State Water Resources Control Board
California Environmental Protection Agency

-DRAFT-

Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem

Prepared Pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009

CALIFORNIA
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STATE WATER RESOURCES CONTROL BOARD
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- All the participants of the proceeding for providing information and serving on panels to answer questions during the proceeding

The State Water Resources Control Board, however, is responsible for any errors and for all interpretations of the information in this report.

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Acronyms and Abbreviations

AFRP	Anadromous Fish Restoration Program
AR	American Rivers
Bay-Delta	San Francisco Bay/Sacramento-San Joaquin Delta Estuary including Suisun Marsh
Bay-Delta Plan or Plan	Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary
BDCP	Bay Delta Conservation Program
BO	Biological Opinion
CCWD	Contra Costa Water District
CDFG	California Department of Fish and Game
Central Valley Regional Board	Central Valley Regional Water Quality Control Board
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
Council	Delta Stewardship Council
CSPA	California Sportfishing Protection Alliance
CVP	Central Valley Project
CWIN	California Water Impact Network
DEFG	Delta Environmental Flows Group
Delta	Confluence of the Sacramento River and San Joaquin River (as defined in Water Code section 12220)
Delta Plan	Delta Stewardship Council comprehensive, long-term management plan for the Delta
Delta Reform Act	Sacramento-San Joaquin Delta Reform Act of 2009
DFG	California Department of Fish and Game
DOI	United States Department of the Interior
DSM2	Delta Simulation Model
DWR	California Department of Water Resources
DWSC	Stockton Deep Water Ship Channel
E/I	Export/Inflow ratio
EC	Electrical Conductivity
EDF	Environmental Defense Fund
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FMWG	Fisheries Management Work Group
FMWT	Fall mid-water trawl
IEP	Interagency Ecological Program
LSZ	Low Salinity Zone
mg/L	milligrams per liter
mmhos/cm	millimhos per centimeter
NCCPA	State Natural Community Conservation Planning Act
NDOI	Net Delta Outflow Index
NEPA	National Environmental Policy Act
NHI	Natural Heritage Institute
NMFS	National Marine Fisheries Service

NOAA Fisheries	National Marine Fisheries Service
NRDC	Natural Resources Defense Council
OCAP	Long-Term Operations Criteria and Plan for coordination of the Central Valley Project and State Water Project
OMR	Old and Middle River
PCFFA	Pacific Coast Federation of Fishermen's Associations
POD	Pelagic Organism Decline
ppt	parts per thousand
PTM	Particle Tracking Model
RMP	Regional Monitoring Program
RPA	Reasonable and Prudent Alternatives
San Francisco Regional Board	San Francisco Regional Water Quality Control Board
SB 1	Senate Bill No. 1 of the 2009-2010 Seventh Extraordinary Session (Stats. 2009 (7th Ex. Sess.) ch. 5, § 39)
SFWC	State and Federal Water Contractors
SJRA	San Joaquin River Agreement
SJRGA	San Joaquin River Group Authority
SJRRP	San Joaquin River Restoration Program
SRWTP	Sacramento Regional Wastewater Treatment Plant
State Water Board	State Water Resources Control Board
SWG	Smelt Working Group
SWP	State Water Project
TBI	The Bay Institute
TNC	The Nature Conservancy
USBR	United States Bureau of Reclamation
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan
WOMT	Water Operations Management Team
X2	2 part per thousand isohaline

1. Executive Summary

The Sacramento-San Joaquin Delta (Delta) is a critically important natural resource for California and the nation. It is both the hub of California's water supply system and the most valuable estuary and wetlands on the western coast of the Americas. The Delta is in ecological crisis, resulting in high levels of conflict that affect the sustainability of existing water policy in California. Several species of fish have been listed as protected species under the California Endangered Species Act (CESA) and under the federal Endangered Species Act (ESA). These two laws and other regulatory constraints have restricted water diversions from the Delta in an effort to prevent further harm to the protected species.

In November 2009, California enacted a comprehensive package of four policy bills and a bond measure intended to meet California's growing water challenges by adopting a policy of sustainable water supply management to ensure a reliable water supply for the State and to restore the Delta and other ecologically sensitive areas. One of these bills, Senate Bill No. 1 (SB 1) (Stats. 2009 (7th Ex. Sess.) ch 5, § 39) contains the Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act), Water Code section 85000 et seq. The Delta Reform Act establishes a Delta Stewardship Council (Council), tasked with developing a comprehensive, long-term management plan for the Delta, known as the Delta Plan, and providing direction to multiple state and local agencies that take actions related to the Delta. The comprehensive bill package also sets water conservation policy, requires increased groundwater monitoring, and provides for increased enforcement against illegal water diversions.

The Delta Reform Act requires the State Water Board to use a public process to develop new flow criteria for the Delta ecosystem. During this process, participants cautioned the the State Water Board on the limitations of any flow criteria (Fleenor *et al*., 2010):

> "How much water do fish need?" has been a common refrain in Delta water management for many years… it is highly unlikely that any fixed or predetermined prescription will be a "silver bullet". The performance of native and desirable fish populations in the Delta requires much more than fresh water flows. Fish need enough water of appropriate quality over the temporal and spatial extent of habitats to which they adapted their life history strategies. Typically, this requires habitat having a particular range of physical characteristics, appropriate variability, adequate food supply and a diminished set of invasive species. While folks ask "How much water do fish need?" they might well also ask, "How much habitat of different types and locations, suitable water quality, improved food supply and fewer invasive species that is maintained by better governance institutions, competent implementation and directed research do fish need?" The answers to these questions are interdependent. We cannot know all of this now, perhaps ever, but we do know things that should help us move in a better direction, especially the urgency for being proactive. We do know that current policies have been disastrous for desirable fish. It took over a century to change the Delta's ecosystem to a less desirable state; it will take many decades to put it back together again with a different physical, biological, economic, and institutional environment."

The State Water Board concurs with this cautionary note.

1.1 Legislative Directive and State Water Board Approach

Legislative Directive

Water Code section 85086, contained in the Delta Reform Act, was enacted as part of the comprehensive package of water legislation adopted in November 2009. Water Code section 85086 requires the State Water Resources Control Board (State Water Board) to use the best available scientific information gathered as part of a public process conducted as an informational proceeding to develop new flow criteria for the Delta ecosystem to protect public trust resources. The purpose of the flow criteria is to inform planning decisions for the Delta Plan and the BDCP. The Legislature intended to establish an accelerated process to determine the instream flow needs of the Delta in order to facilitate the planning decisions required to meet the objectives of the Delta Plan. Accordingly, Water Code section 85086 requires the State Water Board to develop the flow criteria within nine months of enactment of the statute and to submit its flow criteria determinations to the Council within 30 days of their development.

State Water Board Approach

In determining the extent of protection to be afforded public trust resources through the development of the flow criteria, the State Water Board considered the broad goals of the planning efforts the criteria are intended to inform, including restoring and promoting viable, self-sustaining populations of aquatic species. Given the accelerated time frame in which to develop the criteria, the State Water Board's approach to developing criteria was limited to review of instream needs in the Delta ecosystem, specifically fish species and Delta outflows, while also receiving information on hydrodynamics and major tributary inflows. The State Water Board's flow criteria determinations are accordingly limited to protection of aquatic resources in the Delta.

Limitations of State Water Board Approach

When setting flow objectives with regulatory effect, the State Water Board reviews and considers all the effects of the flow objectives through a broad inquiry into all public trust and public interest concerns. For example, the State Water Board would consider other public trust resources potentially affected by Delta outflow requirements and impose measures for the protection of those resources, such as requiring sufficient water for cold water pool in reservoirs to maintain temperatures in Delta tributaries. The State Water Board would also consider a broad range of public interest matters, including economics, power production, human health and welfare requirements, and the effects of flow measures on non-aquatic resources (such as habitat for terrestrial species). The limited process adopted for this proceeding does not include this comprehensive review.

The State Water Board's Public Trust Responsibilities in this Proceeding

Under the public trust doctrine, the State Water Board must take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible. (*National Audubon Society v. Superior Court* (1983) 33 Cal.3d 419, 446.) Public trust values include navigation, commerce, fisheries, recreation, scenic, and ecological values. "[I]n determining whether it is 'feasible' to protect public trust values like fish and wildlife in a particular instance, the [State Water] Board must determine whether protection of those values, or what level of protection, is 'consistent with the public interest.'" (*State Water Resources Control Bd. Cases* (2006) 136 Cal.App.4th 674, 778.) The State Water Board does not make any determination regarding the feasibility of the public trust recommendations and consistency with the public interest in this report.

In this forum, the State Water Board has not considered the allocation of water resources, the application of the public trust to a particular water diversion or use, water supply impacts, or any balancing between potentially competing public trust resources (such as potential adverse effects of increased Delta outflow on the maintenance of coldwater resources for salmonids in upstream areas). Any such application of the State Water Board's public trust responsibilities, including any balancing of public trust values and water rights, would be conducted through an adjudicative or regulatory proceeding. Instead, the State Water Board's focus here is solely on identifying public trust resources in the Delta ecosystem and determining the flow criteria, as directed by Water Code section 85086.

Future Use of This Report

None of the determinations in this report have regulatory or adjudicatory effect. Any process with regulatory or adjudicative effect must take place through the State Water Board's water quality control planning, water rights processes, or public trust proceedings in conformance with applicable law. In the State Water Board's development of Delta flow objectives with regulatory effect, it must ensure the reasonable protection of beneficial uses, which may entail balancing of competing beneficial uses of water, including municipal and industrial uses, agricultural uses, and other environmental uses. The State Water Board's evaluation will include an analysis of the effect of any changed flow objectives on the environment in the watersheds in which Delta flows originate, the Delta, and the areas in which Delta water is used. It will also include an analysis of the economic impacts that result from changed flow objectives.

Nothing in either the Delta Reform Act or in this report amends or otherwise affects the water rights of any person. In carrying out its water right responsibilities, the State Water Board may impose any conditions that in its judgment will best develop, conserve, and utilize in the public interest the water to be appropriated. In making this determination, the State Water Board considers the relative benefit to be derived from all beneficial uses of the water concerned and balances competing interests.

The State Water Board has continuing authority over water right permits and licenses it issues. In the exercise of that authority and duty, the State Water Board may, if appropriate, amend terms and conditions of water right permits and licenses to impose further limitations on the diversion and use of water by the water right holder to protect public trust uses or to meet water quality and flow objectives in Water Quality Control Plans it has adopted. The State Water Board must provide notice to the water permit or license holder and an opportunity for hearing before it may amend a water right permit or license.

If the DWR and/or the USBR in the future request the State Water Board to amend the water right permits for the State Water Project (SWP) and/or the Central Valley Project (CVP) to move the authorized points of diversion for the projects from the southern Delta to the Sacramento River, Water Code section 85086 directs the State Water Board to include in any order approving a change in the point of the diversion of the projects appropriate Delta flow criteria. At that time, the State Water Board will determine appropriate permit terms and conditions. That decision will be informed by the analysis in this report, but will also take many other factors into consideration, including any newly developed scientific information, habitat conditions at the time, and other policies of the State, including the relative benefit to be derived from all beneficial uses of water. The flow recommendations in this report are not pre-decisional in regard to any State Water Board action. (e.g., Wat. Code, § 85086, subd. (c)(1).)

The water supply costs of the flows identified in this report illustrate to the State Water Board the need for an integrated approach to management of the Delta. Best available science supports that it is important to directly address the negative effects of other stressors, including habitat, water quality, and invasive species, that contribute to higher demands for water to protect public trust resources. The flow criteria highlight the continued need for the BDCP to develop an integrated set of solutions and to implement non flow measures to protect public trust resources.

1.2 Summary Determinations

This report contains the State Water Board's determinations as to the flows that protect public trust resources in the Delta, under the narrow circumstances analyzed in this report. As required, the report includes the volume, timing, and quality of flow for protection of public trust resources under different hydrologic conditions. The flow criteria represent a technical assessment only of flow and operational requirements that provide fishery protection under existing conditions. The flow criteria contained in this report do not represent flows that might be protective under other conditions. The State Water Board recognizes that changes in existing conditions may alter the need for flow. Changes in existing conditions that may affect flow needs include, but are not limited to, reduced reverse flows in Delta channels, increased tidal habitat, improved water quality, reduced competition from invasive species, changes in the point of diversion of the State Water Project (SWP) and Central Valley Project (CVP), and climate change.

Flow Criteria and Conclusions

The numeric criteria determinations in this report must be considered in the following context:

- The flow criteria in this report do not consider any balancing of public trust resource protection with public interest needs for water.
- The State Water Board does not intend that the criteria should supersede requirements for health and safety such as the need to manage water for flood control.
- There is sufficient scientific information to support the need for increased flows to protect public trust resources; there is uncertainty regarding specific numeric criteria.

The State Water Board has considered the testimony presented during the Board's informational proceeding to develop flow criteria and to support the following summary conclusions. Several of these summary conclusions rely in whole or in part on conclusions and recommendations made to the State Water Board by the Delta Environmental Flows Group[1] and the University of California at Davis Delta Solutions Group[2].

1. The effects of non-flow changes in the Delta ecosystem, such as nutrient composition, channelization, habitat, invasive species, and water quality, need to be addressed and integrated with flow measures.

[1] The Delta Environmental Flows Group of experts consists of William Bennett, Jon Burau, Cliff Dahm, Chris Enright, Fred Feyrer, William Fleenor, Bruce Herbold, Wim Kimmerer, Jay Lund, Peter Moyle, and Matthew Nobriga

[2] The Delta Solutions Group consists of William Bennett, William Fleenor, Jay Lund, and Peter Moyle

2. Recent Delta flows are insufficient to support native Delta fishes for today's habitats.[3] Flow modification is one of the immediate actions available although the links between flows and fish response are often indirect and are not fully resolved. Flow and physical habitat interact in many ways, but they are not interchangeable.

3. In order to preserve the attributes of a natural variable system to which native fish species are adapted, many of the criteria developed by the State Water Board are crafted as percentages of natural or unimpaired flows. These criteria include:

    - 75% of unimpaired Delta outflow from January through June;
    - 75% of unimpaired Sacramento River inflow from November through June; and
    - 60% of unimpaired San Joaquin River inflow from February through June.

    It is not the State Water Board's intent that these criteria be interpreted as precise flow requirements for fish under current conditions, but rather they reflect the general timing and magnitude of flows under the narrow circumstances analyzed in this report. In comparison, historic flows over the last 18 to 22 years have been:

    - approximately 30% in drier years to almost 100% of unimpaired flows in wetter years for Delta outflows;
    - about 50% on average from April through June for Sacramento River inflows; and
    - approximately 20% in drier years to almost 50% in wetter years for San Joaquin River inflows.

4. Other criteria include: increased fall Delta outflow in wet and above normal years; fall pulse flows on the Sacramento and San Joaquin Rivers; and flow criteria in the Delta to help protect fish from mortality in the central and southern Delta resulting from operations of the State and federal water export facilities.

5. The report also includes determinations regarding: variability and the natural hydrograph, floodplain activation and other habitat improvements, water quality and contaminants, cold water pool management, and adaptive management:
    - Criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the criteria specified above are expressed as a percentage of the unimpaired hydrograph.
    - Inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow unless otherwise indicated.

[3] This statement should not be construed as a critique of the basis for existing regulatory requirements included in the 2006 Bay-Delta Plan and biological opinions. Those requirements were developed pursuant to specific statutory requirements and considerations that differ from this proceeding. Particularly when developing water quality objectives, the State Water Board must consider many different factors including what constitutes reasonable protection of the beneficial use and economic considerations. In addition, the biological opinions for the SWP and CVP Operations Criteria and Plan were developed to prevent jeopardy to specific fish species listed pursuant to the federal Endangered Species Act; in contrast, the flow criteria developed in this proceeding are intended to halt population decline and increase populations of certain species.

- Studies and demonstration projects for, and implementation of, floodplain restoration, improved connectivity and passage, and other habitat improvements should proceed to provide additional protection of public trust uses and potentially allow for the reduction of flows otherwise needed to protect public trust resources in the Delta.
- The Central Valley and San Francisco Regional Water Quality Control Boards should continue developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions.
- The Central Valley Regional Water Quality Control Board should require additional studies and incorporate discharge limits and other controls into permits, as appropriate, for the control of nutrients and ammonia.
- Temperature and water supply modeling and analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.
- A strong science program and a flexible management regime are critical to improving flow criteria. The State Water Board should work with the Council, the Delta Science Program, BDCP, the Interagency Ecological Program, and others to develop the framework for adaptive management that could be relied upon for the management and regulation of Delta flows.
- The numeric criteria recommended in this report are all recommendations that are only appropriate for the current physical system and climate; as other factors change the flow needs advanced in this report will also change. As physical changes occur to the environment and our understanding of species needs improves, the long-term flow needs will also change. Actual flows should be informed by adaptive management.
- Only the underlying principles for the numeric criteria and other measures are advanced as long term recommendations.

6. Past changes in the Delta may influence migratory cues for some fishes. These cues are further scrambled by a reverse salinity gradient in the south Delta. It is important to establish seaward gradients and create more slough networks with natural channel geometry. Achieving a variable more complex estuary requires establishing seasonal gradients in salinity and other water quality variables and diverse habitats throughout the estuary. These goals in turn encourage policies which establish internal Delta flows that create a tidally-mixed upstream- downstream gradient (without cross-Delta flows) in water quality. Continued through-Delta conveyance is likely to continue the need for in-Delta flow requirements and restrictions to protect fish within the Delta.

7. Restoring environmental variability in the Delta is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export. The drinking and agricultural water quality requirements of through-Delta exports, and perhaps even some current in-Delta uses, are at odds with the water quality and variability needs of desirable Delta species.

8. The Delta ecosystem is likely to dramatically shift within 50 years due to large scale levee collapse. Overall, these changes are likely to promote a more variable, heterogeneous estuary. This changed environment is likely to be better for desirable estuarine species; at least it is unlikely to be worse.

9. Positive changes in the Delta ecosystem resulting from improved flow or flow patterns will benefit humans as well as fish and wildlife.

Ecosystems are complex; there are many factors that affect the quality of the habitat that they provide. These factors combine in ways that can amplify the effect of the factors on aquatic resources. The habitat value of the Delta ecosystem for favorable species can be improved by habitat restoration, contaminant and nutrient reduction, changes in diversions, control of invasive species, and island flooding. Each of these non-flow factors has the potential to interact with flow to affect available aquatic habitat in Delta channels.

The State Water Board supports the most efficient use of water that can reasonably be made. The flow improvements that the State Water Board identifies in this report as being necessary to protect public trust resources illustrate the importance of addressing the negative effects of these other stressors that contribute to higher than necessary demands for water to provide resource protection. Future habitat improvements or changes in nutrients and contaminants, for example, may change the response of fishes to flow. Addressing other stressors directly will be necessary to assure protection of public trust resources and could change the demands for water to provide resource protection in the future. Uncertainty regarding the effects of habitat improvement and other stressors on flow demands for resource protection highlights the need for continued study and adaptive management to respond to changing conditions.

The flow criteria identified in this report highlight the need for the BDCP to develop an integrated set of solutions, to address ecosystem flow needs, including flow and non-flow measures. Although flow modification is an action that can be implemented in a relatively short time in order to improve the survival of desirable species and protect public trust resources, public trust resource protection cannot be achieved solely through flows – habitat restoration also is needed. One cannot substitute for the other; both flow improvements and habitat restoration are essential to protecting public trust resources.

1.3 Background and Next Steps

Informational Proceeding

The State Water Board held an informational proceeding on March 22, 23, and 24, 2010, to receive scientific information from technical experts on the Delta outflows needed to protect public trust resources. The State Water Board also received information at the proceeding on flow criteria for inflow to the Delta from the Sacramento and San Joaquin rivers and Delta hydrodynamics. The State Water Board did not solicit information on the need for water for other beneficial uses, including the amount of water needed for human health and safety, during the informational proceeding. Nor did the State Water Board consider other policy considerations, such as the state goal of providing a decent home and suitable living environment for every Californian.

Analytical Methods

The State Water Board received a wide range of recommendations for the volume, quantity and timing of flow necessary to protect public trust resources. Recommendations were also received on non-flow related measures. State Water Board determinations of flow criteria rely upon four types of information:

- Unimpaired flows
- Historical impaired inflows that supported more desirable ecological conditions
- Statistical relationships between flow and native species abundance

- Ecological functions-based analysis for desirable species and ecosystem attributes

The State Water Board emphasizes, however, information based on ecological functions, followed by information on statistical relationships between flow and native species abundance.

In all cases, the flow criteria contained in this report are those supported by the best available scientific information submitted into the record for this proceeding. The conceptual bases for all of the criteria in this report are supported by scientific information on function-based species or ecosystem needs. In other words, there is sufficiently strong scientific evidence to support the need for flows necessary to support particular functions. This does not necessarily mean that there is scientific evidence to support *specific* numeric criteria. Criteria are therefore divided into two categories: Category "A" criteria have more and better scientific information, with less uncertainty, to support specific numeric criteria than do Category "B" criteria. The State Water Board followed the following steps to develop flow criteria and other measures:

1. Establish general goals and objectives for protection of public trust resources in the Delta
2. Identify species to include based on ecological, recreational, or commercial importance.
3. Review and summarize species life history requirements
4. Summarize numeric and other criteria for each of: Delta outflow, Sacramento River inflow, San Joaquin River inflow, and Hydrodynamics, including Old and Middle River flows
5. Review other flow-related and non-flow measures that should be considered
6. Provide summary determinations for flow criteria and other measures

In developing its flow criteria, the State Water Board reviewed the life history requirements of the following pelagic and anadromous species:

- Chinook Salmon (various runs)
- American Shad.
- Longfin Smelt
- Delta Smelt
- Sacramento Splittail
- Starry Flounder
- Bay Shrimp
- Zooplankton

The flow criteria needed to protect public trust resources are more than just the sum of each species-specific flow need. The State Water Board also considered the following issues to make its flow criteria determinations:

- Variability, flow paths, and the natural hydrograph
- Floodplain activation and other habitat improvements
- Water quality and contaminants
- Cold water pool management
- Adaptive management

The Board also made other specific determinations for other measures based on review of these issues.

Regulatory Authority of the State Water Board

The State Water Board was established in 1967 as the State agency with jurisdiction to administer California's water resources. The State Water Board is responsible for water allocation as well as for water quality planning and water pollution control. In carrying out its water quality planning functions under both State and federal law, the State Water Board formulates and adopts state policy for water quality control, which includes water quality principles and guidelines for long-range resource planning, water quality objectives, and other principles and guidelines deemed essential by the State Water Board for water quality control. The State Water Board has adopted a Water Quality Control Plan for the Delta (Bay-Delta Plan). The plan is implemented in part through conditions imposed in both water quality and water right permits.

The State Water Board administers the water rights program for the State, including issuing water right permits. More than two-thirds of the residents of California and more than two million acres of highly productive farmlands receive water exported from the Delta, primarily, although not exclusively, through the SWP and CVP. In addition to the SWP and CVP, there are many other diversions from the Delta and from tributaries to the Delta including the East Bay Municipal Utilities District, the San Francisco Public Utilities Commission, and Contra Costa Water District, to name a few.

Regulatory actions by other agencies

In addition to the State Water Board, other state and federal agencies have authority to take regulatory action that can affect Delta inflows, outflows, and hydrodynamics. As indicated below, the United States Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), and the California Department of Fish and Game (DFG) have authority to impose regulatory conditions that affect water diversions from the Delta. The Federal Energy Regulatory Commission (FERC) also has authority over non-federal hydropower projects that can change the timing and quantity of inflows to the Delta. Over the next six years, there are 16 hydropower projects on tributaries to the Sacramento and San Joaquin rivers with potential to affect Delta tributary flows that have ongoing or pending proceedings before the FERC.

Next Steps

The State Water Board will submit its flow criteria determinations to the Council for its information within 30 days of completing its determinations as required by Water Code section 85086.

The flow criteria contained in this report will be submitted to the Council to inform the Delta Plan. The Council is required to develop the Delta Plan to implement the State's co-equal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The Council is to develop the Delta Plan by January 2012.

The flow criteria will also inform the BDCP. The BDCP is a multispecies conservation plan being developed pursuant to the ESA and the State Natural Community Conservation Planning Act (NCCPA), administered by the USFWS and the NMFS and the DFG, respectively. The CESA and the federal ESA generally prohibit the "take" of species protected pursuant to the acts. Both acts contain provisions that allow entities to seek approvals from the resources agencies, which approvals allow limited take of protected species under some circumstances. The BDCP is intended to meet all regulatory requirements necessary for USFWS and NMFS to issue Incidental Take Permits to allow incidental take of all proposed covered species as a result of covered activities undertaken by DWR, certain SWP contractors, and Mirant Corporation, and to issue biological opinions under the ESA to authorize incidental take for covered actions undertaken by USBR and CVP contractors. The BDCP is also intended to address all of the requirements of the NCCPA for aquatic, wetland, and terrestrial covered species of fish, wildlife, and plants and Delta natural communities affected by BDCP actions and is intended to provide sufficient information for DFG to issue permits under the CESA for the taking of the species proposed for coverage under the BDCP.

Finally, the flow criteria in this report will also inform the State Water Board's on-going and subsequent proceedings, including the review and development of flow objectives in the San Joaquin River, a comprehensive update to the Bay-Delta Plan, and the associated water rights proceedings to implement these Bay-Delta Plan updates.

2. Introduction

The purpose of this report is to identify new flow criteria for the Sacramento-San Joaquin Delta (Delta) ecosystem to protect public trust resources in accordance with the Delta Reform Act of 2009, Water Code § 85000 et seq. The flow criteria, which do not have any regulatory or adjudicative effect, may be used to inform planning decisions for the new Delta Plan being prepared by the newly created Delta Stewardship Council (Council) and the Bay Delta Conservation Plan (BDCP). The public trust resources that are the subject of this proceeding include those resources affected by flow, namely, native and valued resident and migratory aquatic species, habitats, and ecosystem processes. The State Water Resources Control Board (State Water Board or Board) has developed flow criteria to protect these resources that incorporate measures regarding Delta outflows and Delta inflows and has recommended other measures relevant to the protection of public trust resources. After approval by the State Water Board, this report will be submitted to the Council.

3. Purpose and Background

3.1 Background and Scope of Report

Pursuant to Water Code section 85086, subdivision (c), enacted on November 12, 2009, in Senate Bill No. 1 of the 2009-2010 Seventh Extraordinary Session (Stats. 2009 (7^{th} Ex. Sess.) ch. 5, § 39) (SB 1), the State Water Board is required to "develop new flow criteria for the Delta ecosystem necessary to protect public trust resources." The purpose of this report is to comply with the Legislature's mandate to the State Water Board.

Given the limited amount of time the State Water Board had to develop the criteria, the Board initially focused on Delta outflow conditions as a primary driver of ecosystem functions in the Delta. In determining the extent of protection to be afforded public trust resources through the development of the flow criteria, the State Water Board considered the broad goals of the planning efforts the criteria are intended to inform, including restoring and promoting viable, self-sustaining populations of aquatic species. The specific goals for protection are discussed in more detail below.

The notice for this proceeding focused the proceeding on Delta outflows. During the proceeding, however, the State Water Board received useful information from participants regarding Sacramento River inflows, San Joaquin River inflows, and Delta hydrodynamics (including Old and Middle River flows, San Joaquin River at Jersey Point flows, and San

Joaquin River inflow to export ratios) that is relevant to protection of public trust resources in the Delta ecosystem. The hydrodynamic criteria included in this reportare largely dependent on exports and on San Joaquin River inflows, and do not directly affect the outflows considered in this proceeding. The State Water Board believes, however, that this information should be transmitted to the Council for its use in informing the Delta Plan and BDCP. Because the notice for the proceeding focused on Delta outflows, and some of the participants did not submit scientific information on inflows and hydrodynamics for the State Water Board's consideration, the record for inflows and hydrodynamics may not be as complete, and the analyses for these flow parameters accordingly may be limited. As a result, these recommendations do not constitute formal recommendations within the scope of the informational proceeding as noticed, but instead are submitted to the Council with the acknowledgement that they are based on the limited information received by the State Water Board.

3.1.1 The Legislative Requirements

In November 2009, legislation was enacted comprising a comprehensive water package for California. In general, the legislation is designed to achieve a reliable water supply for future generations and to restore the Delta and other ecologically sensitive areas. The package includes a bond bill and four policy bills, one of which is SB 1.

In the Delta Reform Act, the Legislature found and declared, among other matters, that:

> "The Sacramento-San Joaquin Delta watershed and California's water infrastructure are in crisis and existing Delta policies are not sustainable. Resolving the crisis requires fundamental reorganization of the state's management of Delta watershed resources. (Wat. Code, § 85001, subd. (a).)
>
> By enacting this division, it is the intent of the Legislature to provide for the sustainable management of the Sacramento-San Joaquin Delta ecosystem, to provide for a more reliable water supply for the state, to protect and enhance the quality of water supply from the Delta, and to establish a governance structure that will direct efforts across state agencies to develop a legally enforceable Delta Plan." (Wat. Code, § 85001, subd. (c).)

Among other provisions, SB 1 establishes the Delta Stewardship Council, which is charged with responsibility to develop, adopt, and commence implementation of a Delta Plan, a comprehensive, long-term management plan for the Delta, by January 1, 2012. The legislation also establishes requirements for inclusion of the BDCP, a multispecies conservation plan, into the Delta Plan. For purposes of informing the planning efforts for the Delta Plan and BDCP, SB 1 requires the State Water Board, pursuant to its public trust obligations, to develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. (Wat. Code, § 85086, subd. (c).) Regarding the flow criteria, the Legislature provided that the flow criteria shall:

- include the volume, quality, and timing of water necessary for the Delta ecosystem;
- be developed within nine months of enactment of SB 1;
- be submitted to the Council within 30 days of completion;
- inform planning decisions for the Delta Plan and the BDCP;

- be based on a review of existing water quality objectives and the use of the best available scientific information;
- be developed in a public process by the State Water Board as a result of an informational proceeding conducted under the board's regulations set forth at California Code of Regulations, title 23, sections 649-649.5, in which all interested persons have an opportunity to participate.
- not be considered predecisional with regard to any subsequent State Water Board consideration of a permit, including any permit in connection with a final BDCP;
- inform any State Water Board order approving a change in the point of diversion of the State Water Project or the federal Central Valley Project from the southern Delta to a point on the Sacramento River;

3.1.2 The State Water Board's Public Trust Obligations

As stated above, SB 1 requires the State Water Board to develop new flow criteria to protect public trust resources in the Delta ecosystem pursuant to the Board's public trust obligations. The purpose of the public trust is to protect commerce, navigation, fisheries, recreation, ecological values, and fish and wildlife habitat. Under the public trust doctrine, the State of California has sovereign authority to exercise continuous supervision and control over the navigable waters of the state and the lands underlying those waters. (*National Audubon Society v. Superior Court* (*Audubon*) (1983) 33 Cal.3d 419.) A variant of the public trust doctrine also applies to activities that harm a fishery in non-navigable waters. (*People v. Truckee Lumber Co.* (1897) 116 Cal. 397, see *California Trout, Inc. v. State Water Resources Control Board* (1989) 207 Cal.App.3d 585, 630.)

In *Audubon*, the California Supreme Court held that California water law is an integration of the public trust doctrine and the appropriative water right system. (*Audubon*, *supra*, 33 Cal.3d at p. 426.) The state has an affirmative duty to take the public trust into account in the planning and allocation of water resources. The public trust doctrine requires the State Water Board to consider the effect of a diversion or use of water on streams, lakes, or other bodies of water, and "preserve, so far as consistent with the public interest, the uses protected by the trust." (*Audubon*, *supra*, 33 Cal.3d at p. 447.) Thus, before the State Water Board approves a water diversion, it must consider the effect of the diversion on public trust resources and avoid or minimize any harm to those resources where feasible. (*Id.* at p. 426.) Even after an appropriation has been approved, the public trust imposes a duty of continuing supervision. (*Id.* at p. 447.)

The purpose of this proceeding is to receive scientific information and develop flow criteria pursuant to the State Water Board's public trust obligations. In this forum, the State Water Board will not consider the allocation of water resources, the application of the public trust to a particular water diversion or use, or any balancing between potentially competing public trust resources. The State Water Board has also not considered minimum or maximum flows needed to protect public health and safety. Any such application of the State Water Board's public trust responsibilities, including any balancing of public trust values and water rights, would be conducted through an adjudicative or regulatory proceeding. Instead, the State Water Board's focus here is solely on identifying public trust resources in the Delta ecosystem within the scope of SB 1 and determining the flows necessary to protect those resources.

3.1.3 Public Process

The Water Code directs the State Water Board to develop the flow criteria in a public process in the form of an informational proceeding conducted pursuant to the Board's regulations. (Wat. Code, § 85086, subd. (c)(1); Cal. Code Regs., tit. 23, §§ 649-649.5.) The State Water Board conducted this informational proceeding to receive the best available scientific information to use in carrying out its mandate to develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. (Wat. Code, § 85086, subd. (c)(1).) On December 16, 2009, the State Water Board issued the notice for the public informational proceeding to develop the flow criteria. For the informational proceeding, the State Water Board required the participants to submit a Notice of Intent to Appear by January 5, 2010. The State Water Board received 55 Notices of Intent to Appear for the informational proceeding.

On January 7, 2010, the State Water Board conducted a pre-proceeding conference to discuss the procedures for the informational proceeding mandated by Water Code section 85086, subdivision (c). Topics for the pre-proceeding conference included coordination of joint presentations, use of presentation panels, time limits on presentations, and electronic submittal of written information. The conference was used only to discuss procedural matters and did not address any substantive issues.

On January 29, 2010, the State Water Board issued a revised notice amending certain procedural requirements and posted a preliminary list of reference documents. Written testimony, exhibits, and written summaries, along with lists of witnesses and lists of exhibits, were due on February 16, 2010. The State Water Board gave participants and interested parties an opportunity to submit written questions regarding the written testimony, exhibits, and written summaries by March 9, 2010. All submittals were posted on the State Water Board's website.

On March 22 through 24, the State Water Board held the public informational proceeding to develop flow criteria for the Delta ecosystem. The State Water Board received a technical introduction by the Delta Environmental Flows Group[4] at the beginning of the proceeding. The group prepared two documents and an associated list of references that were submitted as State Water Board exhibits:

- Key Points on Delta Environmental Flows for the State Water Resources Control Board, February 2010
- Changing Ecosystems: a Brief Ecological History of the Delta, February 2010

A subset of the group, the UC Davis Delta Solutions Group, prepared three additional papers (which were also submitted as State Water Board exhibits):

- Habitat Variability and Complexity in the Upper San Francisco Estuary
- On Developing Prescriptions for Freshwater Flows to Sustain Desirable Fishes in the Sacramento-San Joaquin Delta

[4] The Delta Environmental Flows Group consists of William Bennett, Jon Burau, Cliff Dahm, Chris Enright, Fred Feyrer, William Fleenor, Bruce Herbold, Wim Kimmerer, Jay Lund, Peter Moyle, and Matthew Nobriga. This group of professors, researchers, and staff from various resource agencies was assembled by State Water Board staff with the intent of informing the Delta flow criteria informational proceeding.

- Ecosystem Investments for the Sacramento-San Joaquin Delta: Development of a Portfolio Framework

Over the course of the hearing, the State Water Board received information from expert witnesses in response to questions posed by Board members. The expert witnesses, representing various participants, as well as experts from the Delta Environmental Flows Group, were grouped into five panels in order to focus the discussions on specific aspects of the Delta flow criteria. These panels addressed the following topics: hydrology, pelagic fish, anadromous fish, other stressors, and hydrodynamics.

At the conclusion of the informational proceeding, participants were given approximately 20 days to submit closing comments. On July 19, 2010, the draft report was released for public review and comment.

3.1.4 Scope of this report

Due to the limited nine-month time period in which the State Water Board must develop new flow criteria, the notice for the informational proceeding requested information on what volume, quality, and timing of Delta outflows are necessary under different hydrological conditions to protect public trust resources pursuant to the State Water Board's public trust obligations and the requirements of SB 1. Delta outflows are of critical importance to various ecosystem functions, water supply, habitat restoration, and other planning issues. The effect of Delta outflows in protecting public trust resources necessarily involves complex interactions with other flows in the Delta and with non-flow parameters including water quality and the physical configuration of the Delta. This report recognizes the role of source inflows used to meet Delta outflows, Delta hydrodynamics, tidal action, hydrology, water diversions, water project operations, and cold water pool storage in upstream reservoirs, and relies upon information submitted on these related topics to inform its recommendations.

The State Water Board intends that the flow criteria developed in this proceeding should meet the following general goal regarding the protection of public trust resources:

- Halt the population decline and increase populations of native species as well as species of commercial and recreational importance by providing sufficient flow and water quality at appropriate times to promote viable life stages of these species.

To meet this goal, the State Water Board also sought to develop criteria that are comprehensive and that can be implemented without undue complexity. This report is limited to consideration of flow criteria needed under the existing physical conditions, so therefore does not consider or anticipate changes in habitat or modification of water conveyance facilities.

The State Water Board does, however, identify other measures that should be considered in conjunction with, and to complement, the flow criteria.

A number of factors outside the scope of the legislative mandate to develop new flow criteria could affect public trust resources and some other factors could affect the interaction of flows with the environment. These factors include contaminants, water quality parameters, future habitat restoration measures, water conveyance facilities modification, and the presence of non-native species.

3.1.5 Concurrent State Water Board Processes

The State Water Board has a number of ongoing proceedings that may be informed by the development of flow criteria. Some of these proceedings will result in regulatory requirements that affect flow, or otherwise affect the volume, quality, or timing of flows into, within, or out of the Delta. In July 2008, the State Water Board adopted a strategic work plan for actions to protect beneficial uses of the San Francisco Bay/Delta (Bay-Delta). In accordance with the work plan, the State Water Board recently completed a periodic review of the 2006 Water Quality Control Plan for the Bay-DeltaEstuary (Bay-Delta Plan) that recommended the Delta Outflow objectives, as well as other flow objectives, for further review in the water quality control planning process. Currently, the State Water Board is in the process of reviewing the southern Delta salinity and the San Joaquin River flow objectives contained in the Bay-Delta Plan.

Clean Water Act Water Quality Certifications

Several non-federal hydropower projects with potential to affect Delta tributary flows have ongoing or pending proceedings before the Federal Energy Regulatory Commission (FERC) that will result in the issuance of new licenses that will govern operations for the 30-50 year term. The relicensing process allows state and federal agencies to prescribe conditions to achieve certain objectives such as state water quality standards and the protection of listed species. New license conditions may include instreams flows requirements or other conditions to protect aquatic species. For example, the new license for the Oroville Dam will require changes in minimum flow requirements and changes in facilities and operations to meet certain water temperature requirements to protect Chinook salmon, steelhead, and green sturgeon. By 2016, more than 25 Delta tributary dams will go through the relicensing process.

The State Water Board will rely upon the FERC license application and the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) documents prepared for the projects, and may require submittal of additional data or studies, to inform its Clean Water Act Section 401 Water Quality Certifications for the projects. The Board's water quality certification will be issued as soon as possible after the environmental documents and any other needed studies are complete, after which FERC will issue a new license. The conditions in the water quality certification are mandatory and must be included in the FERC license.

Information developed as part of the relicensing of these projects will be used to inform on-going Bay Delta proceedings, and any information developed in the State Water Board's Bay Delta proceedings will be used to inform the two water quality certifications.

Table 1 summarizes the dams, tributaries, and license expiration dates for FERC projects in the Delta watershed. Several of these projects are upstream of major dams and reservoirs in the Sacramento and San Joaquin river watershed so operational changes would have little or no direct effect upon Delta flows.

Table 1. Delta Watershed FERC Projects

River	**Dam(s)**	**Storage Capacity** (acre-feet)	**Owner**	**Status of Proceeding**	**FERC License Expiration**
Feather	Oroville	3.5 million	Department of Water Resources (DWR)	Near completion	January 2007
West Branch Feather	Philbrook, Round Valley	6,200	Pacific Gas and Electric Company (PG&E)	Near Completion	October 2009
South Feather	Little Grass Valley	90,000	South Feather Water and Power	Near completion	March 2009

			Agency		
Upper North Fork Feather River	Lake Almanor	1.1 million	PG&E	Near Completion	October 2004
Pit River	McCloud, Iron Canyon, Pit 6, 7	110,000	PG&E	Ongoing	July 2011
North Yuba	New Bullards Bar	970,000	Yuba County Water Agency	Pre-Licensing meetings started	March 2016
Middle and South Yuba, Bear	Yuba-Bear Project, 10+ dams	210,000	Nevada Irrigation District	Ongoing	April 2013
Middle & South Yuba, Bear	Drum-Spaulding Project, 10+ dams	150,000	PG&E	Ongoing	April 2013
Middle Fork American River	French Meadows, Hell Hole	340,000	Placer County Water Agency	Ongoing	February 2013
South Fork American River	Loon Lake, Slab Creek	400,000	Sacramento Municipal Utility District	Near completion	July 2007
South Fork American River	Chili Bar	1,300	PG&E	Near completion	July 2007
Tuolumne	New Don Pedro	2 million	Turlock Irrigation District	To commence late 2010	April 2016
Merced	New Exchequer/ McSwain	1 million	Merced Irrigation District	Ongoing	February 2014
Merced	Merced Falls	650	PG&E	Ongoing	February 2014
San Joaquin	Mammoth Pool	120,000	Southern California Edison	Near Completion	November 2007
San Joaquin	Huntington, Shaver, Florence	320,000	Southern California Edison	Near Completion	February 2009

3.1.6 Delta Stewardship Council and Use of This Report

In accordance with the legislative requirements described above, the State Water Board will submit this report, containing its Delta flow criteria determinations, to the Council within 30 days after this report has been completed. This report will be deemed complete on the date the State Water Board adopts a resolution approving transmittal of the report to the Council.

Additionally, SB 1 requires any order approving a change in the point of diversion of the State Water Project (SWP) or the Central Valley Project (CVP) from the southern Delta to a point on the Sacramento River to include appropriate flow criteria and to be informed by the analysis in this report. (Wat. Code, § 85086, subd. (c)(2).) The statute also specifies, however, that the criteria shall not be considered predecisional with respect to the State Water Board's subsequent consideration of a permit. (*Id*., § 85086, subd. (c)(1).) Thus, any process with regulatory or adjudicative effect must take place through the State Water Board's water quality control planning or water rights processes in conformance with applicable law. Any person who wishes to introduce information produced during this informational proceeding, or the State Water Board's ultimate determinations in this report, into a later rulemaking or adjudicative proceeding must comply with the rules for submission of information or evidence applicable to that proceeding.

3.2 Regulatory Setting

3.2.1 History of Delta Flow Requirements

The State Water Rights Board (a predecessor to the State Water Board) first had an opportunity to consider flow requirements in the Delta when it approved water rights for much of the U.S. Bureau of Reclamation's (USBR) CVP in Water Right Decision 990 (D-990) (adopted in 1961), but it did not impose any fish protection conditions in D-990. In 1967, the State Water Rights Board included fish protections in D-1275 approving the water right permits for the SWP. Effective December 1, 1967, the State Water Rights Board and the State Water Quality Control Board were merged in a new agency, the State Water Board, which exercises both the water quality and water rights adjudicatory and regulatory functions of the state. The State Water Board adopted a new water quality control policy for the Delta and Suisun Marsh in October 1968, in Resolution 68-17. The resolution specified that the objectives would be implemented through conditions on the water rights of the CVP and SWP.

To implement the water quality objectives, the State Water Board adopted Water Right Decision 1379 (D-1379) in 1971[5]. D-1379 established new water quality requirements in both the SWP and CVP permits, including fish flows, and rescinded the previous SWP requirements from D-1275 and D-1291. D-1379 was stayed by the courts and eventually was superseded by Water Right Decision 1485 (D-1485).

In April 1973, in Resolution 73-16, the State Water Board adopted a water quality control plan to supplement the State water quality control policies for the Delta.

