) list and total maximum daily loads (TMDLs) in the North Coast Region of California (Carter 2008) and used to analyze the effects of the long term operations of the Central Valley Project and State Water Project, and to develop the reasonable and prudent alternative actions to address temperature-related issues in the Stanislaus River (NMFS 2009a).

The use of the US EPA 2003 criteria for listing water temperature impaired water bodies in the San Joaquin River basin is scientifically justified. It has been recognized that salmonid stocks do not tend to vary much in their life history thermal needs, regardless of their geographic location. There is not enough significant genetic variation among stocks or among species of salmonids to warrant geographically specific water temperature standards (US EPA 2001). Based upon reviewing a large volume of thermal tolerance literature, McCullough (1999) concluded that there appears to be little justification for assuming large genetic adaptation on a regional basis to temperature regimes. Prior to adoption of the revised water temperature standards for Oregon streams in 1996, there were separate water temperature standards assigned to salmon habitat in the western vs. the eastern portions of the state. Salmon-bearing streams in the western Cascades and Coast Range were assigned a standard of 14.4°C, but salmon-bearing streams in northeastern Oregon had a standard of 20.0°C, largely on the assumption that they would be adapted to the warmer air temperature regimes of the region. The large (5.6°C) difference in adaptation that would be required, however, is not supportable by any known literature (McCullough 1999).

Varying climatic conditions could potentially have led to evolutionary adaptations, resulting in development of subspecies differences in thermal tolerance. However, the literature on genetic variation in thermal effects indicates occasionally significant but very small differences among stocks and increasing differences among subspecies, species, and families of fishes. Many differences that had been attributed in the literature to stock differences are now considered to be statistical problems in analysis, fish behavioral responses under test conditions, or allowing insufficient time for fish to shift from field conditions to test conditions (US EPA 2001).

Although many of the published studies on the responses of Chinook salmon and steelhead to water temperature have been conducted on fish from stocks in Oregon, Washington, and British

Columbia, a number of studies were reported for the Central Valley salmonids. Myrick and Cech (2001, 2004) performed a literature review on the temperature effects on Chinook salmon and steelhead, with a focus on Central Valley populations. Summarized in Table 1 is a comparison of thermal responses between northern and Central Valley stocks.

Table 1. Similar thermal responses of the Central Valley (CV) and northern stocks of salmonids

Parameter	Water Temperature (°C)	Response	Note
Egg incubation	13.9	82% mortality	CV Fall-run
	>12	Increased mortality	CV Fall-run
	>13.3	Increased mortality	CV Winter-run
	13	Optimal	US EPA (2003)
Growth	17-20	Max growth	CV Fall-run, 100% satiation
	19	Max growth	CV Fall-run, 100% satiation
	18.9-20.5	Max growth	Northern Chinook, 100% satiation
	15	Max growth	60% satiation
	16	Optimal	US EPA (2003)
Upper thermal limit	25	50% mortality	7 day exposure, northern Chinook
	24	50% mortality	8 day exposure, CV Chinook

It is evident that the difference in thermal response is minimal in terms of egg incubation, growth, and upper thermal limit. Healey (1979 as cited in Myrick and Cech 2004) concluded that Sacramento River fall-run Chinook salmon eggs did not appear to be any more tolerant of elevated water temperature than eggs from more northern races. Myrick and Cech (2001) concluded that it appears unlikely that there is much variation among races with regard to egg thermal tolerance because data from studies on northern Chinook salmon races generally agree with those from California. They further concluded that fall-run Central Valley and northern Chinook growth rates are similarly affected by water temperature. There was one study on water temperature effects on the Central Valley steelhead growth. When American River steelhead were fed to satiation at water temperatures of 11, 15, and 19 °C, the growth rate was highest at 19 °C (Myrick and Cech 2001, 2004, 2005). The lower optimum water temperature for steelhead growth is expected to be lower at lower ration levels (*e.g.*, 60% satiation). Myrick and Cech (2001) also cautioned that the maximum growth rate at 19 °C was based on a single study and clear conclusions would not be possible until large-scale experiments were conducted.