In August 1978, the State Water Board adopted both D-1485 and the 1978 Delta Plan. Together the 1978 Delta Plan and D-1485 revised existing objectives for flow and salinity in the Delta's channels and ordered USBR and DWR to meet the objectives. In 1987, the State Water Board commenced proceedings to review the 1978 Delta Plan and D-1485. The Board held a hearing at numerous venues in California and released a draft water quality control planin 1988, but subsequently withdrew it and resumed further proceedings.

In 1991, the State Water Board adopted the 1991 water quality control plan. This is the first Bay-Delta plan to adopt objectives for dissolved oxygen and temperature. The 1991 Bay-Delta plan did not amend either the flow or water project operations objectives adopted in the 1978

[5] In 1971, the State Water Board approved interim regional water quality control plans for the entire State, including the Delta and Suisun Marsh. Subsequently, the State Water Board approved long-term objectives for the Delta and Suisun Marsh in the regional plans for the Sacramento-San Joaquin Delta Basin and the San Francisco Bay Basin.

Delta Plan.[6] The United States Environmental Protection Agency (USEPA) approved the objectives in the plan for salinity for municipal, industrial, and agricultural uses, and approved the new dissolved oxygen objectives for fish and wildlife, but disapproved the Delta outflow objectives for the protection of fish and wildlife carried over from the 1978 Delta Plan. The USEPA adopted its own Delta outflow standards in 1994 to supersede the State's objectives.

In the summer of 1994, after the USEPA had initiated its process to develop standards for the Delta, the State and federal agencies with responsibility for management of Bay-Delta resources signed a Framework Agreement, agreeing that: (1) the State Water Board would update and revise its 1991 Bay-Delta Plan to meet federal requirements and would initiate a water right proceeding to implement the plan, after which the USEPA would withdraw its fish and wildlife objectives; (2) a group would be formed to coordinate operations of the SWP and CVP with all regulatory requirements in the Delta; and (3) the State and federal governments would undertake a joint long-term solution finding process to resolve issues in the Bay-Delta. In December 1994, representatives of the State and federal governments, water users, and environmental interests agreed to the implementation of a Bay-Delta protection plan. The plan and institutional documents to implement it are contained in a document titled "Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government." This is commonly referred to as the "Bay-Delta Accord" or "Principles Agreement."

In 1995 the State Water Board adopted the 1995 Bay-Delta Plan, which is consistent with the Principles Agreement.[7] In response to a water right change petition filed by DWR and USBR, the State Water Board then adopted Water Right orders that temporarily allowed DWR and USBR to operate the SWP and CVP in accordance with the 1995 Plan while the State Water Board conducted water right proceedings for a water right decision that would implement the 1995 Bay-Delta Plan. The hearing commenced in 1998 and concluded in 1999. During the 1998-99 water right hearing, DWR and USBR and their water supply contractors negotiated with a number of parties. In 1999, the State Water Board adopted Decision 1641 (D-1641) and subsequently revised D-1641 in 2000.

3.2.2 Current State Water Board Flow Requirements

The current Bay-Delta flow requirements are contained in the 2006 Bay-Delta Plan and in D-1641. D-1641 implements portions of the 1995 Bay-Delta Plan. D-1641 accepts the contribution that certain entities, through their agreements, will make to meet the flow-dependent water quality objectives in the 1995 Plan, and continues the responsibility of DWR and USBR for the remaining measures to meet the flow-dependent objectives and other responsibilities. In addition, D-1641 recognizes the San Joaquin River Agreement (SJRA) and approves, for a period of twelve years, the conduct of the Vernalis Adaptive Management Plan

[6] After adopting the 1991 Plan, the State Water Board conducted a proceeding to establish interim water right requirements for the protection of public trust uses in the Delta. The State Water Board released a draft water right decision known as "Decision 1630" (D-1630), but did not adopt it.

[7] USEPA approved the 1995 Bay-Delta Plan. By approving the 1995 Bay-Delta Plan, the USEPA supplanted its own water quality standards with the standards in the 1995 Bay-Delta Plan. (*State Water Resources Control Board Cases* (2006) 136 Cal.App.4th 674,774-775 [39 Cal.Rptr.3d 189]; 33 U.S.C. § 1313(c)(2)(A),(c)(3).)

(VAMP) under the SJRA instead of meeting the San Joaquin River pulse flow objectives in the 1995 Plan. The 2006 Bay-Delta Plan is consistent with D-1641 and makes only minor changes to the 1995 Bay-Delta Plan, allowing the staged implementation of the San Joaquin River spring pulse flow objectives and other minor changes. The 2006 Bay-Delta Plan also identifies a number of issues requiring additional review and planning including: the pelagic organism decline, climate change, Delta and Central Valley salinity, and San Joaquin River flows.

Current Delta outflow requirements, set forth in Tables 3 and 4 in both the 2006 Bay-Delta Plan and D-1641, take two basic forms based on water year type and season: 1) specific numeric Delta outflow requirements; and 2) position of X2, the 2 part per thousand isohaline. The Delta outflow requirements are expressed in Table 3 as a Net Delta Outflow Index (NDOI). The NDOI is a calculated flow expressed as Delta Inflow, minus net Delta consumptive use, minus Delta exports. Each component is calculated as described in the 2006 Bay-Delta Plan and D-1641. An electrical conductivity (EC) measurement of 2.64 mmhos/cm at Collinsville station C2 can be substituted for the NDOI during February through June. The most downstream location of either the maximum daily average or the 14-day running average of this EC level is commonly referred to as the position of “X2” in the Delta. Table 4 specifies EC measurements at two specific locations and alternatively allows an NDOI calculation at these locations.

3.2.3 Special Status Species

The California Endangered Species Act (CESA) states that all native species of fishes, amphibians, reptiles, birds, mammals, invertebrates, and plants, and their habitats, threatened with extinction and those experiencing a significant decline which, if not halted, would lead to a threatened or endangered designation, will be protected or preserved. The federal Endangered Species Act of 1973 (ESA) provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of the ecosystems on which they depend. A number of species discussed in this report are afforded protections under CESA and ESA. These species and the protections are discussed below.

The longfin smelt (*Spirinchus thaleichthys*) is currently a candidate for threatened species status under the CESA. (DFG 1, p. 9.) In March 2009, the California Fish and Game Commission (Commission) made a final determination that the listing of longfin smelt as a threatened species was warranted and the rulemaking process to officially add the species to the CESA list of threatened species found in the California Code of Regulations was initiated. Upon completion of this rulemaking process, the longfin smelt’s status will officially change from candidate to threatened. (DFG 1, p. 9.) Its status remains unresolved at the federal level. (USFWS 2009.) The delta smelt (*Hypomesus transpacificus*) is listed as endangered and threatened pursuant to the CESA and ESA, respectively. (DFG 1, p. 14; USFWS 1993.) In April 2010, the United States Fish and Wildlife Service (USFWS) considered a petition to reclassify the delta smelt from threatened to endangered. After review of all available scientific and commercial information, the USFWS found that reclassifying the delta smelt from a threatened to an endangered species is warranted, but precluded by other higher priority listing actions. (USFWS 2010.)

Sacramento winter-run Chinook salmon *(Oncorhynchus tshawytscha)* is listed as endangered pursuant to the CESA and ESA. (NMFS 1994; NMFS 2005; DFG 2010.) Central Valley spring-run Chinook salmon (*O. tshawytscha*) is listed as threatened pursuant to both the CESA and ESA. (NMFS 1999; NMFS 2005; DFG 2010.) Central Valley fall/late fall-run Chinook salmon (*O. tshawytscha*) are classified as species of special concern by the National Marine Fisheries Service (NMFS). (NMFS 2004.) Central Valley steelhead (*O. mykiss*) is listed as threatened under the ESA (NMFS 1998; NMFS 2006a.) Southern Distinct Population Segment of North American green sturgeon (*Acipenser medirostris*) is listed as threatened under the ESA. (NMFS 2006b.)

3.2.4 State Incidental Take Permit for Longfin Smelt

The CESA prohibits the take[8] of any species of wildlife designated as an endangered, threatened, or candidate species[9] by the Commission. The Department of Fish and Game (DFG), however, may authorize the take of such species by permit if certain conditions are met (Cal. Code Regs., tit 14, § 783.4). In 2009, DFG issued an Incidental Take Permit for Longfin Smelt to the DWR for the on-going and long-term operation of the SWP. The permit specifies a number of conditions, including two flow measures (Conditions 5.1 and 5.2) intended to minimize take of the longfin smelt and provide partial mitigation for the remaining take by: 1) minimizing entrainment; 2) improving estuarine processes and flow; 3) improving downstream transport of longfin smelt larvae; and 4) providing more water that is used as habitat (increasing habitat quality and quantity) by longfin smelt than would otherwise be provided by the SWP.

Longfin Smelt Incidental Take Permit (2009), p. 9-10, Condition 5.1.
This Condition is not likely to occur in many years. To protect adult longfin smelt migration and spawning during December through February period, the Smelt Working Group (SWG) or DFG SWG personnel staff shall provide Old and Middle River (OMR) flow advice to the Water Operations Management Team (WOMT) and to Director of DFG weekly. The SWG will provide the advice when either: 1) the cumulative salvage index (defined as the total longfin smelt salvage at the CVP and SWP in the December through February period divided by the immediately previous FMWT longfin smelt annual abundance index) exceeds five (5); or 2) when a review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt indicate OMR flow advise is warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average is no more negative than -5,000 cfs and the initial 5-day running average is not more negative than -6,250 cfs. During any time OMR flow restrictions for the USFWS's 2008 Biological Opinion for delta smelt are being implemented, this condition (5.1) shall not result in additional OMR flow requirements for protection of adult longfin smelt. Once spawning has been detected in the system, this Condition terminates and 5.2 begins. Condition 5.1 is not required or would cease if previously required when river flows are 1) > 55,000 cfs in the Sacramento River at Rio Vista; or 2) > 8,000 cfs in the San Joaquin River at Vernalis. If flows go below 40,000 cfs in the Sacramento River at Rio Vista or 5,000 cfs in the San Joaquin River at Vernalis, the OMR flow in Condition 5.1 shall resume if triggered previously. Review of survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt may result in a recommendation to relax or cease an OMR flow requirement.

Longfin Smelt Incidental Take Permit (2009), p. 10-11, Condition 5.2.
To protect larval and juvenile longfin smelt during January -June period, the SWG or DFG SWG personnel shall provide OMR flow advice to the WOMT and the DFG Director weekly. The OMR flow advice shall be an OMR flow between -1,250 and -5,000 cfs and be based on review

[8] Pursuant to Fish and Game Code section 86, "'Take' means hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture or kill."

[9] "Candidate species" are species of wildlife that have not yet been placed on the list of endangered species or the list of threatened species, but which are under formal consideration for listing pursuant to Fish and Game Code section 2074.2

of survey data, including all of the distributional and abundance data, and other pertinent biological factors that influence the entrainment risk of larval and juvenile longfin smelt. When a single Smelt Larval Survey (SLS) or 20 mm Survey sampling period results in: 1) longfin smelt larvae or juveniles found in 8 or more of the 12 SLS or 20mm stations in the central and south Delta (Stations 809, 812, 901, 910, 912, 918, 919) or, 2) catch per tow exceeds 15 longfin smelt larvae or juveniles in 4 or more of the 12 survey stations listed above, OMR flow advice shall be warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average no more negative than the required OMR flow and the 5-day running average is within 25% of the required OMR. This Conditions OMR flow requirement is likely to vary throughout Jan through June. Based on prior analysis, DFG has identified three likely scenarios that illustrate the typical entrainment risk level and protective measures for larval smelt over the period: High Entrainment Risk Period - Jan through Mar OMR range from -1,250 to -5,000 cfs; Medium Entrainment Risk Period - April and May OMR range from -2000 to -5,000 cfs, and Low Entrainment Risk Period - June OMR -5,000 cfs. When river flows are: 1) greater than 55,000 cfs in the Sacramento River at Rio Vista; or 2) greater than 8,000 cfs in the San Joaquin River at Vernalis, the Condition would not trigger or would be relaxed if triggered previously. Should flows go below 40,000 cfs in Sacramento River at Rio Vista or 5,000 cfs in the San Joaquin River at Vernalis, the Condition shall resume if triggered previously. In addition to river flows, the SWG or DFG SWG personnel review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of longfin smelt may result in a recommendation by DFG to WOMT to relax or cease an OMR flow requirement.

3.2.5 Biological Opinions

In 2008 and 2009, the USBR and the DWR concluded consultations regarding the effects of continued long-term operations of the Central CVP and SWP with the USFWS and the NMFS, respectively. Those consultations led to the issuance of biological opinions that require implementation of reasonable and prudent alternatives (RPAs) to avoid jeopardizing the continued existence and potential for recovery of delta smelt (*Hypomesus transpacificus*), Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytscha)*, Central Valley spring-run Chinook salmon (*O. tshawytscha*), Central Valley steelhead (*O. mykiss*), Southern Distinct Population Segment of North American green sturgeon (*Acipenser medirostris*), and Southern Resident killer whales *(Orcinus orca)*.

Pursuant to Section 7 of the ESA, federal agencies must insure that their actions do not jeopardize the continued existence of threatened or endangered species or adversely modify their designated critical habitat. The regulations (50 CFR 402.02) implementing Section 7 of the ESA define RPAs as alternative actions, identified during formal consultation, that: 1) can be implemented in a manner consistent with the intended purpose of the action; 2) can be implemented consistent with the scope of the action agency’s legal authority and jurisdiction; 3) are economically and technologically feasible; and, 4) would, the USFWS or NMFS believes, avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat. (USFWS 2008, p.279.)

Numerous anthropogenic and other factors (e.g., pollutants and non-native species) that may adversely affect listed fish species in the region are not under the direct control of the CVP or the SWP and as such are not addressed in the biological opinions.

<u>USFWS Biological Opinion</u>

On December 15, 2008, the USFWS issued a biological opinion on the Long-Term Operational Criteria and Plan (OCAP) for coordination of the CVP and SWP (UFWS Opinion). The RPA in the USFWS Opinion, divided into six actions, applies to delta smelt and focuses primarily on managing flow regimes to reduce entrainment of delta smelt and on the extent of suitable water conditions in the Delta, as well as on construction or restoration of habitat. (USFWS 2008, pp.329-381.) Flow related components of the RPA include:

- A fixed duration action to protect pre-spawning adult delta smelt from entrainment during the first flush, and to provide advantageous hydrodynamic conditions early in the migration period. This action limits exports so that the average daily net OMR flow is no more negative than -2,000 cubic-feet per second (cfs) for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25 percent) (Action 1, p.329).

- An adaptive process to continue to protect pre-spawning adults from entrainment and, to the extent possible, from adverse hydrodynamic conditions after the action identified above. The range of net daily OMR flows will be more no more negative than -1,250 to -5,000 cfs. From the onset of this action through its termination, the Delta Smelt Working Group would provide weekly recommendations for specific net OMR flows based upon review of the sampling data, from real-time salvage data at the CVP and SWP, and utilizing the most up-to-date technological expertise and knowledge relating population status and predicted distribution to monitored variables of flow and turbidity. The USFWS will make the final determination (Action 2, p.352).

- Upon completion of Actions 1 and 2 or when Delta water temperatures reach 12°C (based on a 3-station average of daily average water temperature at Mossdale, Antioch, and Rio Vista) or when a spent female delta smelt is detected in the trawls or at the salvage facilities, the projects shall operate to maintain net OMR flows no more negative than -1,250 to -5000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25% of the applicable 14-day OMR flow requirement. Action continues until June 30th or when Delta water temperatures reach 25˚C, whichever comes first (Action 3, p.357).

- Improve fall habitat, both quality and quantity, for delta smelt through increasing Delta outflow during fall (fall X2). Subject to adaptive management, provide sufficient Delta outflow to maintain average X2 for September and October no greater (more eastward) than 74 km in the fall following wet years and 81km in the fall following above normal years. The monthly average X2 must be maintained at or seaward of these values for each individual month and not averaged over the two month period. In November, the inflow to CVP/SWP reservoirs in the Sacramento Basin will be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up to the fall target. The action will be evaluated and may be modified or terminated as determined by the USFWS (Action 4, p. 369).

- To minimize entrainment of larval and juvenile delta smelt at the State and federal south Delta export facilities or from being transported into the south and central Delta, where they could later become entrained, do not install the Head of Old River Barrier (HORB) if delta smelt entrainment is a concern. If installation of the HORB is not allowed, the agricultural barriers would be installed as described in the Project Description of the biological opinion. If installation of the HORB is allowed, the Temporary Barrier Project flap gates would be tied in the open position until May 15 (Action 5, p. 377).

- Implement habitat restoration activities designed to improve habitat conditions for delta smelt by enhancing food production and availability to supplement the benefits resulting from the flow actions described above. DWR shall implement a program to create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh. The restoration efforts shall begin within 12 months of signature of this biological opinion and be completed within a 10 year period (Action 6, p. 379).

NMFS Biological Opinion

On June 4, 2009, NMFS issued its Biological and Conference Opinion on the Long-Term Operations of the CVP and SWP (NMFS Opinion), which provides RPA actions to protect winter-run and spring-run Chinook salmon, Central Valley steelhead, green sturgeon, and killer whales from project effects in the Delta and upstream areas. (NMFS 3.) The RPA consists of five actions with a total of 72 subsidiary actions. Included within the RPA are actions related to: formation of technical teams, research and adaptive management, monitoring and reporting, flow management, temperature management, gravel augmentation, fish passage and reintroduction, gate operations and installation (Red Bluff Diversion Dam, Delta Cross Channel Gate, South Delta Improvement Program), funding for fish screening, floodplain and other habitat restoration, hatchery management, export restrictions, CVP and SWP fish collection facility modifications, and fish collection and handling. The flow related components of the opinion include:

- In the Sacramento River Basin – flow requirements for Clear Creek; release requirements from Whiskeytown Dam for temperature management; cold water pool management of Shasta Reservoir; development of flow requirements for Wilkins Slough; and restoration of floodplain habitat in the lower Sacramento River basin to better protect Chinook salmon, steelhead, and green sturgeon. (*Id at* pp.587-611.)

- In the American River - flow requirements and cold water pool management requirements to provide protection for steelhead. (*Id at* pp. 611-619.)

- In the San Joaquin River Basin – cold water pool management, floodplain inundation flows, and flow requirements for the Stanislaus River (NMFS 3, pp. 619-628, Appendix 2-E) and an interim minimum flow schedule for the San Joaquin River at Vernalis during April and May effective through 2011 for the protection of steelhead. (*Id at* pp. 641-645.)

- In the Delta – Delta Cross-Channel Gate operational requirements; net negative flow requirements toward the export pumps in Old and Middle rivers; and export limitations based on a ratio of San Joaquin River flows to combined SWP and CVP export during April and May for the protection of Chinook salmon and steelhead. (*Id. at* pp. 628-660.)

It is important to note that the flow protections described in the project description and RPA are the minimum flows necessary to avoid jeopardy. (NMFS written summary, p.3.) In addition, NMFS considered provision of water to senior water rights holders to be non-discretionary for purposes of the ESA as it applies to Section 7 consultation with the USBR, which constrained development of RPA Shasta storage actions and flow schedules. San Joaquin River flows at Vernalis were constrained by the NMFS Opinion’s scope extending only to CVP New Melones operations. Operations on other San Joaquin tributaries were not within the scope of the consultation. (*Id.*)

Recent Litigation

Both the USFWS Opinion and the NMFS Opinion are the subject of ongoing litigation in the United States District Court for the Eastern District of California. Plaintiffs challenged the validity of the opinions under various legal theories, including claims under the ESA and the NEPA. Most recently, this year plaintiffs Westlands Water District and San Luis Delta Mendota Water Authority sought preliminary injunctions against the implementation of certain RPAs identified by NMFS and USFWS in their biological opinions for the protection of Delta smelt and Central Valley steelhead and salmonids. In May 2010, Judge Wanger issued a ruling concluding that injunctive relief was appropriate with respect to the NMFS biological opinion PRA Action IV.2.1, which limits pumping based on San Joaquin River inflow from April 1 through May 31, and RPA Action IV.2.3, which imposes restrictions on negative OMR flows in generally between January 1 and June 15. Later that month, he also ruled that injunctive relief was appropriate with respect to RPA Component 2 of Action 3 of the USFWS Opinion, which requires net OMR flows to remain between -1,250 and -5,000 cfs during a certain period for the protection of larval and juvenile delta smelt. The validity of the biological opinions likely will continue to be litigated in the foreseeable future, creating uncertainty about implementation of the RPAs.

3.3 Environmental Setting

Figure 1 is a map of the Bay-Delta Estuary that was included in the 2006 Bay-Delta Plan. The map depicts the location of monitoring stations used to collect baseline water quality data for the Bay-Delta Estuary and stations used to monitor compliance with water quality objectives set forth in the Bay-Delta Plan.

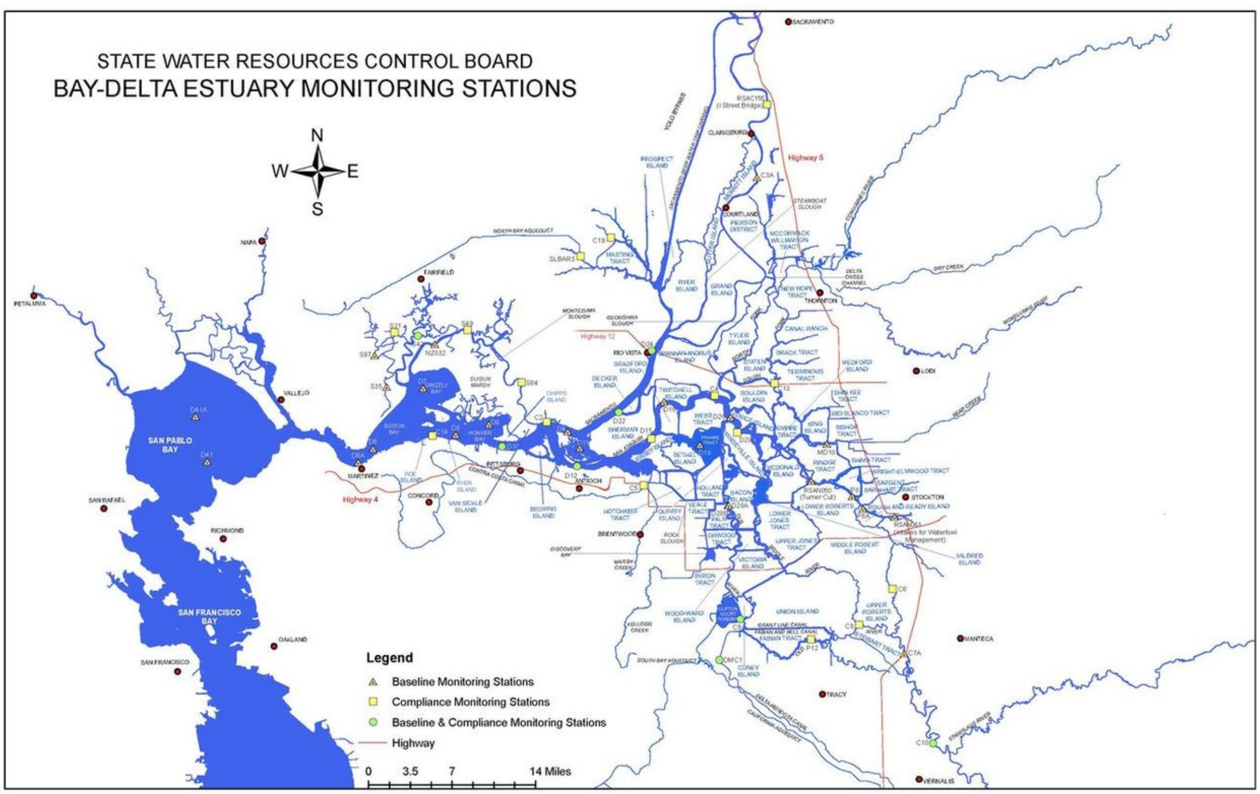


Figure 1. Map of the Bay-Delta Estuary

3.3.1 Physical setting

The Delta is located where California's two major river systems, the Sacramento and San Joaquin rivers, converge from the north and south and are joined by several tributaries from the Central Sierras to the east, before flowing westward through the San Francisco Bay to the Pacific Ocean. The Sacramento and San Joaquin rivers drain water from the Central Valley Basin, which includes about 40 percent of California's land area.

Outflow from the Delta enters Suisun Bay just west of the confluence of the Sacramento and San Joaquin rivers. Suisun Marsh, which is located along the north shore of Suisun Bay, is one of the few major marshes remaining in California and is the largest remaining brackish wetland in Western North America. The marsh is subject to tidal influence and is directly affected by Delta outflow. Suisun Marsh covers approximately 85,000 acres of marshland and water ways and provides a unique diversity of habitats for fish and wildlife.

The Old Delta

The Delta formed as a freshwater marsh through the interaction of river inflow and the strong tidal influence of the Pacific Ocean and San Francisco Bay. The growth and decay of tules and other marsh plants resulted in the deposition of organic material, creating layers of peat that formed the soils of the marsh. Hydraulic mining during the Gold Rush era washed large amounts of sediment into the rivers, channels and bays, temporarily burying the wetlands. The former wetland areas were reclaimed into more than 60 islands and tracts that are devoted primarily to farming. A network of levees protects the islands and tracts from flooding, because most of the islands lie near or below sea level due to the erosion and oxidation of the peat soils. As shown in Figure 2 (Courtesy, Chris Enright, DWR, using Atwater data), prior to reclamation, the channels in the Delta were connected in a dendritic, or tree-like, pattern and may have included 5 to 10 times as many miles of interconnected channels as it does today, with largely unidirectional flow.

Figure 2. The Old Delta (*ca.* 1860).

The Recent Delta

Today's Delta covers about 738,000 acres, of which about 48,000 acres are water surface area, and is interlaced with about 700 miles of waterways. As shown in Figure 3 (Courtesy, Chris Enright, DWR, using Atwater data), today's remaining Delta waterways have been greatly modified to facilitate the bi-directional movement of water and the river banks have been armored to protect against erosion, thus changing the geometry of the stream channels and eliminating most of the natural vegetation and habitat of the aquatic and riparian environment. The interconnected geometry and channelized sloughs of the present Delta result in much less variability in water quality than the past dendritic pattern, and today's mostly open ended sloughs results in water quality and habitat being relatively homogenous throughout the system. (Moyle *et al.* 2010.)

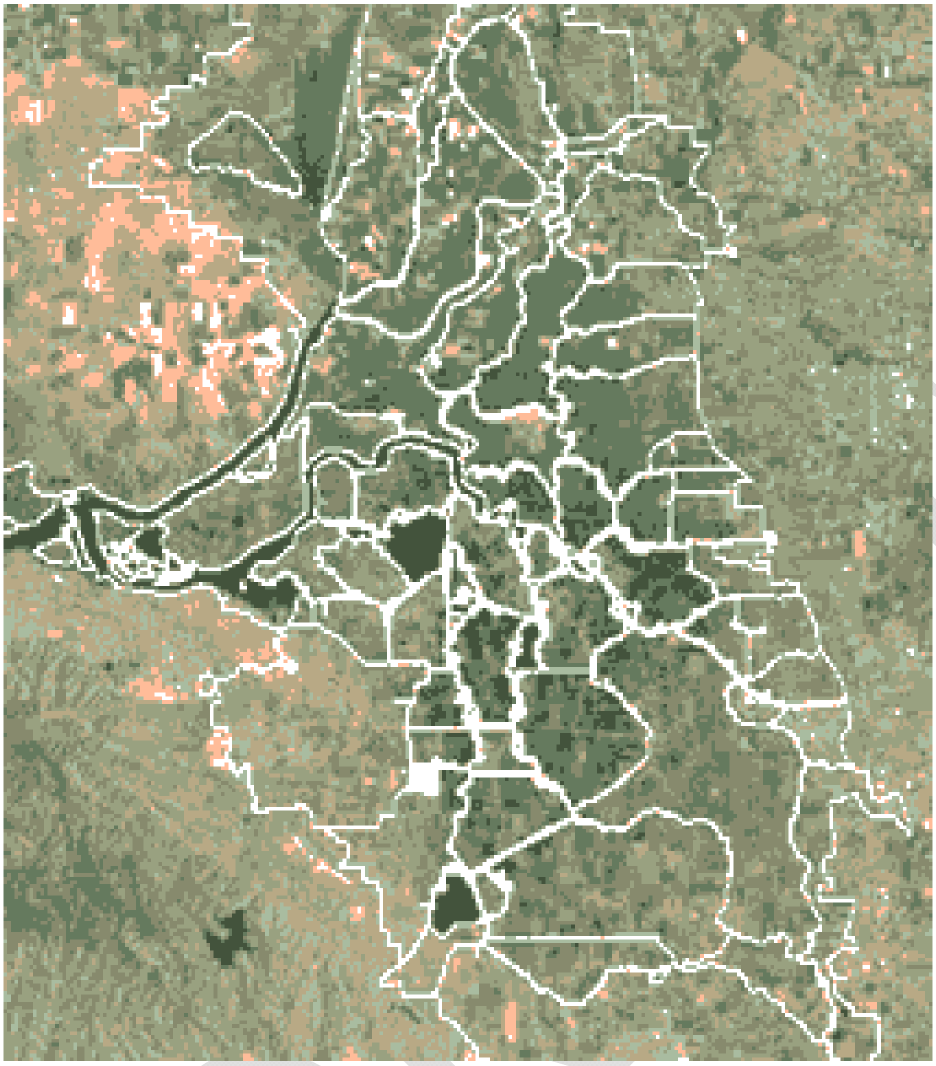


Figure 3. The Recent Delta

The Changing Delta
Moyle *et al.* (2010) describe in *Changing Ecosystems: a Brief Ecological History of the Delta* how the Delta has undergone significant physical and biological modification over the past 150 years. Initial development occurred during the Gold Rush when large amounts of sediment washed into the Delta, followed by diking and dredging of rivers. This was followed by increasing diversions and developments, including fixing of levees and channels, and most recently with large-scale dam development and diversions from the Delta. The Moyle *et al.* history also suggests what is likely to happen in the future:

> "The Delta ecosystem is likely to dramatically shift again within 50 years due to large-scale levee collapse in the Delta and Suisun Marsh. Major levee failures are inevitable due to continued subsidence, sea level rise, increasing frequency of large floods, and high probability of earthquakes. These significant changes will create large areas of open water and increased salinity intrusion, as well as new tidal and subtidal marshes. Other likely changes include reduced freshwater inflow during prolonged droughts, altered hydraulics from reduced export pumping, and additional alien invaders (e.g., zebra and quagga mussels). The

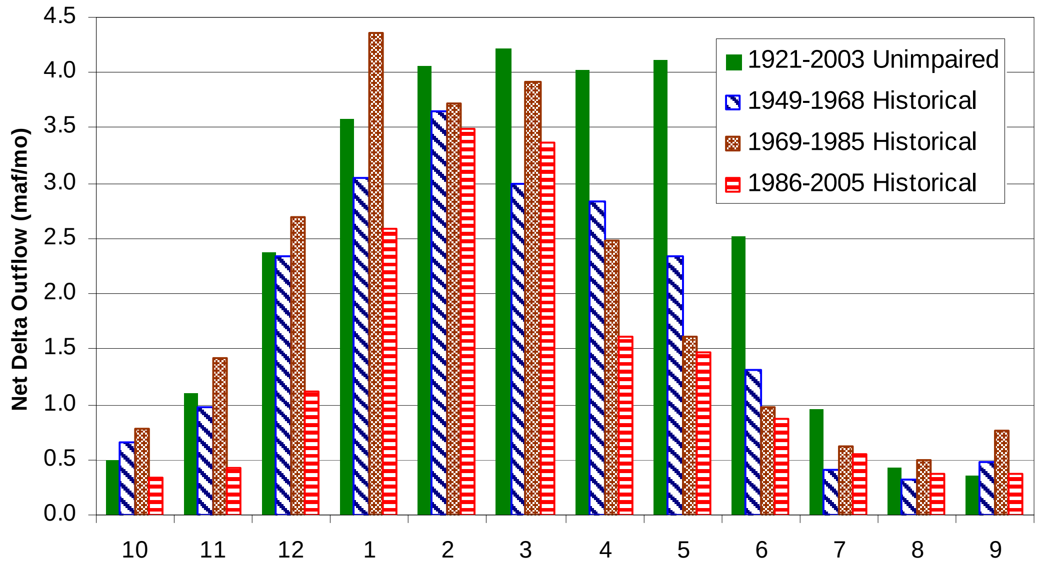
extent and effects of all these changes are unknown but much will depend on how the estuary is managed in response to change or even before change takes place. Overall, these major changes in the estuary's landscape are likely to promote a more variable, heterogeneous estuary, especially in the Delta and Suisun Marsh. This changed environment is likely to be better for desirable estuarine species; at least it is unlikely to be worse."

3.3.2 Hydrology/Hydrodynamics

California's climate and hydrology are Mediterranean, which is characterized by most precipitation falling during the winter-spring wet season, a dry season extending from late spring through early fall, and high inter-annual variation in total runoff. The life history strategies of all native estuarine Delta fishes are adapted to natural variability. (Moyle and Bennett 2008, as cited in Fleenor *et al.* 2010.) Although the unimpaired flow record does not indicate precise, or best, flow requirements for fish under current conditions, the general timing (e.g., seasonality), magnitudes, and directions of flows seen in the unimpaired flow record are likely to remain important for native species under contemporary and future conditions. (Fleenor *et al.* 2010.)

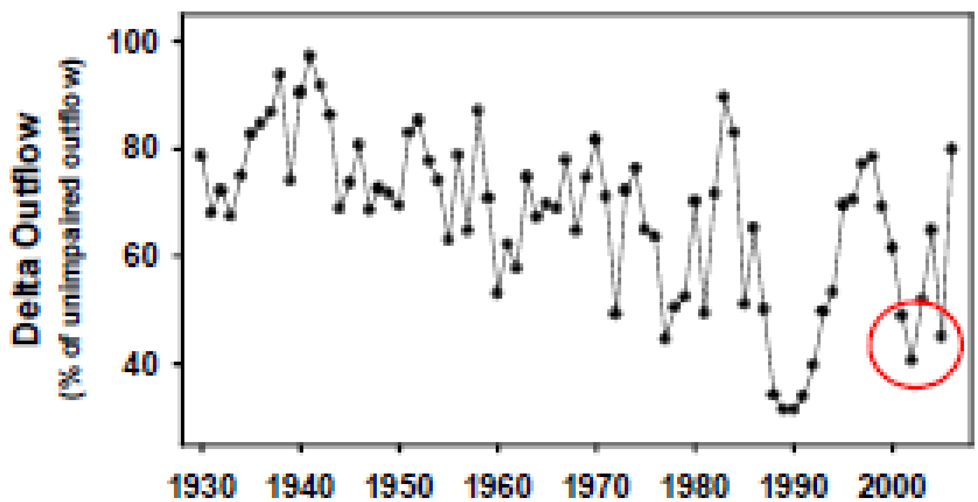
Inflow to the Delta comes primarily from the Central Valley Basin's Sacramento and San Joaquin river systems and is chiefly derived from winter and spring runoff originating in the Cascade and Sierra Nevada mountains, with minor amounts from the Coast Ranges. Precipitation totals vary annually with about 80 percent of the total occurring between the end of October and the beginning of April. Snow storage in the high Sierra delays the runoff from that area until the snow melts in April, May, and June. Normally, about half of the annual runoff from the Central Valley Basin occurs during this period. In recent years, the Sacramento River contributed roughly 75 to 80% of the Delta inflow in most years, while the San Joaquin River contributed about 10 to 15%. The minor flows of the Mokelumne, Cosumnes, and Calaveras rivers, which enter into the eastern side of the Delta, contributed the remainder of the inflow to the Delta.

Net Delta outflow represents the difference between the sum of freshwater inflows from tributaries to the Delta and the sum of exports and net in-Delta consumptive uses. (Kimmerer 2004, DOI 1, p.17.) As noted above, the majority of the freshwater flow into the Delta occurs in winter and spring; however, upstream storage and diversions have reduced the winter-spring flow and increased flow in summer and early fall. (Figure 4, Kimmerer 2002b; Kimmerer 2004; DOI 1, p. 16.) The April-June reductions are largely the result of the San Joaquin River diversions. (Fleenor *et al.* 2010.) During the summer-fall dry season the Delta channels essentially serve as a conveyance system for moving water from reservoirs in the north to the CVP and SWP export facilities, as well as the smaller Contra Costa Water District facility, for subsequent delivery to farms and cities in the San Joaquin Valley, southern California, and/or other areas outside the watershed. (Kimmerer 2002b.) Figure 5 shows the reduction in annual Delta outflow as a percentage of unimpaired outflow. The combined effects of water exports and upstream diversions reduced average annual net outflow from the Delta from unimpaired conditions by 33% and 48% during the 1948 – 1968 and 1986 – 2005 periods, respectively (Fleenor *et al*. 2010.)



This figure shows monthly average net delta outflows (maf/mo) compared to the unimpaired flows from 1921-2003. Unimpaired flow data is from DWR (2006) and other from Dayflow web site. (Source: Fleenor *et al.* 2010, Figure 7.)

Figure 4. Monthly Average Net Delta Outflows from Fleenor et al. 2010

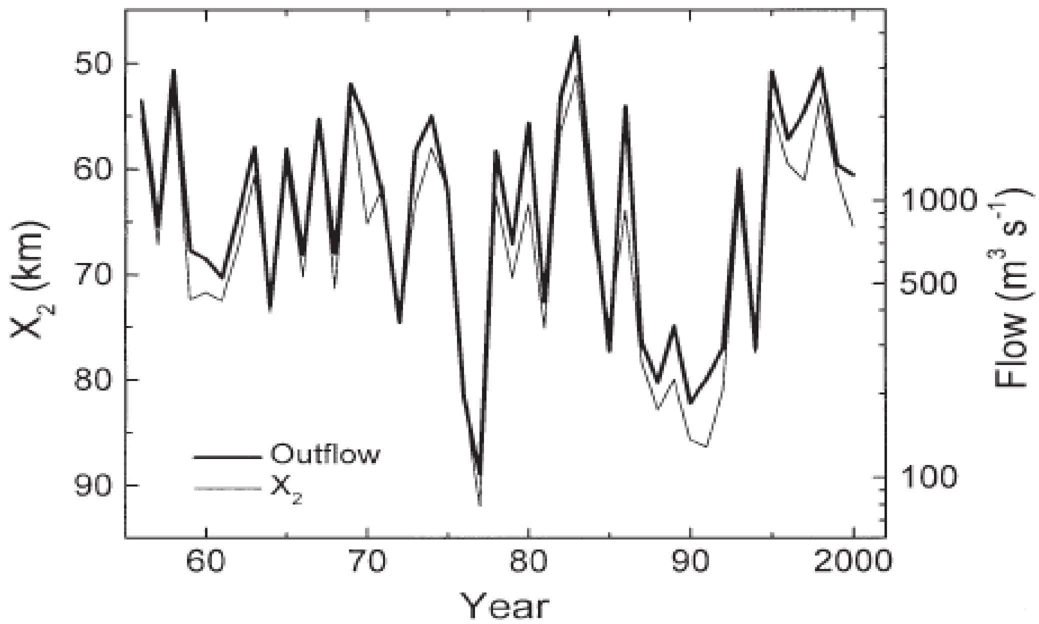


Delta outflow shown as a percentage of unimpaired outflow (1930-2005); in the last decade annual outflow is reduced by more than 50% in 2001, 2002, and 2005. (Source: TBI 2007, as cited in DOI 1, p. 17.)

Figure 5. Delta Outflow as a Percent of Unimpaired Outflow from TBI 2007

Delta outflows and the position of X2 are closely and inversely related, with a time lag of about two weeks. (Jassby *et al.* 1995; Kimmerer 2004.) A time series of the annual averages for January to June of X2 and Delta outflow is depicted in Figure 6. X2 is defined as the horizontal distance in kilometers up the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical salinity units (psu). (Jassby *et al.* 1995, Kimmerer 2002a.) The position of X2 roughly equates to the center of the low salinity zone (defined as salinity of 0.5 to 6 psu). (Kimmerer 2002a.) The X2 objectives in the 2006 Bay-Delta

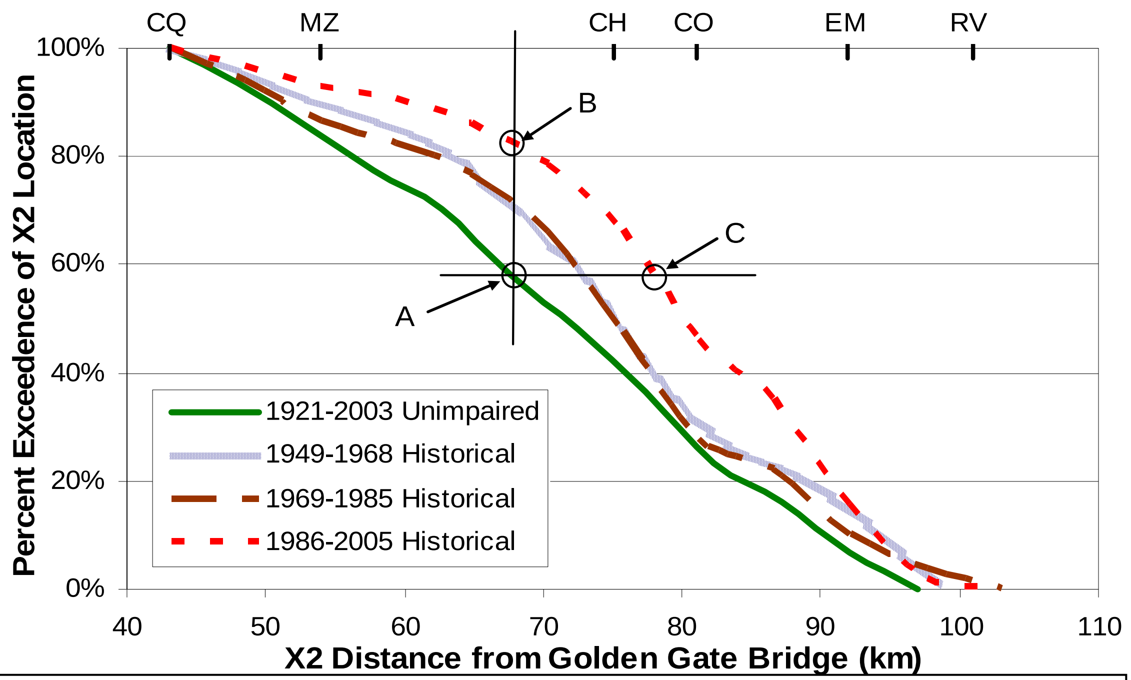
Plan were designed to restore a more natural hydrograph and salinity pattern by requiring maintenance of the low salinity zone at specified points and durations based on the previous month's Eight River Index. (State Water Board 2006a.) The relationships between outflow and several measures of the health of the Bay-Delta Estuary have been known for some time (Jassby *et al*. 1995) and are the basis for the current X2 objectives.



Time series of X2 (thin line, left axis, scale reversed) and flow (heavy line, right axis, log scale), annual averages for January to June; flow data fromDWR; X2 calculated as in Jassby *et al.* (1995) (Source: Kimmerer 2002a, Figure 3).

Figure 6. X2 and Delta Outflow for January to June from Kimmerer 2002a

Both Delta outflow and the position of X2 have been altered as a result of numerous factors including development and operation of upstream storage and diversions, land use changes, and increasing water demand. Hydrodynamic simulations conducted by Fleenor *et al.* (2010) indicate that the position of X2 has been skewed eastward in the recent past, as compared to unimpaired conditions and earlier impaired periods, and that the variability of salinity in the western Delta and Suisun Bay has been significantly reduced (Figure 7). The higher X2 values shown in this figure (refer to Point 'B') indicate the low salinity zone is farther upstream for a more prolonged period of time. Point 'B' demonstrates that during the period from 1986 to 2005 the position of X2 was located upstream of 71 km nearly 80% of the time, as opposed to unimpaired flows which were equally likely to place X2 upstream or downstream of the 71 km location (50% probability). (Fleenor *et al*. 2010.) Historically, X2 exhibited a wide seasonal range tracking the unimpaired Delta outflows; however, seasonal variation in X2 range has been reduced by nearly 40%, as compared to pre-dam conditions. (TBI 2003, as cited in DOI 1, pp. 21-22.)



This graph shows the cumulative probability distributions of daily X2 locations showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (light solid blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line), illustrating progressive reduction in salinity variability from unimpaired conditions. Paired letters indicate geographical landmarks: CQ, Carquinez Bridge; MZ, Martinez Bridge; CH, Chipps Island; CO, Collinsville; EM, Emmaton; and RV, Rio Vista (Source: Fleenor *et al.* 2010, Figure 8).

Figure 7. Cumulative Probability of Daily X2 Locations from Fleenor *et al*. 2010

In their key points on Delta environmental flows for the State Water Board, the Delta Environmental Flows Group (2010) noted that the recent flow regimes both harm native species and encourage non-native species and provided the following justification:

> "The major river systems of the arid western United States have highly variable natural flow regimes. The present-day flow regimes of western rivers, including the Sacramento and San Joaquin, are highly managed to increase water supply reliability for agriculture, urban use, and flood protection (Hughes *et al*. 2005, Lund *et al*. 2007). Recent Delta inflow and outflow regimes appear to both harm native species and encourage non-native species. Inflow patterns from the Sacramento River may help riverine native species in the north Delta, but inflow patterns from the San Joaquin River encourage non-native species. Ecological theory and observations overwhelmingly support the argument that enhancing variability and complexity across the estuarine landscape will support native species. However, the evidence that flow stabilization reduces native fish abundance in the upper estuary (incl. Delta) is circumstantial:
>
> 1) High winter-spring inflows to the Delta cue native fish spawning migrations (Harrell and Sommer 2003; Grimaldo *et al*. 2009), improve the reproductive success of resident native fishes (Meng *et al*. 1994; Sommer

et al. 1997; Matern *et al*. 2002; Feyrer 2004), increase the survival of juvenile anadromous fishes migrating seaward (Sommer *et al*. 2001; Newman 2003), and disperse native fishes spawned in prior years (Feyrer and Healey 2003; Nobriga *et al*. 2006).

2) High freshwater outflows (indexed by X2) during winter and spring provide similar benefits to species less tolerant of freshwater including starry flounder, bay shrimp, and longfin smelt (Kimmerer 2002; Kimmerer *et al*. 2009). Freshwater flows provide positive benefits to native fishes across a wide geographic area through various mechanisms including larval-juvenile dispersal, floodplain inundation, reduced entrainment, and increased up-estuary transport flows. Spring Delta inflows and outflow have declined since the early 20th century, but average winter-spring X2 has not had a time trend during the past 4-5 decades (Kimmerer 2004).

3) The estuary's fish assemblages vary along the salinity gradient (Matern *et al*. 2002; Kimmerer 2004), and along the gradient between predominantly tidal and purely river flow. In tidal freshwater regions, fish assemblages also vary along a gradient in water clarity and submerged vegetation (Nobriga *et al*. 2005; Brown & Michniuk 2007), and smaller scale, gradients of flow, turbidity, temperature and other habitat features (Matern *et al*. 2002; Feyrer & Healey 2003). Generally, native fishes have their highest relative abundance in Suisun Marsh and the Sacramento River side of the Delta, which are more spatially and temporally variable in salinity, turbidity, temperature, and nutrient concentration and form than other regions.

4) In both Suisun Marsh and the Delta, native fishes have declined faster than non-native fishes over the past several decades (Matern *et al*. 2002; Brown and Michniuk 2007). These declines have been linked to persistent low fall outflows (Feyrer *et al*. 2007) and the proliferation of submerged vegetation in the Delta (Brown and Michniuk 2007). However, many other factors also may be influencing native fish declines including differences in sensitivity to entrainment (sustained or episodic high "fishing pressure" as productivity declines), and greater sensitivity to combinations of food-limitation and contaminants, especially in summer-fall when many native fishes are near their thermal limits.

The weight of the circumstantial evidence summarized above strongly suggests flow stabilization harms native species and encourages non-native species, possibly in synergy with other stressors such as nutrient loading, contaminants, and food limitation."

Diversion and use

Irrigation is the primary use of water in the Sacramento and San Joaquin river watershed. Water is used to a lesser extent to meet municipal, industrial, environmental, and instream needs. Water is also exported from the Central Valley Basin for many of these same purposes. Local irrigation districts, municipal utility districts, county agencies, private companies and corporations, and State and federal agencies have developed surface water projects throughout the basin to control and conserve the natural runoff and provide a reliable water supply for beneficial uses. Many of these projects are used to produce hydroelectric power and to enhance recreational opportunities. Flood control systems, water storage facilities, and diversion works exist on all major streams in the basin, altering the timing, location, and quantity of water and the habitat associated with the natural flow patterns of the basin. (State Water Board 1999.)

The major surface water supply developments of the Central Valley include the CVP, other federal projects built by the USBR and the U.S. Army Corps of Engineers, the SWP, and numerous local projects (including several major diversions). The big rim dams, developed mostly since the 1940s, dramatically changed river flow patterns. The dams were built to provide flood protection and a reliable water supply. Collection of water to storage decreased river flows in winter and spring, and changed the timing of high flow periods (except for extreme flood flows). The San Joaquin River has lost most of its natural summer flows because the majority of the water is exported via the Friant project or diverted from the major tributaries for use within the basin. Even though natural flows have been substantially reduced, agricultural return flows during the summer have actually resulted in higher flows than would have occurred under unimpaired conditions at times. Winter and spring flows collected to storage by the State and federal projects in the Sacramento Basin are released in the late spring and throughout the summer and fall, largely to be rediverted from the Delta for export. The federal pumping plants in the southern Delta started operating in the 1950s, exporting water into the Delta-Mendota Canal. The State pumps and the California Aqueduct started operating in the late 1960s, further increasing exports from the Delta. (Changing Ecosystems. Moyle, *et al.* 2010.)

In-Delta Diversions and Old and Middle River Reverse Flows

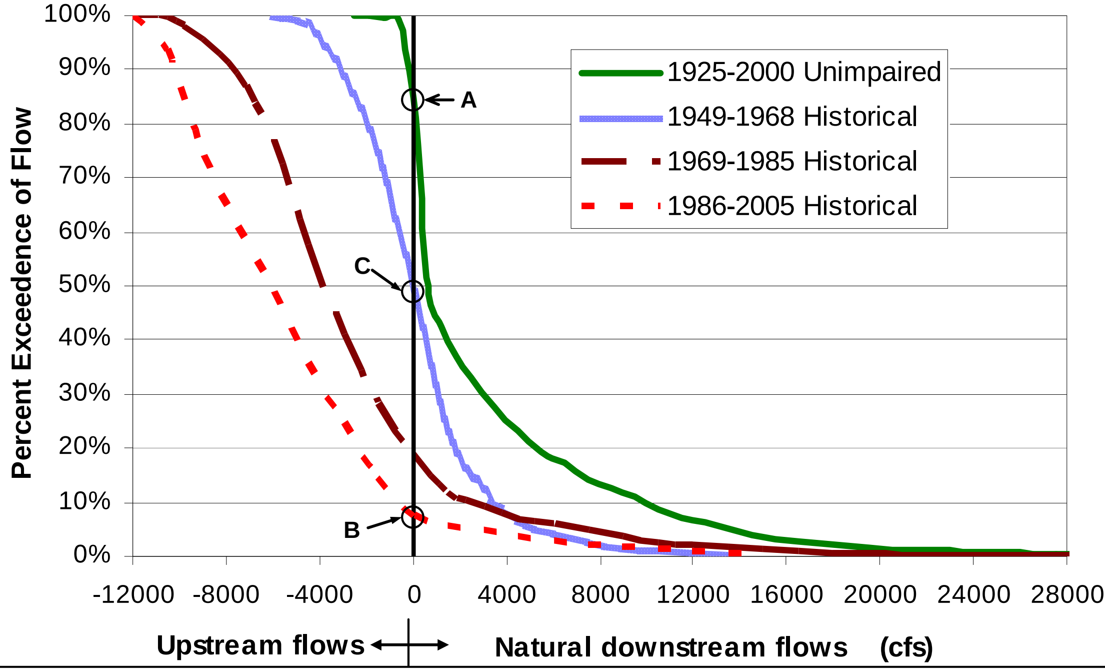
The USBR and the DWR are the major diverters in the Delta. The USBR exports water from the Delta at the Tracy Pumping Plant and the Contra Costa Water District diverts CVP water at Rock Slough and Old River under a water supply contract with the USBR. The DWR exports from the Delta at the Banks Delta Pumping Plant and Barker Slough to serve the SWP contractors. Operation of the CVP and SWP Delta export facilities are coordinated to meet water quality and flow standards set by the Board, the Army Corps of Engineers, and by fisheries agencies. In addition, there are approximately 1,800 local diversions within the Delta that amount to a combined potential instantaneous flow rate of more than 4,000 cfs. (State Water Board 1999.)

Net OMR reverse flows are now a regular occurrence in the Delta (Figure 8). Net OMR reverse flows are caused by the fact that the major freshwater source, the Sacramento River, enters on the northern side of the Delta while the two major pumping facilites, the SWP and CVP, are located in the south (Figure 1). This results in a net water movement across the Delta in a north-south direction along a web of channels including Old and Middle rivers instead of the more natural pattern from east to west or from land to sea. Net OMR is calculated as half the flow of the San Joaquin River at Vernalis minus the combined SWP and CVP pumping rate. (CCWD closing comments, p. 2.) A negative value, or a reverse flow, indicates a net water movement across the Delta along Old and Middle river channels to the State and Federal pumping facilities. Fleenor *et al* (2010) has documented the change in both the magnitude and frequency of net OMR reverse flows as water development occurred in the Delta (Figure 1). The 1925-2000 unimpaired line in Figure 8 represents the best estimate of “quasi-natural” or net OMR values before most modern water development. (Fleenor *et al.* 2010.) The other three lines represent changes in the frequency and magnitude of net OMR flows with increasing development. Net OMR reverse flows are estimated to have occurred naturally about 15%of the time before most modern water development, including construction of the major pumping facilities in the South Delta (point A, Figure 8). The magnitude of net OMR reverse flows was seldom more negative than a couple of thousand cfs. In contrast, between1986-2005 net OMR reverse flows had become more frequent than 90 percent of the time (Point B). The magnitude of net OMR reverse flows may now be as much as -12,000 cfs. High net OMR reverse flows have several negative ecological consequences. First, net reverse OMR flows draw fish, especially the weaker swimming larval and juvenile forms, into the SWP and CVP export facilities. The export facilities have been documented to entrain most species of fish present in the upper estuary. (Brown *et al*. 1996,.) Approximately 110 million fish were salvaged at the SWP pumping facilities and returned to the Delta over a 15 year period, (Brown *et al.* 1996.) However, this number underestimates the actual number of fish entrained, as it does not include losses at the CVP nor does it account for fish less than 20 mm in length which are not collected and counted at the fish collection facilities. Second, net OMR reverse flows reduce spawning and rearing habitat for native species, like delta smelt. Any fish that enters the Central or Southern Delta has a high probability of being entrained and lost at the pumps. (Kimmerer and Nobriga, 2008.) This has restricted their habitat to the western Delta and Suisun and Grizzly bays. Third, net OMR reverse flows have led to a confusing environment for migrating juvenile salmon leaving the San Joaquin Basin. Through-Delta exports reduce salinity in the central and southern Delta and as a result juvenile salmon migrate from higher salinity in the San Joaquin River to lower salinity in the southern Delta, contrary to the natural historical conditions and their inherited migratory cues. Finally, net OMR reverse flows reduce the natural variability in the Delta by drawing Sacramento River water across and into the Central Delta. The UC Davis Delta Solutions Group recommends:

> "Achieving a variable, more complex estuary requires establishing seaward gradients in salinity and other water quality variables…These goals in turn encourage policies which… establish internal Delta flows that create a tidally-mixed, upstream-downstream gradient (without cross-Delta flows) in water quality… and … restoring environmental variability in the Delta is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export. The drinking and agricultural water quality requirements of through-Delta exports, and perhaps even some current in-Delta uses, are at odds with the water quality and variability needs of desirable Delta species." (Moyle *et al*., 2010.)

Net OMR reverse flow restrictions are included in the USFWS Opinion (Actions 1 through 3), the NMFS Opinion (Action IV.2.3), and the DFG Incidental Take Permit (Conditions 5.1 and 5.2) for the protection of delta smelt, salmonids, and longfin smelt, respectively. (NMFS 3. p. 648; USFWS 2008, DFG 2009.) Additional net OMR reverse flow restrictions are recommended in this report for protection of longfin and delta smelt and Chinook salmon.

Further north in the Delta, the Delta Cross Channel is used to divert a portion of the Sacramento River flow into the interior Delta channels. The purpose of the Delta Cross Channel is to preserve the quality of water diverted from the Sacramento River by conveying it to southern Delta pumping plants through eastern Delta channels rather than allowing it to flow through more saline western Delta channels. The Delta Cross Channel is also operated to protect fish and wildlife beneficial uses (specifically Chinook salmon), while recognizing the need for fresh water to be moved through the system. With a capacity of 3,500 cfs, the Delta Cross Channel can divert a significant portion of the Sacramento River flows into the eastern Delta, particularly in the fall.



Cumulative probability distribution of sum of Old and Middle River flows (cfs) resulting from through Delta conveyance showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (solid light blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line) (Source: Fleenor *et al*. 2010, Figure 9).

Figure 8. Old and Middle River Cumulative Probability Flows from Fleenor *et al*. 2010

3.3.3 Water quality

Water quality in the Delta may be negatively impacted by contaminants in sediments and water, low dissolved oxygen levels, and blue green algal blooms. Additionally, changes in hydrology and hydrodynamics affect water quality. The conversion of tidal wetlands to levied Delta islands has altered the tidal exchange and prism. These changes can contribute to spatial and temporal shifts in salinity and other physical and chemical water quality parameters (temperature, dissolved oxygen, contaminants, etc.).

Contaminants

The Delta and San Francisco Bay are listed under section 303(d) of the Federal Clean Water Act as impaired for a variety of toxic contaminants that may contribute to reduced population abundance of important fish and invertebrates. The contaminants include: organophosphate and pyrethrin pesticides, mercury, selenium and unknown toxicity. In addition, low dissolved oxygen levels periodically develop in the San Joaquin River in the Stockton Deep Water Ship Channel (DWSC) and in Old and Middle rivers. The low dissolved oxygen levels in the DWSC inhibit the upstream migration of adult fall-run Chinook salmon and adversely impact other resident aquatic organisms. The Central Valley and San Francisco Regional Boards are systematically developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions.

There is concern that a number of non-303(d) listed contaminants, such as ammonia, pharmaceuticals, endocrine disrupting compounds and blue-green algal blooms could also limit biological productivity and impair beneficial uses. More work is needed to determine their impact on the aquatic community. Sources of these contaminants include: agricultural, municipal, and industrial wastewater; urban storm water discharges; discharges from wetlands; and channel dredging activities.

Ammonia has emerged as a contaminant of special concern in the Delta. Recent hypotheses are that ammonia is causing toxicity to delta smelt, other local fish, and zooplankton, and is reducing primary production rates in the Sacramento River below the Sacramento Regional Wastewater Treatment Plant (SRWTP) and in Suisun Bay. A third, newer, hypothesis is that ammonia and nitrogen to phosphorus ratios have altered phytoplankton species composition, and these changes have had a detrimental effect on zooplankton and fish population abundance. (Glibert, 2010.)

The SRWTP is the primary source of ammonia to the Delta. (Jassby 2008.) The SRWTP has converted the Delta from a nitrate to an ammonia dominated nitrogen system. (Foe *et al.* 2010.) Seven-day flow-through bioassays by Werner *et al.* (2008, 2009) have demonstrated that ammonia concentrations in the Delta are not acutely toxic to delta smelt. Monthly nutrient monitoring by Foe *et al*. (2010) has demonstrated that ammonia concentrations are below the recommended USEPA (1999) chronic criterion for the protection of juvenile fish. Results from the nutrient monitoring suggest that ammonia-induced toxicity to fish is not regularly occurring in the Delta.

Elevated ammonia concentrations inhibit nitrate uptake and appear to be one factor preventing spring diatom blooms from developing in Suisun Bay. (Dugdale *et al.* 2007; Wilkerson *et al.* 2006.) One of the primary hypotheses for the pelagic organism decline is a decrease in the availability of food at the base of the food web. (Sommer *et al.* 2007.) Staff from the San Francisco Regional Board has informed the Central Valley Regional Board that ammonia may be impairing aquatic life beneficial uses in Suisun Bay (letter to Kathy Harder with the Central Valley Regional Board from Bruce Wolfe of the San Francisco Regional Board dated June 4, 2010).

Ammonia concentrations are higher in the Sacramento River below the SRWTP than in Suisun Bay. The findings in Suisun Bay led to a hypothesis that ammonia might be inhibiting nitrate uptake and reducing primary production rates in the Sacramento River and downstream Delta. Experimental results for the Sacramento River are more ambiguous than for Suisun Bay. (Parker *et al*., 2010.) Experiments conducted on Sacramento River water demonstrate no consistent difference above and below the SRWTP. However, effluent dosed into upstream Sacramento River water at environmentally realistic concentrations does show a decrease in primary production. Elevated ammonia concentrations consistently decrease nitrate uptake. Whether the shift in nitrogen utilization indicates that different algal species are beginning to grow in the ammonia rich water is not known. Finally, a recent paper by Glibert (2010) demonstrates significant correlations between the form and concentration of nutrients discharged by the SRWTP, and changes in phytoplankton, zooplankton, and fish abundance in the Delta.

<u>Salinity</u>

Elevated salinity can impair the uses of water by municipal, industrial, and agricultural users and by organisms that require lower salinity levels. There are at least three factors that may cause salinity levels to exceed water quality objectives in the Delta: saltwater intrusion from the Pacific Ocean and San Francisco Bay moving into the Delta on high tides during periods of relatively low flows of fresh water through the Delta; salts from agricultural return flows, municipalities, and other sources carried into the southern and eastern Delta with the waters of the San Joaquin River; and localized increases in salinity due to irrigation return flows into dead-end sloughs and low-capacity channels (null zones). The effects of saltwater intrusion are seen primarily in the western Delta. Due to the operation of the State and federal export pumping plants near Tracy, the higher salinity areas caused by salts in the San Joaquin River tend to be restricted to the southeast corner of the Delta. Null zones, and the localized areas of increased salinity associated with them, exist predominantly in three areas of the Delta: Old River between Sugar Cut and the CVP intake; Middle River between Victoria canal and Old River; and the San Joaquin River between the head of Old River and the City of Stockton.

Suspended Sediments and Turbidity

Turbidity in the Delta is caused by factors that include suspended material such as silts, clays, and organic matter coming from the major tributary rivers; planktonic algal populations; and sediments stirred up during dredging operations to maintain deep channels for shipping. Turbidity affects large river and estuarine fish assemblages because some fishes survive best in turbid (muddy) water, while other species do best in clear water. Studies suggest that changes in specific conductance and turbidity are associated with declines in upper estuary habitat for delta smelt, striped bass, and threadfin shad. Laboratory studies have shown that delta smelt require turbidity for successful feeding.

Turbidity in the Delta has decreased through time. The primary hypotheses to explain the turbidity decrease are: (1) reduced sediment supply; (2) sediment washout from very high inflows during the 1982 to 1983 El Nino; and (3) trapping of sediment by submerged aquatic vegetation. (Wright and Schoellhamer 2004, Jassby *et al.* 2005, Nobriga *et al.* 2005, and Brown and Michniuk 2007 as cited in Nobriga *et al.* 2008.)

Dissolved Oxygen

Low dissolved oxygen levels are found along the lower San Joaquin River and in certain localized areas of the Delta. Dissolved oxygen impairment is caused, in part, by loads of oxygen demanding substances such as dead algae or waste discharges. Low dissolved oxygen in the Delta occurs mainly in the late summer and coincides with low river flows and high temperatures. Fish vary greatly in their ability to tolerate low dissolved oxygen concentrations, based on the environmental conditions the species has evolved to inhabit. Salmonids are relatively intolerant of low dissolved oxygen concentrations. Within the lower San Joaquin River, dissolved oxygen concentrations can become sufficiently low to impair the passage and/or cause mortality of migratory salmonids. (DFG 3, p. 3; DOI 1, p. 25; TBI/NRDC 3, p. 26.)

The DWSC is a portion of the lower San Joaquin River between the City of Stockton and the San Francisco Bay that has been dredged to allow for the navigation of ocean-going vessels to the Port of Stockton. A 14-mile stretch of the DWSC, from the City of Stockton to Disappointment Slough, is listed as impaired for dissolved oxygen and, at times, does not meet the objectives set forth in the San Joaquin Riverwater quality control plan. Studies have identified three main contributing factors to the problem: loads of oxygen demanding substances that exert an oxygen demand (particularly the death and decay of algae); DWSC geometry, which reduces the assimilative capacity for loads of oxygen demanding substances by reducing the efficiency of natural re-aeration mechanisms and by magnifying the effect of oxygen demanding reactions; and, reduced flow through the DWSC, which reduces the assimilative capacity by reducing upstream inputs of oxygen and increasing the residence time for oxygen demanding reactions. (Central Valley Regional Board 2003.)

3.3.4 Biological setting

The Bay-Delta Estuary is one of the largest, most important estuarine systems for fish and waterfowl production on the Pacific Coast of the United States. The Delta provides habitat for a wide variety of freshwater, estuarine, and marine fish species. Channels in the Delta range from dead-end sloughs to deep, open water areas that include several flooded islands that provide submerged vegetative shelter. The complex interface between land and water in the Delta provides rich and varied habitat for wildlife, especially birds. The Delta is particularly important to waterfowl migrating via the Pacific Flyway as these birds are attracted to the winter-flooded fields and seasonal wetlands. (State Water Board 1999.)

Existing setting

A wide variety of fish are found throughout the waterways of the Central Valley and the Bay-Delta Estuary. About 90 species of fish are found in the Delta. Some species, such as the anadromous fish, are found in particular parts of the Bay-Delta Estuary and the tributary rivers and streams only during certain stages of their life cycle. The Delta's channels serve as a migratory route and nursery area for Chinook salmon, striped bass, white and green sturgeon, American shad, and steelhead trout. These anadromous fishes spend most of their adult lives either in the lower bays of the estuary or in the ocean, moving inland to spawn. Resident fishes in the Bay-Delta Estuary include delta smelt, longfin smelt, threadfin shad, Sacramento splittail, catfish, largemouth and other bass, crappie, and bluegill.

Food supplies for Delta fish communities consist of phytoplankton, zooplankton, benthic invertebrates, insects, and forage fish. The entrapment zone, where freshwater outflow meets and mixes with the more saline water of the Bay, concentrates sediments, nutrients, phytoplankton, some fish larvae, and other fish food organisms. Biological standing crop (biomass) of phytoplankton and zooplankton in the estuary has generally been highest in this zone. However, the overall productivity at the lower trophic levels has decreased over time. (State Water Board 1999.)

Non-native and invasive species

Invasive aquatic organisms are known to have deleterious effects on the Delta ecosystem. These effects include reductions in habitat suitability, reductions in food supply, alteration of the aquatic food-web, and predation on or competition with native species. There are many notable examples of exotic species invasions in the Bay-Delta, so much so, that the Delta has been labeled "the most invaded estuary on earth."

Of particular importance potentially in the recent decline in pelagic organisms is the introduction of the Asian clam, *Corbula amurensis*. The introduction of the clam has lead to substantial declines in the lower trophic production of the Bay-Delta Estuary. In addition to reductions in planktonic production caused by *Corbula*, the planktonic food web composition has changed dramatically over the past decade or so. Once dominant copepods in the food web have declined leading to speculation that estuarine conditions have changed to favor alien species. The decrease in these desirable copepods may further increase the likelihood of larval fish starvation or result in decreased growth rates. (State Water Board 2008.)

The proliferation of invasive, aquatic weeds, such as *Egeria densa*, which filter out particulate materials and further reduce planktonic growth, are also having a impact on the Bay-Delta. Areas with low or no flow, such as warm, shallow, dead-end sloughs in the eastern Delta also support objectionable populations of plants during summer months including planktonic blue-green algae and floating and semi-attached aquatic plants such as water primrose, water hyacinth, and *Egeria densa*. All of these plants contribute organic matter that reduces dissolved oxygen levels in the fall, and the floating and semi-attached plants interfere with the passage of small boat traffic. In addition, native fishes in the Bay-Delta face growing challenges associated with competition and predation by non-native fish. (State Water Board 1999; State Water Board 2008.)

Recent species declines

Historical fisheries within the Central Valley and the Bay-Delta Estuary were considerably different than the fisheries present today. Many native species have declined in abundance and distribution, while several introduced species have become well established. The Sacramento perch is believed to have been extirpated from the Delta; however, striped bass and American shad are introduced species that, until recently, have been relatively abundant and have contributed substantially to California's recreational fishery. (State Water Board 1999.)

In 2005, scientists with the Interagency Ecological Program announced observations of a precipitous decline in several pelagic organisms in the Delta, beginning in 2002, in addition to declining levels of zooplankton. Zooplankton are the primary food source for older life stages of species such as delta smelt. The decline in pelagic organisms included delta smelt, striped bass, longfin smelt, and threadfin shad. Scientists hypothesized that at least three general factors may be acting individually, or in concert, to cause this recent decline in pelagic productivity: 1) toxic effects; 2) exotic species effects; and 3) water project effects. Scientists and resources agencies have continued to investigate the causes of the decline, and have prepared plans that identify actions designed to help stabilize the Delta ecosystem and improve conditions for pelagic fish species. (State Water Board 2008.)

In January of 2008, the Pacific Fisheries Management Council reported unexpectedly low Chinook salmon returns to California, particularly to the Central Valley, for 2007. Adult returns to the Sacramento River, the largest of Central Valley Chinook salmon runs, failed to meet resource management goals (122,000-180,000 spawners) for the first time in 15 years. (State Water Board 2008.) The Sacramento River fall Chinook salmon escapement to the Central Valley was estimated to be 88,000 adults in 2007; 66,000 in 2008; and 39,530 – the lowest on record -- in 2009. (PCFFA 2.) The NMFS concluded that poor ocean conditions were a major factor contributing to the low fall-run abundance; however, other conditions may exacerbate these effects. (State Water Board 2008.)

In April 2008, the Pacific Fisheries Management Council and the Commission adopted the most restrictive ocean and coastal salmon seasons ever for California by closing the ocean and coastal fishery to commercial and recreation fishing for the 2008 fishing season. The Commission further banned salmon fishing in all Central Valley rivers, with the exception of limited fishing on a stretch of the Sacramento River. (State Water Board 2008.) The ban on all salmon fishing was extended through the 2009 season, but the restrictions were eased somewhat for 2010.

3.3.5 How flow-related factors affect public trust resources

Flow is important to sustaining the ecological integrity of aquatic ecosystems, including the public trust resources that are the subject of this proceeding. Flow affects water quality, food resources, physical habitat, and biotic interactions. Alterations in the natural flow regime affect aquatic biodiversity and the structure and function of aquatic ecosystems.

In its key points on Delta environmental flows for the State Water Board, the Delta Environmental Flows Group (2010) noted that:

- Flow related factors that affect public trust resources include more than just volumes of inflow and outflow and no single rate of flow can protect all public trust resources at all times. The frequency, timing, duration, and rate of change of flows, the tides, and the occurrence of overbank flows, all are important. Seasonal, interannual, and spatial variability in flows, to which native species are adapted, are as important as the quantity of flow. Biological responses to flows rest on combinations of quantity, timing, duration, frequency and how these inputs vary spatially in the context of a Delta that is geometrically complex, highly altered by humans, and fundamentally tidally driven.

- Recent flow regimes in the Delta have contributed to the decline of native species and encouraged non-native species. Flows into and within the estuary affect turbidity, salinity, aquatic plant communities, and nutrients that are important to both native and non-native species. However, flows and habitat structure are often mismatched and now favor non-native species.

- Flow is a major determinant of habitat and transport. The effects of flow on transport and habitat are controlled by the geometry of the waterways. Further, because the geometry of the waterways will change through time, flow regimes needed to maintain desired habitat conditions will also change through time. Delta inflow is an important factor affecting the biological resources of the Delta because inflow has a direct effect on flood plain inundation, in-Delta net channel flows, and net Delta outflows.

- Flow modification is one of the few immediate actions available to improve conditions to benefit native species. However, habitat restoration, contaminant and nutrient reduction, changes in diversions, control of invasive species, as well as flood plain inundation and island flooding all interact with flow to affect aquatic habitats.

4. Methods and Data

The notice for the informational proceeding requested scientific information on the volume, quality, and timing of water needed for the Delta ecosystem under different hydrologic conditions to protect public trust resources pursuant to the State Water Board's public trust obligations and the requirements of SB 1. Specifically, the notice focused on Delta outflows, but also requested information concerning the importance of the source of those flows and information concerning adaptive management, monitoring, and special study programs. In addition to the requested information concerning Delta outflows, the State Water Board also received information on Sacramento River inflows, San Joaquin River inflows, hydrodynamics including Old and Middle River flows, and other information that is relevant to protection of public trust resources in the Delta ecosystem. This section presents the recommendations received by the State Water Board and discusses approaches used to evaluate the recommendations and develop flow criteria responsive to SB1.

4.1 Summary of Participants' Submittals

Information submitted by interested parties over the course of this proceeding has resulted in the development of a substantive record; submittals are available on the State Water Board's website at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/entity_index.shtml

The exhibits include discussions pertaining to: the State Water Board's public trust obligations; methodologies that should be used to develop flow criteria; the importance of the source of flows when determining outflow; means by which uncertainty should be addressed; and specific recommendations concerning Delta outflows, Sacramento and San Joaquin river inflows, hydrodynamics, operation of the Delta Cross Channel Gates, and floodplain activation.

The State Water Board received a wide range of recommendations for the volume, quantity and timing of flow necessary to protect public trust resources. Delta outflow recommendations ranged from statements that the current state of scientific understanding does not support development of numeric Delta flow criteria that differ from the current outflow objectives included in D-1641 (DWR closing comments; SFWC closing comments) to flow volumes during above normal and wet water year types that are two to four times greater than currently required under D-1641 (TBI/NRDC closing comments; AR/NHI closing comments; EDF closing comments, CSPA closing comments; CWIN closing comments).
Appendix A: Summary of Participant Recommendations, provides summary tables of the recommendations received for Delta outflows, Sacramento River inflows, San Joaquin River inflows, hydrodynamics, floodplain inundation, and Delta Cross Channel Gate closures.

4.2 Approach to Developing Flow Criteria

Fleenor *et al.* (2010) examined the following four approaches for prescribing environmental flows for the Delta:

- Unimpaired (quasi-natural) inflows
- Historical impaired inflows that supported more desirable ecological conditions
- Statistical relationships between flow and native species abundance
- The appropriate accumulation of flows estimated to provide specific ecological functions for desirable species and ecosystem attributes based on available literature.

Fleenor *et al*. (2010) concludes:

> "Generally, approaches that rely on data from the past will become more risky as the underlying changes in the Delta accumulate. However, since the objective is to provide flows for species which evolved under past conditions, information on past flows and life history strategies of fish provide considerable insight and context. Aggregate statistical approaches, which essentially establish correlations between past conditions and past species abundance, are likely to be less directly useful as the Delta changes. However, statistical approaches will continue to be useful, especially if developed for causal insights. More focused statistical relationships can be of more enduring value in the context of more causal models, even given underlying changes. In the absence of more process-based science, empirical relationships might be required for some locations and functions on an interim basis. Insights and information can be gained from each approach. Given the importance of the problem and the uncertainties involved,

> the strengths of each approach should be employed to provide greater certainty or improve definition of uncertainties."

Among other things, the Fleenor report recommends:

1. Flow prescriptions should be supported preferably by causally or process-based science, rather than correlative empirical relationships or other statistical relationships without supporting ecological basis. Having a greater causal basis for flow prescriptions should make them more effective and readily adapted to improvements in knowledge and changing conditions in the Delta. A more explicit causal basis for flow prescriptions will also create incentives for improved scientific understanding of this system and its management as well as better integration of physical, chemical, and biological aspects of the problem.
2. Ongoing managed and unmanaged changes in the Delta will make any static set of flow standards increasingly irrelevant and obsolete for improving conditions for native fishes. Flows should be tied to habitat, fish, hydrologic, and other management conditions, as well as our knowledge of the system. Flows needed for fish native to the Delta will change.

Information received during this proceeding supports these conclusions and recommendations. The record for this proceeding contains a mix of data and analyses that uses the four approaches identified by Fleenor *et al.* (2010):

- Unimpaired flows
- Historical impaired inflows that supported more desirable ecological conditions
- Statistical relationships between flow and native species abundance
- Ecological functions-based analysis for desirable species and ecosystem attributes

All four types of information are relied upon to develop the flow criteria in this report. Emphasis, however, is placed on ecological function-based information, followed by information on statistical relationships between flow and native species abundance. In all cases, the criteria are supported by the best available scientific information submitted into the record for this proceeding. The species and ecosystem function-based needs assessments and recommendations in this report are supported by references to specific scientific and empirical evidence, and cite to exhibits and testimony in the record or conclusions in published and peer reviewed articles. Criteria based upon statistical relationships between flow and native species abundance are also supported by references to specific scientific and empirical evidence, and cite to exhibits and testimony in the record or conclusions in published and peer reviewed articles.

Furthermore, the conceptual bases for all of the recommendations in this report are supported by scientific information on function-based species or ecosystem needs. In other words, there is sufficiently strong scientific evidence to support the need for functional flows. This does not necessarily mean that there is scientific evidence to support *specific* numeric criteria. Recommendations are therefore divided into two categories: Category "A" criteria have more and better scientific information, with less uncertainty, to support specific numeric criteria than do Category "B" criteria. In all cases, the recommendations identify and discuss the assumptions upon which they are based. The following steps were followed to develop flow criteria and other recommendations:

1. Establish general goals and objectives for protection of public trust resources in the Delta
2. Identify species to include based on ecological, recreational, or commercial importance
3. Review and summarize species life history requirements, including description of:
    - general life history and species needs
    - population distribution and abundance
    - population abundance and relationship to flow
    - specific population goals
    - species-specific basis for flow criteria
4. Summarize numeric and other criteria for each of: Delta outflows, Sacramento River inflows, San Joaquin River inflows, and hydrodynamics
5. Review other flow-related and non-flow measures that should be considered
6. Provide summary determinations for flow criteria and other measures

To better understand the physical constraints of the hydrologic system, the DWR conducted modeling of the hydrological effects of the numeric criteria. The purpose of this modeling was to:

- determine to what extent the recommended flow criteria conflict with the needs to preserve cold water in tributaries; and
- estimate water supply impacts

The modeling was also used to limit flows to levels that would not cause flooding in the Delta or tributaries. Details on this modeling are provided in Appendix B.

The following information was assembled and considered for each species, if available in the record for this proceeding:

- Life history information including timing of migrations
- Seasons or time periods when flow characteristics are most important
- Relationships of species abundance or habitat to Delta outflows, Delta inflows, hydrodynamics, or water quality parameters linked to flow, etc.
- Species environmental requirements (e.g., dissolved oxygen, temperature preferences, salinity, X2 location, turbidity, toxicity to specific pollutants, etc.)
- Relationship of species abundance to invasive species, to the extent possible
- Key quantifiable population responses or habitat characteristics linked to flow
- Mechanisms or hypotheses about mechanisms that link species abundance, habitat, and other metrics to flow or other variables

4.2.1 Goals and Objectives

The goals of this report are discussed in Section 3.1.4 (Scope of this Report). The following biological and management objectives are used to guide the development of criteria that support species life history requirements.

<u>Biological Objectives</u>

- Depending on water year type or hydrologic condition, provide sufficient flow to increase abundance of desirable species that depend on the Delta (longfin smelt, delta smelt, starry flounder, bay shrimp, American shad, and zooplankton)

- Create shallow brackish water habitat for longfin smelt, delta smelt, starry flounder, bay shrimp, American shad, and zooplankton in Suisun Bay (and farther downstream)

- Provide floodplain inundation of appropriate timing and sufficient duration to enhance spawning and rearing opportunities to support Sacramento splittail, Chinook salmon, and other native species

- Manage net Old and Middle River reverse flows and other hydrodynamic conditions to protect sensitive life stages of desirable species

- Provide sufficient flow in the San Joaquin River to transport salmon smolts through the Delta during spring in order to contribute to attainment of the State Water Board's salmon protection water quality objective (2009 Bay-Delta Plan, p. 14)

- Provide sufficient flow in the Sacramento River to transport salmon smolts through the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective (*Id.*)

- Provide sufficient flow in eastside streams that flow to the Delta, including the Mokelumne and Consumes rivers, to transport salmon smolts to the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective

- Maintain water temperatures and dissolved oxygen in mainstem rivers that flow into the Delta and their tributaries at levels that will support adult Chinook salmon migration, egg incubation, smolting, and early-year and late-year juvenile rearing

Management Objectives

- Combine freshwater flows needed to protect species and ecosystem functions in a manner that is comprehensive, does not double count flows, uses an appropriate time step, and is well-documented

- Establish mechanisms to evaluate Delta environmental conditions, periodically review underpinnings of the biological objectives and flow criteria, and change biological objectives and flow criteria when warranted

- Periodically review new research and monitoring to evaluate the need to modify biological objectives and flow criteria

- Do not recommend overly complex flow criteria so as not to infer a greater understanding of specific numeric flow criteria than the available science supports

4.2.2 Selection of Species[10]

Information received during the informational proceeding links the abundance and habitat of several key species that live in, move through, or otherwise depend upon for their survival, the Delta and its ecosystem. DFG Exhibits 1 through 4 present information on the relationship

[10] This section is largely drawn from DFG exhibits 1 through 4.

between abundance and the quantity, quality, and timing of flow for the following species: (1) Chinook salmon, (2) Pacific herring, (3) longfin smelt, (4) prickly sculpin, (5) Sacramento splittail, (6) delta smelt, (7) starry flounder, (8) white sturgeon, (9) green sturgeon, (10) Pacific lamprey, (11) river lamprey, (12) bay shrimp, (13) mysid shrimp and a copepod, *Eurytemora affinis*, and (14) American shad. In general, the available data and information indicates:

- For many species, abundance is related to timing and quantity of flow (or the placement of X2).
- For many species, more flow translates into greater species production or abundance.
- Species are adapted to use the water resources of the Delta during all seasons of the year, yet for many species, important life history stages or processes consistently coincide with the winter-spring seasons and its associated increased flows because this is the reproductive season for most native fishes, and the time that most salmonid fishes are emigrating.
- The source, quantity, quality, and timing of Central Valley tributary outflow affects the same characteristics of mainstem river flow into and through the Delta. Flows in all three of these areas, Delta outflows, tributary inflows, and hydrodynamics, influence production and survival of Chinook salmon in both the San Joaquin River and Sacramento River basins.
- Some invasive species negatively influence native species abundance.

This report is consistent with DFG's recommendation to establish flow criteria for species of priority concern that will benefit most by improving flow conditions. (DFG closing comments, p. 3.) Table 2 (from DFG closing comments p.4) identifies select species that have the greatest ecological, commercial, or recreational importance and are influenced by Delta inflows (including mainstem river tributaries) or Delta outflows. The table identifies the species life stage most affected by flows, the mechanism most affected by flows, and the time when flows are most important to the species.

Table 2. Species of Importance (from DFG closing comments p.4)

Priority Species	**Life Stage**	**Mechanism**	**Time When Water Flows are Most Important**	**Reference**
Chinook salmon (San Joaquin River basin)	Smolt	Outmigration	March – June	DFG Exhibit 1 – page 2; DFG Exhibit 3 – pages 7-10, 21-35.
Chinook salmon (Sacramento River basin)	Juvenile	Outmigration	November – June	DFG Exhibit 1 – page 1-2, 6-8
Chinook salmon (San Joaquin River tributaries)	Egg/fry	Temperature, dissolved oxygen, upstream barrier avoidance	October – March	DFG Exhibit 3, pages 2-4; DFG Exhibit 4
Longfin smelt	Egg	Freshwater-brackish habitat	December – April	DFG Exhibit 1 – page 2, 9-12
Longfin smelt	Larvae	Freshwater-	December – May	DFG Exhibit

Priority Species	Life Stage	Mechanism	Time When Water Flows are Most Important	Reference
		brackish habitat; transport; turbidity		1 – page 2, 9-12
Sacramento Splittail	Adults	Floodplain inundating flows	January – April	DFG Exhibit 1 – page 2, 13-14
Sacramento Splittail	Eggs and larvae	Floodplain habitat persistence	January – May	DFG Exhibit 1 – page 3, 13-14
Delta smelt	Larvae and Pre-adult	Transport; habitat	March – November September – November	DFG Exhibit 1 – page 2,14-15
Starry flounder	Settled juvenile; Juvenile-2 yr old	Estuary attraction; habitat	February – May	DFG Exhibit 1 – page 3, 15-16
Bay shrimp	Late-stage larvae and small juveniles	Transport	February – June	DFG Exhibit 1 – page 4; 22-25
Bay shrimp	Juveniles	Nursery habitat	April – June	DFG Exhibit 1 – page 4; 22-25
Mysid shrimp (zooplankton)	All	Habitat	March – November	DFG Exhibit 1 – page 5; 25-26
Eurytemora affinis (zooplankton)	All	Habitat	March – May	DFG Exhibit 1 – page 5; 25-26
American shad	Egg/larvae	Transport; dispersal; habitat	March – June	DFG Exhibit 1 – page 5; 26-28

While many species found in the Delta are of ecological, commercial, and/or recreational interest, specific flow needs for some of those species may not be directly addressed in this report because: they overlap with the needs of more sensitive species otherwise addressed in the report; the relationships between flow and abundance of those species are not well understood; or the needs of those species may be outside the scope of this report. For example, placement of X2 at certain locations in the Delta to protect longfin smelt or starry flounder will also protect striped bass (*Morone saxatilis*). Striped bass survival from egg to 38 mm is significantly increased as X2 shifts downstream in the estuary. (Kimmerer 2002a.) Kimmerer *et al.* (2009) showed that as X2 location moved downstream, several measures of striped bass survival and abundance significantly increased, as did several measures of striped bass habitat. Similarly, it is assumed that improved stream flow conditions for Chinook salmon will benefit steelhead, but additional work is needed to assure that these flow criteria are adequate for the protection of steelhead. Adult steelhead in the Central Valley migrate upstream beginning in June, peaking in September, and continuing through February or March. (Hallock *et al*. 1961, Bailey 1954, McEwan and Jackson 1996, as cited in SJRRP FMWG 2009.)

Spawning occurs primarily from January through March, but may begin as early as December and may extend through April. (Hallock *et al.* 1961, as cited in McEwan and Jackson 1996.) Steelhead also rear in tributaries to the Delta throughout the year. Consequently, additional inflow criteria may be needed to protect steelhead at times when flows are not specifically recommended to protect Chinook salmon. As will be discussed in the species needs section for Chinook salmon, additional flow criteria may also be needed to protect various runs and life-stages of Chinook salmon. Adequate information is not currently available, however, upon which to base criteria.

Other species are influenced by very high and infrequent flows, far in excess of what could be provided by the State and federal water projects because they occur only during very wet years when project operations are not controlling. For example, white sturgeon are influenced by high winter and spring Delta and river flows (March-June Delta outflow greater than 60,000 cfs) that attract migrating adults, cue spawning, transport larvae, and enhance nursery habitat. These types of flows occur episodically in very wet years. Historical flow patterns combined with the unique life history (long-lived, late maturing, long intervals between spawning, high fecundity) result in infrequent strong recruitment.