5. The SWRCB did not appropriately consider the CDFG's findings and the CVRWQCB approved and SWRCB staff recommended 303(d) listing of the water temperature impaired water bodies in the San Joaquin, Merced, Tuolumne, and Stanislaus rivers.

The CDFG (2007) prepared and submitted the water temperature data and information to the CVRWQCB for 303(d) listing of the water temperature impaired water bodies in the San Joaquin, Merced, Tuolumne, and Stanislaus rivers. The CVRWQCB (2009) approved the 2008 Integrated Report with the updated 303(d) list of impaired water bodies including water temperature limited segments in the these rivers on June 11, 2009. The SWRCB staff (2010) recommended no changes to the CVRWQCB's listing of water temperature impaired water bodies in these rivers, although they recommended a number of changes to other waterbody-pollutant combinations. However, the SWRCB did not appropriately consider these scientific findings and recommendations, and removed the water temperature impaired water bodies from the California 2010 303(d) list.

In conclusion, water temperatures in segments of the San Joaquin, Merced, Tuolumne, and Stanislaus rivers are impaired. The 303(d) listing of these temperature impaired water bodies by the CDFG and CVRWQCB is based on the best available data, methods, and standards, which are consistent with applicable Federal and state laws, regulations, or policies. The impaired water temperature will continue to adversely impact the survival and/or recovery of the listed salmonid species in the Central Valley unless these water bodies are placed on the 303(d) list and further actions (e.g., developing and implementing total maximum daily load) are taken to reduce the impacts of warm water temperatures on the listed salmonid species. NMFS recommends that water segments in the San Joaquin, Merced, Tuolumne, and Stanislaus rivers be 303(d) listed in the California 2010 Integrated Report for water temperature impairment.

NMFS appreciates the opportunity to comment on this critical issue and asks that these comments be included as part of the final administrative record. If you have any question or need further information, please do not hesitate to contact Dr. Li-Ming He of my staff via e-mail at li-ming.he@noaa.gov or telephone at (916) 930-5615.

Sincerely,

Maria Rea

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Sacramento Office Area Supervisor

cc:

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Comments on
Water Quality Issues Associated with SWRCB's Developing Flow Criteria for Protection of the Public Trust Aquatic Life Resources of the Delta

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February 11, 2010

In accord with the California Legislature's Senate Bill No. 1, the State Water Resources Control Board (SWRCB) is required to develop new flow criteria for the Sacramento San Joaquin Delta ecosystem to protect public trust ecosystem and the aquatic life resources of the Delta. The legislature has also required that in developing those criteria the SWRCB consider the impacts of Sacramento (Sac) and San Joaquin River (SJR) water flow into, and flow within, the Delta channels on the aquatic life resources of the Delta. The SWRCB has scheduled an informational meeting to obtain input on these issues. This discussion summarizes the known water quality problems that have occurred in the Delta as a result of the operation of the DWR and USBR South Delta export projects and presents a summary of the water quality issues/potential chemical contaminant impacts to Delta aquatic life resources that need to understood and controlled as part of developing public trust flows into and in the Delta.

We have been involved in Delta and Delta tributary water quality issues for more than 20 years. Over this period we have found that the SWRCB's water rights decisions pertaining to allowed water diversions and flow manipulations have significantly adversely impacted the aquatic life resources of the Delta. Impacts on aquatic life/public trust aquatic life resources of the Delta have been largely ignored or disregarded in the SWRCB's water rights decisions. It will be important that the SWRCB's implementation of the legislature's mandated public trust review of impact of Delta inflow and flow through the Delta channels directions and magnitude include appropriate and reliable consideration of water quality issues that, in turn, impact the aquatic life resources of the Delta.

Many of our work and findings on these issues have been addressed in the following report, which is being submitted as an attachment to these comments:

> Lee, G. F., and Jones-Lee, A., "Updated and Expanded Discussion of Water Quality Issues That Should Be Considered in Evaluating the Potential Impact of Water Manipulations of Chemical Pollutants on Aquatic Resources of the Delta," Report of G. Fred Lee & Associates, El Macero, CA, February 11, (2010).
> gfredlee.com/SJR-Delta/UpdateWQIssuesDelta.pdf

That report discusses how the DWR and USBR South Delta export projects at the Tracy (Jones) and Banks pumping plants impact the flow of SJR and Sac River water into the Delta and through the Delta channels; as discussed, the flow manipulations effected by those projects have adversely impacted water quality in the Delta. One of the most significant is the alterations of the SJR flow through the Deep Water Ship Channel (DWSC) that are brought about by the operations of the export pumps that contribute to low-DO conditions in channel near the Port of

Stockton; the low-DO conditions, in turn, lead to blockage of the migration of fall-run Chinook salmon to their home stream for spawning in the SJR tributaries upstream of the DWSC. In addition, the low DO in the DWSC near the Port of Stockton also adversely affects a variety of aquatic life resources of the DWSC and other areas of the Delta.

The alterations in flow of SJR through the upper South Delta and Middle Delta brought about by the export projects pumps also interferes with the transport of the fish homing chemical signals from the SJR tributaries that guide the fall-run salmon to their home streams for spawning in SJR tributaries upstream of the DWSC. This interference appears to result in salmon's straying from their home stream for spawning, which could adversely impact reproduction of anadromous fish.

The DWR and USBR export of South Delta water adversely impacts agricultural use of South Delta for irrigation because it lowers water levels in the South Delta channels sufficiently to prohibit the pumping of channel water for irrigation. In an effort to try to minimize the low water levels in South Delta channels, DWR constructed barriers on some channels. Those barriers have resulted in the development of null/no-flow zones that lead to low-DO conditions in some South Delta channels. Those low-DO conditions have adverse impacts on aquatic life resources and have resulted in fish kills.

The SJR USBR export of South Delta water has resulted in the drawing of sea water into the western Delta Old River channel, which leads to reverse flow from the northwest Delta to the pumps. In addition to causing the loss (capture) of larval fish in the pump screens/pumps, and increased salinity in the South Delta, these projects' import of sea water increases the amount of bromide in South Delta waters. Bromide is a significant pollutant causing brominated trihalomethane carcinogenic chemicals in water treated for domestic water supply by ozone for disinfection. The import of sea water-derived bromide has contaminated the USBR Delta Mendota canal water with bromide that through the use of the canal water for irrigation and the associated tailwater releases pollutes the SJR with bromide.

Another unaddressed issue is the impact of the DWR USBR export of South Delta water and the associated alteration of Delta flow on the location and magnitude of known violations of water quality standards/objectives that are impacting south Delta aquatic resources. The export could also be affecting the presence of unmonitored, unregulated chemicals that are possibly adversely impacting aquatic life resources in Delta channels both by lethal and sublethal toxic impacts as well as by the excessive bioaccumulation of legacy pesticides and PCBs in Delta fish that pose a threat to human health when those fish are eaten by people.

The proposed Bay Delta Conservation Plan (BDCP) steering committee's deliberation on developing altered flow of Sacramento River around and/or through the Delta (peripheral canal) to "improve the reliability, quantity, and quality of the water exported to south and west of the Delta" has the potential to significantly adversely impact Delta water quality and aquatic life resources. While such a Sac River diversion may decrease the capture of listed fish species in the South Delta pumps, it can significantly adversely impact Delta aquatic life resources. As part of its consideration of altered flow of the Sac River around and/or through the Delta, and under the public trust protection mandate for the Delta, the SWRCB needs to conduct a full review of the potential impacts of flow diversion on Delta water quality and all aquatic life resources of the Delta and its tributaries.

Information on each of the issues summarized above concerning the DWR USBR South Delta export projects is provided in the appended report and in references contained therein.