There is adequate information in the record, and adequate time to evaluate life history requirements and develop species-specific flow criteria for the following species:

- Chinook Salmon (various runs) (primarily mirgration flows)
- American Shad
- Longfin Smelt
- Delta Smelt
- Sacramento Splittail
- Starry Flounder
- Bay Shrimp
- Zooplankton

4.2.3 Life History Requirements – Anadromous Species

Following are life history and species-specific requirements for Chinook Salmon (including Sacramento River winter-run, Central Valley spring-run, Central Valley fall-run, and Central Valley late fall-run) and American shad.

Chinook Salmon (Sacramento River Winter-Run, Central Valley Spring-Run, Central Valley Fall-Run, and Central Valley Late Fall-Run)

Status

Sacramento River winter-run Chinook salmon is listed as endangered pursuant to the ESA and the CESA. Central Valley spring-run Chinook salmon is listed as threatened pursuant to both the ESA and the CESA. Central Valley fall/late fall-run Chinook salmon are classified as species of special concern pursuant to the ESA.[11]

[11] Source: http://www.dfg.ca.gov/fish/Resources/Chinook/index.asp

Life History[12]

Chinook salmon exhibit two generalized freshwater life history types (Healey 1991). Adult "stream-type" Chinook salmon enter freshwater up to several months before spawning, and juveniles reside in freshwater for a year or more, whereas "ocean-type" Chinook salmon spawn soon after entering freshwater and migrate to the ocean as fry or parr within their first year. Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over-summering by adults and/or juveniles.

Chinook salmon typically mature between 2 and 6 years of age (Myers *et al.* 1998). Freshwater entry and spawning timing generally are thought to be related to local water temperature and flow regimes. Runs are designated on the basis of adult migration timing. However, distinct runs also differ in the degree of maturation of the fish at the time of river entry, thermal regime, and flow characteristics of their spawning sites, and the actual time of spawning (Myers *et al.* 1998). Both winter-run and spring-run tend to enter freshwater as immature fish, migrate far upriver, and delay spawning for weeks or months. Fall-run enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry (Healey 1991).

During their upstream migration, adult Chinook salmon require streamflows sufficient to provide olfactory and other orientation cues used to locate their natal streams. Adequate streamflows are necessary to allow adult passage to upstream holding habitat. The preferred temperature range for upstream migration is 38ºF to 56ºF (Bell 1991, DFG 1998). Boles (1988) recommends water temperatures below 65ºF for adult Chinook salmon migration, and Lindley *et al.* (2004) report that adult migration is blocked when temperatures reach 70ºF, and that fish can become stressed as temperatures approach 70ºF.

Information on the migration rates of adult Chinook salmon in freshwater is scant and primarily comes from the Columbia River basin (Matter and Sanford 2003). Keefer *et al.* (2004) found migration rates of Chinook salmon ranging from approximately 10 kilometers (km) per day to greater than 35 km per day and to be primarily correlated with date, and secondarily with discharge, year, and reach, in the Columbia River basin. Matter and Sanford (2003) documented migration rates of adult Chinook salmon ranging from 29 to 32 km per day in the Snake River.

Adult Chinook salmon inserted with sonic tags and tracked throughout the Delta and lower Sacramento and San Joaquin rivers were observed exhibiting substantial upstream and downstream movement in a random fashion, for several days at a time, while migrating upstream (CALFED 2001). Adult salmonids migrating upstream are assumed to make greater use of pool and mid-channel habitat than channel margins (Stillwater Sciences 2004), particularly larger salmon such as Chinook salmon, as described by Hughes (2004). During their upstream migration, adults are thought to be primarily active during twilight hours.

Spawning Chinook salmon require clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper runs, and suitable water temperatures, depths, and velocities for redd construction and adequate oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds that are located at the tails of holding pools (USFWS 1995). The range of

[12] This section was largely extracted from NMFS 3, pages 76 through 79.

water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad. The upper preferred water temperature for spawning Chinook salmon is 55ºF to 57ºF (Chambers 1956, Smith 1973, Bjornn and Reiser 1991, and Snider 2001).

Incubating eggs are vulnerable to adverse effects from floods, siltation, desiccation, disease, predation, poor gravel percolation, and poor water quality. Studies of Chinook salmon egg survival to hatching conducted by Shelton (1995) indicated 87% of fry emerged successfully from large gravel with adequate subgravel flow. The optimal water temperature for egg incubation ranges from 41ºF to 56ºF [44ºF to 54ºF (Rich 1997), 46ºF to 56ºF (NMFS 1997), and 41ºF to 55.4ºF (Moyle 2002)]. A significant reduction in egg viability occurs at water temperatures above 57.5ºF and total embryo mortality can occur at temperatures above 62ºF (NMFS 1997). Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50% pre-hatch mortality were 61ºF and 37ºF, respectively, when the incubation temperature was held constant. As water temperatures increase, the rate of embryo malformations also increases, as well as the susceptibility to fungus and bacterial infestations. The length of development for Chinook salmon embryos is dependent on the ambient water temperature surrounding the egg pocket in the redd. Colder water necessitates longer development times as metabolic processes are slowed. Within the appropriate water temperature range for embryo incubation, embryos hatch in 40 to 60 days, and the yolk-sac fry remain in the gravel for an additional 4 to 6 weeks before emerging from the gravel.

During the 4 to 6 week period when alevins remain in the gravel, they utilize their yolk-sac to nourish their bodies. As their yolk-sac is depleted, fry begin to emerge from the gravel to begin exogenous feeding in their natal stream. Fry typically range from 25 mm to 40 mm at this stage. Upon emergence, fry swim or are displaced downstream (Healey 1991). The post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on zooplankton, small insects, and other microcrustaceans. Some fry may take up residence in their natal stream for several weeks to a year or more, while others are displaced downstream by the stream's current. Once started downstream, fry may continue downstream to the estuary and rear there, or may take up residence in river reaches farther downstream for a period of time ranging from weeks to a year (Healey 1991).

Fry then seek nearshore habitats containing riparian vegetation and associated substrates important for providing aquatic and terrestrial invertebrates, predator avoidance, and slower velocities for resting (NMFS 1996). The benefits of shallow water habitats for salmonid rearing have been found to be more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer *et al.* 2001).

When juvenile Chinook salmon reach a length of 50 to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento exhibited larger-sized juveniles captured in the main channel and smaller-sized fry along the margins (USFWS 1997). When the channel of the river is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Migrational cues, such as increasing turbidity from runoff, increased flows, changes in day length, or intraspecific competition from other fish in their natal streams, may spur outmigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (Kjelson *et al.* 1982, Brandes and McLain 2001).

As fish begin their emigration, they are displaced by the river's current downstream of their natal reaches. Similar to adult movement, juvenile salmonid downstream movement is crepuscular. Juvenile Chinook salmon migration rates vary considerably presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson *et al*. (1982) found Chinook salmon fry to travel as fast as 30 km per day in the Sacramento River, and Sommer et *al.* (2001) found travel rates ranging from approximately 0.5 miles up to more than 6 miles per day in the Yolo Bypass. As Chinook salmon begin the smoltification stage, they prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (ppt, Healey 1980, Levy and Northcote 1981).

Fry and parr may rear within riverine or estuarine habitats of the Sacramento River, the Delta, and their tributaries (Maslin *et al.* 1997, Snider 2001). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960, Dunford 1975, Meyer 1979, Healey 1980). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson *et al.* 1982, Sommer et al. 2001, MacFarlane and Norton 2002). Shallow water habitats are more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer et al. 2001). Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 54ºF to 57ºF (Brett 1952). In Suisun and San Pablo bays, water temperatures reach 54ºF by February in a typical year. Other portions of the Delta (*i.e*., South Delta and Central Delta) can reach 70ºF by February in a dry year. However, cooler temperatures are usually the norm until after the spring runoff has ended.

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levings 1982, Levy and Northcote 1982, Levings *et al.* 1986, Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle *et al.* (1989) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson *et al.* (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicate that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly oceantype life history observed (*i.e.*, fall-run), MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry.

Population Distribution and Abundance

Four seasonal runs of Chinook salmon occur in the Central Valley, with each run defined by a combination of adult migration timing, spawning period, and juvenile residency and smolt migration periods. (Fisher 1994 as cited in Yoshiyama *et al.* 2001 p. 73.) The runs are named after the season when adults move upstream to migrate-- winter, spring, fall, and late-fall. The

Sacramento River basin supports all four runs resulting in adult salmon being present in the basin throughout the year. (Stone 1883a; Rutter 1904; Healey 1991; Vogel and Marine 1991 as cited in Yoshiyama *et. al,* 2001 p. 73.) Historically, different runs occurred in the same streams staggered in time to correspond to the appropriate stream flow regime for which that species evolved, but overlapping. (Vogel and Marine 1991; Fisher 1994 as cited in Yoshiyama *et al.,* 2001, p. 73.) Typically, fall and late-fall runs spawn soon after entering natal streams and spring and winter runs typically "hold" for up to several months before spawning. (Rutter 1904; Reynolds and others 1993 as cited in Yoshiyama *et. al,* 2001, p. 73.) These runs and their life-cycle timing are summarized in Table 3 and described in more detail below.

<u>Winter-Run</u> - Due to a need for cool summer flows, Sacramento River winter-run originally likely only spawned in the upper Sacramento River tributaries, including the McCloud, Pit, Fall, and Little Sacramento rivers and Battle Creek. (NMFS 5, p. 16.) As a result of construction of Shasta and Keswick Dams, today all spawning habitat above Keswick Dam has been eliminated and approximately 47 of the 53 miles of habitat in Battle Creek has been eliminated. (Yoshiyama *et al.* 1996, as cited in NMFS 5, p. 16.) Currently, winter-run habitat is likely limited to the Sacramento River reach between Keswick Dam downstream of the Red Bluff Diversion Dam. (NMFS 5, p. 16.)

The winter-run population is currently very vulnerable due to its low population numbers and the fact that only one population exists. (Good *et al.* 2005, as cited in NMFS 5, p. 16.) In the late 1960s escapement was near 100,000 fish declining to fewer than 200 fish in the 1990s. (*Id*.) Recent escapement estimates from 2004 to 2006 averaged 13,700 fish. (DFG Website 2007, as cited in NMFS 5, p. 16.) However, in 2007 and 2008 escapements were less than 3,000 fish. Since 1998, hatchery produced winter-run have been released likely contributing to the observed increased escapement numbers. (Brown and Nichols 2003 as cited in NNFS 5, p. 16.) In addition, a temperature control device was installed on Shasta Dam in 1997 likely improving conditions for winter-run. (NMFS 5, p. 18.)

<u>Spring-Run</u> - Historically, spring-run were likely the most abundant salmonid in the Central Valley inhabiting headwater reaches of all major river systems in the Central Valley in the absence of natural migration barriers. (NMFS 5, p. 28.) Since the 1880s, construction of dams and other factors have significantly reduced the numbers and range of spring-run in the Central Valley. (*Id*.) Currently, the only viable populations occur on Mill, Deer, and Butte creeks, but those populations are small and isolated. (DFG 1998, as cited in NMFS 5, p. 28.) In addition, the Feather River Fish Hatchery which opened in 1967 produces spring-run salmon. However, significant hybridization of these hatchery fish with fall-run has occurred. (NMFS 5, p. 28-31.)

Historically, Central Valley spring-run numbers were estimated to be as large as 600,000 fish. (DFG 1998 as cited in NMFS 5, p. 28.) Nearly 50,000 spring-run adults were counted on the San Joaquin River prior to construction of Friant Dam. (Fry 1961 as cited in NMFS 5, p. 28.) Shortly after construction of Friant Dam, spring-run were extirpated on the San Joaquin River. (Yoshiyama *et al.* 1998 as cited in NMFS 5, p. 28.) Since 1970, estimates of spring-run populations in the Sacramento River have been as high as 30,000 fish and as low as 3,000 fish. (NMFS 5, p. 28.)

<u>Fall-Run</u> - Historically, fall run likely occurred in all Central Valley streams that had adequate flows during the fall months, even if the streams were intermittent during other parts of the year. (Yoshiyama *et. al* 2001, p. 74.) Due to their egg-laden and deteriorating physical condition, fall-run likely historically spawned in the valley floor and lower foothill reaches and probably were limited in their upstream migration. (Rutter 1904 as cited in Yoshiyama *et. al* 2001, p. 74.)

Currently, fall-run Chinook inhabit both the Sacramento and San Joaquin river basins and are currently the most abundant of the Central Valley races, contributing to large commercial and recreational fisheries in the ocean and popular sportfisheries in the freshwater streams. Fall-run Chinook are raised at five major Central Valley hatcheries which release more than 32 million smolts each year. In the past few years, there have been large declines in fall-run populations with escapements of 88,0000 and 66,000 fish in 2007 and 2008. (NMFS 2009, p. 4.) NMFS concluded that the recent declines were likely primarily due to poor ocean conditions in 2005 and 2006. (*Id.*) Other factors contributing to the decline of fall-run include: loss of spawning grounds due to dams and other factors, degradation of spawning habitat from water diversions, introduced species, altered sediment dynamics, hatchery practices, degraded water quality, and loss of riparian and estuarine habitat. (*Id.*)

Late-Fall Run - Historically, late fall-run probably spawned in the mainstem Sacramento River and major tributary reaches and possibly in the San Joaquin River upstream of its tributaries. (Hatton and Clark 1942; Van Cleve 1945; Fisher 1994 as cited in Yoshiyama *et. al* 2001.) Today, late-fall run are mostly found in the upper Sacramento River where the river remains deep and cool enough in the summer for juvenile rearing. (Moyle 2002, p. 254.) The late fall-run has continued low, but potentially stable abundance. (NMFS 2009, p. 4.) Estimates from 1992 ranged from 6,700 to 9,700 fish and in 1998 were 9,717 fish. However, changes in estimation methods, lack of data, and hatchery influences make it difficult to accurately estimate abundance trends for this run. (*Id.*)

Table 3. Generalized Life History Timing of Central Valley Chinook Salmon Runs

	Migration Period	**Peak Migration**	**Spawning Period**	**Peak Spawning**	**Juvenile Emergence Period**	**Juvenile Stream Residency**
Sacramento River Basin Late Fall-Run	October–April	December	Early January–April	February–March	April-June	7-13 months
Winter-Run	December-July	March	Late April-early August	May-June	July-October	5-10 months
Spring-Run	March-September	May- June	Late August-October	Mid-September	November-March	3-15 months
Fall Run	June-December	September-October	Late September-December	October-November	December-March	1-7 months
San Joaquin (Tuolumne River) Fall-Run	October-early January	November	Late October-January	November	December-April	1-5 months

Source: Yoshiyama *et al*. (1998) as cited in Moyle 2002, p. 255.

Population Abundance and Relationship to Flow

Delta outflows and inflows affect rearing conditions and migration patterns for Chinook salmon in the Delta watershed. Freshwater flow serves as an important cue for upstream adult migration and directly affects juvenile survival and abundance as they move downstream through the Delta. (DOI 1, p. 23.) Decreased flows may decrease migration rates and increase exposure to unsuitable water quality and temperature conditions, predators, and entrainment at water diversion facilities. (DFG 1, p. 1.) For the most part, relationships between salmon survival and abundance have been developed using tributary inflows rather than Delta outflows, however, the Delta is an extension of the riverine environment until salmon reach the salt water interface. (DOI 1, p. 29.) Prior to development and channelization, the Delta provided hospitable habitat for salmon. With channelization and other development, the environment is no longer hospitable for salmon. As a result, the most beneficial Delta outflow pattern for salmon may currently be one that moves salmon through the Delta faster. (*d*.)

Salmon respond behaviorally to variations in flows. Monitoring shows that juvenile and adult salmon begin migrating during the rising limb of the hydrograph. (DOI 1, p. 30.) For juveniles, pulse flows appear to be more important than for adults. (*Id*.) For adults, continuous flows through the Delta and up to each of the natal tributaries appears to be more important. (*Id*.) Flows and water temperatures are also important to maintain populations with varied life history strategies in different year types to insure continuation of the species over different hydrologic and other conditions. For salmon migrating as fry within a few days of emigration from redds, increased flows provide improved transport downstream and improved rearing habitat, and for salmon that stay in the rivers to rear, increased flows provide for increased habitat and food production. (DOI 1, 30.)

Population Abundance Goal

The immediate goal is to significantly improve survival of all existing runs of Chinook salmon that migrate through the Delta in order to facilitate positive population growth in the short term and subsequently achieve the narrative salmon protection objective identified in the 2006 Bay-Delta Plan to double the natural production of Chinook salmon from the average production from 1967 to 1991 consistent with the provisions of State and federal law. (State Water Board 2006a, p. 14.)

Species- Specific Recommendations

Delta Outflow

No specific Delta outflow criteria are recommended for Chinook salmon. Any flow needs would generally be met by the following inflow recommendations and by the Delta outflow criteria determined for estuarine dependant species discussed elsewhere in this report.

Sacramento River Inflows

The 2006 Bay-Delta Plan includes flow objectives for the Sacramento River at Rio Vista for the protection of fish and wildlife beneficial uses from September through December ranging from 3,000 to 4,500 cfs. (State Water Board 2006a, p. 15.) These flow objectives are in part intended to provide attraction and transport flows and suitable habitat conditions for Chinook salmon. (State Water Board 2006b, p. 49.) The 2006 Bay-Delta Plan includes Delta outflow objectives for the remainder of the year, which effectively provide Sacramento River inflows. However, the Bay-Delta Plan does not include any specific Sacramento River flow requirements for the remainder of the year, including the critical spring period.

Habitat alterations in the Delta limit Sacramento River salmon production primarily through reduced survival during the outmigrant (smolt) stage. Decreases in flow through the estuary, increased temperatures, and the proportion of flow diverted through the Delta Cross Channel and Georgiana Slough on the Sacramento River are associated with lower survival in the Delta of marked juvenile fall-run Sacramento River salmon. (DOI 1, p. 24.) In 1981 (p. 17-18) and 1982 (p. 404), Kjelson *et al.* reported that flow was positively correlated with juvenile fall-run Chinook salmon survival through the Delta and that temperature was negatively correlated with survival. In testimony before the State Water Board in 1987 Kjelson presented additional analyses that again showed that survival of fall-run Chinook salmon smolts through the Delta between Sacramento and Suisun Bay was found to be positively correlated to flow and negatively correlated to water temperature. (p. 36.) Smolt survival increased with increasing Sacramento River flow at Rio Vista, with maximum survival observed at or above about 20,000 and 30,000 cfs from April through June (p. 36), while no apparent relationship was found at flows between 7,000 and 19,000 cfs (p. 27), suggesting a potential threshold response to flow. Smolt survival was also found to be highest when water temperatures were below 66ºF. (p. 61.) In addition to increased survival, juvenile abundance has also been found to be higher with greater Sacramento River flow. (DFG 3, pp. 1 and 6.) The abundance of juvenile Chinook salmon leaving the Delta at Chipps Island was found to be highest when Rio Vista flows averaged above 20,000 cfs from April through June. (*Id*.)

Dettman *et al.* (1987) reanalyzed data from the 1987 Kjelson experiments and found a positive correlation between an index of spawning returns, based on coded-wire tagged fish, and both June and July outflow from the Delta. (p. 1.) In 1989, Kjelson and Brandes updated and confirmed Kjelson's 1987 findings again reporting that survival of smolts through the Delta from Sacramento to Suisun Bay was highly correlated to mean daily Sacramento River flow at Rio Vista. (p. 113.) In the State Water Board's 1992 hearings, USFWS (1992) presented additional evidence, based on data collected from 1988 to 1991, that increased flow in the Delta may increase migration rates of both wild and hatchery fish migrating from the North Delta (Sacramento and Courtland) to Chipps Island. (DOI 1, p. 26.)

In 2001, Brandes and McLain confirmed the relationships between water temperature, flow, and juvenile salmonid survival. (p. 95.) In 2006, Brandes *et al.* updated findings regarding the relationship between Sacramento River flows and survival and found that the catch of Chinook salmon smolts surveyed at Chipps Island between April and June of 1978 to 2005 was positively correlated with mean daily Sacramento River flow at Rio Vista between April and June. (p. 41-46.)

In addition to the flow versus juvenile fall-run Chinook salmon survival relationships discussed above, several studies show that loss of migrating salmonids within Georgiana Slough and the interior Delta is approximately twice that of fish remaining in the mainstem Sacramento River. (Kjelson and Brandes 1989; Brandes and McLain 2001; Vogel 2004, 2008; and Newman 2008 as cited in NMFS 3, p. 640). Recent studies and modeling efforts have found that increasing Sacramento River flow such that tidal reversal does not occur in the vicinity of Georgiana Slough and at the Cross Channel Gates would lessen the proportion of fish diverted into channels off the mainstem Sacramento River. (Perry *et al.* 2008, 2009.) Thus, closing the Delta Cross Channel and increasing the flow on the Sacramento River to levels where there is no upstream flow from the Sacramento River entering Georgiana Slough on the flood tide during the juvenile salmon migration period (November to June) will likely reduce the number of fish that enter the interior Delta and improve survival. (DOI 1, p. 24.) To achieve no bidirectional flow in the mainstem Sacramento River near Georgiana Slough, flow levels of 13,000 (personal communication Del Rosario) to 17,000 cfs at Freeport are needed. (DOI 1, p. 24.)

Monitoring of emigration of juvenile Chinook salmon on the lower Sacramento River near Knights Landing also indicates a relationship between timing and magnitude of flow in the Sacramento River and the migration timing and survival of Chinook salmon approaching the Delta from the upper Sacramento River basin. (Snider and Titus 1998, 2000a, 2000b, 2000c, and subsequent draft reports and data as cited in DFG 1, p. 7.) The emigration timing of juvenile late fall, winter, and spring-run Chinook salmon from the upper Sacramento River basin depends on increases in river flow through the lower Sacramento River in fall, with significant precipitation in the basin by November to sustain downstream migration of juvenile Chinook salmon approaching the Delta. (Titus 2004 as cited in DFG 1, p. 7.) Sacramento River flows at Wilkins Slough of 15,000 to 20,000 cfs following major precipitation events are associated with increased emigration. (DFG 1, p. 7 and NMFS 7, p. 2-4.)

Delays in precipitation producing flows result in delayed emigration which may result in increased susceptibility to in-river mortality from predation and poor water quality conditions. (DFG 1, p. 7.) Allen and Titus (2004) suggest that the longer the delay in migration, the lower the survival of juvenile salmon to the Delta. (as cited in DFG 1, p. 7.) DFG indicates that juvenile Chinook salmon appear to need increases in Sacramento River flow that correspond to flows in excess of 20,000 cfs at Wilkins Slough by November with similar peaks continuing past the first of the year. (DFG 1, p. 7.) Pulse flows in excess of 15,000 to 20,000 cfs may also be necessary to erode sediment in the upper Sacramento River downstream of Shasta to create turbid inflow pulses to the Delta. (AR/NHI 1, p. 32.)

Salmon are the only species considered for the Sacramento River inflow criteria; discussion of the flow criteria for Sacramento River inflows is therefore continued in Section 5.2, Sacramento River Inflow recommendations.

San Joaquin River Inflows

Currently the Merced, Tuolumne, and Stanislaus river tributaries to the San Joaquin River support fall-run Chinook salmon. Historically spring-run also inhabited the basin. Pursuant to the San Joaquin River Restoration effort, there are plans to reintroduce spring-run Chinook salmon to the main-stem river beginning in 2012. Since the 1980s (1980-1989), San Joaquin basin fall-run Chinook salmon escapement numbers have declined from approximately 26,000 fish to 13,000 fish in the 2000s (2000-2008). (TBI/NRDC 3, p. 22.) Flow related conditions are believed to be a significant cause of this decline.

The 2006 Bay-Delta Plan includes flow objectives for the San Joaquin River at Vernalis, largely for the protection of fall-run Chinook salmon. The plan includes base flows during the spring (February through June with the exception of mid-April through mid-May) that vary between 700 and 3,420 cfs based on water year type and required location ofX2. To improve juvenile fall-run Chinook salmon outmigration, the Plan also includes spring pulse flows (mid-April through mid-May) that vary between 3,110 and 8,620 cfs, however, those flows have never been implemented and have instead been replaced with the Vernalis Adaptive Management Plan (VAMP) flow targets for the past 10 years. The VAMP flows are lower than the pulse flow objectives and vary between 2,000 and 7,000 cfs based on existing flows and other conditions. (State Water Board 2006a, p. 24-26.) The 2006 Bay-Delta Plan also includes a flow objective of 1,000 to 2,000 cfs during October to support adult fall-run Chinook salmon migration. (State Water Board 2006b, p. 15-16.) The 2006 Bay-Delta Plan does not include any specific flow requirements during the remainder of the year. (State Water Board 2006b, pg. 50.)

Inflows from the San Joaquin River affect various life stages of Chinook salmon including adult migration, spawning, egg incubation, juvenile rearing, and juvenile emigration to the ocean. Evidence indicates that to maintain a viable Chinook salmon population, escapements should not decline below approximately 833 adult salmon per year (a total of 2,500 salmon in 3 years), and fluctuations in escapement between wet and dry years should be reduced by increasing dry year escapements and the percentages of hatchery fish should be reduced to no more than 10%. (Lindley and others 2007, as cited in CSPA 14, p. 3-4.) Mesick estimates that the Tuolumne River population is currently at a high risk of extinction (Mesick 2009); and that the Stanislaus and Merced river populations are also likely soon to be at a high risk of extinction due to high percentages of hatchery fish. (CSPA 7, p.4.)

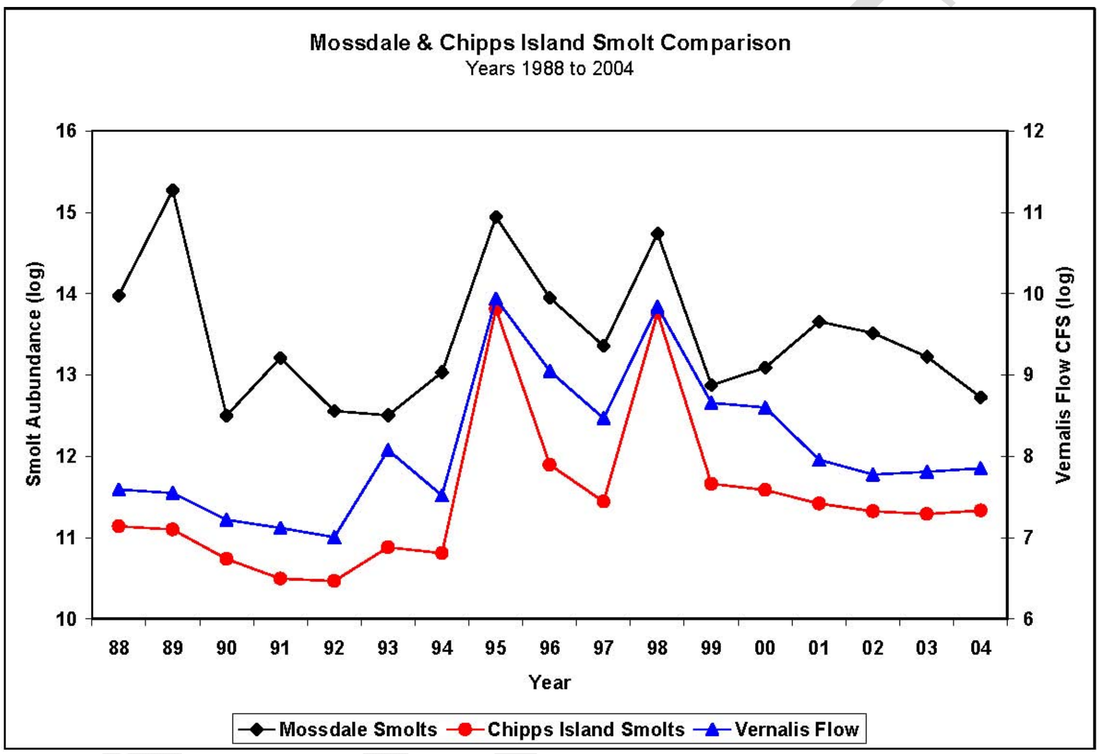
Mesick estimates that the decline in escapement on the Tuolumne River from 130,000 salmon in the 1940s to less than 500 in recent years is primarily due to inadequate minimum instream flow releases from La Grange Dam in late winter and spring during non-flood years. (CSPA 14, p. 1.) Mesick suggests that 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. (CSPA 14, p. 2.) Mesick indicates that 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. (CSPA 14, p. 1.)

Successful adult Chinook salmon migration depends on environmental conditions that cue the response to return to natal streams. Optimal conditions help to reduce straying and maintain egg viability and fecundity rates. (DFG 3, p. 2 and CSPA 7, p. 1.) Analyses of flow needs for the protection of adult fall-run migration conducted by Hallock and others from 1964 to 1967 indicate that the presence of Sacramento River water in the central and south Delta channels results in migration delays for both San Joaquin River and Sacramento River basin salmon. (Hallock *et al.,* 1970 as cited in DOI 1, p. 25.) These analyses also show that reverse flows on the San Joaquin River delay and potentially hamper migration. (*Id.*) In addition, analyses by Hallock show that water temperatures in excess of 65˚ F and low dissolved oxygen conditions of less than 5 mg/l in the San Joaquin River near Stockton act as a barrier to adult migration. (as cited in AFRP 2005, p. 11.) Delayed migration may result in reduced gamete viability under elevated temperatures and mortality to adults prior to spawning. (AFRP 2005, p. 12.)

Mesick found that up to 58% of Merced River Hatchery Chinook salmon strayed to the Sacramento River Basin when flows in the San Joaquin River were less than 3,500 cfs for ten days in late October, but stray rates were less than 6% when flows were at least 3,500 cfs. (CSPA 14, p. 15 and CSPA 7, p. 1.) Mesick indicates that providing 1,200 cfs flows from the tributaries to the San Joaquin River (Merced, Tuolumne, and Stanislaus) for ten days in late October increases escapement by an average of 10%. (Mesick 2009 as cited in CSPA 7, p. 1.) The 2005 AFRP includes similar recommendations for flows of 1,000 cfs from each of the San Joaquin River tributaries. (AFRP, p. 12.) Such flows would likely improve dissolved oxygen conditions, temperatures, and olfactory homing fidelity for San Joaquin basin salmon. (Harden Jones 1968, Quinn *et al.* 1989, Quinn 1990 as cited in EDF 1, p. 48.) To achieve olfactory homing fidelity and continuous flows for adult migration, the physical source of this water is at least as important as the volume or rate of flow, especially given that the entire volume of the San Joaquin River during the fall period is typically diverted at the southern Delta export facilities. (EDF 1. p. 48.) Even in the absence of exports, 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 rivers. (NMFS 2009, p.407 as cited in EDF 1, p. 48.)

Outmigration success of juvenile Chinook salmon is affected by multiple factors, including water diversions and conditions related to flow. Data show that smolt survival and resulting adult production is better in wet years. (Kjelson and Brandes, 1989, SJRGA, 2007 as cited in DOI 1, p. 24.) VAMP analyses indicate that San Joaquin River flow at Vernalis is positively associated with the probability of survival for outmigrating smolts from Dos Reis (downstream of the Old River bifurcation) to the Delta (Jersey Point). (Newman, 2008 as cited in DOI 1, p. 24.) A positive relationship has also been shown between salmon survival indices and flow at Jersey Point for fish released at Jersey Point. (USFWS 1992, p. 21 as cited in DOI 1, p. 24.) Data indicate that maximum San Joaquin basin adult fall-run chinook salmon escapement may be achieved with flows exceeding 20,000 cfs at Vernalis during the smolt emigration period of April 15 through June 15. (2006 VAMP report page 65; DOI 1, p. 25.) As indicated below in Figure

9, DFG found that more spring flow from the San Joaquin River tributaries results in more juvenile salmon leaving the tributaries, more salmon successfully migrating to the South Delta, and more juvenile salmon surviving through the Delta. (DFG 3, p. 17.) DFG concludes that the primary mechanism needed to substantially produce more smolts at Jersey Point is to substantially increase the spring Vernalis flow level (magnitude, duration, and frequency) which will produce more smolts leaving the San Joaquin River tributaries, and produce more smolts surviving to, and through, the South Delta. (DFG 3, p. 17-18.) DFG indicates that random rare and unpredictable poor ocean conditions may cause stochastic high mortality of juvenile salmon entering the ocean, but that the overwhelming evidence is that more spring flow results in higher smolt abundance, and higher smolt abundance equates to higher adult production. (DFG 3, p.17.)



Note: This figure shows the relationship of smolt abundance (log transformed) at Mossdale to estimate smolt abundance at Chipps Island by average spring (3/15 to 6/15) Vernalis flow level (log transformed). To estimate the number of smolts at Chipps Island the smolt survival vs. flow level relationship developed by Dr. Hubbard was applied on a daily basis to the Mossdale smolt abundance and out-migration pattern. Smolt abundance at Chipps Island (or stated differently smolt survival through the Delta on an annual basis) can change by an order of magnitude pending Vernalis flow rate. (DFG 3, p. 16.)

Figure 9. Salmon Smolt Survival and San Joaquin River Vernalis Flows

Elevated flows during the smolt outmigration period function as an environmental cue to trigger migration, facilitate transport of juveniles downstream, improve migration corridor conditions to inundate floodplains, reduce predation and improve temperature and other water quality conditions; these are all functions that are currently extremely impaired on the San Joaquin River. (e.g., “Steelhead stressor matrix,” NMFS 2009 as cited in TBI/NRDC 3, p. 7.) Under the 2006 Bay-Delta Plan, elevated flows are limited to approximately the mid-April to mid-May period. However, outmigration timing in the San Joaquin River basin occurs over a prolonged time frame from mid-March through June. (TBI/NRDC 3, p. 12-13.) This restricted window may impair population viability by limiting survival of fish that migrate outside of this time period, thus reducing the life history diversity and the genetic diversity of the population. (TBI/NRDC 3, p. 11-12.) Diverse migration timing increases population viability by making it more likely that at least some portion of the population is exposed to favorable ecological conditions in the Delta and into the ocean. (Smith *et al.* 1995 as cited in TBI/NRDC 3, p. 12.)

Temperature conditions in the San Joaquin River basin may limit smolt outmigration and survival. Lethal temperature thresholds for Pacific salmon depend, to some extent, on acclimation temperatures. (Myrick and Cech 2004 as cited in TBI/NRDC 3, p. 18.) Central Valley salmonids are generally temperature-stressed through at least some portion of their freshwater life-cycle. (e.g. Myrick and Cech 2004, 2005 as cited in TBI/NRDC 3, p. 18.) Lethal temperature effects commence in a range between 71.6˚ and 75.2˚ F (Baker *et al.*1995 as cited in TBI/NRDC 3, p. 18), with sub-lethal effects occurring at lower temperatures. Access to food also affects temperature responses. When fish have adequate access to food, growth increases with increasing temperature, but when food is limited (which is typical), optimal growth occurs at lower temperatures. (TBI/NRDC 3, p 18.) Marine and Cech (2004) observed decreased growth, smoltification success, and predator avoidance at temperatures above 68˚ F and that fish reared at temperatures between 62.6˚ and 68˚ F experienced increased predation compared to fish reared at between 55.4˚ and 60.8˚ F. (as cited in TBI/NRDC 3, p. 18.) Several studies indicate that optimal rearing temperatures for Chinook salmon range from 53.6˚ to 62.6F (Richter and Kolmes 2005 as cited in TBI/NRDC 3, p. 18.) Mesick found that Tuolumne River smolt outmigration rates and adult recruitment were highest when water temperatures were at or below 59˚F when smolts were migrating in the lower river. (Mesick 2009, p. 25.) Elevated temperatures may also affect competition between different species. (Reese and Harvey 2002 as cited in TBI/NRDC 3, p. 18.)

Temperature is determined by a number of factors including reservoir releases, channel geometry, and ambient air temperatures. As a result, a given flow may achieve different water temperatures depending on the other conditions listed above. Cain estimates that flows over 5,000 cfs in late spring (April to May) generally provide water temperatures (below 65˚ F) suitable for Chinook salmon, but that flows less than 5,000 cfs may be adequate to provide sufficient temperature conditions. (Cain 2003 as cited in TBI/NRDC 3, p 13-14.) Mesick indicates that salmon smolt survival can be improved by maintaining water temperatures near 59˚F from March 15 to May 15 and as low as practical from May 16 to June 15. (CSPA 7, p. 2-3.) To maintain mean water temperatures near 59˚F and maximum temperatures below 65˚F from March 15 to May 15 in the tributaries downstream to the confluence with the San Joaquin River, Mesick indicates that flows need to be increased in response to average air temperature. (CSPA 7, p. 3.)

There are several different estimates for flow needs on the San Joaquin River during the spring period to improve or double salmon populations on the San Joaquin River. The USFWS's 2005 *Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin* (2005 AFRP) concludes that the declines in salmon in the San Joaquin River basin primarily resulted from reductions in the frequency and magnitude of spring flooding in the basin from 1992-2004 compared to the baseline period of 1967-1991. (2005 AFRP, p. 1.) The AFRP states that the most likely method to increase production of fall-run Chinook salmon is to increase flows from February to March to increase survival of juveniles in the tributaries and smolts in the mainstem and then to increase flows from April to mid-June to increase smolt survival through the Delta. (*Id*.) Using salmon production models for the San Joaquin River Basin, the AFRP provides recommendations for the amount of flow at Vernalis that would be needed to double salmon production in the San Joaquin River basin. On average, over the four month period of February to May, the AFRP recommends that flows range from less than 4,000 cfs in critical years to a little more than 10,000 cfs in wet years. From March through June, AFRP recommends that flows average between about 4,500 cfs in critical years to more than 12,000 cfs in wet years. (2005 AFRP, p. 8-10.)

Using a non-linear regression empirical data driven fall-run Chinook salmon production model, DFG developed flow recommendations for the San Joaquin River from March 15 through June 15 to double Chinook salmon smolt production. DFG developed a variety of modeling scenarios to evaluate the effects of various combinations of flow magnitudes and durations in order to identify the combination of flow levels varied by water year type to achieve doubling of juveniles. Base flows for the March 15 through June 15 period vary between 1,500 cfs in critical years to 6,315 cfs in wet years. Pulse flow recommendations vary between 7,000 cfs and 15,000 cfs for durations of 31 to 70 days depending on water year type. (DFG 3, p. 34.)

In analyzing the relationship between Vernalis flow and cohort return ratios of San Joaquin River Chinook salmon, TBI/NRDC found that Vernalis average March through June flows of approximately 4,600 cfs corresponded to an equal probability for positive population growth or negative population growth. (TBI/NRDC 3, p. 24.) TBI/NRDC found that average March through June flows exceeding 5,000 cfs resulted in positive population growth in 84% of years with only 66% growth in years with flows less than 5,000 cfs. (*Id.)* TBI/NRDC found that flows of 6,000 cfs produced a similar response as the 5,000 cfs flows and flows of 4,000 cfs or lower resulted in significantly reduced population growth of only 37% of years. (*Id*.) The TBI/NRDC analysis suggests that 5,000 cfs may represent an important minimum flow threshold for salmon survival on the San Joaquin River. (*Id*.) Based on abundance to prior flow relationships, TBI/NRDC estimates that average March through June inflows of 10,000 cfs are likely to achieve the salmon doubling goal. (TBI/NRDC 3, p. 16-17.)

In addition to fall pulse flows for adult migration and spring flows to support juvenile emigration, additional flows on the San Joaquin River may be needed at other times of year to support Chinook salmon and their habitat. The 2006 Bay-Delta Plan does not include base flow objectives for the San Joaquin River. However, the Central Valley Regional Board's Water Quality Control Plan for the Sacramento and San Joaquin River Basins does include a year round dissolved oxygen objective of 5.0 mg/l at all times on the San Joaquin River within the Delta. (Central Valley Regional Board 2009,. III-5.0). The 2006 Bay-Delta Plan and the Central Valley Basin Plan also include a dissolved oxygen objective of 6.0 mg/L between Turner Cut and Stockton from September 1 through November 30. (*Id*.)

Current flow conditions on the San Joaquin River result in dissolved oxygen conditions below the existing DO objectives in the fall and winter in lower flow years. These conditions may result in delayed migration and mortality to San Joaquin River Chinook salmon, steelhead and other species. Increased flows would improve DO levels in the lower San Joaquin River. Additional flows at other times of year in the tributaries to the San Joaquin River would also provide improved conditions for steelhead inhabiting tributaries to the San Joaquin River (NMFS 3, p. 105) and would have additional benefits by reducing nutrients pollution and biological oxygen demand. (TBI/NRDC 3, p. 27.)

To reduce crowding of spawning adults during the fall, increased flows in the tributaries may also be needed from November through January to ensure protection of Chinook salmon. (AFRP, p. 12.) However, there is no evidence that increased flows would reduce spawner crowding or improve juvenile production. (*Id*.) Habitat modeling indicates that flows of up to 300 cfs on the San Joaquin River tributaries may provide optimum physical habitat during the fall. (AFRP 2005, p. 14.)

To maintain the ecosystem benefits of a healthy riparian forest, minimum flows and ramping rates for riparian recruitment may also be needed during late spring and early summer. (AFRP 2005, p. 14.) To protect over-summering steelhead and salmon, flows in the tributaries during the summer and fall are needed. To maintain minimal habitat of a suitable temperature (less than 65˚ F), flows between 150 and 325 cfs may be needed on each of the tributaries to the San Joaquin River. (AFRP 2005, pp. 14-15.)

The magnitude, duration, timing, and source of San Joaquin River inflows are important to San Joaquin River Chinook salmon migrating through the Delta and several different aspects of their life history. Inflows are needed to provide appropriate conditions to cue upstream adult migration to the San Joaquin River and its tributaries, adult holding, egg incubation, juvenile rearing, emigration from the San Joaquin River and its tributaries, and other functions. San Joaquin River inflows are important during the fall to provide attraction flows and are especially important during juvenile emigration periods. Flows on tributaries to the San Joaquin River are also important for egg incubation and rearing, in addition to migration.

As with the Sacramento River inflows, Chinook salmon are the only species considered for the San Joaquin River inflow criteria; discussion of flow criteria for San Joaquin River inflows is therefore continued in Section 5.3, San Joaquin River Inflow recommendations.

Hydrodynamics

All Central Valley Chinook salmon must migrate out of the Delta as juveniles and back through the Delta as adults returning to spawn. In addition, many Central Valley Chinook salmon also rear in the Delta for a period of time. (DOI 1, p. 53.) Delta exports affect salmon migrating through and rearing in the Delta by modifying tidally dominated flows in the channels. It is, however, difficult to quantitatively evaluate the direct and indirect effects of these hydrodynamic changes. Delta exports can cause a false attraction flow drawing fish to the export facilities where direct mortality from entrainment may occur. (DOI 1, p. 29.) More important than direct entrainment effects, however, may be the indirect effects caused by export operations increasing the amount of time salmon spend in channelized habitats where predation is high. (*id.*) Steady flows during drier periods (as opposed to pulse flows that occur during wetter periods) may increase these residence time effects. (DOI 1.)

Direct mortality from entrainment at the south Delta export facilities is most important for San Joaquin River and eastside tributary salmon (and steelhead). (DOI 1, p. 29.) Juvenile salmonids emigrate downstream on the San Joaquin River during the winter and spring. Salmonids from the Calaveras River basin and the Mokelumne River basin also use the lower San Joaquin River as a migration corridor. This lower reach of the San Joaquin River between the Port of Stockton and Jersey Point has many side channels leading toward the export facilities that draw water through the channels to the export pumps. (NMFS 3, p. 651.) Particle tracking model simulations and acoustic tagging studies indicate that migrating fish may be diverted into these channels and may be affected by flow in these channels. (Vogel 2004, SJRGA 2006, p. 68, SJRGA 2007, pp. 76-77, and NMFS 3, p. 651.) Analyses indicate that tagged fish may be more likely to choose to migrate south toward the export facilities during periods of elevated diversions than when exports were reduced. (Vogel 2004.)

Similarly, salmon that enter the San Joaquin River through Georgiana Slough from the Sacramento River may also be vulnerable to export effects. (NMFS 3, p. 652.) While fish may eventually find their way out of the Central Delta channels after entering them, migratory paths through the Central Delta channels increase the length and time that fish take to migrate to the ocean increasing their exposure to predation, increased temperatures, contaminants, and unscreened diversions. (NMFS 3, p. 651-652.)

Particle tracking modeling analyses indicate that as net reverse flows in Old and Middle rivers increase from -2,500 cfs to -3,500 cfs, particle entrainment changes from 10% to 20% and then again to 40% when flows are -5,000 cfs and 90% when flows are -7,000 cfs. (*id*.) Based on these findings, NMFS's OCAP Biological Opinion includes requirements that exports be reduced to limit negative Old and Middle river flows to -2,500 cfs to -5,000 cfs depending on the presence of salmonids from January 1 through June 15. (NMFS 3, p. 648.)

In addition to effects of net reverse flows in Old and Middle rivers, analyses concerning the effects of net reverse flows in the San Joaquin River at Jersey Point were also conducted and documented in the USFWS, 1995b *Working Paper on Restoration Needs, Habitat Restoration Actions to Double the Natural Production of Anadromous Fish in the Central Valley California* (USFWS, 1995b Working Paper). These analyses show that net reverse flows at Jersey Point decrease the survival of smolts migrating through the lower San Joaquin River. (USFWS 1992b as cited in AFRP 1995, p. 3Xe-19.) Net reverse flows on the lower San Joaquin River and diversions into the central Delta may also result in reduced survival for Sacramento River fall-run Chinook salmon. (AFRP 1995, p. 3Xe-19) Based on these factors, the AFRP includes a recommendation to maintain positive flows at Jersey Point of 1,000 cfs in critical and dry years, 2,000 cfs in below- and above-normal years, and 3,000 cfs in wet years from October 1 through June 30 to improve survival for all races and stocks of juvenile salmon and steelhead migrating through and rearing in the Delta. (*id*.)

In addition to relationships between reverse flows and entrainment effects, flows on the San Joaquin River versus exports also appear to be an important factor in protecting San Joaquin River Chinook salmon. Various studies show that, in general, juvenile salmon released downstream of the effects of the export facilities (Jersey Point) have higher survival out of the Delta than those released closer to the export facilities. (NMFS 3-Appendix 3, p. 74.) Studies also indicate that San Joaquin basin Chinook salmon production increases when the ratio of spring flows to exports increases. (DFG 2005, SJRGA 2007 as cited in NMFS 3-Appendix 3, p. 74.) However, it should be noted that flow at Vernalis appears to be the controlling factor. Increased flows in the San Joaquin River in the Delta may also benefit Sacramento basin salmon by reducing the amount of Sacramento River water that is pulled into the central Delta and increasing the amount of Sacramento River water that flows out to the Bay. (NMFS 3, Appendix 3, p. 74-75.) Based on these findings, the NMFS BO calls for export restrictions from April 1 through May 31 with Vernalis flows to export ratios ranging from 1.0 to 4.0 based on water year type, with unrestricted exports above flows of 21,750 cfs at Vernalis, in addition to other provisions for health and safety requirements. (NMFS 3, Appendix 3, p.73-74.)

Analyses by TBI/NRDC indicate that Vernalis flow to export ratios above 1.0 during the San Joaquin basin juvenile salmon outmigration period in the spring consistently correspond to higher escapement estimates two and half years later, with more than 10,000 fish in 76% of years. (TBI/NRDC 4, p. 11.) Vernalis flows to export ratios of less than 1.0 correspond to lower escapement estimates two and half years later, with more than 10,000 fish in only 33% of years. (id.) TBI/NRDC estimates that Vernalis flows to export ratios of greater than 4.0 would reach population abundance goals. (TBI/NRDC 4, pp. 11-12.)

Vernalis flows to export ratios also appear to be important during the fall period to provide improved migration conditions for adult San Joaquin basin salmon. Adult San Joaquin basin salmon migrate upstream through the Delta primarily during October when San Joaquin River flows are typically low. (AFRP 2005, p. 12.) As a result, when exports are high, little if any flow from the San Joaquin basin may make it out to the ocean to help guide San Joaquin basin salmon back to the basin to spawn. (*id*.) Analyses indicate that increased straying occurs when more than 400% of the flow at Vernalis is exported at the Delta pumping facilities (equivalent to a Vernalis flow to export ratio of 0.25). (*id*.) Straying rates decreased substantially when export rates were less than 300% of Vernalis flow. (*id.*)

Export related recommendations for salmon are provided in section 5.4, Hydrodynamic Recommendations.

<u>Floodplain Flows</u>

Juvenile salmon will rear on seasonally inundated floodplains when available. Such rearing in the Central Valley, in the Yolo Bypass and the Cosumnes River floodplain, has been found to have a positive effect on growth and apparent survival of juvenile Central Valley salmon through the Delta. (Sommer *et al*. 2001 and Jeffres *et al*. 2005 as cited in DOI 1, p. 27 and Sommer *et al*. 2005 and Jeffres *et al*. 2008 as cited in NMFS 3, p. 609.) The increased growth rates may be due to increased temperatures and increased food supplies. (DOI 1, p. 27, DFG 3, p. 3.) Floodplain rearing provides conditions that promote larger and faster growth which improves outmigration, predator avoidance, and ultimately survival. (Stillwater Science 2003 as cited in DFG 3, p. 6.) Increased survival may also be related to the fact that ephemeral floodplain habitat and other side-channels provide better habitat conditions for juvenile salmon than intertidal river channels during high flow events when, in the absence of such habitat, juvenile salmon may be displaced to these intertidal areas. (Grosholz and Gallo 2006 as cited in DOI 1, p. 27 and Stillwater Science as cited in DFG 3, p. 6.) The improved growing conditions provided by floodplain habitat are also believed to improve ocean survival resulting in higher adult return rates. (Healy 1982, Parker 1971 as cited in DOI 1, p. 28.)

While floodplain habitat is generally beneficial to salmon, it may also be detrimental under certain conditions. Areas with engineered water control structures have comparatively higher rates of stranding. (Sommer *et al*. 2005 as cited in DOI 1, p. 28.) In addition, high temperatures, low dissolved oxygen, and other water quality conditions that may occur on floodplains may adversely affect salmon. (DFG 3, p. 6.) Reduced depth may also make salmon more susceptible to predation. (*Id*.) Water depths of 30 cm or more are believed to reduce the risk of avian predation. (Gawlik 2002 as cited in DFG 3, p. 6.) Further, the most successful native fish are those that use the floodplain for rearing, but leave before the floodplain becomes disconnected to the river. (Moyle *et al*. 2007, DFG 3, p. 6.) From a restoration perspective, projects should be designed to drain completely to minimize formation of ponds in order to avoid stranding. (Jones and Stokes, 1999 as cited in DOI 1, p. 28.) Bioenergetic modeling indicates that with regard to increased temperatures, increased food availability may be sufficient to offset increased metabolic demands from higher water temperatures. (DFG 3, p. 6.) However, as temperatures increase, juveniles may be unable to migrate to areas of lower temperatures due to reduced swimming ability. (DFG 3, p. 7.) As a result, as summer temperatures increase, floodplain habitat should also decrease. (*id*.)

The timing of floodplain inundation for the protection of Central Valley Chinook salmon should generally occur from winter to mid-spring to coincide with the peak juvenile Chinook salmon outmigration period (which itself generally coincides with peak flows) and to avoid non-native access to the floodplain (which would generally occur in late-spring). (AR/NHI 1, p. 25.) The benefits of floodplain inundation generally increase with increasing duration, with even relatively short periods of two-weeks providing potential benefits to salmon. (Jeffres *et al*., 2008 as cited in AR/NHI 1, p. 25.) Benefits to salmon may also increase with increasing inter-annual frequency of flooding. Repeated pulse flows and associated increased residence times may be associated with increased productivity which would benefit salmon growth rates and potentially reduce stranding. (*id*.)

Table 4, developed by AR/NHI, provides estimated thresholds for inundating floodplain habitat under existing and potentially modified conditions. Inundation threshold refers to the discharge when floodwaters begin to inundate the floodplain. Target discharge is the amount of water necessary to produce substantial inundation and flow across the floodplain. (Source: AR/NHI 1, p. 30.)

Floodplain inundation recommendations for protection of salmon are provided in section 5.6.2, Floodplain Activation, under Other Measures.

Table 4. Inundation thresholds for floodplains and side channels at various locations along the Sacramento River

Location	**Stage (in feet)**	**Inundation Threshold (cfs)**	**Target Discharge (avg. cfs)**	**Gauge Location**	**Source**
Freemont Weir					
Existing crest	33.5	56,000	63,000	Verona	USGS
Proposed notch	17.5	23,100	35,000	Verona	USGS
Sutter Bypass					
Tisdale weir	45.5	21,000		Colusa	NOAA; Feyrer
Tisdail with notch					
Lower Sutter Bypass	25	30,000	30,000	Verona	USGS
Upper Sacramento Meander belt side channels	Various	10,000	12,000	Red Bluff	USGS

<u>American Shad (*Alosa sapidissima*)</u>

Status

This species is not listed pursuant to either theESA or CESA.

Life History[13]

The American shad (*Alosa sapidissima*) is an anadromous fish, introduced into California in the late 1880s, that has become an important sport fish within the San Francisco Estuary. American shad range from Alaska to Mexico and use major rivers between British Columbia and the Sacramento watershed for spawning. (Moyle 2002.)

[13] This section was largely extracted from CDFG Exhibit 1, pp. 26-27

American shad adults, at 3 to 5 years of age, return from the ocean and migrate into the freshwater reaches of the Sacramento and San Joaquin rivers during March through May, with peak migration occurring in May (Stevens *et al*. 1987). Within California, the major spawning run occurs in the Sacramento River up to Red Bluff and in adjoining American, Feather, and Yuba rivers with lesser use of Mokelumne, Cosumnes, and Stanislaus rivers and the Delta (Moyle 2002). Spawning takes place from May through early July (Stevens *et al*. 1987). Following their first spawning event, American shad will return annually to spawn up to seven years of age (Stevens *et al*. 1987). It is believed that river flow will affect the distribution of first time spawners, with numbers of newly mature adults spawning in rivers proportional to flows at time of arrival (Stevens *et al*. 1987). Spawning takes place in the main channels of the rivers with flows washing negatively buoyant eggs downstream. Depending upon temperature, larvae hatch from eggs in 3 to 12 days and will remain planktonic for 4 weeks (Moyle 2002). The lower Feather River and the Sacramento River from Colusa to the northern Delta provide the major summer nursery for larvae and juveniles, and flows drive the transport of young downstream, with wet years changing the location of the concentration of young and nursery area further downstream into the northern Delta (Stevens *et al*. 1987). Out migration of young American shad through the Delta occurs June through November (Stevens 1966). American shad spawned and rearing in the Delta and those that travel through the Delta during out migration are vulnerable to entrainment at the State and Federal pumping facilities; catches at the facilities some years have numbered in the millions (Stevens and Miller 1983). During migration to the ocean, young fish feed upon zooplankton, including copepods, mysids, and cladocerans, as well as amphipods (Stevens 1966, Moyle 2002). Most migrate to the ocean by the end of their first year, but some remain in the estuary (Stevens *et al*. 1987).

Population Abundance and its Relationship to Flow

Year class strength correlates positively with river flow during the spawning and nursery period (April-June) (Stevens and Miller 1983). American shad exhibit a weak but significant relationship to X2, (Kimmerer 2002a). After 1987, the relationship changed such that abundance increased per unit flow (Kimmerer 2002a, Kimmerer 2009). The X2 versus abundance relationship has remained intact into recent years (Kimmerer *et al*. 2009). In addition, Kimmerer *et al*. (2009) found that American shad had a habitat relationship (defined by salinity and Secchi depth) to X2 that appeared consistent with its relationship of abundance to X2 (i.e., slopes for abundance versus X2 and habitat versus X2 were similar), which provides some support for the idea that increasing quantity of habitat could explain the X2 relationship for this species (a possible causal mechanism for the abundance versus X2 relationship). Stevens and Miller (1983) determined that the apparent general effect of high flow on all of the species they examined, including American shad, is to increase the quality and quantity of nursery habitat and more widely disperse the young fish, thus reducing density-dependent mortality.

Population Goal

Immediate goal is to maintain viable populations of this species by providing sufficient flows to facilitate attraction of spawners, survival of eggs and larvae, and dispersal of young fish to suitable nursery habitats.

Species-Specific Recommendations

<u>Delta Outflow</u>

The DFG's current science-based conceptual model is that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry (DFG 2, p. 6). Maintaining X2 at 75 km and 64 km corresponds to net

Delta outflows of approximately 11,400 cfs and 29,200 cfs, respectively. As noted by DFG, X2, in this instance, is a surrogate for tributary and mainstem river inflows to the Delta that support egg and larval survival. The species specific flow criteria to protect American shad shown in Table 5 are consistent with those submitted by DFG (closing comments, p. 7).

<u>Inflows</u>

No explicit recommendations for American shad inflow requirements were identified in the record. The DFG provided outflow criteria for this species based on positioning X2 in Suisun Bay (DFG closing comments, p. 7); noting that in this instance X2 is a surrogate for tributary and mainstem river inflows. As noted above, year class strength correlates positively with river flow during the spawning and nursery period (April to June) (Steven and Miller 1983). Flows must be sufficient to attract American shad spawners into Sacramento River tributaries, transport and disperse the young fish to suitable nursery habitat, and reduce the probability of entrainment of young fish and their food organisms in water diversions (DFG 1987 [Exh 23, p. 23]). Water development has reduced flows during the spring and early summer periods which are most critical in this respect (DFG 1987 [Exh 23, p. 23]). The spawning and nursery period, during which inflows appear to be most critical for this species, generally correspond to important periods for other more sensitive species (e.g., salmon outmigration, longfin smelt spawning and rearing). It is anticipated that by providing sufficient flows to meet the outflow criteria recommended above, favorable river conditions will be provided to support American shad spawning and rearing.

<u>Old and Middle River Flows</u>

American shad spawned and rearing in the Delta and those that travel through the Delta during out migration are vulnerable to entrainment at the State and Federal export facilities; in some years catches at the facilities have numbered in the millions (Stevens and Miller 1983). Although evaluations of screening efficiency comparable to studies for striped bass and salmon had not been completed for American shad, DFG believed in 1987 that larger fish in the fall were screened fairly efficiently, while screening efficiencies for newly metamorphosed juveniles in the late spring and early summer were quite low (DFG 1987 [Exh 23, p. 20]). American shad are notoriously intolerant of handling. Tests have shown that losses of American shad that were successfully screened exceeded 50 percent during the summer months, with slightly lower mortalities during the cooler fall months (DFG 1987 [Exh 23, p. 22]). These high handling mortalities suggest the only practical strategy for reducing losses may be pumping schedules that minimize shad entrainment (DFG 1987 [Exh 23, p. 22]). However, no recommendations specific to American shad and OMR flows or pumping restrictions were identified in the record. OMR flow criteria are intended to protect salmon, delta smelt, and longfin smelt populations, as well as restrictions stipulated in the OCAP Biological Opinions (NMFS 3, pp. 648-653; USFWS 2008) are likely to reduce the number of American shad entrained at the export facilities.

Table 5. Delta Outflows to Protect American Shad

Effect or Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spawning; Nursery	All	--	--	--	X2[1] – 75 to 64 km (~11400 – 29200 cfs)			--	--	--	--	--	--
[1] For this species, X2 is a surrogate for tributary and mainstem river inflows to the Delta that support egg and larval survival. Source: DFG 1, p. 26; DFG 2, p. 6, DFG closing comments, p. 7													

4.2.4 Life History Requirements – Pelagic Species

Following are life history and species-specific requirements for Longfin Smelt, Delta Smelt, Sacramento Splittail, Starry Flounder, Bay Shrimp, and Zooplankton

<u>Longfin Smelt (*Spirinchus thaleichthys*)</u>

Status

Longfin smelt is listed as a candidate for threatened status under the California Endangered Species Act (DFG 2010).

Life History

Longfin smelt are a native species that live two years with females reproducing in their second year. Both juveniles and adults feed on zooplankton. Smelt are an anadromous, open water species moving between fresh and salt water. Adults spend time in San Francisco Bay and may go outside the Golden Gate for short periods. Adults aggregate in Suisun Bay and the western Delta in late fall and migrate upstream to spawn in freshwater as water temperatures drop below 18˚C (Baxter *et al*. 2009). The spawning habitat is between the confluence of the Sacramento and San Joaquin Rivers (around Point Sacramento) to Rio Vista on the Sacramento side and Medford Island on the San Joaquin River. Spawning activity appears to decrease with distance from the low salinity zone, so the location of X2 influences how far spawning migrations extend into the Delta (Baxter *et al*. 2009). Spawning takes place between November and April with peak reproduction in January. Eggs are deposited on the bottom and hatch between December and May into buoyant larvae. Peak hatch is in February. Net Delta outflow transports the larvae and juvenile fish to higher salinity water.

Population Abundance and its Relationship to Flow

The population abundance of longfin smelt is positively correlated with spring Delta outflow and inversely related to Old and Middle River spring reverse flows (OMR). The correlations are interpreted to mean that net Delta outflow and OMR are, at least partially, responsible for controlling the abundance of smelt. Modifications in the two flow regimes are intended to begin to stabilize and increase the population abundance of longfin smelt. Each correlation is discussed below.

The population abundance of longfin smelt is positively related to Delta outflow during winter and spring (Jassby *et al*. 1995; Rosenfield and Baxter 2007; Kimmerer 2002a; Kimmerer *et al*. 2009). The statistically strongest outflow averaging period is January-June. The abundance relationships are from the fall mid-water trawl (FMWT) survey, the bay study mid-water trawl, and the bay study otter trawl. All three surveys show statistically significant positive relationships between the abundance of juveniles/adults and Delta outflow. There has been a decrease in the carrying capacity of the estuary since 1988, presumably because of the invasion of the clam *Corbula*, but the overall winter spring relationship is still statistically significant. More spring outflow results in more smelt as measured by all three indices. The biological basis for the spring outflow relationship is not known. Baxter *et al.* (2009) speculate that the larvae may benefit from increased downstream transport, increased food production, and a reduction in entrainment losses at the State Water Project (SWP) and Central Valley Project (CVP) pumps.

The population abundance of juvenile and adult longfin smelt, as measured by the FMWT index, is also inversely related to the number of fish salvaged at the SWP and CVP pumping facilities (TBI/NRDC 4, pp. 19-20). High pumping rates at the two facilities cause reverse flows on Old and Middle Rivers which passively move all age groups of longfin smelt toward entrainment at the pumps. A subset of the juvenile and adult populations are counted at the pumping facilities Larval smelt (<20 mm) pass through the louvers and are not counted. Peak adult and juvenile smelt salvage occur in January and April to May, respectively (Baxter *et al*. 2009). Entrainment of larval smelt, although not counted, are likely greatest between March and April (TBI/NRDC 4, p.16). Adult and juvenile longfin smelt salvage is an inverse logarithmic function of OMR flows (Grimaldo *et al*. 2009). Increasing Old and Middle reverse flows results in an exponential increase in salvage loss. Juvenile smelt salvage is a negative function of Delta outflow between March and May (TBI/NRDC 4, p.17). Higher outflow in these three months results in lower entrainment loss. This may result from the fact that during low outflow years spawning occurs higher in the system, placing adults and subsequent larvae and juveniles closer to the pumps. Also, negative OMR can either passively draw fish to the pumps or at high levels mis-cue them as to the direction of higher salinity.. A consequence is that juvenile smelt are most in danger of entrainment at the CVP and SWP pumping facilities during low outflow years with high OMR flow.

The OMR results are consistent with the findings of Baxter *et al* (2009). The authors used the Delta Simulation Model (DSM2, particle tracking subroutine) to predict the fate of larval longfin smelt. The particle tracking model predicted that larva entrainment at the SWP might be substantial (2 to10%), particularly during the relatively low outflow conditions modeled. Baxter *et al*. (2009) also identified a significant negative relationship between spring (April to June) OMR flows and the sum of combined SWP and CVP juvenile longfin smelt salvage. Juvenile smelt salvage increased rapidly as OMR became more negative than 2,000 cfs. However, as winter-spring or just spring outflows increased, shifting the position of X2 downstream, the salvage of juvenile longfin smelt decreased significantly. Also, particle entrapment decreased, even with a high negative OMR, when the flow of the Sacramento River at Rio Vista increased above 40,000 cfs. Entrainment of particles almost ceased at flows of 55,000 cfs.

TBI/NRDC (TBI/NRDC 2, pp. 15-19) conducted a generation to generation population abundance analysis for longfin smelt versus Delta outflow. The authors found that the probability of an increase in the FMWT smelt index was greater than 50% in years when Delta outflow averaged 60,000 and 35,000-cfs between January to March and March to May, respectively. The analysis is important because it suggests a potential outflow trigger for growing the population.

There is also evidence that longfin smelt is food limited (SFWC 1, p.59). The FMWT index for longfin smelt is positively correlated in a multiple linear regression with the previous spring's *Eurytemora affinis* abundance (an important prey organism) after weighting the data by the proportion of smelt at each *Eurytemora* sampling station and normalizing by the previous years FMWT index. The spring population abundance of *Eurytemora* has itself been positively correlated with outflow between March and May since the introduction of *Corbula* (Kimmerer, 2002a). The positive correlation between *Eurytemora* abundance and spring outflow provides further support for a spring outflow criterion.

Longfin smelt populations are at an all time low. The average FMWT index for years 2001-2009 are only 3 percent of the average value for 1967 to 1987, a time period when pelagic fish did better in the estuary. The FMWT index for two of the last three years is the lowest on record.

Delta outflow recommendations to protect longfin smelt received from participants are summarized in Table 6. The Department of Fish and Game (DFG closing Comments, p.7) recommended an outflow between 12,400 and 28,000 cfs from January to June of all water year types to help transport larval/juvenile smelt seaward in the estuary. TBI/NRDC (TBI/NRDC 2, pp. 19-26; TBI/NRDC Closing Comments, pp. 6-7) also made spring outflow recommendations based on five sets of hydrologic conditions for the Central Valley. The TBI/NRDC recommendations range between 14,000 and 140,000 cfs for January through March and 10,000 to 110,000 cfs between April and May. The TBI/NRDC recommendations are based on their longfin smelt population abundance analysis which demonstrated positive growth in years with high spring outflow.

The four sets of OMR recommendations to protect longfin smelt received from participants are summarized in
Table 7. TBI/NRDC (TBI/NRDC 4, pp. 21 & 30; TBI/NRDC Closing Comments, p. 11) recommended reducing entrainment losses of smelt in dry years (March to May when outflow is less than 18,000 cfs) and population abundance is low (FMWT index less than 500) by maintaining positive OMR flows in April and May. Alternatively, if the index is greater than 500 and outflow is low, then OMR should not be more negative than -1,500 cfs. The Department of the Interior (DOI 1, p.53) made a non-species specific recommendation that OMR should be positive in all months between January and June. CSPA/CWIN made a non-species specific recommendations that combined export rates equal zero from mid-March through June (CSPA 1, p.8; CWIN 2, p. 26). Finally, the California Department of Fish and Game has issued an Incidental Take Permit for longfin smelt (2081-2009-001-03) that restrict OMR in some years based on the recommendations of the Delta Smelt Workgroup (Baxter *et al*. 2009)

Table 6. Participant Recommendations for Delta Outflow to Protect Longfin Smelt

Organization	Water Year	Jan	Feb	Mar	April	May	Jun
TBI/NRDC	81-100% (driest years)	14,000 – 21,000			10,000 – 17,500		3000 – 4200
	61-80%	21,000 – 35,200			17,500 – 29,000		4200 – 5000
	41-60%	35,200 – 55,000			29,000 – 42,000		5000 – 8500
	21-40%	55,000 – 87,500			42,000 – 62,500		8500 – 25000
	0-20% (wettest years)	87,500 – 140,000			62,500 – 110,000		25000 – 50000
DFG	all	12,400 to 28,000					

Population Goal

The immediate goal is to stabilize the longfin smelt population, as measured by the FMWT index, and to begin to grow the population. The long-term goal is to achieve the objective of the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (US Fish and Wildlife Service 1995). The plan says longfin smelt will be considered recovered when its abundance is similar to the 1967 to 1984 period.

Species- Specific Recommendations

Table 8 contains the species-specific flow criteria to protect longfin smelt. The purpose of the outflow recommendations is to stabilize and begin to grow the longfin smelt population; positive population growth is expected in half of all years with these flows. The OMR flow recommendations are intended to protect the smelt population from entrainment in the CVP and SWP pumping facilities during years with limited outflow (dry and critically dry years). As noted above, longfin smelt spawn in the Delta on both the Sacramento and San Joaquin rivers. Longfin smelt optimally need positive flow on both river systems to move buoyant larvae downstream and away from the influence of the pumps.

Table 7. Participant Recommendations for Old and Middle Reverse Flows to Protect Longfin Smelt

Organization	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006 Bay-Delta Plan	all	Some restrictions, given in terms of E/I ratios											
DFG Take Permit	all	-1,250 to -5,000[1]											
TBI/NRDC	C/D				>0[2] or -1,500[3]								
DOI	all	>0											
CSPA/CWIN	all			Combined export rates = 0									

[1] This condition is not likely to occur in many years and is based on requirements in the California Department of Fish and Game Incidental Take Permit 2081-2009-001-03 and the advice of the Smelt Working Team. The condition is most likely to occur in dry or critical years when longfin spawn higher in the Delta and hydrology does not rapidly transport hatched larvae from the central and south Delta

[2] If FMWT index is less than 500

[3] If FMWT index is greater than 500

Table 8. Delta Outflows to Protect Longfin Smelt

Flow Type	Water Year Type	Jan	Feb	Mar	April	May	Jun
Net Delta Outflow	C	14,000 – 21,000			10,000 – 17,500		3,000 – 4,200
	D	21,000 – 35,200			17,500 – 29,000		4,200 – 5,000
	BN	35,200 – >50,000			29,000 – 42,000		5,000 – 8,500
	AN	>50,000			>42,000		8,500 – 25,000
	W	>50,000			>42,000		25,000 – 50,000
OMR	C/D				>0[1] or -1,500[2]		

[1] If FMWT index is less than 500

[2] If FMWT index is greater than 500

Delta Smelt (*Hypomesus transpacificus*)

Status

Delta smelt is listed as endangered under the California Endangered Species Act and threatened under the Federal Endangered Species Act (DFG 2010).

Life History

Delta smelt are endemic to the Sacramento-San Joaquin Delta. Smelt have an annual, one-year life cycle although some females may live and reproduce in their second year (Bennett 2005). Smelt complete their entire life cycle in the Delta and upper estuary. Delta smelt feed primarily on planktonic copepods, cladocerans, and amphipods (Baxter *et al*. 2008). In September or October smelt begin a slow upstream migration toward their freshwater spawning areas in the upper Delta, a process that may take several months (Moyle 2002). The upstream migration may be triggered by Sacramento River flows in excess of 25,000 cfs (DSWG 2006). Spawning can occur from late February to July, although most reproduction appears to take place between early April and mid-May (Moyle 2002). Spawning areas include the lower Sacramento, Mokelumne, and San Joaquin rivers, the west and south Delta, Suisun Bay, Suisun Marsh, and occasionally in wet years, the Napa River (Wang 2007). Eggs are negatively buoyant and adhesive with larvae hatching in about 13 days (Wang, 1986; Mager 1996). Upon hatching, the larvae are semi-buoyant staying near the bottom. Within a few weeks, larvae develop an air bladder and become pelagic, utilizing vertical water column movement to maintain their longitudinal position in the estuary (Moyle 2002).

Freshwater outflow during spring (March to June) affects the distribution of larvae by transporting them seaward toward the low salinity zone (Dege and Brown 2004). High outflow during spring can carry some smelt downstream of their traditional rearing areas in the west Delta and Suisun Bay and into San Pablo Bay where long-term growth and survival may not be optimal. Conversely, periods of low outflow increase residence time in the Delta. Increasing residence time in the Delta probably prolongs the exposure of smelt to higher water temperatures and increased risk of entrainment at the State and Federal pumping facilities (Moyle 2002). Ideal rearing habitat conditions are believed to be shallow water areas most commonly found in Suisun Bay (Bennett 2005). When the mixing zone was located in Suisun Bay, it may in the past have provided optimal conditions for algal and zooplankton growth, an important food source for delta smelt (Moyle 2002). However, the quality of habitat in Suisun Bay appears to have deteriorated with the introduction of the clam *Corbula* which now consumes much of the phytoplankton that previously supported large populations of zooplankton. Since 2005 approximately 40% of the smelt population now remains in the Cache Slough complex north of the Delta. This may represent an alternative life history strategy in which the fish stay upstream of the low salinity zone (LSZ) through maturity (Sommer *et al*., 2009).

Population Abundance and Relationship to Flow

Delta smelt population abundance is measured in the summer tow net survey, the fall mid water trawl (FMWT) survey and the 20-mm spring-summer survey of juvenile fish (Kimmerer *et al*. 2009). All three indices indicate that smelt populations are at an all time low and may be in danger of extinction. The average FMWT index for 2001-2009 is only 20 percent of the value measured between 1967 and 1987, a time period when pelagic fish did better in the estuary. FMWT indices for the last six years (2004 to 2009) include all of the lowest values on record. The cause of the decline is unclear but likely includes some combination of flow, export pumping, food limitation, and introduced species.

Three types of flow have been hypothesized to affect delta smelt abundance. These are spring and fall Delta outflow and Old and Middle Rivers (OMR) reverse flow. Testimony was received at the Outflow Proceeding recommending management changes to all three types of flow (Table 9 and Table 10). In the past there has been a weak negative relationship between spring Delta outflow and smelt abundance as measured by the FMWT, however, the relationship has now disappeared (Kimmerer *et al*. 2009). The cause for the disappearance of the spring outflow-abundance relationship is not known but may result from the deterioration of rearing habitat in Suisun Bay because of colonization by the clam *Corbula.*

Several organizations recommend a fall outflow criterion for protection of delta smelt (Table 9). The primary purpose of a fall outflow criterion is to increase the quality and quantity of rearing habitat for smelt (Nobriga *et al*. 2008; Feyrer *et al*. 2007; Feyrer *et al*., in review). Rearing habitat is hypothesized to increase when the fall LSZ is downstream of the confluence of the Sacramento and San Joaquin Rivers. This corresponds to outflows greater than about 7,500 cfs between September and November, which would have to be achieved by release of water from upstream reservoirs. Grimaldo *et al*. (2009) found that X2 was a predictor for salvage of adult delta smelt at the intra-annual scale when Old and Middle River flows were negative. Moving X2 westward in the fall serves to increase the geographic and hydrologic distance of delta smelt from the influence of the export facilities and therefore likely reduces the risk of entrainment (DOI 1, p. 34). The U.S. Fish and Wildlife Service (2008) recommended in their Delta Smelt Biological Opinion that the LSZ be maintained in the fall of above normal and wet water year types in Suisun Bay (Action 4). The action was restricted to above average water years to insure that sufficient cold water pool remained for steelhead and salmon and because these are the years in which project operations have most significantly affected fall conditions (USFWS 2008). The National Academy of Sciences (2010) commented on this action in their review:

> ”The statistical relationship is complex. When the area of highly suitable habitat …is low, either high or low FMWT indices can occur. In other words, delta smelt can be successful even when habitat is restricted. More important, however, is that the lowest abundances all occurred when the habitat-area index was less than 6,000 ha. This could mean that reduced habitat area is a necessary condition for the worst population collapses, but it is not the only cause of the collapse… The … action is conceptually sound … to the degree that the amount of habitat available for smelt limits their abundance… however…the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand”. The National Academy of Sciences noted approvingly that the U.S. Fish and Wildlife Service (2008) required “additional studies addressing elements of the habitat conceptual model to be formulated … and … implemented promptly.”

Table 9. Participant Recommendations for Delta Outflow to Protect Delta Smelt

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006 Bay-Delta Plan [1]	C	4500 [2]	7100 – 29200 [3]					4000	3000	3000	3000	3500	
	D	4500	7100 - 29200					5000	3500	3000	4000	4500	
	BN	4500	7100 - 29200					6500	4000	3000	4000	4500	
	AN	4500	7100 - 29200					8000	4000	3000	4000	4500	
	W	4500	7100 - 29200					8000	4000	3000	4000	4500	
USFWS OCAP[1]	AN									7000 [4]			
	W									12400			
EDF/Stillwater Sciences	C			26800	17500	17500	7500	4800	4800	4800	4800	4800	
	D			26800	17500	17500	7500	4800	4800	4800	4800	4800	
	BN			26800	26800	26800	11500	7500	7500	7500	7500	7500	
	AN			26800	26800	26800	11500	11500	11500	11500	11500	11500	
	W			26800	26800	26800	17500	17500	17500	17500	17500	17500	
TBI/NRDC	81-100%									5750 - 7500			
	61-80%									7500 - 9000			
	41-60%									9700 - 12400			
	21-40%									12400 - 16100			
	0-20%									16100 - 19000			

[1] 2006 Bay-Delta Plan and USFWS-OCAP Biological Opinion flows shown for comparative purposes

[2] All water year types - Increase to 6000 if the Dec 8RI is > than 800 TAF

[3] Minimum Delta outflow calculated from a series of rules that are described in Tables 3 and 4 of the 2006 Bay-Delta Plan

[4] Delta smelt biological opinion (RPA concerning Fall X2 requirements [pp282-283] - improve fall habitat [quality and quantity] for DS) (references USFWS 2008, Feyrer *et al* 2007, Feyrer *et al* in revision) - Sept-Oct in yrs when the preceding precipitation and runoff period was wet or above normal, as defined by the Sacramento Basin 40-30-30 Index, USBR and DWR shall provide sufficient Delta outflow to maintain monthly average X2 no greater than 74 km and 81 km in Wet and Above Normal yrs, respectively. During any November when the preceding water yr was W or AN, as defined by Sac Basin 40-30-30 index, all inflow into the CVP/SWP reservoirs in the Sac Basin shall be added to reservoir releases in Nov to provide additional increment of outflow from Delta to augment Delta outflow up to the fall X2 of 74 km and 81 km for W and AN water yrs, respectively. In the event there is an increase in storage during any Nov this action applies, the increase in reservoir storage shall be released in December to augment the December outflow requirements in the 2006 Bay-Delta Plan.

Table 10. Participant Recommendations for Old and Middle River Flows to Protect Delta Smelt

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006 Bay-Delta Plan	all	Some restrictions, given in terms of E/I ratios											
USFWS - OCAP Bio Op	all	Action 1: -2000 cfs for 14 days once turbidity or salvage trigger has been met. Action 2: range btw -1250 and -5000 cfs [1]			Range between -1,250 and -5,000 [2]								See Jan-Mar
USFWS	all	>0 [3]											
CSPA/CWIN				Combined Export Rates = 0[3]									
TBI/NRDC	all	>-1,500											>-1500

[1] USFWS OCAP Bio Opinion - RPA re: OMR flows. Component 1 - Adults (Dec - Mar) - Action 1 (protect up migrating delta smelt) - once turbidity or salvage trigger has been met, -2000 cfs OMR for 14 days to reduce flows towards the pumps. Action 2 (protect delta smelt after migration prior to spawning) - OMR range between -1250 and -5000 cfs determined using adaptive process until spawning detected. pp.280-282

[2] USFWS OCAP Bio Opinion - RPA re: OMR flows. Component 2 - Larvae/Juveniles - action starts once temperatures hit 12 degrees C at three Delta monitoring stations or when spent female is caught. OMR range between -1250 and -5000 cfs determined using adaptive process. OMR flows continue until June 30 or when Delta water temperatures reach 25 degrees C, whichever comes first. pp. 280-282

[3] This recommendations by the USFWS and CSPA/CWIN were not species specific.

It should be reiterated that this measure should be implemented within an adaptive framework, including completing studies designed to clarify the mechanism(s) underlying the effects of fall habitat on the delta smelt population, and a comprehensive review of the outcomes of the action and its effectiveness. Additional fall flows, beyond those stipulated in the Fall X2 action, for the protection of delta smelt are not recommended at this time if it will compete with preservation of the cold water pool for salmonids before additional studies are conducted demonstrating its importance to the survival of delta smelt.

OMR can affect delta smelt by pulling them into the central Delta where they are at risk of entrainment in the SWP and CVP pumps. Recent studies have shown that entrainment of delta smelt and other pelagic species increases as OMR flows become more negative (Grimaldo *et al*. 2009; Kimmerer 2008). Delta smelt are at risk as juveniles in the spring during the downstream migration to their rearing area, and as adults between the fall and early spring, as they move upstream to spawn. Salvage of age-0 delta smelt at the intra-annual scale has been found to be related to the abundance of these fish in the Delta, while OMR flow and turbidity were also strong predictors (Grimaldo *et al*. 2009). This suggests that within a given year, the mechanism influencing entrainment is probably a measure of the degree to which their habitat overlaps with the hydrodynamic “footprint” of the OMR flows (Grimaldo *et al*. 2009). Particle tracking model (PTM) results suggest that entrainment is a function of both OMR and river outflow (Kimmerer and Nobriga 2008). PTM results may be more applicable to neutrally buoyant larvae and poorly swimming juveniles than adult smelt. Particle entrainment increased as a logarithmic function of increasing negative OMR and decreases in river outflow. The highest entrainment was observed at high negative OMR and low outflow. PTM results suggest that entrainment loss might be as high as 40% of the total smelt population in some years (Kimmerer 2008). Similar results were obtained by Baxter *et al*. (2009) when evaluating entrainment of longfin smelt using PTM. Juvenile longfin smelt salvage increased rapidly as OMR became more negative than 2,000 cfs. Also, particle entrapment decreased, even with a high negative OMR, when the flow of the Sacramento River at Rio Vista increased above 40,000 cfs. Entrainment of particles almost ceased at flows of 55,000 cfs.

Field population investigations support some of the spring PTM results. Gravid females and larvae are present in the Delta as early as March and April (Bennett 2005). However, analysis of otolith data on individuals collected later in the year by Bennett *et al*. (unpublished data) showed that few of the early progeny survived if spawned prior to the Vernalis Adaptive Management Project (VAMP) time period (typically 15 April to 15 May). The hydrodynamic data showed high negative OMR flows in the months preceding and after the VAMP, leading the researchers to conclude that high winter and early spring OMR were selectively entraining the early spawning and/or early hatching cohort of the delta smelt population. However, Baxter *et al*. (2008) stated that “under this hypothesis, the most important result of the loss of early spawning females would manifest itself in the year following the loss, and would therefore not necessarily be detected by analyses relating fall abundance indices to same-year predictors.” No statistical relationships have been found between either OMR or CVP and SWP pumping rates and smelt population abundance (Bennett 2005).

Entrainment of adult delta smelt occurs following the first substantial precipitation event ("first flush"), characterized by sudden increases in river inflows and turbidity, in the estuary as they begin their migration into the tidal freshwater areas of the Delta (Grimaldo *et al*. 2009). Patterns of adult entrainment are distinctly unimodal, suggesting that migration is a large population-level event, as opposed to being intermittent or random (DOI 1, p. 36). Grimaldo *et al*. (2009) provided evidence suggesting that entrainment during these "first flush" periods could be reduced if export reductions were made at the onset of such periods.

The USFWS Biological Opinion (2008) identifies turbidity criteria for which to trigger first flush export reductions, but total Delta outflow greater than 25,000 cfs could serve as an alternate or additional trigger since such flows are highly correlated with turbidity (Grimaldo *et al*. 2009, DOI 1, p. 36). Managing OMR flows to thresholds at which entrainment or populations losses increase rapidly, represents a strategy for providing additional protection for adult smelt in the winter period (Dec-Mar) (DOI 1, p.36). The USFWS Biological Opinion (2008) identified the lower OMR threshold as -5000 cfs based on observed OMR versus salvage relationships from a longer data period (USFWS 2008) and additional data summarized over a more recent period (Grimaldo *et al*. 2009). The -5000 cfs OMR threshold is appropriate because it is the level where population losses consistently exceed 10% (USFWS 2008, DOI 1, p. 36). Adult delta smelt entrainment varies according to their distribution in the Delta following their upstream migration. The population is at higher entrainment risk if the majority of the population migrates into the south Delta, which may require OMR flows to be more positive than -5000 cfs to reduce high entrainment. Conversely, if the majority of the population migrates up the lower Sacramento River or north Delta, a smaller entrainment risk is presumed, which would allow for OMR flow to be more negative than 5000 cfs for an extended period of time or until conditions warrant a more protective OMR flow (DOI 1, p.36).

The U.S. Fish and Wildlife Service (2008) Biological Opinion for delta smelt includes OMR restrictions to protect both spawning adult and out-migrating young. Component 1 of the Opinion has two action items; both are to protect adult delta smelt. Action 1 restricts OMR flow in fall to -2,000 cfs for 14 days when a turbidity or salvage trigger has been met. Both triggers have previously been correlated with the upstream movement of spawning adult smelt. Action 2 commences immediately after Action 1. Action 2 is to protect adult smelt after migration, but prior to spawning, by restricting OMR to between -1250 and -5,000 cfs based on the recommendations of the Delta Smelt Workgroup. Component 2 of the Biological Opinion is to protect larval and juvenile fish. Component 2 actions start once water temperatures hit 12^{o}C at three monitoring stations in the Delta or when a spent female is caught. OMR flows during this phase are to be maintained more positive than -1,250 to -5000 cfs based on a 14-day running average. Component 2 actions are to continue until 30 June or when the 3-day-mean water temperature at Clifton Court Forebay is 25^{o}C. The Smelt Working Group will make recommendations on the specific OMR flow between -1250 and -5000 cfs.

The National Academy of Sciences (2010) reviewed the U.S. Fish and Wildlife Service (2008) OMR requirements and concluded:

> "…it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt populations. Thus, the concept of reducing OMR negative flows to reduce mortality of smelt at the SWP

> and CVP facilities is scientifically justified … but the data do not permit a confident identification of the threshold values to use … and … do not permit a confident assessment of the benefits to the population…As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management and additional analyses that permit regular review and adjustment of strategies as knowledge improves."

The negative impact of OMR flows on delta smelt, like on longfin smelt, is likely to be greatest during time periods with high negative OMR and low Sacramento River outflow (Baxter *et al*. 2009; Kimmerer and Nobriga 2008). The work of Grimaldo *et al*, (2009) suggests that impacts associated with the export facilities can be mitigated on a larger scale by altering the timing and magnitude of exports based on the biology of the fishes and changes in key physical and biological variables. The State Water Board's Delta outflw criteria concur with the Bay Institute's recommendations for net Delta outflows to protect longfin smelt.

For the protection of Longfin smelt, flow criteria between January and March range from 35,000 in below normal to greater than 50,000 cfs in wet water years (Table 8). For the protection of Longfin smelt, flow criteria between April and May range from 29,000 to more than 42,000 cfs. These flows should also afford protection for larval delta smelt from excessive OMR entrainment at the CVP and SWP pumping facilities. Under this criterion, lower outflows will still likely occur during critically dry and dry water year types (Table 6). These outflows may not be sufficient to prevent longfin and delta smelt entrainment at the pumping facilities. Therefore, the recommended criterion for longfin smelt specifies that OMR should not be more negative than -1500 cfs in April and May of dry and critically dry years to protect longfin smelt. The State Water Board determines that this criterion should be extended to include March and June of dry and critically dry water years to protect early and late spawning delta smelt (Table 11).