As discussed in these comments, there continue to be numerous, known violations of water quality standards/objectives in the Delta that are likely to cause adverse impacts on aquatic life resources of the Delta. We have documented, through our own studies and those of others, that SWRCB-permitted operation of the DWR USBR South Delta export projects are causing significant, recognized adverse impacts on Delta water quality that, in turn, adversely impact Delta aquatic life resources. The magnitude and location of adverse impacts are influenced by allowed flow manipulations in the Delta as part of the operations of the SJR USBR South Delta export projects. The impacts of known, current violations of water quality standards, however, are only a small part the real water quality problems that exist in the Delta. There exist CWA water quality impairments in the Delta and SJR that are caused by TOC, nutrients, and other contaminants for which there are no federal or state water quality criteria/objectives. In addition to there being no water quality criteria for those common water pollutants, there are situations in which the current water quality criteria/standards are well-recognized as not being protective of aquatic life resources. For example, the water quality criterion for selenium in the SJR and Delta is not protective of some aquatic life.

Beginning in the late 1960s, Dr. G. Fred Lee pioneered in the development of approaches for evaluating the water quality/environmental impact of chemicals. His work has focused on the integration of aquatic chemistry and toxicology in evaluating the sources, fate, water quality impact, and control of chemicals in aquatic systems. Dr. Lee has also been involved in the development, evaluation, and implementation of water quality criteria and state standards since the early 1960s. A summary of his experience in those areas is provided at http://www.gfredlee.com/exp/wqexp.htm. During the 1960s, while he held the position of Professor of Water Chemistry and Director of the Water Chemistry Program at the University of Wisconsin, Madison he served as an advisor to the Wisconsin Department of Natural Resources on the development and implementation of water quality criteria and standards. During that time and subsequently he has served as an advisor to numerous governmental agencies including municipalities, industry, and environmental/citizens' groups on water quality criteria issues. During the 1960s through the mid-1970s he served as an advisor to the International Joint Commission for the US-Canadian Great Lakes in developing water quality objectives for the Great Lakes, and in their implementation. His about $1 million studies in the 1970s served as the basis for the US Army Corps of Engineers development of dredged sediment disposal criteria. These criteria are still being used today by the US EPA and Corps of Engineers to regulated dredged sediment disposal in open waters.

In the early 1970s Dr. Lee served as an invited peer reviewer for the National Academies of Science and Engineering's "Blue Book" "Water Quality Criteria - 1972." In the late 1970s, he served as an invited member of the American Fisheries Society Water Quality Panel that conducted a review of the US EPA's 1976 "Red Book" of water quality criteria. In the early to mid-1980s he served as a US EPA invited peer reviewer for the water quality criteria development approach used for the 1986 "Gold Book" water quality criteria, and for several of the specific chemical criteria. His pioneering work on PCB pollution in the 1960s led to his being selected to head the US Public Health Service committee on developing drinking water standards for PCBs.

It is with this background that Dr. Lee can authoritatively discuss the potential importance of the failure of the existing water quality criteria to address many of the issues that need to be considered in evaluating the potential impacts of chemicals on aquatic life. The current US EPA criteria development approach only considers some and in some cases a small part of the impacts of chemical contaminates on aquatic life. For example, the approach currently used to develop water quality criteria does not include additive/synergistic properties of regulated chemicals that occur in concentration below the water quality criteria allowing unanticipated adverse impacts to aquatic life. Adverse impacts of chemicals to aquatic life that occur for especially sensitive species, such as zooplankton which serve as fish food organism were not included in the development of the water quality criteria. These criteria are only applicable to protecting about 90% of the species. Therefore there could readily be fish species in the Delta and its tributaries that are more sensitive to a chemical than those used to establish the water quality criterion value. There is also very limited information on chronic exposure to sublethal impacts of a chemical and mixtures of chemicals to fish populations. Another issue is that other stressor such as low DO, ammonia etc. that can impact the lethal and especially sublethal impacts of chemicals. It has been well know for over 40 years through biomarker studies that fish and other organism show organisms biochemical responses to chemical exposures at concentrations well below the water quality criterion. The significance of these biomarker responses to an organism or group of organisms is largely unknown. Chemicals can adversely impact the health of the fish and other aquatic life that weaken their ability to resist adverse impact of stressors such as low DO, elevated temperature and predation as well to disease. It's been known for over 40 years that very low levels of copper affect the "breathing" rate of some fish.

Overall a water sample that meets all the current water quality criteria/standards should not be considered a suitable habitat for development of unrestricted healthy fish populations.