Minimizing OMR reverse flows during periods when adult delta smelt are migrating into the Delta could also substantially reduce mortality of the critical life stage. For example, one potential strategy is to reduce exports during the period immediately following the "first flush", based on a turbidity or flow trigger (Grimaldo *et al*. 2009). This supports a recommendation that OMR be more positive than -5000 cfs during the period between December and March. Additional curtailments may be warranted during periods when significant portions of the adult population migrate into the south or central Delta. In such instances, the determination of specific thresholds should be determined through an adaptive approach that takes into account a variety of factors including relative risk (e.g., biology, distribution and abundance of fishes), hydrodynamics, water quality, and key physical and biological variables. The State Water Board agrees with the National Academy of Sciences (2010) that the data, as currently available, do not permit a confident assessment of the threshold flow values nor of the overall benefit to the smelt population. Development of a comprehensive life-cycle model for delta smelt would be valuable in that it would allow for an assessment of population level impacts associated with entrainment. Such life-cycle models for delta smelt are currently under development. Therefore, OMR recommendations need to be accompanied by a strong monitoring program and adaptive management to adjust OMR flows as more knowledge becomes available.

Delta smelt are food limited. Delta smelt survival is positively correlated with zooplankton abundance (Feyrer *et al*., 2007; Kimmerer 2008; Grimaldo *et al*., 2009). A new analysis by the SFWC (SFWC 1, p.60) also demonstrates a positive relationship between FMWT smelt indices and the previous spring and summer abundance of *Eurytemora* and *Psuedodiaptomus.* There are several hypotheses for the cause of the decline in zooplankton abundance. First, zooplankton abundance in Suisun and Grizzly Bays, prime habitat for smelt, declined after the introduction of the invasive clam *Corbula. Corbula* is thought to compete directly with zooplankton for phytoplankton food and lower phytoplankton levels may limit zooplankton abundance. A second hypothesis is that changes in nutrient loading and nutrient form in the Delta that result from the Sacramento Regional Wastewater Treatment Plant discharge can have major impacts on food webs, from primary producers through secondary producers to fish (Glibert, 2010). Changes in nutrient concentrations and their ratios may have caused the documented shift in phytoplankton species composition from large diatoms to smaller, less nutritious algal forms for filter feeding organisms like zooplankton. If true, both of the above hypotheses could indirectly result in lower densities of delta smelt. Therefore, all recommended flow modifications should be accompanied by a strong monitoring and adaptive management plan to determine whether changes in OMR result in an improvement in smelt population levels.

Population Abundance Goal
The immediate goal is to stabilize delta smelt populations, as measured by the FMWT index, and begin to grow the population. The long term goal should be to achieve the objective of the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1995).

Species-Specific Recommendations
Although a positive correlation between outflow and delta smelt is lacking, outflow did have significant positive effects on several measures of delta smelt habitat (Kimmerer *et al*. 2009), and spring outflow is positively correlated with spring abundance of *Eurytemora affinis* (Kimmerer 2002a), an important delta smelt prey item. No specific spring outflow criteria are therefore recommended for delta smelt. Flow criteria to protect longfin smelt in the spring of wetter years (
Table 6) may, however, afford some additional protection for the smelt population.

The State Water Board advances the OMR flow criteria in Table 11 for dry and critically dry years to protect the delta smelt population from entrainment in the CVP and SWP pumping facilities during years with limited outflow. The OMR restrictions are an extension of the recommendations for longfin smelt. In addition, the State Water Board includes criteria for OMR flows more positive than -5,000 cfs between December and February of all water year types to protect upstream migrating adult smelt. The -5,000 cfs recommendation may need to be made more protective in years when smelt move into the Central Delta to spawn. The more restrictive OMR flow requirements would be recommended after consultation with the U.S. Fish and Wildlife Service's smelt working group. In the absence of any other specific information, the State Water Board determines that the existing 2006 Bay-Delta Plan Delta outflow objectives for July through December are needed to protect delta smelt.

Table 11. OMR Flows for the Protection of Delta Smelt.

Flow Type	Water Year Type	Dec	Jan	Feb	Mar through June
OMR	C/D				> -1,500 cfs
OMR	All	> - 5000 cfs (thresholds determined through adaptive management)			

Sacramento Splittail (*Pogonichthys macrolepidotus*)

Status

The species is currently recognized by the DFG as a species of special concern. Splittail was listed as a threatened species pursuant to the federal ESA in 1999; however, its status was remanded in 2003 on the premise of recent increases in abundance and population stability. This decision was subsequently challenged and the USFWS is revisiting the species' status and will make a new 12-month finding on whether listing is warranted by 30 September 2010.

Life History

The Sacramento splittail (*Pogonichthys macrolepidotus*) is a cyprinid native to California that can live seven to nine years and has a high tolerance to a wide variety of water quality parameters including moderate salinity levels (Moyle 2002, Moyle *et al*. 2004).

Adult splittail are found predominantly in the Suisun Marsh, Suisun Bay, and the western Delta, but are also found in other brackish water marshes in the San Francisco Estuary as well as the fresher Sacramento-San Joaquin Delta. Splittail feed on detritus and a wide variety of invertebrates; non-detrital food starts with cladocerans and aquatic fly larvae on the floodplains, progresses to insects and copepods in the rivers, and to mysid shrimps, amphipods and clams for older juveniles and adults (Daniels and Moyle 1983, Feyrer *et al*. 2003, Feyrer *et al*. 2007a, as cited in DFG 1, p. 13). In winter and spring when California's Central Valley experiences increased runoff from rainfall and snowmelt, adult splittail move onto inundated floodplains to forage and spawn (Meng and Moyle 1995, Sommer *et al*. 1997, Moyle *et al*. 2004, as cited in DFG 1, p. 13). Spawning takes place primarily between late-February and early July, and most frequently during March and April (Wang 1986, Moyle 2002) and occasionally as early as January (Feyrer *et al*. 2006a). The eggs, laid on submerged vegetation, begin to hatch in a few days and the larval fish grow fast in the warm and food rich environment (e.g., Moyle *et al*. 2004, Ribeiro *et al*. 2004). After spawning the adult fish move back downstream.

Once they have grown a few centimeters, the juvenile splittail begin moving off of the floodplain and downstream into similar habitats as the adults. These juveniles become mature in two to three years. In the Yolo Bypass, two flow components appear necessary for substantial splittail production (Feyrer *et al*. 2006a): (1) inundating flows in winter (January to February) to stimulate and attract migrating adults; and (2) sustained floodplain inundation for 30 or more days from March through May or June to allow successful incubation through hatching (3 to 7 days, see Moyle 2002) and extended rearing until larvae are competent swimmers (10 to 14 days; Sommer *et al*. 1997) and beyond to maximize recruitment (DFG 1, p. 13).

Large-scale spawning and juvenile recruitment occurs only in years with significant protracted (greater than or equal to 30 days) floodplain inundation, particularly in the

Sutter and Yolo bypasses (Meng and Moyle 1995, Sommer *et al*. 1997, Feyrer *et al*. 2006a, as cited in DFG 1, p. 13). Some spawning also occurs in perennial marshes and along the vegetated edges of the Sacramento and San Joaquin rivers (Moyle *et al*. 2004). During periods of low outflow, splittail appear to migrate farther upstream to find suitable spawning and rearing habitats (Feyrer *et al*. 2005). Moyle *et al*. (2004) noted that though modeling shows splittail to be resilient, managing floodplains to promote frequent successful spawning is needed to keep them abundant.

Population Abundance and its Relationship to Flow

Splittail age-0 abundance has been significantly correlated to mean February through May Delta outflow and days of Yolo Bypass floodplain inundation, representing flow/inundation during the incubation and early rearing periods (Meng and Moyle 1995, Sommer *et al*. 1997). The flow-abundance relationship is characterized by increased abundance (measured by the FMWT) as mean February–May X2 decreases, indicating a significant positive relationship between FMWT abundance and flow entering the estuary during February–May (Kimmerer 2002a).

Feyrer *et al*. (2006a) proposed the following lines of evidence to suggest the mechanism supporting this relationship for splittail lies within the covarying relationship between X2 and flow patterns upstream entering the estuary: the vast majority of splittail spawning occurs upstream of the estuary in freshwater rivers and floodplains (Moyle *et al*. 2004), the averaging time frame (February–May) for X2 coincides with the primary spawning and upstream rearing period for splittail, the availability of floodplain habitat, as indexed by Yolo Bypass stage, is directly related to X2 during February–May ($y = 4.38 - 2.21x$; $p<0.001$; $r^2 = 0.97$), the center of age-0 splittail distribution does not reach the estuary until summer (Feyrer *et al*. 2005), and the splittail X2-abundance relationship has not been affected by dramatic food web changes (Kimmerer 2002a) that have significantly altered the diet of young splittail in the estuary (Feyrer *et al*. 2003).

Population Abundance Goal

The immediate goal is to stabilize the Sacramento Splittail population, as measured by the FMWT index, and to begin to grow the population. The long-term goal is to maintain population abundance index as measured by FMWT in half of all years above the long term population index value.

Species- Specific Recommendations

<u>Delta Outflow</u> - Upstream covariates of X2, such as the availability of suitable floodplain and off-channel spawning and nursery habitat, appear to be the attributes supporting the flow-abundance relationship for splittail. Therefore, the flow needs of this species, with respect to spawning and rearing habitat, are most effectively dealt with through establishment of flow criteria that address the timing, duration, and magnitude of floodplain inundation from a river inflow standpoint.

<u>Delta Inflow</u> - Information in the record on conditions conducive to successful spawning and recruitment of splittail shows that the species depends on inundation of off-channel areas. Sufficient flows are therefore needed to maintain continuous inundation for at least 30 consecutive days in the Yolo Bypass, once floodplain inundation has been achieved based on runoff and discharge for ten days between late-February and May, during above normal and wet years (Table 12) (DFG closing comments, p. 7).

Opportunities to provide floodplain inundation in other locations (e.g., the San Joaquin River) warrant further examination.

Feyrer *et al* (2006a) noted that manipulating flows entering Yolo Bypass such that floodplain inundation is maximized during January through June will likely provide the greatest overall benefit for splittail, especially in relatively dry years when overall production is lowest. Within the Yolo Bypass, floodplain inundation of at least a month appears to be necessary for a strong year class of splittail (Sommer *et al*. 1997); however, abundance was highest when the period of inundation extended 50 days or more (Meng and Moyle 1995). Floodplain inundation during the months of March, April and May appears to be most important (Wang 1986, Moyle 2002). Managing the frequency and duration of floodplain inundation during the winter and spring, followed by complete drainage by the end of the flooding season, could favor splittail and other native fish over non-natives (Moyle *et al*. 2007, Grimaldo *et al*. 2004). Duration and timing of inundation are important factors that influence ecological benefits of floodplains.

<u>Yolo Bypass Inundation</u> – The Fremont Weir is a passive facility that begins to spill into the Yolo Bypass when the Sacramento River flow at Verona exceeds 55,000 to 56,000 cfs (AR/NHI 1, p. 21; EDF 1, p. 50; TBI/NRDC 3, p. 35; Sommer *et al*. 2001b). Water also enters the Bypass at the Sacramento Weir and from the west via high flow events in small west-side tributaries (Feyrer *et al*. 2006b). Each of these sources joins the Toe Drain, a perennial channel along the east side of the Yolo Bypass floodplain, and water spills onto the floodplain when the Toe Drain flow exceeds approximately 3,500 cfs (Feyrer *et al*. 2006b). The Yolo Bypass typically floods in winter and spring in about 60% of years (DOI 1, p. 54; Sommer *et al*. 2001a; Feyrer *et al*. 2006a), with inundation occurring as early as October and as late as June, with typical peak period of inundation during January-March (Sommer *et al*. 2001b). In addition, studies suggest phytoplankton, zooplankton, and other organic material transported from the Yolo Bypass enhances the food web of the San Francisco Estuary (Jassby and Cloern 2000; Mueller-Solger *et al*. 2002; Sommer *et al*. 2004). Much of the water diverted into the bypass drains back into the north Delta near Rio Vista. Besides the Yolo Bypass, the only other Delta region with substantial connectivity to portions of the historical floodplain is the Cosumnes River, a small undammed watershed (Sommer *et al*. 2001b).

Multiple participants provided recommendations concerning the magnitude and duration of floodplain inundation along the Sacramento River, lower San Joaquin River, and within the Yolo and Sutter bypasses (AR/NHI 1, p. 32; DFG closing comments; DOI 1, p. 54, EDF 1, pp. 50-52, 53-55; SFWC closing comments; TBI/NRDC 3, p. 36). In addition, the draft recovery plan for the Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley Steelhead (NMFS 2009) calls for the creation of annual spring inundation of at least 8,000 cfs to fully activate the Yolo Bypass floodplain (NMFS 5, p.157).

Overtopping the existing weirs and flooding the bypasses (e.g., Yolo and Sutter) to achieve prolonged periods (30 to 60 days) of floodplain inundation in below normal and dry water years would require excessive amounts flows given the typical runoff patterns during those year types (AR/NHI 1, p. 29). From a practical standpoint, it is probably only realistic to achieve prolonged inundation during drier water year types by notching the upstream weirs and possibly implementing other modifications to the existing system (AR/NHI 1, p. 29).

The Bay BDCP is currently evaluating structural modifications to the Fremont Weir (e.g., notch weir and install operable “inundation gates”), as a means of increasing the interannual frequency and duration of floodplain inundation in the Yolo Bypass (BDCP 2009). TBI/NRDC (TBI/NRDC 3, p. 36) and AR/NHI (AR/NHI 1, p. 32) provided floodplain inundation recommendations for the Yolo Bypass assuming structural modifications to the Fremont Weir were implemented. A potential negative impact of notching the Fremont Weir is that it will affect stage height and Sutter Bypass flooding, and the resulting spawning and rearing of splittail and spring Chinook salmon (personal communication R. Baxter).

The NMFS OCAP Biological Opinion stipulates that USBR and DWR, in cooperation with DFG, USFWS, NMFS, and USACE, shall, to the maximum extent of their authorities (excluding condemnation authority), provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type (NMFS 3, p.608). Reclamation and DWR are to submit a plan to implement this action to NMFS by 31 December 2011 (NMFS 3, p. 608). This plan is to include an evaluation of options to, among other things, increase inundation of publicly and privately owned suitable acreage within the Yolo Bypass and modify operations of the Sacramento Weir or Fremont Weir to increase rearing habitat (NMFS 3, p. 608). In the event that this action conflicts with Shasta Operations Actions I.2.1 to I.2.3 (e.g., carryover storage requirements), the Shasta Operations Actions shall prevail (NMFS 3, p. 608).

Old and Middle River Flows - Entrainment of splittail at the SWP and CVP export facilities is highest during adult spawning migrations and periods of peak juvenile abundance in the Delta (Meng and Moyle 1995, Sommer *et al*. 1997). The incidence of age-0 splittail entrainment increased during wet years when abundance was also high (Sommer *et al*. 1997). However, analyses conducted by Sommer *et al*. (1997) suggested that entrainment at the export facilities did not have an important population-level effect. However, Sommer *et al*. (1997) noted that their evidence does not demonstrate that entrainment never affects the species. For example, if the core of the population’s distribution were to shift toward the south Delta export facilities during a dry year there could be substantial entrainment effects to a year-class (Sommer *et al*. 1997). Criteria for net OMR flows intended to protect salmon, delta smelt, and longfin smelt populations, as well as restrictions stipulated in the OCAP Biological Opinions (NMFS 3, pp. 648-653; USFWS 2008) are likely to reduce the number of splittail entrained at the export facilities.

Table 12. Floodplain Inundation Criteria for Sacramento Splittail

Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spawning and Rearing Habitat	AN / W	--	≥ 30 day floodplain inundation				--	--	--	--	--	--	--

Starry Flounder (*Platichthys stellatus*)

Status

Starry flounder is not listed pursuant to either the California or Federal Endangered Species Act.

Life History

Starry flounder is a native to the San Francisco Bay Delta Estuary. The geographic distribution of flounder is from Santa Barbara, California, to Alaska and in the western Pacific as far south as the Sea of Japan (Miller and Lea 1972). Starry flounder are an important in both the recreational and commercial catch in both central and northern California (Haugen 1992; Karpov *et al*. 1995).

Starry flounder is an estuarine dependent species (Emmett *et al*. 1991). Spawning occurs in the Pacific Ocean near the entrance to estuaries and other freshwater sources between November and February (Orcutt 1950). Juveniles migrate from marine to fresh water between March and June and remain through at least their second year of life before returning to the ocean (Baxter 1999). Young individuals are found in Suisun Bay and Marsh and in the Delta. Older individuals range from Suisun to San Pablo Bays. Maturity is reached by males at the end of their second year and by females in their third or fourth years (Orcott 1950).

Population abundance of young of the year and one year old starry flounder have been measured by the San Francisco Otter Trawl Study since 1980 and reported as an annual index (Kimmerer *et al*. 2009). The index declined between 2000 and 2002 but has since recovered to values in the 300 to 500 range. The median index value for the 29 years of record is 293.

Population Abundance Relationship to Flow

Starry flounder age-1 abundance in the San Francisco Bay otter trawl study is positively correlated with the March through June outflow of the previous year (Kimmerer *et al*. 2009). The mechanism underlying the abundance outflow relationship is not known but may be increased passive transport of juvenile flounder by strong bottom currents during high outflows years (Moyle 2002). There has been a decline in the abundance of flounder for any given outflow volume since 1987, presumably because of the invasion by the clam *Corbula*, however, the overall abundance-flow relationship is still statistically significant (Kimmerer 2002a).

Population Abundance Goal

The goal is to maintain the starry flounder population abundance index, as measured by the San Francisco Otter Trawl Study, in half of all years above the long term population median index value of 293.

Species-Specific Recommendations

Outflow recommendations were only received from the DFG (Exhibit 1, page 16). DFG recommends maintaining X2 between 65 and 74 km between February and June. This corresponds to an average outflow of 11,400 to 26,815 cfs. Table 13 contains the criteria needed for protection of starry flounder. The purpose of this outflow recommendation is to maintain population abundance near the long term median index value of 293. This net Delta outflow recommendation is similar to those proposed for the protection of longfin smelt, delta smelt, and *Crangon sp*. The State Water Board's criteria for Delta outflow for the protection of both longfin and delta smelt and *Crangon* will also protect starry flounder. The proposed outflow is consistent with California Department of Fish and Game recommendation for starry flounder. There is no information in the record to support recommendations for inflows or hydrodynamics to protect starry flounder.

Table 13. Criteria for Delta Outflow to protect Starry Flounder

Flow Type	Water Year Type	Jan	Feb	Mar	April	May	Jun
Net Delta Outflow	C	14,000 – 21,000			10,000 – 17,500		
	D	21,000 – 35,200			17,500 – 29,000		
	BN	35,200 – >50,000			29,000 – 42,000		
	AN	>50,000			>42,000		
	W	>50,000			>42,000		

California Bay Shrimp (*Crangon franciscorum*)

Status

The California Bay shrimp is not listed pursuant to either the California or the Federal Endangered Species Act.

Life History

There are three native species of Crangon, collectively known as bay shrimp or grass shrimp, common to the San Francisco Estuary: *Crangon franciscorum, C. nigricauda*, and *C. nigromaculata* (Hieb 1999). Bay shrimp are fished commercially in the lower estuary and sold as bait (Reilly *et al*. 2001). *C. franciscorum* species is targeted by the commercial fishery because of its larger size. Bay shrimp are also important prey organisms for many fish in the estuary (Hatfield, 1995).

The California bay shrimp (*Crangon franciscorum*) is an estuary dependent species that is distributed along the west coast of North America from Alaska to San Diego. Larvae hatch from eggs carried by females in winter in the lower estuary or offshore in the Pacific Ocean. Most late-stage larvae and juvenile *C. franciscorum* migrate into the estuary and upstream to nursery areas between April and June. Juvenile shrimp are common in San Pablo and Suisun Bays in high outflow years. Their center of distribution moves upstream to Honker Bay and the lower Sacramento and San Joaquin rivers during low flow years (Hieb 1999). Mature shrimp migrate back down to higher salinity waters after a four to six month residence in the upper estuary (Hatfield 1985). *C. franciscornum* mature at one year and may live up to two years. Some females hatch more than one brood of eggs during a breeding season.

Population abundance of juvenile *C. franiscorum* is measured by DFG's San Francisco Bay Study and is reported as an annual index (Jassby *et al*. 1995. Hieb 1999). Indices over the 29 years of record have varied from 31 to 588 with a median value of about 103.

Population Abundance and Relationship to Flow

There is a positive correlation between the abundance of *C. franciscorum* and net Delta outflow from March to May of the same year (Jassby *et al*. 1995; Kimmerer *et al*. 2009). The statistical relationship has remained constant since the early years of the San Francisco Bay Study, which began in 1980. The mechanism underlying the abundance relationship is not known but may be an increase in the passive transport of juvenile shrimp up-estuary by strong bottom currents during high outflows years (Kimmerer *et al*. 2009. Moyle 2002, DFG 1992). Other potential mechanisms include the affects of freshwater outflow on the amount and location of habitat, the abundance of food organisms and predators, and the timing of the downstream movement of mature shrimp (DFG 1, p. 23).

Delta outflow recommendations (**Error! Reference source not found.**) were received from both the California Department of Fish and Game (Exhibit 1, page 23) and TBI/NRDC (Exhibit 2, page 17). TBI/NRDC analyzed the productivity of *C. franciscorum* as a function of net Delta outflow between March and May. The analysis suggested that estuary populations increased in about half of all years when flows between March and May were approximately 5MAF or about 28,000 cfs per month. TBI/NRDC recommended that flow be maintained in most years above 28,000 cfs during these three months to insure population growth about half the time. The California Department of Fish and Game recommended a net Delta outflow criterion of 11,400 to 26,800 cfs between February and June of all water years to aid immigration of late stage larvae and small juveniles.

Table 14. Participant Recommendations for Delta Outflow to Protect Bay Shrimp

	Water Year	Feb	Mar	Apr	May	Jun
TBI/NRDC Exhibit 2	Most years		28,000			
Fish and Game Exhibit 1	all	11,400 to 26,815				

Population Abundance Goal

The goal is to maintain the juvenile C*. franciscorum* population abundance index, as measured by the San Francisco Bay Study otter trawl, in half of all years above a target value of 103. An index of 103 is the median longterm index value for this species in San Francisco Estuary.

Species-Specific Recommendations

The State Water Board determines the Delta outflow criteria in

Table 15 are needed to protect C*rangon franciscorum*. The purpose of the outflow recommendations is to maintain population abundance at a long term median index value of 103. Positive population growth is expected in half of all years under these flow conditions. The outflow recommendations are similar to those proposed for protection of both longfin smelt and delta smelt. The nursery area for C*. franciscorum* is usually downstream of the influence of the pumps, therefore no Old and Middle River recommendations were received and no review was conducted.

Table 15. Staff Recommendation for Delta Outflow to Protect Bay Shrimp

Flow Type	Water Year Type	Jan	Feb	Mar	April	May
Net Delta Outflow	C	14,000 – 21,000			10,000 – 17,500	
	D	21,000 – 35,200			17,500 – 29,000	
	BN	35,200 – >50,000			29,000 – 42,000	
	AN	>50,000			>42,000	
	W	>50,000			>42,000	

Zooplankton (*E. affinis* and *N. mercedis*)

Status

Eurytemora affinis is a non-native species that is not listed pursuant to either the State or federal ESA. *Neomysis mercedis* is a native species that is not listed pursuant to either the State or federal ESA.

Life History[14]

Zooplankton is a general term for small aquatic animals that constitute an essential food source for fish, especially young fish and all stages of pelagic fishes that mature at a small size, such as longfin smelt and delta smelt (DFG 1987b). Although DFG follows trends of numerous zooplankton taxa (e.g., Hennessy 2009), two upper estuary zooplankton taxa of particular importance to pelagic fishes have exhibited abundance relationships to Delta outflow. The first is the mysid shrimp *Neomysis mercedis*, which before its decline, beginning in the late 1980s, was an important food of most small fishes in the upper estuary (see Feyrer *et al*. 2003). Prior to 1988, *N. mercedis* mean summer abundance (June through October) increased significantly as X2 moved downstream (mean March through November location, Kimmerer 2002a. Table 1). After 1987, *N. mercedis* abundance declined rapidly and is currently barely detectable (cf., Kimmerer 2002a, Hennessy 2009). The second is a calanoid copepod, *Eurytemora affinis*, which also declined sharply after 1987, but more so in summer than in spring (Kimmerer 2002a). Before 1987, *E. affinis* was abundant in the low salinity habitat (0.8-6.3 ‰) throughout the estuary (Orsi and Mecum 1986). *E. affinis* is an important food for most small fishes, particularly those with winter and early spring larvae, such as longfin smelt, delta smelt and striped bass (Lott 1998, Nobriga 2002, Bryant and Arnold 2007, DFG unpublished).

Population Abundance and Relationship to Flow

E. affinis was historically abundant throughout the year, particularly in spring and summer, but after 1987 abundance declined in all seasons, most notably in summer and fall (Hennessy 2009, as cited in DFG 1, p. 26). After 1987, *E. affinis* spring abundance (March through May) has significantly increased as spring X2 has moved downstream (Kimmerer 2002a. Table 1, as cited in DFG 1, p. 26). Relative abundance in recent years is highest in spring and persistence of abundance is related to spring outflow. As

[14] This section was largely extracted from DFG Exhibit 1, p. 25.

flows decrease in late spring, abundance decreases to extremely low levels throughout the estuary (Hennessey 2009, as cited in DFG 1, p. 26).

The only outflow recommendation identified in the record specifically for *E. affinis* and *N. mercedis* was submitted by DFG, in their closing comments (Table 16). According to DFG, their current science-based conceptual model is that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry (DFG 2, p. 6). Maintaining X2 at 75 km and 64 km corresponds to net Delta outflows of approximately 11,400 cfs and 29,200 cfs, respectively. The Bay Institute provided flow recommendations for a suite of species, including *E. affinis (*Table 17*).*

Table 16. DFG Outflow Recommendation to Protect E. affinis and N. mercedis

Department of Fish and Game Outflow Criteria Recommendation (Closing Comments)						
Species	Parameter	Effect or Mechanism	Timing	Minimum	Maximum	Reference
Zooplankton	Flows	Habitat	February - June	X2 at 75 km	X2 at 64 km	DFG Exhibit 1, p.25-26; Exhibit 2, p.6

Table 17. Bay Institute Recommendations for Delta Outflow to Protect Zooplankton Species Including E. affinis

Summary of Participant Flow Recommendations by Month														
Species	Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eurytemora affinis	Habitat	81-100% (driest years)	14000-21000 cfs		10000-17500 cfs			3000-4200 cfs						
		61-80%	21000-35000 cfs		17500-29000 cfs			4200-5000 cfs						
		41-60%	35200-55000 cfs		29000-42500 cfs			5000-8500 cfs						
		21-40%	55000-87500 cfs		42500-62500 cfs			8500-25000 cfs						
		0-20% (wettest years)	87500-140000 cfs		62500-110000 cfs			25000-50000 cfs						

Species-Specific Recommendations

Table 18 shows the State Water Board's determination for Delta outflows needed to protect zooplankton. These recommendations are consistent with those submitted by DFG (closing comments, p. 7). The State Water Board concurs with DFG's current science-based conceptual model which concludes that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry (DFG 2, p. 6). Maintaining X2 at 75 km and 64 km corresponds to net Delta outflows of approximately 11,400 cfs and 29,200 cfs, respectively. No explicit recommendations concerning zooplankton and inflow or Old and Middle River hydrodynamic requirements were identified in the record.

Table 18. Criteria for Delta outflow to Protect Zooplankton

Effect or Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Habitat	All	--	X2[1] – 75 to 64 km (~11400 – 29200 cfs)					--	--	--	--	--	--

4.3 *Other Measures*

Information in the record for this proceeding broadly supports the five key points submitted by the Delta Environmental Flows Group of experts (2010):

1) Environmental flows are more than just volumes of inflows and outflows
2) Recent flow regimes both harm native species and encourage non-native species
3) Flow is a major determinant of habitat and transport
4) Recent Delta environmental flows are insufficient to support native Delta fishes for today's habitats
5) A strong science program and a flexible management regime are essential to improving flow criteria

These key points recognize that although adequate environmental flows are a necessary element to protect public trust resources in the Delta ecosystem, flows alone are not sufficient to provide this protection. These key points and other information in the record warrant a brief summary discussion of other information in the record that should be considered in the development of flow criteria, consistent with the charge of SB1 that "the flow criteria include the volume, quality, and timing of water necessary for the Delta ecosystem. " Based on review of the information in the record this charge is expanded to include specific consideration of:

- Variability, flow paths, and the hydrograph
- Floodplain activation and other habitat improvements
- Water quality and contaminants
- Cold water pool management
- Adaptive management

4.3.1 Variability, Flow Paths, and the Hydrograph

The first of the five key points submitted by the Delta Environmental Flows Group of experts stated, in part: "There is no one correct flow number. Seasonal, interannual, and spatial variability, to which our native species are adapted, are as important as quantity." Species and biological systems respond to combinations of quantity, timing, duration, frequency and how these inputs vary spatially (DEFG 1). Based on their review of the literature in *Habitat Variability and Complexity in the Upper San Francisco Estuary*, Moyle *et al* (2010) find:

> "… unmodified estuaries are highly variable and complex systems, renowned for their high production of fish and other organisms (McClusky and Elliott 2004). The San Francisco Estuary, however, is one of the most highly modified and controlled estuaries in the world (Nichols et al. 1986). As a consequence, the estuarine ecosystem has lost much of its former variability and complexity and has recently suffered major declines of many of its fish resources (Sommer et al. 2007).
>
> …the concept of the "natural flow regime" (Poff et al. 1997) is increasingly regarded as an important strategy for establishing flow regimes to benefit native species in regulated rivers (Postel and Richter 2003; Poff et al. 2007; Moyle and Mount 2007). For estuaries worldwide, the degree of environmental variability is regarded as fundamental in regulating biotic assemblages (McLusky and Elliott 2004). Many studies have shown that estuarine biotic assemblages are generally regulated by a combination of somewhat predictable changes (e.g., tidal cycles, seasonal freshwater inflows) and stochastic factors, such as recruitment variability and large-scale episodes of flood or drought (e.g., Thiel and Potter 2001). The persistence and resilience of estuarine assemblages is further decreased by various human alterations, ranging from diking of wetlands, to regulation of inflows, to invasions of alien species (McLusky and Elliott 2004, Peterson 2003).
>
> …a key to returning the estuary to a state that supports more of the desirable organisms (e.g., Chinook salmon, striped bass, delta smelt) is increasing variability in physical habitat, tidal and riverine flows, and water chemistry, especially salinity, over multiple scales of time and space. It is also important that the stationary physical habitat be associated with the right physical-chemical conditions in the water at times when the fish can use the habitat most effectively (Peterson 2003)."

An example of a major change in the natural flow regime of the Delta is demonstrated by the increase in reverse flows in Old and Middle Rivers just north of the SWP and CVP pumping facilities. Reverse flows are now a regular occurrence in the Delta channels because Sacramento River water enters on the northern side of the Delta while the two major pumping facilities, the SWP and CVP, are located in the south. This results in a net water movement across the Delta in a north-south direction along a web of channels including Old and Middle River instead of the more natural pattern from east to west or from land to sea. In contrast, positive net flows, connected flow paths, and salinity gradients are important features of an estuary. Natural net channel flow moved water and some biota toward Suisun Bay and maintained downstream directed salinity gradients. Today, Delta gates and diversions can substantially redirect tidal flows creating net flow patterns and salinity and turbidity distributions that did not occur historically. These changes may influence migratory cues for some fishes. These cues are further scrambled by a reverse salinity gradient in the south Delta caused by higher salinity in agricultural runoff (DEFG 1).

Per the Delta Environmental Flows Group's paper, *Habitat Variability and Complexity in the Upper San Francisco Estuary* (Moyle *et al*, 2010), a more variable Delta has multiple benefits:

> "Achieving a variable, more complex estuary requires establishing seaward gradients in salinity and other water quality variables, diverse habitats throughout the estuary, more floodplain habitat along inflowing rivers, and improved water quality. These goals in turn encourage policies which: (1) establish internal Delta flows that create a tidally-mixed, upstream-downstream gradient (without cross-Delta flows) in water quality; (2) create slough networks with more natural channel geometry and less diked rip-rapped channel habitat; (3) improve flows from the Sacramento and San Joaquin rivers; (4) increase tidal marsh habitat, including shallow (1-2 m) subtidal areas, in both fresh and brackish zones of the estuary; (5) create/allow large expanses of low salinity (1-4 ppt) open water habitat in the Delta; (6) create a hydrodynamic regime where salinities in parts of the Delta and Suisun Bay and Marsh range from near-fresh to 8-10 ppt periodically (does not have to be annual) to discourage alien species and favor desirable species; (7) take species-specific actions that reduce abundance of non-native species and increase abundance of desirable species; (8) establish abundant annual floodplain habitat, with additional large areas that flood in less frequent wet years; (9) reduce inflow of agricultural and urban pollutants; and (10) improve the temperature regime in large areas of the estuary so temperatures rarely exceed 20°C during summer and fall months."

Similarly, reliance upon water year classification as a trigger for flow volumes has contributed to reduced flow variability in the estuary. The information received during this proceeding supports the notion that reliance upon water year classification as a trigger for flow volumes is an imperfect means of varying flows. Any individual month or season might have a dramatically different hydrology than the overall hydrology for the year. A critically dry year, for example, can have one or two very wet months, just as a wet year may have several disproportionately dry months. Figure 10 demonstrates how this actually occurs. Unimpaired Delta outflow for the month of June from 1922 through 2003 has historically been highly variable. Many June months that occur in years classified as wet have had much lower flows than June flows in years classified as below normal. The opposite is also true; several June flows in years classified as critically dry are higher than some years classified as above normal. Depending on the direction of this divergence of monthly flows (higher or lower) relative to the water year, reliance upon water year classification can provide less than optimal protection of the ecosystem or more than needed water supply impacts. The figure also shows the actual June flows for various periods of years, demonstrating how much lower actual flows have been than unimpaired flows. The primary reason for the lower historical flows is consumption of water in the watershed. The three periods shown, however, are not directly comparable to the unimpaired flow record because the shorter time frame may have been wetter or drier than the full historical record.

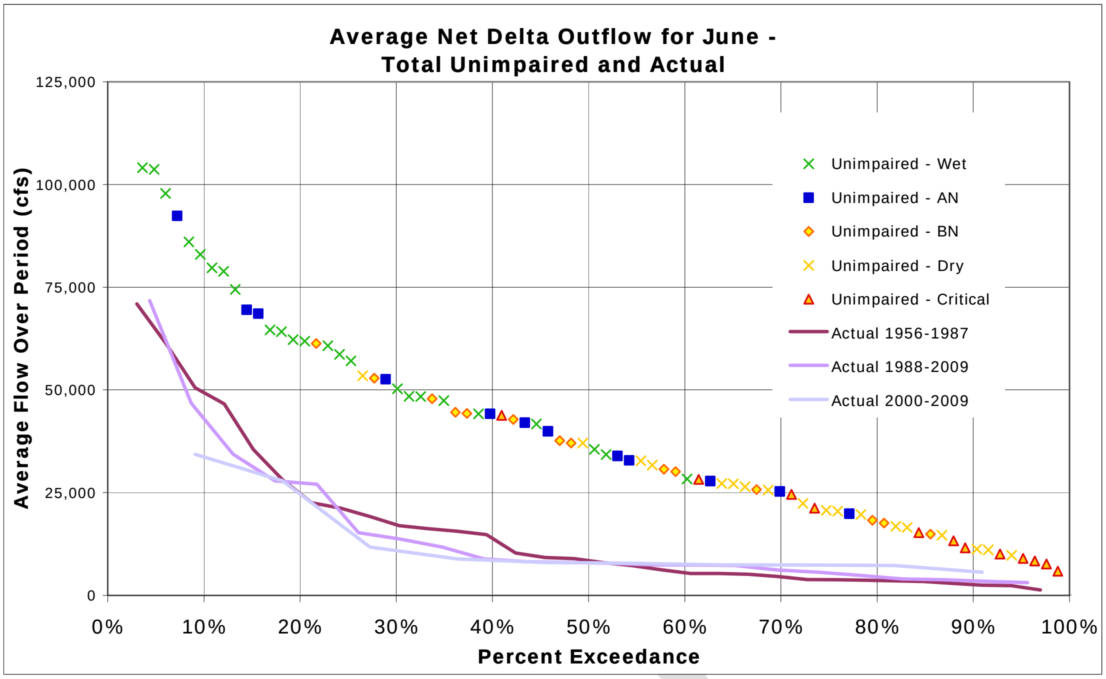


Figure 10. Actual and Unimpaired June Delta Outflow

Proportionality is one of the key attributes of restoring ecosystem functions by mimicking the natural hydrograph in tributaries to the Delta and providing for connectivity. Currently, inflows to the Delta are largely controlled by upstream water withdrawals and releases for water supply, power production, and flood control. As a result, inflows from tributaries frequently do not contribute flow to the Delta in the same proportions as they would have naturally, and to which native fish adapted. There is consensus in contemporary science that improving ecosystem function in the watershed, mainstem rivers, and the Delta is a means to improving productivity of migratory species. (e.g.,Williams 2005; NRC 1996, 2004a, 2004b as cited in NAS 2010, p. 42.) NAS found that, “Watershed actions would be pointless if mainstem passage conditions connecting the tributaries to, and through, the Delta were not made satisfactory.” (NAS 2010, p. 42.) “Propst and Gido (2004) support this hypothesis and suggest that manipulating spring discharge to mimic a natural flow regime enhances native fish recruitment (Propst and Gido, 2004 and Marchetti and Moyle, 2001).” (DOI, p. 25.) Specifically, providing pulse flows to mimic the natural hydrograph could diversify ocean entry size and timing for anadromous fishes so that in many years at least some portion of the fish arrive in saltwater during periods favoring rapid growth and survival. (DOI 1, p. 30.) Food productions may also be improved by maintaining the attributes of a natural hydrograph (EFG 1, p. 8.) Connectivity between natal streams and the Delta is critical for anadromous species that require sufficient flows to emigrate out of natal streams to the Delta and ocean, and sufficient flows upon returning, including flows necessary to achieve homing fidelity. Specifically, it is necessary for the scent of the river to enter the Bay in order for adult salmonids to find their way back to their natal river. (NMFS 2009, p.407 as cited in EDF 1, p. 48.) Further, insuring adequate flows from all of the tributaries that support native fish is important to maintain genetic diversity and species resilience in the face of catastrophic events.

4.3.2 Floodplain Activation and Other Habitat Improvements

Most floodplains in the Central Valley have been isolated from their rivers by levees. Due to the effects of levees and dams, side channel and floodplain inundating flows have been substantially reduced. At present, besides the Yolo Bypass, the only other Delta region with substantial connectivity to portions of the historical floodplain is the Cosumnes River, a small undammed watershed (Sommer *et al*. 2001b). Floodplains are capable of providing substantial benefits to numerous aquatic, terrestrial, and wetland species (Sommer *et al*. 2001b). Inundation of floodplains facilitates an exchange of organisms, nutrients, sediment, and organic material between the river and floodplain, and provides a medium in which biogeochemical processes and biotic activity (e.g., phytoplankton blooms, zooplankton and invertebrate growth and reproduction) can occur (AR/NHI 1, p. 22). This exchange of material can benefit downstream areas. For example, studies suggest phytoplankton, zooplankton, and other organic material transported from the Yolo Bypass enhances the food web of the San Francisco Estuary (Jassby and Cloern 2000; Mueller-Solger *et al*. 2002; Sommer *et al*. 2004).

Many fishes rear opportunistically on floodplains (Moyle *et al*. 2007, as cited in Moyle *et al*. 2010), and juvenile salmon grow faster and become larger on floodplains than in the main-stem river channels (Sommer *et al*. 2001a; Jeffres *et al*. 2008; DOI 1, p. 27; AR/NHI 1, p. 24). Splittail require floodplains for spawning (Moyle *et al*. 2007), with large-scale juvenile recruitment occurring only in years with significant protracted (greater than or equal to 30 days) floodplain inundation, particularly in the Sutter and Yolo bypasses (Meng and Moyle 1995, Sommer *et al*. 1997, Feyrer *et al*. 2006a). Managing the frequency and duration of floodplain inundation during the winter and spring, followed by complete drainage by the end of the flooding season, could favor splittail and other native fish over non-natives (Moyle *et al*. 2007, Grimaldo *et al*. 2004). In addition, modeling conducted by Moyle *et al*. (2004) shows that while splittail are resilient, managing floodplains to promote frequent successful spawning is needed to keep them abundant. Improving management of the Yolo Bypass for fish, increasing floodplain areas along other rivers (e.g., Cosumnes and Mokelumne rivers), and developing floodplain habitat along the lower San Joaquin River, including a bypass in the Delta, represent opportunities to increase the frequency and extent of floodplain inundation (Moyle *et al*. 2010). The Bay Delta Conservation Plan (BDCP) is currently evaluating structural modifications to the Fremont Weir (e.g., notch weir and install operable “inundation gates”), as a means of increasing the interannual frequency and duration of floodplain inundation in the Yolo Bypass (BDCP 2009).

The NMFS OCAP Biological Opinion stipulates that USBR and DWR, in cooperation with DFG, USFWS, NMFS, and USACE, shall, to the maximum extent of their authorities (excluding condemnation authority), provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type (NMFS 3, p. 608). Per this Biological Opinion, Reclamation and DWR are to submit a plan to implement this action to NMFS by 31 December 2011 (NMFS 3, p. 608). This plan is to include an evaluation of options to, among other things, increase inundation of publicly and privately owned suitable acreage within the Yolo Bypass, and modify operations of the Sacramento Weir or Fremont Weir to increase rearing habitat (NMFS 3, p. 608).

Moyle *et al.* (2010) discuss the value of creating more slough networks with natural geometry and less diked, rip-rapped channel habitat, the value of tidal marsh habitat, and low salinity, open water habitat in the Delta:

> "Re-establishing the historical extensive dendritic sloughs and marshes is essential for re-establishing diverse habitats and gradients in salinity, depth and other environmental characteristics important to desirable fish and other organisms (e.g., Brown and May 2008). These shallow drainages are likely to increase overall estuarine productivity if they are near extensive areas of open water, because they can deliver nutrients and organic matter to the more open areas. Dendritic slough networks will develop naturally in Suisun Marsh after large areas become inundated following dike failures and they can be recreated fairly readily in the Cache Slough region by reconnecting existing networks. In the Delta, the present simplified habitat in the channels between islands needs to be made more suitable as habitat for desirable species. Many levees are maintained in a nearly vegetation-free state, providing little opportunity for complex habitat (e.g., marshes and fallen trees) to develop. Much of the low-value channel habitat in the western and central Delta will disappear as islands flood, but remaining levees in submerged areas should be managed to increase habitat complexity (e.g., through planting vegetation), especially in the cooler northern and eastern parts of the Delta.
>
> [Subtidal] habitat has been greatly depleted because marshes in the Delta and throughout the estuary have been diked and drained, mostly for farming and hunting (Figure 3). Unfortunately, most such habitat in shallow water today is dominated by alien fishes, including highly abundant species such as Mississippi silverside which are competitors with and predators on native fishes (Moyle and Bennett 1996; Brown 2003). Such habitat could become more favorable for native fishes with increased variability in water quality, especially salinity. In particular, increasing the amount of tidal and subtidal habitat in Suisun Marsh should favor native fishes, given the natural variability in salinity and temperature that occurs there. The few areas of the marsh with natural tidal channels tend to support the highest diversity of native fishes, as well as more striped bass (Matern et al. 2002; Moyle, unpublished data). With sea level rise, many diked areas of Suisun Marsh currently managed for waterfowl (mainly dabbling ducks and geese) will return to tidal marsh and will likely favor native fishes such as splittail and tule perch (Hysterocarpus traski), as well as (perhaps) migratory fishes such as juvenile Chinook salmon. Experimental (planned) conversions of some of these areas would be desirable for learning how to manage these inevitable changes to optimize habitat for desired fishes.
>
> Open water habitat is most likely to be created by the flooding of subsided islands in the Delta, as well as diked marshland 'islands' in Suisun Marsh (Lund et al. 2007, 2010; Moyle 2008). The depth and hydrodynamics of many of these islands when flooded should prevent establishment of alien aquatic plants while variable salinities in the western Delta should prevent establishment of dense populations of alien clams (Lund et al. 2007).

> Although it is hard to predict the exact nature of these habitats, they are most likely to be better habitat for pelagic fishes than the rock-lined, steep-sided and often submerged vegetation-choked channels that run between islands today (Nobriga et al. 2005). Experiments with controlled flooding of islands should provide information to help to ensure that these changes will favor desired species. Controlled flooding also has the potential to allow for better management of hydrodynamics and other characteristics of flooded islands (through breach location and size) than would be possible with unplanned flooding."

4.3.3 Water Quality and Contaminants

Toxic effects are one of three general factors identified in 2005 by scientists with the Interagency Ecological Program contributing to the decline in pelagic productivity. The life history requirements and water quality sections above identify specific water quality issues specific species sensitivities to water quality

Though the information received in this proceeding supports the recommendation that modification to flow through the Delta is a necessary first step in improving the health of the ecosystem, it also supports the recommendation that flow alone is insufficient. The Delta and San Francisco Bay are listed under section 303(d) of the Federal Clean Water Act as impaired for a variety of toxic contaminants that may contribute to reduced population abundance of important fish and invertebrates. The contaminants include organophosphate and pyrethrin pesticides, mercury, selenium and unknown toxicity. In addition, low dissolved oxygen levels periodically develop in the San Joaquin River at the DWSC and in Middle and Old Rivers. The low oxygen levels in the DWSC inhibit the upstream migration of adult fall run salmon and adversely impact other resident aquatic organisms.

There is concern that a number of non-303(d) listed contaminants, such as ammonia, pharmaceuticals, endocrine disrupting compounds and blue-green algal blooms could also limit biological productivity and impair beneficial uses. Sources of these contaminants include agricultural, municipal and industrial wastewater, urban storm water discharges, discharges from wetlands, and channel dredging activities. More work is needed to determine their impact on the aquatic community.

Ammonia has emerged as a contaminant of special concern in the Delta. Recent hypotheses are that ammonia is causingtoxicity to delta smelt, other local fish, and zooplankton and is reducing primary production rates in the Sacramento River below the Sacramento Regional Wastewater Treatment Plant and in Suisun Bay. A newer hypothesis is that ammonia and nitrogen to phosphorus ratios have altered phytoplankton species composition and these changes have had a detrimental effect on zooplankton and fish population abundance (Glibert 2010). More experiments are needed to evaluate the effect of nutrients, including ammonia, on primary production and species composition in the Sacramento River and Delta.

4.3.4 Cold Water Pool Management

As mentioned in the specific flow recommendations, the flow criteria contained in this report should be tempered by the additional need to maintain cold water resources in reservoirs on tributaries to the Delta until improved passage and other measures are taken that would reduce the need for maintaining cold water reserves in reservoirs. As discussed in the Chinook salmon section, salmon have specific temperature tolerances during various portions of their life-cycle. Historically salmonids were able to take advantage of cooler upstream temperatures for parts of their life-cycle to avoid adverse temperature effects. Since construction of the various dams in the Central Valley, access to much of the cooler historic spawning and rearing habitat has been blocked. To mitigate for these impacts, reservoirs must be managed to preserve cold water resources for release during salmonid spawning and rearing periods. As reservoir levels drop, availability of cold water resources also diminishes. Accordingly, it may not be possible to attain all of the identified flow criteria in all years and meet the thermal needs of the various runs of Chinook salmon and other sensitive species. Thorough temperature and water supply modeling analyses should be conducted to adaptively manage any application of these flow criteria to suit real world conditions and to best manage the competing demands for water needed for the protection of public trust resources, especially in the face of future climate change.

Specifically, these criteria should not be construed as contradicting existing and future cold water management requirements that may be needed for the protection of public trust resources, including those for the Sacramento River needed to protect the only remaining population of winter-run Chinook salmon (see NMFS 3, p. 590-603).

4.3.5 Adaptive Management

Any environmental flow prescription for native species in the Delta will be imperfect. The problem is too complex, uncertainties are too large, and the situation in the Delta is changing too rapidly in too many ways for any single flow prescription to be correct, or correct for long (Fleenor *et al*. 2010). Some degree of certainty regarding future conditions in the Delta is needed before long term flow criteria can be developed. Since it is unlikely that certainty will be achieved before actions or responses are required by geologic, biological, and legal processes, it might be valuable to provide substantial financial and water reserve resources, along with responsible institutional wherewithal to respond to changes and undertake necessary experiments for more successfully transitioning into the largely unexplored new Delta (Fleenor *et al*. 2010). This confounding need for certainty of operations and water supply at the same time there is uncertainty underlying ecosystem needs, provides good rationale to rely upon adaptive management to address this uncertainty.

The Delta is continually changing. Flow criteria developed for the present Delta ecosystem will become less reflective of ecosystem needs with the passage of time. Accordingly, it is important that flow criteria be adaptive to future changes. Flows, habitat restoration, and measures to address other stressors should be managed adaptively (AR/NHI Closing Comments).

Adaptive management is “an iterative process, based on a scientific paradigm that treats management actions as experiments subject to modification, rather than as fixed and final rulings, and uses them to develop an enhanced scientific understanding about whether or not and how the ecosystem responds to specific management actions.” (NRC 1999 as cited in DOI Ex.1). This notion of treating actions as experiments is key, because information received in this proceeding indicates that the mechanisms underlying the relationship between flows and the health of the Delta ecosystem are, at times, unclear. Adaptive management is the most suitable approach for managing with uncertainty (DEFG 1).

Murray and Marmorek (2004) describe an adaptive management approach as:

- exploring alternative ways to meet management objectives
- predicting the outcomes of alternatives based on the current state of knowledge
- implementing one or more of these alternatives
- monitoring to learn about the impacts of management actions
- using the results to update knowledge and adjust management actions

An adaptive approach provides a framework for making good decisions in the face of critical uncertainties, and a formal process for reducing uncertainties so that management performance can be improved over time (Williams *et al*. 2007).

Adaptive management does not postpone action until "enough" is known but acknowledges that time and resources are too short to defer *some* action, particularly actions to address urgent problems (Lee 1999). Adaptive management provides a means of informing planning and management decisions in spite of uncertainty. Key point number 5 of the Delta Environmental Flows Group states: "a strong science program and a flexible management regime are essential to improving flow criteria (DEFG 1).

Adaptive management can be used to manage uncertainty in two ways, over two time frames. Over the short-term, adaptive management could allow for a specific response to real time conditions so long as the response is otherwise consistent with the constraints of some overarching regulatory framework. Over the longer term, adaptive management could allow for the more nimble modification of regulatory constraints, so long as these modifications fell within the clearly defined parameters of the overarching regulatory framework.

<u>Short-term Adaptive Management</u>
Per the Delta Environmental Flow Group's assessment regarding the role of uncertainty…

> "…despite [our] extensive scientific understanding substantial knowledge gaps remain about the ecosystem's likely response to flows. First, ecosystem processes in a turbid estuary are mostly invisible, and can be inferred only through sampling. Second, monitoring programs only scratch the surface of ecosystem function by estimating numbers of fish and other organisms, whereas the system's dynamics depend on birth, growth, movement, and death rates which can rarely be monitored. Third, this system is highly variable in space (vertical, cross-channel, along-channel, and larger-scale), time (tidal, seasonal, and interannual), flow, salinity, temperature, physical habitat type, and species composition. Each of the hundreds of species has a different role in the system, and these differences can be subtle but important. As a result, we have little ability to predict how the ecosystem will respond to the numerous anticipated deliberate and uncontrolled changes." (DEFG 1.)

Flexible management can be designed into a regulatory framework so that any requirements rely upon real time information and real time decisions to guide specific real-time action. A current example of this is the Delta Smelt Working Group that provides information and analyses used to guide real time operation of export facilities so that these facilities in a manner that conforms with current Biological Opinions. Any such flexible management will need to consider the processes and governance structures required to make sound scienfically-based real-time conditions. The Delta Smelt Working Group is a good example of how scientific assessment of real-time data, including the presence of fish, can better inform the real time operation of export facilities.

Long-term Adaptive Management

Over the longer term, adaptive management can be used to more nimbly modify regulatory constraints so that fishery and water resource agencies are not locked into prescriptive constraints well past the time that current scientific understanding can support. This longer term adaptive management has bearing on a number of the flow criteria being considered in this report because many of these criteria lack sufficiently robust information to support a specific numeric criterion. Although the functional basis for a beneficial flow may be understood, the basis for a specific numeric criteria may not. Some regulatory flows may therefore need to take the form of an informed experimental manipulation. Such flows would need to be implemented… "as if they were experiments, with explicit conceptual and simulation models, predicting outcomes, and feedback loops so that the course of management and investigation can change as the system develops and knowledge is gained. A talented group of people tasked to integrate, synthesize, and recommend actions based on the data being gathered are essential for making such a system work. Failure to implement an effective adaptive management program will likely lead to a continued failure to learn from the actions, and a lack of responsiveness to changing conditions and increased understanding." (DEFG 1.)

The Delta Science Program, IEP, and other institutions could be relied upon to evaluate experimental flows and make recommendations to be considered for modifications of such flows.

4.4 Expression of recommendations as percentage of unimpaired flow

In some cases, participants' recommendations were expressed as specific flows in specific months, to be applied during specific water year types or with specified probabilities of exceedance. Review of unimpaired hydrology shows there is great variability in the quantity of unimpaired flow during these specified months when categorized by water year type. Reliance upon monthly or seasonal flow prescriptions based on water year type would therefore result in widely ranging relative amounts of unimpaired flow depending upon the specific hydrology of the month or season. Also, the rather coarse division of the hydrograph into five water year types can lead to abrupt step-wise changes in flow requirements. In an attempt to more closely reflect the variation of the natural hydrograph, The State Water Board recommends that, when possible, the flow criteria be expressed as a percentage of unimpaired flow.

To develop recommendations in this way, the unimpaired flow rate for a specified time period (e.g. average monthly flow over a range of months) was plotted on an exceedance probability graph (using the Weibull plotting position formula) along with the flow recommendations and desired return frequencies. The unimpaired flow rates were also plotted such that the associated water year type can be identified and their percent exceedance estimated. A percentage of unimpaired flow was selected by trial and error so that the desired flow rate and exceedance frequency was achieved. A separate exceedance plot was produced for each time period being evaluated.

The unimpaired flow estimates used in the development of these flow recommendations are based on those developed in the California Department of Water Resources (DWR) May 2007 document: *"California Central Valley Unimpaired Flow Data" Fourth Edition Draft* (DWR 2007). This report contains estimates of the monthly flow for 24 sub-basins in the Central Valley. Each sub-basin uses a separate calculation dependant on conditions specific to that sub-basin, available gauge data, and relationships to other sub-basins. In many cases the methods change over the period of record to incorporate changes to infrastructure within the sub-basins that need to be accounted for. Estimates are provided for 83 water years from 1922 through 2003. A water year begins in October of the previous calendar year through September of the named water year. The following describes the unimpaired flow estimates that are the basis for flow recommendations for the Sacramento River at Rio Vista, the San Joaquin River at Vernalis, and Net Delta Outflow.

Sacramento Valley Unimpaired Total Outflow

Estimates of the unimpaired Sacramento Valley outflow were computed as the sum of estimates from 11 sub-basins in the watershed and are understood to represent the flow that would occur on the Sacramento River at approximately Freeport. These 11 sub-basins include the Sacramento Valley Floor, Putah Creek near Winters, Cache Creek above Rumsey, Stony Creek at Black Butte, Sacramento Valley West Side Minor Streams, Sacramento River near Red Bluff, Sacramento Valley East Side Minor Streams, Feather River near Oroville, Yuba River at Smartville, Bear River near Wheatland, American River at Fair Oaks.

The unimpaired Sacramento Valley outflow from DWR 2007 is used as the basis for flow recommendations on the Sacramento River at Rio Vista, even though it is understood they are more representative of unimpaired flows expected at Freeport. This is a necessary simplification as such estimates do not exist at Rio Vista, but should be adequate for the purpose of these recommendations. If future flow requirements are to be established at Rio Vista based on a percentage of unimpaired flow, it is recommended that new estimates of unimpaired flow be developed specific for this location.

San Joaquin Valley Unimpaired Total Outflow

Estimates of the unimpaired San Joaquin Valley outflow were computed as the sum of estimates from nine sub-basins in the watershed and are understood to represent the flow that would occur on the San Joaquin River at Vernalis. These nine sub-basins include the Stanislaus River at Melones Reservoir, San Joaquin Valley Floor, Tuolumne River at Don Pedro Reservoir, Merced River at Exchequer Reservoir, Chowchilla River at Buchanan Reservoir, Fresno River near Daulton, San Joaquin River at Millerton Reservoir, Tulare Lake Basin Outflow, San Joaquin Valley West Side Minor Streams.

Delta Unimpaired Total Outflow

Estimates of unimpaired Net Delta outflow in DWR 2007 were computed generally as Delta Unimpaired Total Inflow minus unimpaired net use in the Delta, including both lowlands and uplands. Delta Unimpaired Total Inflows was calculated as the sum of the

Sacramento Valley and San Joaquin Valley Unimpaired Total Outflows as described above and the East Side Streams Unimpaired Total Outflow. The later consists of four sub-basins including San Joaquin Valley East Side Minor Streams, Cosumnes River at Michigan Bar, Mokelumne River at Pardee Reservoir, and Calaveras River at Jenny Lind. Generally the unimpaired net use in the Delta is an estimate of the consumptive use from riparian and native vegetation (replacing historical irrigated agriculture and urban areas), plus evaporation from water surfaces, minus precipitation, and assumes that existing Delta levees and island remain intact. Unimpaired flow graphs in this report use the unimpaired flow record from 1922 to 2003.

5. Flow Criteria Recommendations

Two types of recommendations are provided in this report: numeric flow criteria, and other, non-numeric, measures that should be considered to complement the numeric criteria. Numeric criteria are subdivided into two categories: category “A” criteria have more and better scientific information, with less uncertainty, to support specific numeric criteria than do Category “B” criteria. Summary numeric criteria are provided for Delta outflow, as well as Sacramento River and San Joaquin River inflows, and Hydrodynamics (Old and Middle River, Inflow-Export Ratios, and Jersey Point flows) in Tables 19 through 22.

In addition to new criteria for Delta outflows, inflows, and hydrodynamics, some of the objectives for the protection of fish and wildlife from the 2006 Bay-Delta Plan are advanced as criteria in this report. While the State Water Board did not specifically reevaluate the methodology and basis for the Bay-Delta Plan objectives, the State Water Board recognizes that these flows provide some level of existing protection for fish and wildlife and, in the absence of more specific information, merit inclusion in these criteria. At the time the Bay-Delta Plan objectives were adopted, they were supported by substantial evidence, including scientific information. While the purpose of this report is to develop flow criteria using best available scientific information, water quality objectives are established taking into account scientific and other factors pursuant to Water Code section 1241.

5.1 Delta Outflow

Following are Delta outflow criteria based on analysis of the species-specific flow criteria and other measures:

1) Net Delta Outflow: 75 percent of 14-day average unimpaired flow for January through June
2) Delta Smelt Fall X2 for September through November
    - Wet years X2 less than 74 km (greater than approximately 12,400 cfs)
    - Above normal years X2 less than 81 km (greater than approximately 7,000 cfs)
3) 2006 Bay-Delta Plan Delta Outflow Objectives for July through December

Delta Outflow criteria 1 and 2 are Category A criteria because they are supported by more robust scientific information. Delta Outflow criteria 3 is a Category B criterion because there is less scientific information to support specific numeric criteria, but there is enough information to support the conceptual need for flows. Category A and B criteria are both equally important for protection of the public trust resource, but there is more uncertainty about the appropriate volume of flow required to implement Category B criteria. Following is discussion and rationale for these criteria.

The narrative objective of the flow criteria is to halt the population decline and increase populations of native species as well as species of commercial and recreational importance. The need to estimate the magnitude, duration, timing, and quality of Delta outflow necessary to support viable populations of these species is inherent to this objective. McElhany *et al*. (2000) proposed that four parameters are critical for evaluating population viability: abundance, population growth rate, population spatial structure, and diversity. Delta outflow may affect one, all, or some combination of these parameters for a number of resident and anadromous species. A species-specific analysis of flow needs for a suite of upper estuary species is included in section 4.2.4.

An analysis of generation to generation population abundance versus Delta outflow indicates that the “likelihood” of an increase in the longfin smelt FMWT abundance index in 50% of years corresponded with flow volumes of approximately 9.1 MAF (51,000 cfs) and 6.3 MAF (35,000 cfs) during January through March and March through May, respectively (TBI/NRDC 2, pp. 17-19). The provision of sufficient flows to achieve these flow volumes during January through March and March through May in 40% and 50% of years, respectively, is intended to promote increased abundance and improved productivity for longfin smelt and other desirable estuarine species. Based on a comparison of the flows needs identified in section 4.2.4, it appears that winter-spring outflows designed to be protective of longfin smelt would benefit the other upper estuary species evaluated. The DFG recommended that spring outflows extend through June to fully protect a number of estuarine species (DFG 1, pp. 2-5). During June, sufficient outflow should be provided to maintain X2 in Suisun Bay (between 75 km and 64 km) (DFG closing comments, p. 7; DFG 2, p. 6).

The State Water Board recognizes that the target flow volumes of 9.1 MAF (Jan-Mar, 51,000 cfs) and 6.3 MAF (Mar-May, 35,000 cfs) in greater than or equal to 40% and 50% of years, respectively, and the positioning of X2 in Suisun Bay during the month of June are necessary in order to promote increased abundance and improved productivity for longfin smelt and other desirable estuarine species. An approach based on a percentage of unimpaired flows is intended as a means of distributing flows to meet the above-mentioned criteria in a manner that more closely resembles the natural hydrograph. Such an approach also recognizes the importance of preserving the general attributes of the flow regimes to which the native estuarine species are adapted.

Analyses of historic conditions (1921 to 2003), indicates that at 75% of unimpaired flows, average flows of 51,000 cfs occurred between January and March in approximately 35% of years, while average flows of 35,000 cfs happened between March and May in 70% of years. At 75% of unimpaired flow, X2 would be maintained west of Chipps Island more than 90% of the time between January and June (analyses not shown).
Rather than advance multiple static flow criteria for the January through March, March through May, and June time periods, the State Water Board determines, as a Category A criterion, that 75% of 14-day average unimpaired flow is needed during the January through June time period to promote increased abundance and improved productivity for longfin smelt and other desirable estuarine species. It is important to note that this criterion is not a precise number; rather it reflects the general timing and magnitude of flows needed to protect public trust resources in the Delta ecosystem. However, this

criterion could serve as the basis from which future analysis and adaptive management could proceed.

Given the extensive modifications to the system there may be a need to diverge from the natural hydrograph at certain times of the year to provide more flow than might have actually occurred to compensate for such changes. Fall outflow recommendations, intended to improve conditions for Delta smelt by enhancing the quantity and quality of habitat in wet and above normal water years, represent such an instance. As a Category B criterion, the State Water Board determines that sufficient outflow is needed from September through November of wet and above normal water year types to position X2 at less than or equal to 74 km and 81 km, respectively (Fall X2 action). In addition, the Delta Outflow Objectives contained within the Bay-Delta Plan for July through December are advanced as a Category B criterion. The State Water Board does not recommend increasing fall flows beyond those stipulated in the Bay-Delta Plan and Fall X2 action at this time. The quantity and timing of fall outflows necessary to protect public trust resources warrants further evaluation.

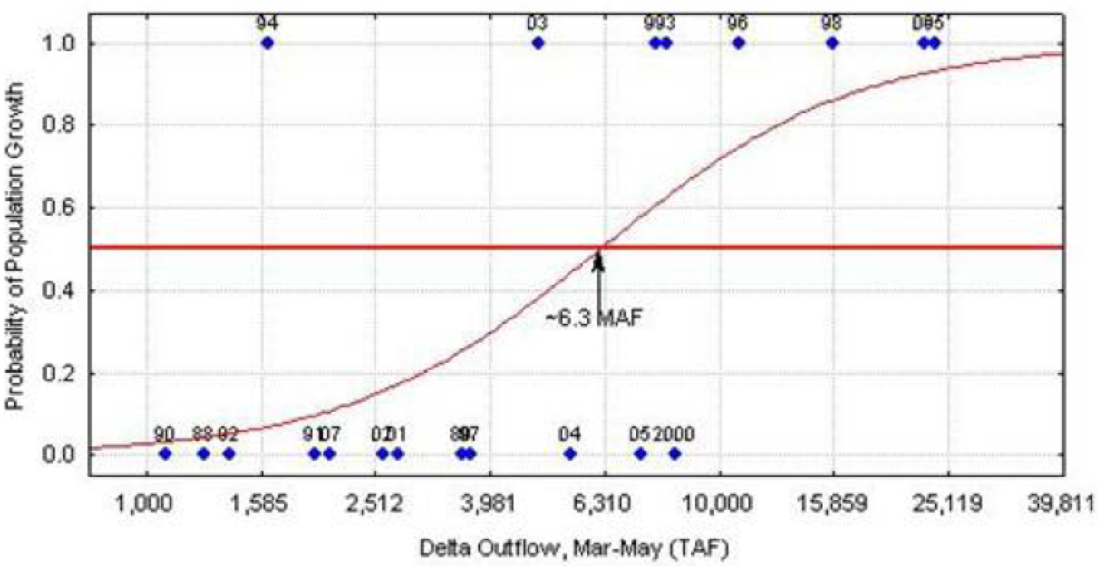
<u>Category A: Winter – Spring Net Delta Outflow</u>
The flow regime is important in determining physical habitat in aquatic ecosystems, which is in turn is a major factor in determining biotic composition (Delta Environmental Flows Group 2010). Bunn and Arthington (2002) highlight four principles by which the natural flow regime influences aquatic biodiversity: 1) developing channel form, habitat complexity, and patch disturbance, 2) influencing life-history patterns such as fish spawning, recruitment, and migration, 3) maintaining floodplain and longitudinal connectivity, and 4) discouraging non-native species. Altering flow regimes affects aquatic biodiversity and the structure and function of aquatic ecosystems. The risk of ecological change increases with greater flow regime alteration (Poff and Zimmerman 2010).

A suite of native, and recreationally or commercially important species were evaluated in an effort to assess the timing, volume, and quality of water necessary to protect public trust resources. Flow criteria were developed for each of the species identified by DFG as those that are priority concern and will benefit the most as a result of improved flow conditions (DFG closing comments, p. 3). For Delta outflow, this included longfin smelt, delta smelt, starry flounder, American shad, bay shrimp (*Crangon* sp.), mysid shrimp, and *Eurytemora affinis*. Through this process, data or information pertaining to life history attributes (e.g., timing of migration, spawning, rearing), relationships of species abundance or habitat to Delta outflow, season or time period when flow characteristics are most important, factors influencing and/or limiting populations, and other characteristics were assessed and summarized in the individual species write-ups.

Statistically significant relationships between annual abundance and X2 (or outflow) have been demonstrated for a diverse assemblage of species within the estuary (Stevens and Miller 1983; Jassby *et al*. 1995; Kimmerer 2002a; Rosenfield and Baxter 2007; Kimmerer *et al*. 2009). The causal mechanisms underlying the variation in annual abundance indices of pelagic species in the estuary are poorly understood, but likely vary across species and life stages.

Longfin smelt have the strongest X2-abundance relationship of those species for which such a relationship has been demonstrated (Kimmerer *et al*. 2009). Abundance indices for this species are inversely related to X2 during its winter-spring spawning and early rearing periods (Stevens and Miller 1983; Jassby *et al*. 1995; Kimmerer 2002a; Rosenfield and Baxter 2007; Kimmerer *et al*. 2009). However, a four-fold decline in the relationship, with no significant change in slope, occurred after 1987, coincident with the introduction and spread of the introduced clam *Corbula amurensis* (Kimmerer 2002a). Reduced prey availability due to clam grazing has been identified as a likely mechanism for the decline in the X2-abundance relationship (Kimmerer 2002a).

One of the key biological objectives of the informational proceeding was to identify the flows needed to increase abundance of native and other desirable species. Logit regression (StatSoft 2010, as cited in TBI/NRDC 2, p.17) was used to address the question: What outflow corresponded to positive longfin smelt population growth 50% of the time in the past? Logit regression is used to find a regression solution when the response variable is binary. For the purpose of this analysis, the generation-over-generation changes in abundance indices were converted to a binary variable (increase = 1 or decrease = 0). The analysis was conducted using FMWT abundance indices for the period extending from 1988 to 2007 (post-*Corbula*). Two periods of the winter-spring seasons (January to March and March to May) were evaluated, as different life stages of longfin smelt are present in the Delta during those periods (spawning adults and larvae/juveniles, respectively) and the mechanisms underlying the flow-abundance relationship may occur and/or vary in some or all of the months during these periods (TBI/NRDC 2, p. 13). The results were statistically significant ($p < 0.015$) and revealed that the "likelihood" of an increase in FMWT abundance index in 50% of years corresponded with flows of approximately 9.1 MAF and 6.3 MAF during January through March and March through May, respectively (Figure 11, TBI/NRDC 2, pp. 17-19).



Logit regression showing relationship between March through May Delta outflow and generation-over-generation change in abundance of longfin smelt (measured as the difference between annual FMWT abundance indices). Positive changes in the abundance index were scored at "1" and declines were scored as "0". Arrow indicates flows above which growth occurred in more than 50% of years. Point labels indicate year of the FMWT index. (Source: TBI 2, Figure 15).

Figure 11. Logit Regression Showing Relationship Between March through May Delta Outflow and Generation-Over-Generation Change in Longfin Smelt Abundance

A similar analysis was conducted for bay shrimp (*Crangon* sp.), a species whose flow-abundance relationship did not experience a "step decline" following the invasion of *Corbula* (Kimmerer 2002a). Results of the logit analysis indicate that abundance indices for this species increased in about 50% of years when flows during March through May were approximately 5 MAF (TBI/NRDC 1, p. 17). Therefore, flows associated with positive changes in the longfin smelt abundance index are anticipated to improve the likelihood of increases in bay shrimp abundance as well.

An analysis of historical longfin smelt flow-abundance relationships that corresponded to recovery targets in the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996) was also conducted. During the periods of January through March and March through May, cumulative Delta outflows of greater than 9.5 MAF and greater than 6.3 MAF, respectively, historically corresponded to abundance indices equal to or exceeding the recovery targets (TBI/NRDC 2, p. 14). These results are based on the intersection of the 1967 to1987 flow-abundance relationship and the recovery target. Use of the 1988 to 2007 flow-abundance relationship predicts lower abundance indices per any given flow, as compared to the historical relationship. Use of the pre-*Corbula* flow-abundance relationship underscores the need to address other stressors that may be affecting longfin smelt abundance concurrently with improved flow conditions (TBI/NRDC 2, p. 14). Applying this method and the logit regression produces very similar results.

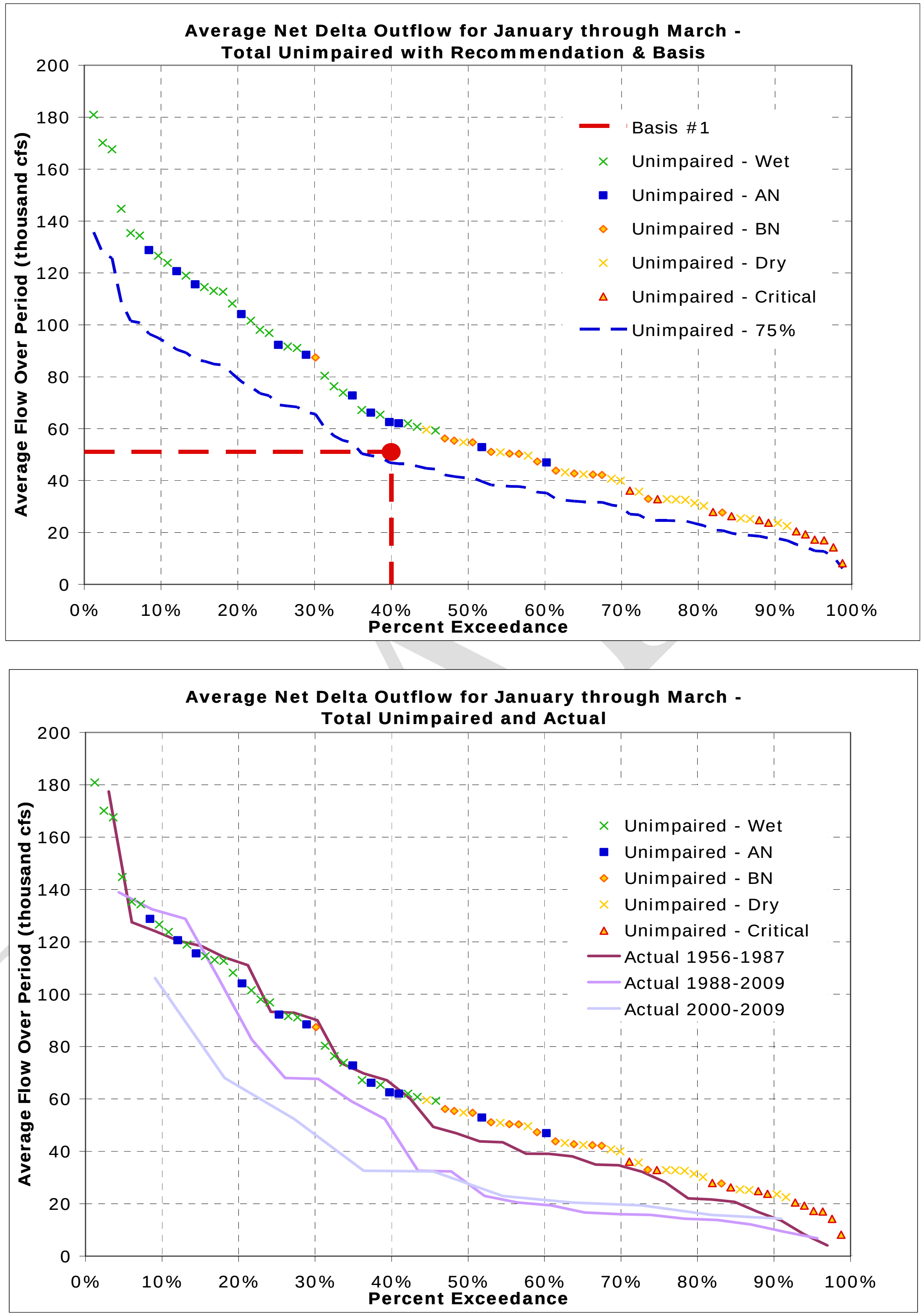
As noted above, the results of the logit analysis indicated that the "likelihood" of an increase in the longfin smelt FMWT abundance index in 50% of years corresponded with flows of approximately 9.1 MAF and 6.3 MAF during January through March and March through May, respectively (TBI/NRDC 2, pp. 17-19). Hereafter, these two flow volumes are reported in cubic feet per second, as 51,000 cfs and 35,000 cfs, respectively. Analyses indicate that under historic unimpaired conditions (1921 to 2003) average flows of 51,000 cfs occurred between January and March in approximately 50% of years (Figure 12a), while average flows of 35,000 cfs happened between March and May approximately 85% of the time (Figure 13a). The review of the historic record suggests that it is unrealistic to expect a 100% return frequency for the two magnitudes. A point of reference for determining a more realistic return frequency might be the actual (impaired) flows that occurred from 1956 to 1987. This was a time period when native fish were more abundant than today. Actual average flows between 1957 and 1987 of 51,000 cfs occurred between January and March in approximately 45% of years (Figure 9b). Similarly average flows of 35,000 cfs occurred between March and May 47% of the time (Figure 10b). However, since 2000, average flows of this magnitude only occurred about 27% and 33% of the time, respectively (Figures 9b and 10b). At 75% of unimpaired flow, average flows of 51,000 and 35,000 cfs would happen 35% and 70% of the time, respectively (Figures 9b and 10b). Finally, the DFG has indicated that spring outflows should continue through June to fully protect a number of estuarine species (DFG 1, pp.2-5).

A fixed 75% of unimpaired flow would extend the flow criteria to other years and distribute flows in a manner that more closely resembles the natural hydrograph.

Expression of this criterion as a 14-day running average would better reflect the timing of actual flows (compared with a 30-day running average) while still allowing for a time-step to which reservoirs could be operated. The appropriateness of the 14 day averaging period warrants further evaluation. The unimpaired flows from which the 75% criterion is calculated and shown in Figures 10, 11, and 12 are monthly values. Estimates of 14-day unimpaired flow have not been published, but a cursory analysis indicates that they are likely to generate an exceedance curve similar to one generated with monthly values.

The State Water Board therefore determines that the Net Delta Outflow criteria be 75 percent of the 14-day average unimpaired flow between January and June (Figure 14a, Table 19). DFG (closing comments, p. 7) recommended that X2 be maintained between 65 and 74 km (Chipps Island and Port Chicago) from January through June. With a criteria of 75% of unimpaired flow, X2 would be maintained west of Chipps Island more than 90% of the time between January and June (analyses not shown). The return frequency for all months combined is about 98% of the time (Figure 12a). This compares with about a 90% percent return frequency between 2000 and 2009 (Figure12b)

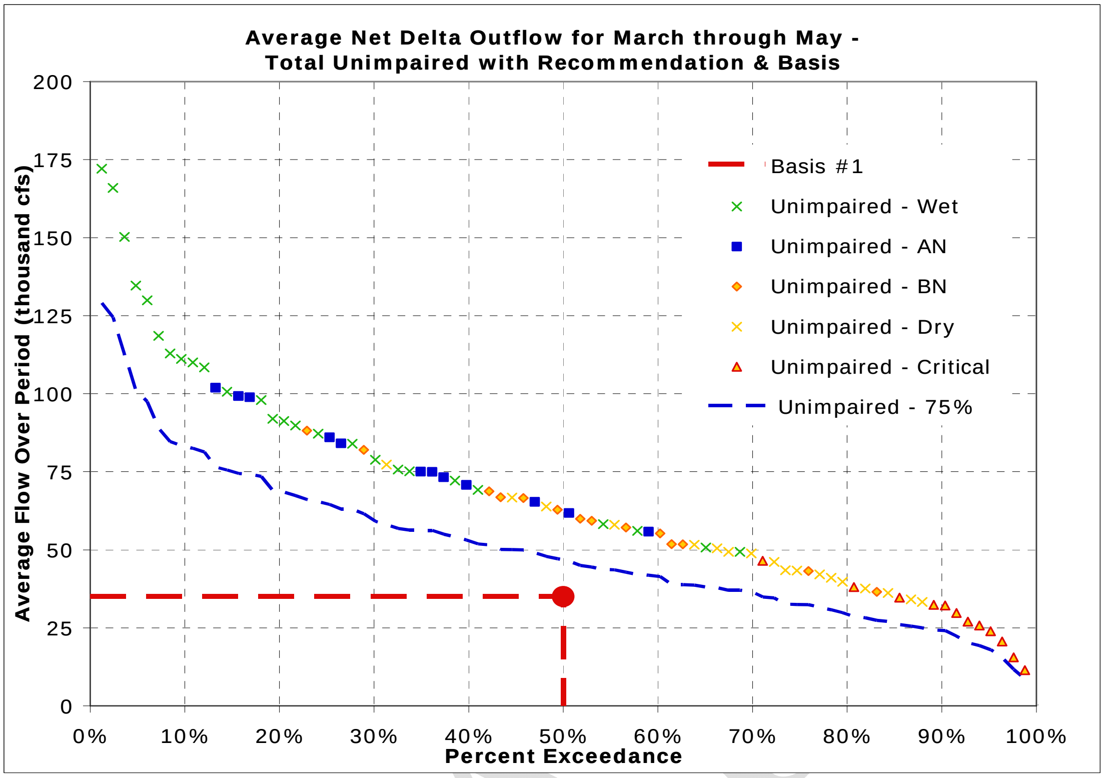
a)



b)

Figure 12. Net Delta Outflow Flow Exceedance Plot - January through March

a)



b)

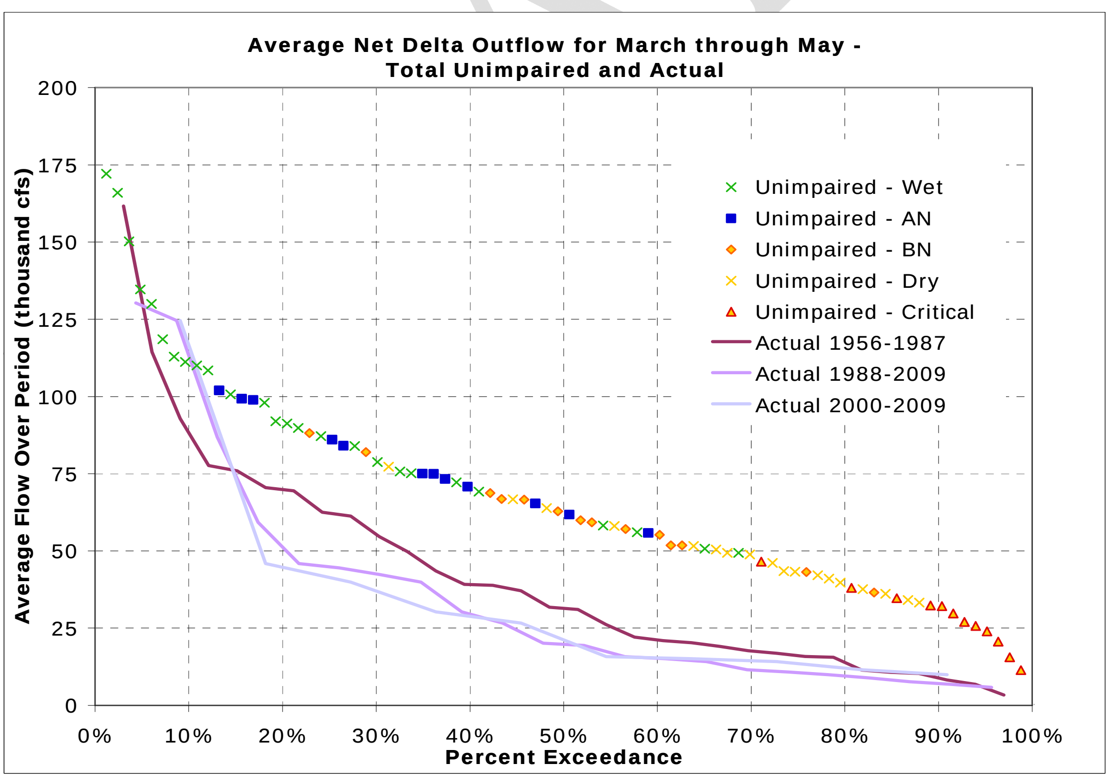
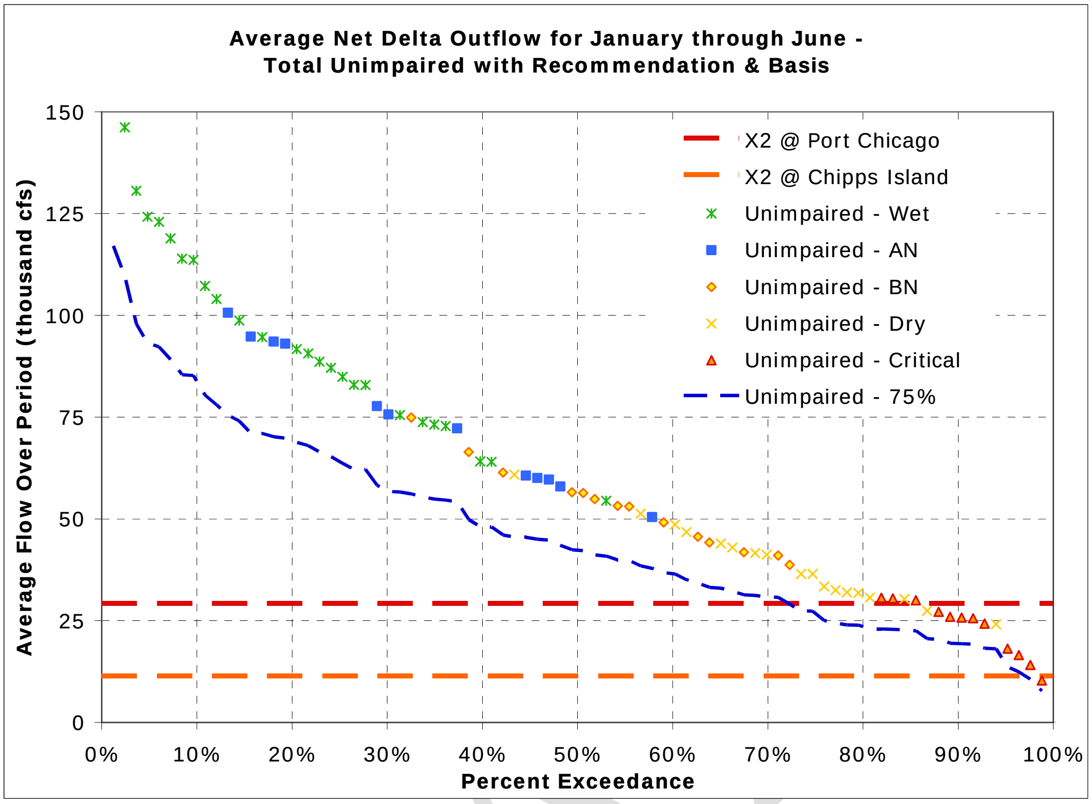


Figure 13. Net Delta Outflow Flow Exceedance Plot - March through May

a)



b)

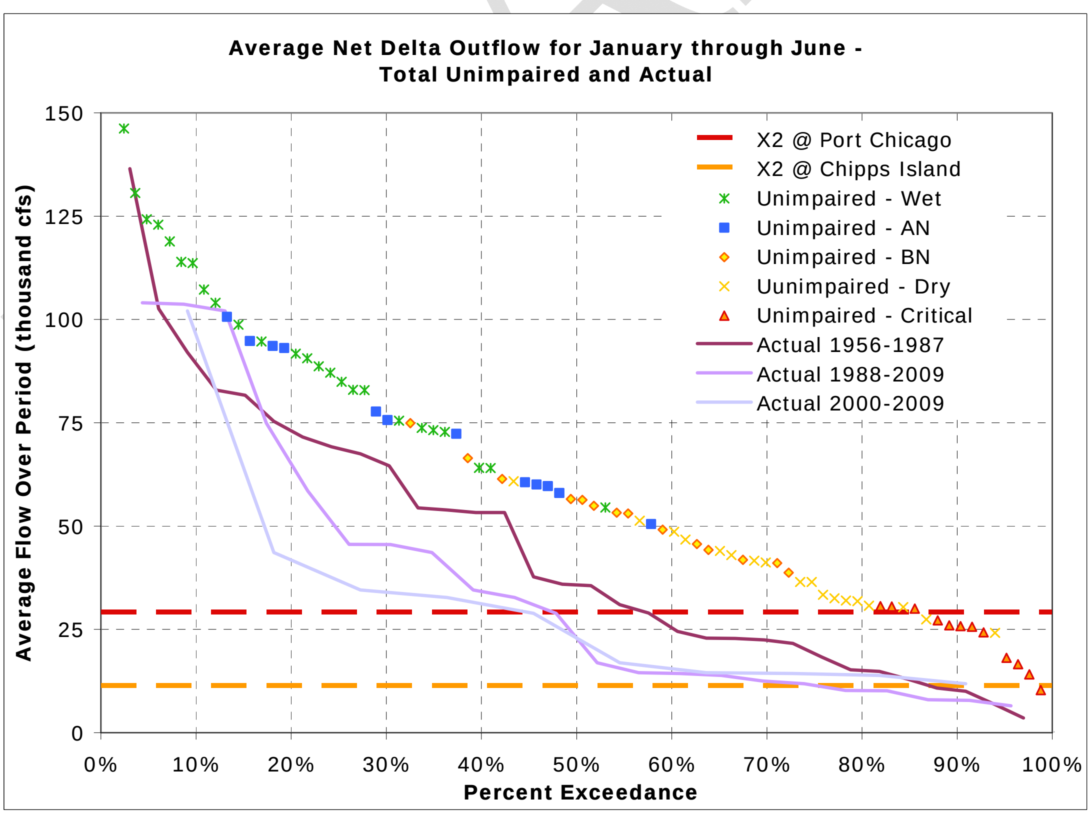


Figure 14. Net Delta Outflow Flow Exceedance Plot - January through June

The net Delta outflow criteria of 75% of unimpaired flows from January through June is anticipated to increase the likelihood of positive population growth for a number of other public trust species, notably those for which abundance-X2 relationships have been demonstrated, including American shad, striped bass, starry flounder, bay shrimp (*Crangon franciscorum*), and *Eurytemora affinis* (spring abundance). For example, the spring (March through May) abundance of *Eurytemora affinis* has been positively related to flow, following the invasion of *Corbula* (Kimmerer 2002a). This species represents an important prey item for most small fishes, particularly those with winter and early spring larvae, such as longfin smelt, delta smelt and striped bass (Lott 1998, Nobriga 2002, Bryant and Arnold 2007, DFG unpublished). Increases in the abundance of prey species, such as *E. affinis* and bay shrimp, has the potential to improve productivity of the estuarine food web and benefit a number of fishes, especially given that food limitation has been identified as a potential contributing factor in the POD (Baxter *et al*. 2008). Additional information concerning the relationship of population abundance to flow for these species is provided in the species life history section of this report.