The US EPA water quality criteria development program has had limited support for the development of new or revised water quality criteria for chemicals that have the potential to be adverse to aquatic life. As discussed in our Stormwater Runoff Water Quality Newsletters at http://www.gfredlee.com/newsindex.htm as well as in Delta water quality issues reports, many thousands of unregulated chemicals, including pharmaceuticals and personal care products, industrial chemicals, and other potentially hazardous chemicals, are discharged to waterways, including the Delta and its tributaries, in domestic wastewaters, agricultural runoff and waste waters. Some of those are now being found to be adverse to aquatic life; many have yet to be investigated.

In April 2009, a California Ocean Protection Council et al. workshop, "Managing Contaminants of Emerging Concern in California: A Workshop to Develop Processes for Prioritizing, Monitoring and Determining Thresholds of Concern," was held in Costa Mesa, CA; a report on issues and discussions at that workshop was made available in September (2009) [http://www.nwri-usa.org/pdfs/CACCECReport.pdf].

Figure 1 presents a summary, derived from that report, of current information on numbers of chemicals from various sources that are of concern as potential pollutants.

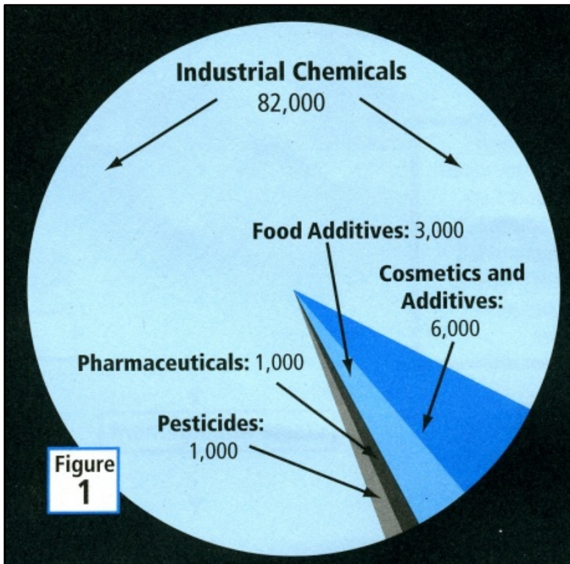

Figure 1. Approximately 100,000 individual chemicals have been registered for commercial use in the United States over the past 30 years. Chemical classes that receive the majority of public attention (e.g., pharmaceuticals, cosmetics and food additives, and pesticides) constitute only a small percentage of this inventory. Very little environmental fate and toxicity information is available for the majority of these chemicals and analytical methods are currently available for only several hundred of the non-regulated chemicals.

Source:
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[http://www.sfestuary.org/pages/newsletter.php]
(Based on Figure 1 in: Muir, D., and Howard, P., "Are There Other Persistent Organic Pollutants? A Challenge for Environmental Chemists," *Environ. Sci. & Technol.* 40:7157-7166 (2006);
subsequently updated in: "Managing Contaminants of Emerging Concern in California: Developing Processes for Prioritizing, Monitoring, and Determining Thresholds of Concern," Report of California Ocean Protection Council et al. workshop, "Managing Contaminants of Emerging Concern in California: A Workshop to Develop Processes for Prioritizing, Monitoring and Determining Thresholds of Concern," Costa Mesa, CA, April 28-29 (2009);
[http://www.nwri-usa.org/pdfs/CACCECReport.pdf]
and updated further for *Estuary News*.)

Many of these same types of sources and chemicals can be part of the Delta's chemical soap that can be affecting aquatic life in the Delta that is in turn impacted by allowed flow diversions and manipulations as part of diversion projects .

As part of developing public trust flows to protect the Delta ecosystem/aquatic life resources of the Delta, the SWRCB must also consider the array of chemicals whose aquatic life impacts are presently unknown due to the present inadequacy of investigation and information. To afford aquatic life resource protection, adequate flows of high-quality Sierra runoff water are needed to dilute the large number of pollutants discharged to the Delta and its tributaries. Such dilution flows should be used to rapidly transport the pollutants through the Delta.