Delta smelt abundance does not respond to freshwater outflow in a predictable manner similar to that of other numerous estuarine species (Stevens and Miller 1983; Jassby *et al*. 1995; Kimmerer 2002a). However, freshwater outflow during spring (March to June) does affect the distribution of delta smelt larvae by transporting them seaward toward the low salinity zone (Dege and Brown 2004). Ideal rearing habitat conditions for this species are believed to be shallow water areas most commonly found in Suisun Bay (Bennett 2005). Outflows that locate X2 in Suisun Bay (mean April through July location) produce the highest delta smelt abundance levels; however, low abundances have also been observed under the same conditions, which indicates several mechanisms must be operating (Jassby *et al*. 1995; DFG 1, p. 15). A criterion of 75% of unimpaired flow is expected to place X2 in Suisun Bay from March through June in nearly all years.

DFG's current science-based conceptual model is that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry (DFG 2, p. 6). DFG (closing comments, p. 7) provided recommended flow criteria for the Delta based on the placement of X2, for January through June (exact period varied by species), for longfin smelt, starry flounder, bay shrimp, zooplankton, and American shad. For each of these species, DFG (closing comments, p. 7) recommended that sufficient outflow be provided to position X2 between 75 km and 64 km. These recommendations are generally consistent with spring X2 requirements in the 2006 Bay-Delta Plan, which requires salinity at one compliance point (81 km) not to exceed 2 psu continuously, and at two other compliance points (64 km [Port Chicago] and 75 km [Chipps Island]) not to exceed 2 psu for a set number of days during February through June. Positioning X2 at 75 km and 64 km is equivalent to a 3-day running average Net Delta Outflow Index of 11,400 cfs and 29,200 cfs, respectively. Implementation of the 75% of unimpaired flow recommendations would be largely consistent with the intent of DFG's recommendations by placing X2 between Chipps Island and Port Chicago, or further to the west, in nearly all years during the January through June period.

The step-decline in the abundance-X2 relationship that occurred after 1987 for many of these species in combination with the lack of understanding concerning the causal mechanisms underlying those relationships leads to uncertainty regarding the future response of these species to elevated flows. In addition, a number of major changes to the Delta landscape, including levee failure and island flooding, are likely to occur over the next several decades (Lund *et al*. 2007, 2008). Flow regimes needed to maintain desired environmental conditions will change through time, in response to changes in the geometry of waterways, climate, and other factors. A number of "stressors" are currently being evaluated as potential contributors to the POD, including attributes of physical and chemical fish habitat (Sommer *et al*. 2007; Baxter *et al*. 2008). Increasing flows, without concurrent improvements to habitat and water quality, would decrease the extent of expected improvements in native species abundances and habitats (DOI 1, p. 40). However, the scientific information received during this proceeding supports the conclusion that flow, though not sufficient in and of itself, is necessary to protect public trust resources and that the current flow regime has harmed native species and benefited non-native species. Each of these issues adds further support to the need for a strong adaptive management program.

The specific flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water resources to support egg incubation, juvenile rearing, and holding in the Sacramento River, San Joaquin River, and associated tributary basins. It may not be possible to attain the outflow criteria and meet the thermal needs of the various runs of Chinook salmon and other sensitive species in certain years. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both outflow and cold water temperature goals.

<u>Category B: Delta Smelt Fall X2</u>
Abiotic habitat parameters for delta smelt have been described for both the summer and fall seasons as combinations of salinity, temperature, and turbidity (Nobriga *et al*. 2008; Feyrer *et al*. 2007; Feyrer *et al*. in review). During fall, delta smelt typically occur in low salinity rearing habitats located around the confluence of the Sacramento and San Joaquin Rivers. Suitable abiotic habitat for delta smelt during fall has been defined as relatively turbid water (Secchi depths < 1.0 m) with a salinity of approximately 0.6-3.0 psu (Feyrer *et al*. 2007). Long-term trend analysis has shown that environmental quality, as defined by salinity and turbidity, has declined across a broad geographical range, most notably within the south-eastern and western regions of the Delta, leaving a relatively restricted area in the lower Sacramento River and around the confluence of the Sacramento and San Joaquin rivers with the least habitat alteration, compared to the rest of the upper estuary (Feyrer *et al*. 2007, DOI 1, p.34).

The amount of habitat available to delta smelt is controlled by freshwater flow and how that flow affects the position of X2, geographically, in the estuary (Figure 15) (Feyrer *et al*. in review). Through the use of a 3D hydrodynamic model, Kimmerer *et al*. (2009) showed that the extent of delta smelt habitat, as defined by salinity, increases as X2 moves seaward. When X2 is located downstream of the confluence of the Sacramento and San Joaquin rivers, suitable abiotic habitat extends into Suisun and Grizzly bays, resulting in a large increase in the total area of suitable abiotic habitat (Feyrer *et al*. in review). The average X2 during fall has moved upstream, resulting in a corresponding reduction in the amount and location of suitable abiotic habitat (Feyrer *et al*. 2007; Feyrer *et al*. in review).

Average Net Delta Outflow for September, October and November are presented in Figures Figure 16, Figure 17, and Figure 18. Historically, unimpaired flows in fall were independent of water year type. Interestingly, actual outflow was greater than unimpaired flow between 1956 and 1987. However, fall outflows have fallen and since 2000 are almost always less than unimpaired flow. This is consistent with the observations of Feyrer *et al*. (2007) that fall X2 has moved upstream and this has reduced the amount of available habitat for smelt in fall.

Fall conditions may be very important for delta smelt, since these fish represent pre-spawning adults (Feyrer *et al*. 2007). In general, reductions in habitat constrict the range of these fishes, which combined with an altered food web, may affect their health and survival (Feyrer *et al*. 2007). There is a statistically significant stock-recruitment relationship for delta smelt in which pre-adult abundance measured by the FMWT positively affects the abundance of juveniles the following year in the Summer Townet (Bennett 2005; Feyrer *et al*. 2007, as cited in USFWS 2008). Incorporating the combined effects of specific conductance and Secchi depth improved the stock-recruitment relationship (Feyrer *et al*. 2007).

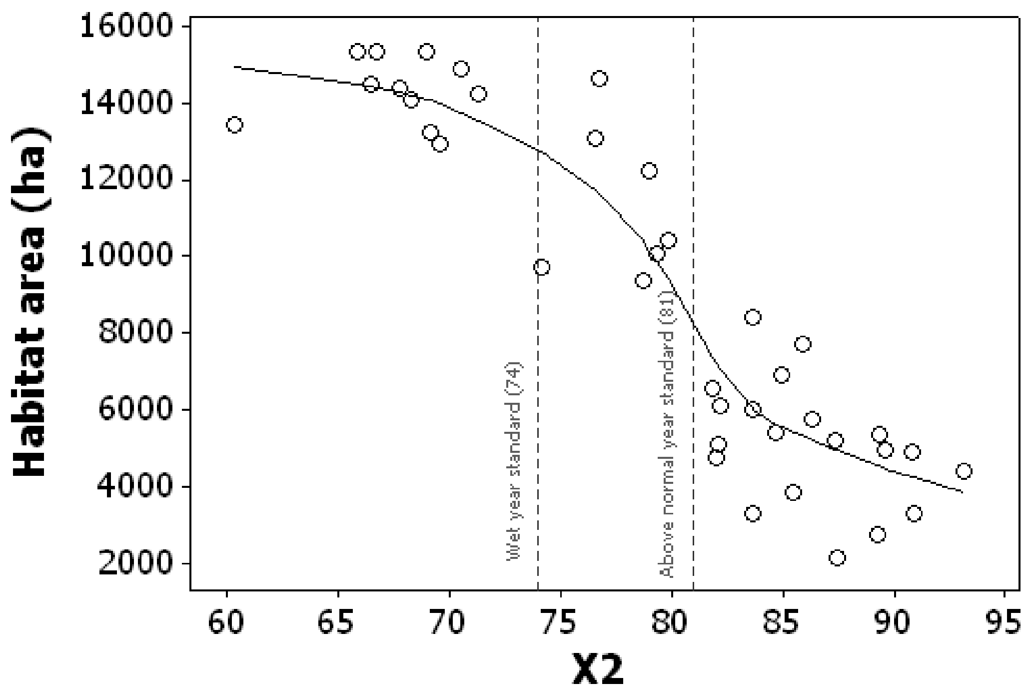
Feyrer *et al*. (In Review) demonstrated that delta smelt is more abundant when there is a large amount of habitat available. However, the relationship between habitat area and FMWT abundance is complex and not strong (NAS 2010). When the area of highly suitable habitat is low, either high or low FMWT indices can occur (Figure 16). Therefore, delta smelt can be successful in instances where habitat is limited. More important, however, is that the lowest abundances all occurred when the habitat-area index was less than 6,000 ha (Feyrer *et al*. in review; NAS 2010). This potentially suggests that while reduced habitat area may be an important factor associated with the worst population collapses, it is not likely the only cause of the collapse (NAS 2010).

The Fall X2 action is focused on wet and above normal years because these are the years in which project operations have most significantly affected fall outflows. Actions in these years are more likely to benefit delta smelt (USFWS 2008). The action proposes to maintain X2 in the fall of wet years and above-normal years at 74 km and 81 km, respectively (Figures 14, 15, and 16; USFWS 2008). In addition to increasing the quality and quantity of habitat for delta smelt, moving X2 westward in the fall may also reduce the risk of entrainment by increasing the geographic and hydrologic distance of smelt from the influence of the Project export facilities (DOI 1, p. 34).

The National Academy of Sciences (2010) commented on this action in their review of the Biological Opinion and concluded: "The X2 action is conceptually sound in that to the degree that habitat for smelt limits their abundance, the provision of more or better habitat would be helpful. However, the examination of uncertainty in the derivation of the details of this action lacks rigor. The action is based on a series of linked statistical analyses (e.g., the relationship of presence/absence data to environmental variables, the relationship of environmental variables to habitat, the relationship of habitat to X2, the relationship of X2 to smelt abundance), with each step being uncertain. The relationships are correlative with substantial variance being left unexplained at each step. The action also may have high water requirements and may adversely affect salmon and steelhead under some conditions (memorandum from USFWS and NMFS, January 15, 2010). As a result, how specific X2 targets were chosen and their likely beneficial effects need further clarification."

The State Water Board determines that inclusion of the delta smelt fall X2 action as a Category B flow criterion (Table 19), consistent with requirements stipulated in the Biological Opinion (USFWS 2008) will likely improve habitat conditions for delta smelt.

However, in light of the uncertainty about specific X2 targets and the overall effectiveness of the fall X2 action, the State Water Board recommends this action be implemented within the context of an adaptive management program. The program should include studies designed to clarify the mechanisms underlying the effects of fall habitat on the delta smelt populations, the establishment and peer review of performance measures and performance evaluation related to the action, and a comprehensive review of the outcomes of the action and effectiveness of the adaptive management program (USFWS 2008). Absent study results demonstrating the importance of fall X2 to the survival of delta smelt, fall flows beyond those stipulated in the Fall X2 action for the protection of delta smelt are not recommended at this time.



Relationship between X2 and habitat area for delta smelt during fall, with standard shown for wet and above normal years. (Source: USFWS 2008, Figure B17).

Figure 15. X2 Versus Habitat Area for Delta Smelt During Fall

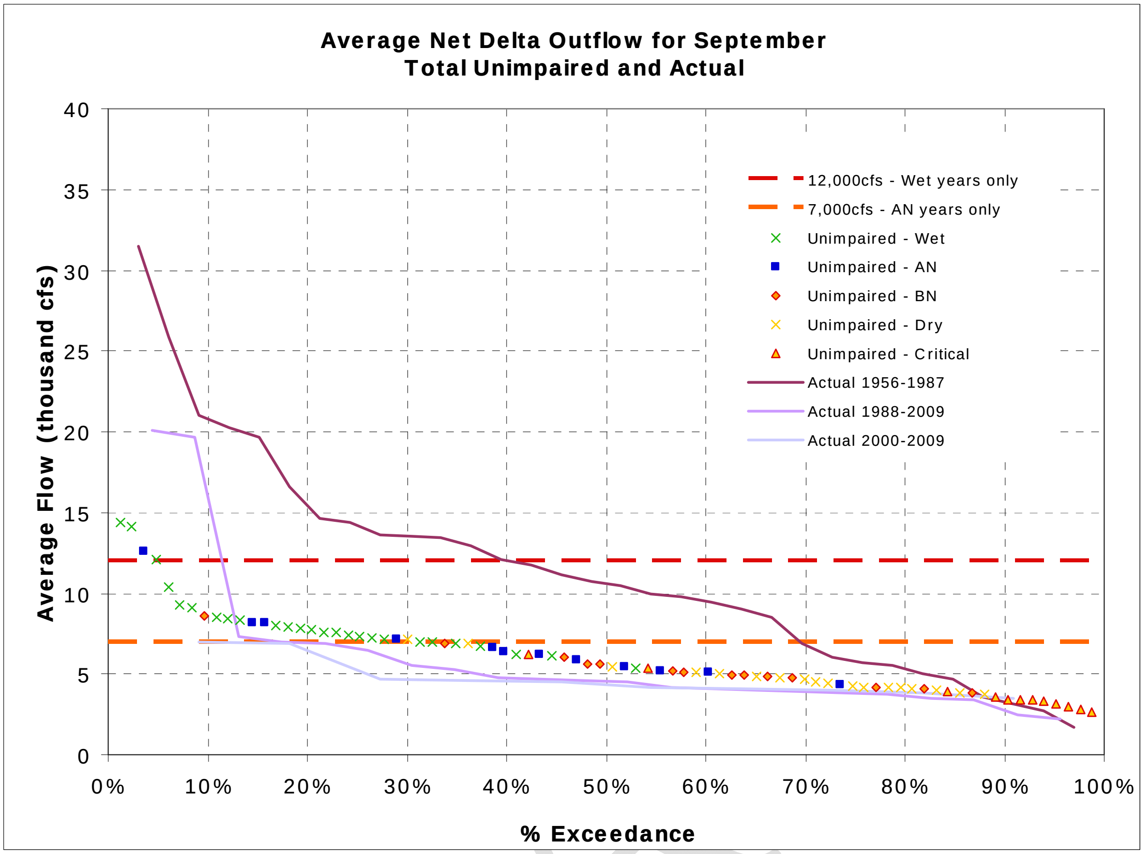


Figure 16. Net Delta Outflow Flow Exceedance Plot - September

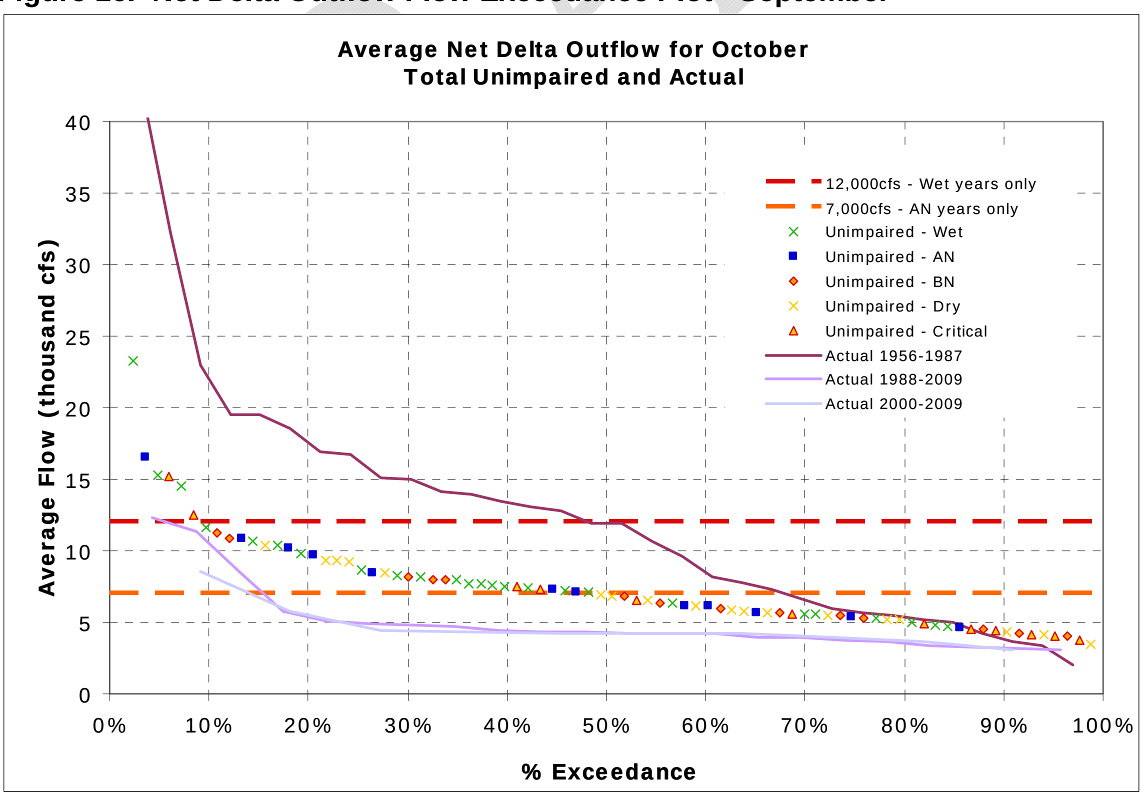


Figure 17. Net Delta Outflow Flow Exceedance Plot - October

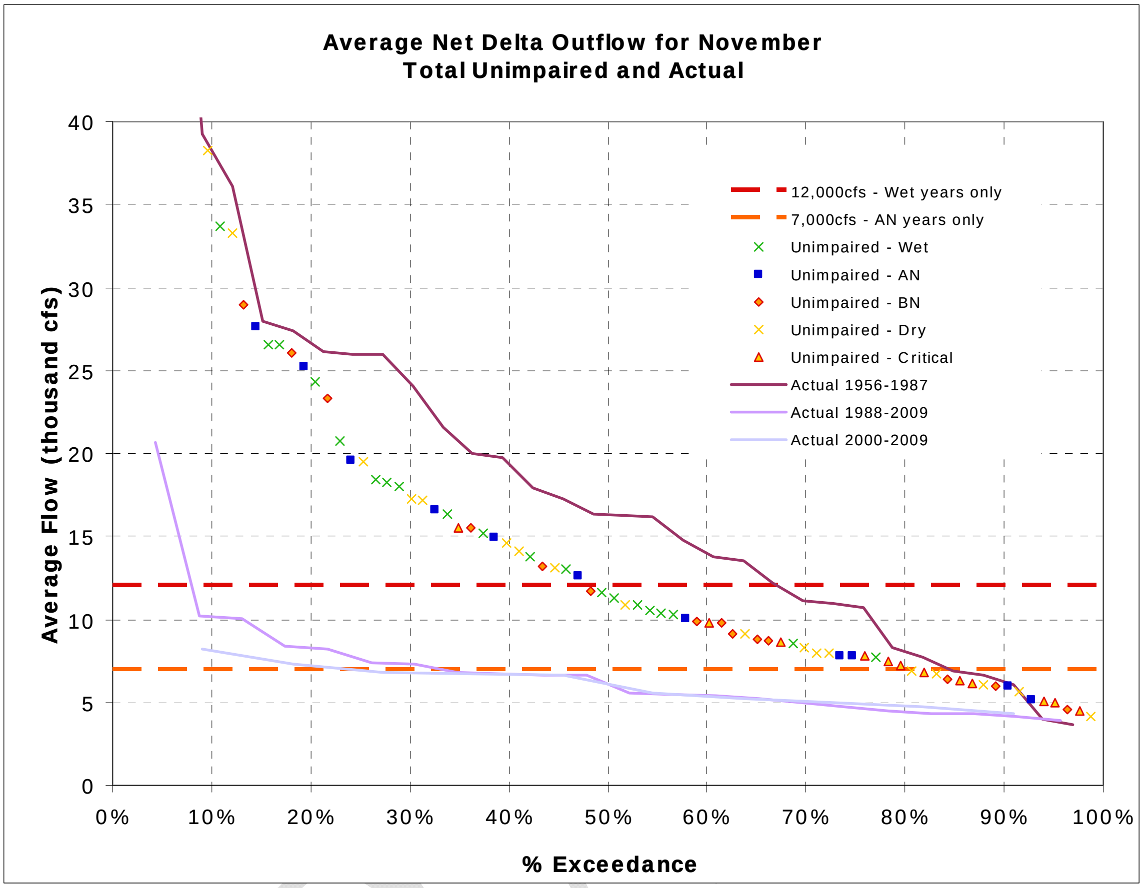


Figure 18. Net Delta Outflow Flow Exceedance Plot - November

The specific Delta Outflow flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water and tributary specific flows on tributaries to the Delta. It may not be possible to attain both the flow criteria and meet the thermal and tributary specific flow needs of all of the sensitive species in the Delta Watershed. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

Category B: 2006 Bay-Delta Plan Summer – Fall Delta Outflow

Resident estuarine species, such as delta smelt, require flows sufficient to provide adequate habitat throughout the year. Recommended Delta outflows for January through June are discussed above. In addition to providing flows to support resident species, sufficient flows must also be provided in the fall to provide attraction cues and a homing mechanism for returning adult salmon. Recommendations for salmon fall attraction flows on the Sacramento and San Joaquin rivers are discussed in Sections 5.2 and 5.3. The 2006 Bay-Delta Plan contains summer – fall Delta outflow water quality objectives for fish and wildlife beneficial uses, which are summarized below in Table 19.

Table 19. 2006 Bay-Delta Plan Delta Outflow Objectives for July through December

Water Year	July	Aug	Sept	Oct	Nov	Dec
Critical	4000	3000	3000	3000	3500	3500
Dry	5000	3500	3000	4000	4500	4500
Below Normal	6500	4000	3000	4000	4500	4500
Above Normal	8000	4000	3000	4000	4500	4500
Wet	8000	4000	3000	4000	4500	4500

Multiple participants submitted testimony concerning the need for additional flows in the fall to benefit delta smelt, striped bass, and other resident species (CSPA 1, p. 7; CWIN 2, p. 29; DOI 1, pp. 46-48; EDF 1, pp. 49-50; TBI/NRDC 2, pp. 27-37), and as a means to potentially control the spread of harmful invasive species (e.g., *Corbula* and toxic algae) (TBI/NRDC 2, pp. 27-37). The recommendations were based largely on recent research conducted by Feyrer *et al*. (2007 and In Review) and the Fall X2 action in the USFWS's (2008) delta smelt biological opinion. Additional information concerning the basis for the Fall X2 is provided below (Category B: Delta Smelt Fall X2). The Fall X2 action in the biological opinion (USFWS 2008) requires that sufficient outflow be provided in September through November of Above Normal and Wet water year types to position X2 at 81 km and 74 km, respectively. This action was restricted to Above Normal and Wet years because these are the years in which project operations have most significantly affected fall outflows and to limit potential conflicts with cold water pool storage (USFWS 2008).

Following its review of the biological opinion, the National Academy of Sciences (2010) noted that "[a]lthough there is evidence that the position of X2 affects the distribution of smelt, the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand… The X2 action is conceptually sound in that to the degree that the amount of habitat available for smelt limits their abundance, the provision of more or better habitat would be helpful… the committee concludes that how specific X2 targets were chosen and their likely beneficial effects need further clarification." The biological opinion (USFWS 2008) also recognized uncertainty concerning the position of fall X2 and subsequent abundance of delta smelt and requires that the action be implemented with an adaptive management program to provide for learning and improvement of the action over time.

However, some participants provided flow recommendations that called for increased fall outflows during all water year types, as compared to the objectives in the 2006 Bay-Delta Plan, and in certain instances in excess of those required by the USFWS (2008) biological opinion. Given the need for improved understanding concerning the Fall X2 action, including the mechanisms underlying the effects of fall habitat on delta smelt populations, determination of specific X2 targets, potential conflicts with cold water pool storage, and the likely effectiveness of the action, the State Water Board does not determine that increasing fall flows in Critical, Dry, and Below Normal water year types beyond those required in the 2006 Bay-Delta Plan and in Above Normal and Wet water year types beyond those stipulated in the Fall X2 action (Category B) is warranted at this time. The quantity and timing of fall outflows necessary to protect public trust resources warrants further evaluation and underscores the need for a well-designed adaptive management program. The potential to use variability in flows during summer and fall months as a means of controlling the distribution and abundance of invasive species should also be evaluated.

5.2 Sacramento River

Following are the Sacramento River inflow criteria based on analysis of the species-specific flow criteria and other measures:

1) Sacramento River Flow at Rio Vista: 75 percent of 14-day average unimpaired flow from April through June to increases juvenile salmon outmigration survival for fall-run Chinook salmon
2) Sacramento River Flow at Rio Vista: 75 percent of 14-day average unimpaired flow from November through March to increases juvenile salmon outmigration survival for other runs of Chinook salmon
3) Sacramento River at Wilkins Slough: Provide pulse flows of 20,000 cfs for 7 days starting in November coincident with fall/early winter storm events; the timing, magnitude, duration, and number of pulses should be determined on an adaptive management basis informed by unimpaired flow conditions and monitoring of juvenile salmon migration to promote juvenile salmon emigration
4) Sacramento River Flow at Freeport: Provide flows of 13,000 to 17,000 cfs in the Sacramento River downstream of confluence with Georgiana Slough when salmon are migrating through the Delta from November through June to increase juvenile salmon outmigration survival by reducing straying into Georgiana Slough and the central Delta
5) Sacramento River at Rio Vista: 2006 Bay-Delta Plan flow objectives for September and October to provide Fall adult Chinook salmon attraction flows

The magnitude, duration, timing, and source of Sacramento River inflows are important to all runs of Chinook salmon migrating through the Bay-Delta and several different aspects of their life history. Inflows are needed to provide appropriate conditions to cue upstream adult migration to the Sacramento River and its tributaries, adult holding, egg incubation, juvenile rearing, emigration from the Sacramento River and its tributaries, and other functions. Sacramento River inflows are important throughout the year to support various life stages of the different Chinook salmon runs inhabiting the Sacramento River. However, given the focus of this proceeding on inflows to the Delta and the importance of the juvenile salmon emigration period, the Sacramento River inflow criteria included in this report focus primarily on flows needed to support emigrating juvenile Chinook salmon from natal streams through the Delta. Following is a brief summary of the Sacramento River inflow criteria that were developed based on the species-specific flow needs analyses for salmon included in section 4.2.3 followed by a detailed discussion.

Available scientific information indicates that average April through June flows of 20,000 to 30,000 cfs on the Sacramento River at Rio Vista represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon. Less information is available for the other runs of Chinook salmon on the Sacramento River. However, outmigration flows needed to protect other races are assumed to be generally the same since factors that affect fall-run survival are generally applicable to other runs with some exceptions. In addition, analyses indicate that providing pulse flows of 20,000 cfs at Wilkins Slough on the Sacramento River beginning in November and extending through the first of the year provides for earlier migration timing and increased survival of juvenile winter, spring, and late-fall run Chinook salmon. In addition, information indicates that flows of 13,000 cfs to 17,000 cfs may be needed on the Sacramento River at Freeport to prevent salmon from migrating through Georgiana Slough and the interior Delta where survival is substantially lower.

Continuity of flows from natal stream through the Delta and flow variability are also important so rather than static April through June threshold flows of 20,000 to 30,000 cfs, the State Water Board determines, as a Category A criterion, that 75% of unimpaired flow is needed to achieve a threshold flow of 25,000 cfs (average of 20,000 and 30,000 cfs) approximately 50% of the time. The same percentage of unimpaired flow for the November through March period is also advanced as a Category B criterion due to the lack of information upon which this criterion was based. In addition, as Category B criteria, the State Water Board determines that shorter pulse flows of 20,000 cfs for 7 days at Wilkins Slough are needed starting in November and extending through the first of the year and flows of 13,000 cfs to 17,000 cfs at Freeport are needed from November through June to provide additional protection for Sacramento River Chinook salmon. The State Water Board also advances the Sacramento River flow objectives from the Bay-Delta Plan during September and October to provide a minimal level of protection during these months pending development of additional information concerning flow needs during this period. All of the Sacramento River flow criteria are not precise; rather they reflect the general timing and magnitude of flows needed to protect public trust resources, but could serve as a reasonable basis from which future analysis and adaptive management could proceed. The criteria also do not consider other Sacramento River flow needs.

<u>Sacramento River Inflow as a Percentage of Unimpaired Flows</u>
It appears to be important to preserve the general attributes of the natural hydrograph to which the various salmon runs adapted over time. Information indicates that Chinook salmon respond to variations in flows and need some continuity of flow between natal streams and the Delta for transport and homing fidelity. As such, the historic practice of developing monthly flow criteria to be met from limited sources may be less than optimal for protecting Chinook salmon runs. At the same time, given the impediments to fish passage into historic spawning and rearing areas, there may also be a need to diverge from the natural hydrograph at certain times of year to provide more flow than might have naturally occurred or less flow such that those flows are available at other times of year to mitigate for passage and habitat issues (e.g. cold water pool management).

Based on the above, the State Water Board developed Sacramento River inflow criteria, intended to mimic the natural hydrograph during the peak emigration period, to protect emigrating juvenile Chinook salmon. While emigration of some runs may occur outside of this period, peak emigration is generally believed to occur between November through June. As such, the criteria are recommended to apply to this time period. To achieve the attributes of a natural hydrograph, the criteria are recommended as a percentage of unimpaired flow on a 14-day average, to be provided generally on a proportional basis from the tributaries to the Sacramento River. The 14-day average is intended to better capture the peaks of actual flows compared to a 30-day average time-step, while still allowing for a time-step at which facilities can be operated. The appropriateness of this time-step for protecting public trust resources should be further evaluated.

Spring Sacramento River Inflows at Rio Vista
The species-specific flow needs analyses for salmon in section 4.2.3 indicates that average April through June flows of 20,000 to 30,000 cfs on the Sacramento River at Rio Vista provide for improved survival and abundance of juvenile fall-run Chinook salmon on the Sacramento River.

Flow exceedance graphs were used to determine the percentage of flow needed to achieve various flows needed to protect Chinook salmon. Analysis of unimpaired flows (Figure 19) shows that under historic unimpaired conditions, average April through June flows of 30,000 cfs or more would occur in approximately 60% of years. Flows of 25,000 cfs or more would occur is approximately 72% of years, and flows of 20,000 cfs or more would occur in roughly 85% of years. At 75% of unimpaired flows, average flows of 30,000 cfs would be achieved between April and June in roughly 37% of years, flows of 25,000 cfs would be achieved in roughly 50% of years, and flows of 20,000 cfs would be achieved in approximately 70% of years. At 50% of unimpaired flows, flows of 30,000 cfs would be achieved in approximately 15% of years, flows of 25,000 cfs in roughly 25% of years, and flows of 20,000 cfs in roughly 35% of years. Actual flows of 30,000, 25,000, and 20,000 cfs were met in 26, 32, and 39% of years, respectively between 1986 and 2005. It is important to note, however, that unimpaired flows between 1986 through 2005 are not necessarily representative of the longer term unimpaired flow record. Flow criteria equal to 75% of unimpaired flows during the April through June period, on average, would therefore provide favorable conditions for fall-run juvenile Chinook salmon in at least 50% of years (assuming 25,000 cfs flows). As a result, the State Water Board advances 75% of unimpaired flows on a 14-day average from April through June as a potential means to achieve the 20,000 to 30,000 cfs Sacramento River flow threshold discussed above while maintaining variability and the attributes of the natural hydrograph. This criteria is included as criterion 1) for Sacramento River flows and is a Category A criteriod. The unimpaired estimates from which the 75% criterion is calculated are monthly estimates. Estimates of 14-day unimpaired flow have not been published, but are expected to generate an exceedance curve similar to one generated with monthly estimates. This specific percent of unimpaired flow and the averaging period should be adaptively managed. More information and analyses should be conducted to determine if there are maximum flows above which no, or significantly diminishing, additional biological or geomorphological benefits are obtained. This criteria would allow for flows to vary over time coincident with precipitation events reflecting the natural hydrograph. Climate change, however, and its associated effect on flow patterns will likely change how effective such flows are in protecting Chinook salmon. As such these flow criteria would need to be adaptively managed in the future to ensure the protection of Chinook salmon.

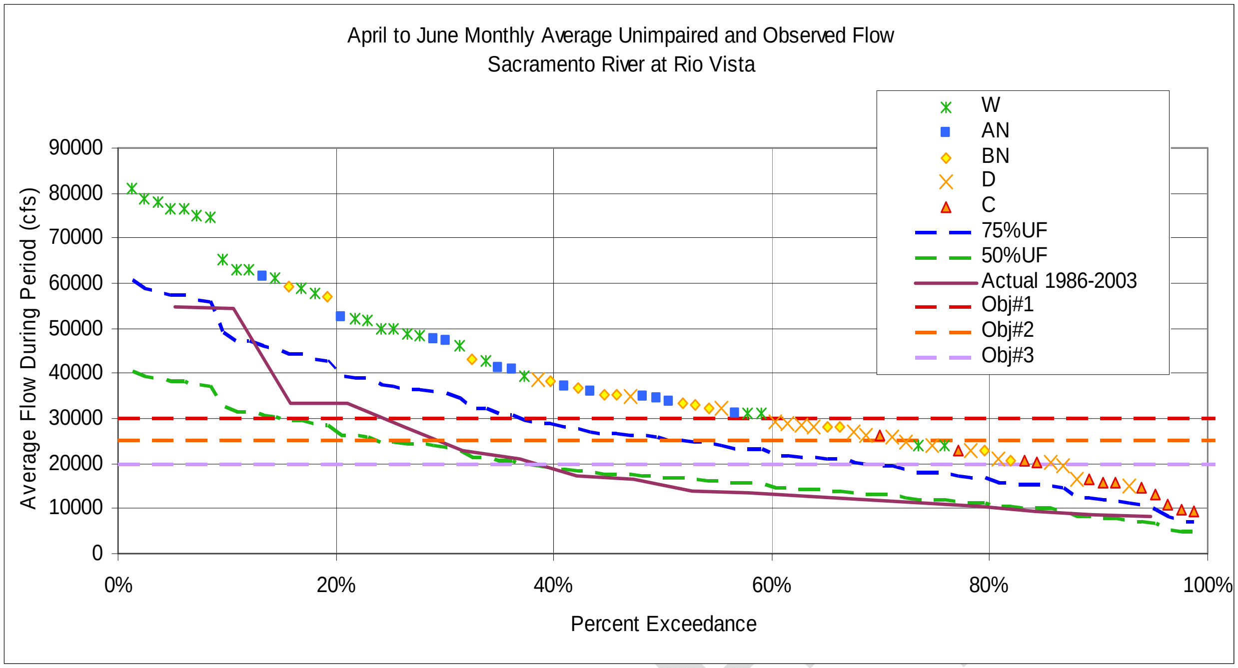


Figure 19. Sacramento River Flow Exceedance Plot - April through June

Fall and Winter Sacramento River Inflows at Rio Vista
Available data and analysis focus primarily on juvenile fall-run Chinook salmon outmigration. Outmigration flows to protect other races and life stages are assumed to be generally the same since factors that affect fall-run survival are generally applicable to other runs, with some exceptions including temperature, which may not be a concern in the winter months. (USFWS 1992, p. 8.) In the absence of sufficient data and analyses regarding flows needed for other Chinook salmon runs, however, the State Water Board advances 75% of unimpaired flows between November and March as an initial criterion from which future analysis and adaptive management could proceed. There is, however, no specific information that indicates that 75% is the correct percent of unimpaired flow. Additional quantitative analyses should be conducted to determine the specific flow needs of winter, spring, and late-fall run Chinook salmon.

<u>Sacramento River Flow at Freeport</u>
Analyses show that Chinook salmon survival is significantly lower for fish migrating through Georgiana Slough. Reverse flows in the vicinity of Georgiana Slough increase the occurrence of salmon migrating through Georgiana Slough. The available data show that flows of 13,000 to 17,000 cfs on the Sacramento River at Freeport provide adequate flow conditions to prevent reverse flows in Georgiana Slough. Flow criteria of 13,000 to 17,000 cfs on the Sacramento River at Freeport when salmon are migrating through the Delta during the November through June period is offered as a Category B criterion. Additional analyses should be conducted to verify that flows of this magnitude are needed to achieve the desired outcome of significantly reducing straying of outmigrating juvenile Chinook salmon. These flows are also expected to benefit adult Chinook salmon returning to the Sacramento River basin to spawn during this period. However, additional analyses regarding the relationship of adult Chinook salmon and reverse flows in Georgiana Slough should also be conducted.

Sacramento River Flow at Wilkins Slough
Information discussed in the species-specific flow needs analyses for salmon in section 4.2.3 indicates that significant precipitation in the Sacramento River in the fall facilitates emigration of juvenile Chinook salmon. When this flow is delayed, emigration of salmon is also delayed resulting in reduced survival to the Delta. The available data show that juvenile salmon require flows of 15,000 cfs to 20,000 cfs at Wilkins Slough by November continuing through the first of the year to facilitate emigration. These flows are needed to provide ecological continuity from natal streams to the Delta. Information supports a range of pulse flows of 15,000 cfs to 20,000 cfs at Wilkins Slough to be provided coincident with fall and early winter storm events. This range should be adaptively managed and further evaluated. Absent additional information, flows of 20,000 cfs for seven days are advanced. Such an approach will retain the attributes of the natural hydrograph and provide for ecological continuity. The timing, magnitude, duration, and number of pulses should be determined through adaptive management, informed by unimpaired flow conditions and monitoring of juvenile salmon migration. Additional analyses should be conducted regarding this flow relationship to refine these criteria and inform adaptive management.

Sacramento River at Rio Vista: 2006 Bay-Delta Plan Objectives
The above criteria cover flows on the Sacramento River from the November through June time period. In addition, the Bay-Delta Plan provides minimum flows from September through December. Aside from what is discussed above, there was no new information submitted in the record for this proceeding on fall flows and the Sacramento River fall flow objectives were not specifically reviewed. In the absence of any new information, the State Water Board advances Bay Delta Plan Sacramento River inflow objectives for September and October as a Category B criterion. Given that Chinook salmon may also be present in the Sacramento River during July and August, it is likely warranted that some minimal flows be provided during those months as well. However, adequate information on which to base such flows was not readily available for this proceeding. Further, adequate minimal flows during this time period may be provided by temperature and other requirements and reservoir releases for power production and export operations.

The specific Sacramento River flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water and tributary specific flows in the Sacramento River basin. It may not be possible to attain both the flow criteria and meet the thermal and tributary specific flow needs of the various runs of Chinook salmon and other sensitive species in the Sacramento River basin. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

5.3 San Joaquin River

Following are the San Joaquin River inflow criteria based on analysis of the species-specific flow criteria and other measures:

1) San Joaquin River at Vernalis: 60 percent of 14-day average unimpaired flow from February through June
2) San Joaquin River at Vernalis: 10 day minimum pulse of 3,600 cfs in late October
3) San Joaquin River at Vernalis: 2006 Bay-Delta Plan flow objective for October

San Joaquin River inflow criteria 1 and 2 are Category A criteria because they are supported by sufficiently robust scientific information. The 2006 Bay-Delta Plan San Joaquin River inflow objective for October is included as a Category B criterion because it is not clear that eliminating this criterion in lieu of criteria 2 would provide adequate protection to migrating adult Chinook salmon. Following is discussion and rationale for these criteria. Category A and B criteria are both equally important for protection of the public trust resource, but there is more uncertainty about the appropriate volume of flow required to achieve the goals of the Category B criterion. Following is discussion and rationale for these criteria.

As discussed in the Sacramento River inflow section, the magnitude, duration, timing, and source of San Joaquin River inflows are important to Chinook salmon migrating through the Bay-Delta and several different aspects of their life history. Inflows are needed to provide appropriate conditions to cue upstream adult migration to the San Joaquin River and its tributaries, adult holding, egg incubation, juvenile rearing, emigration from the San Joaquin River and its tributaries, and other functions. San Joaquin River inflows are important for much of the year to support various life stages of San Joaquin basin fall-run Chinook salmon (and spring-run when they are reintroduced). However, given the focus of this proceeding on inflows to the Delta and the lack of information received concerning spring-run flow needs on the San Joaquin River, the San Joaquin River inflow criteria included in this report focus on flows needed to support migrating fall-run Chinook salmon from and to natal streams through the Delta. Following is a brief summary of the San Joaquin River inflow criteria that were developed based on the species-specific flow needs analyses for salmon included in section 4.2.3 followed by a detailed discussion.

Available scientific information indicates that average March through June flows of 5,000 cfs on the San Joaquin River at Vernalis represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon and that average flows of 10,000 cfs during this period may provide conditions necessary to achieve doubling of San Joaquin basin fall-run. Both the AFRP and DFG flow recommendations to achieve doubling also seem to support these general levels of flow, though the time periods are somewhat different (AFRP is for February through May and DFG is for March 15 through June 15). Available information also indicates that flows of 3,000 to 3,600 cfs for 10 to 14 days are needed during mid to late October to reduce straying, improve olfactory homing fidelity, and improve gamete viability for San Joaquin basin returning adult Chinook salmon.

Continuity of flows from natal stream through the Delta and flow variability are also important, so rather than advancing static flow criteria for the spring period to support emigration of juvenile San Joaquin basin fall-run Chinook salmon, the State Water Board determines, as a Category A criterion, that 60% of unimpaired flow from February through June is needed in order to achieve a threshold flow of 5,000 cfs or more in most years (over 85% of years) and flows of 10,000 cfs slightly less than half of the time (45% of years). Given that the focus of this proceeding is on protection of public trust resources, the State Water Board determines that the time period for these flows should be extended to cover all three periods supported by the DFG, AFRP, and TBI/NRDC analyses concerning flow needs. In addition, the State Water Board determines, as a Category A criterion, that flows of 3,600 cfs are needed for 10 days in late October. These flows could also be provided in a manner that better reflects the natural hydrograph to coincide with natural storm events. Until additional information is developed, maintaining the October pulse flow called for in the 2006 Bay-Delta Plan is also determined to be a Category B criterion to assure that the existing protection provided during this period is not diminished. All of the San Joaquin River flow criteria are not precise; rather they reflect the general timing and magnitude of flows needed to protect public trust resources, but could serve as a reasonable basis from which future analysis and adaptive management could proceed. The criteria also do not consider other Sacramento River flow needs.

San Joaquin River Inflows as a Percentage of Unimpaired Flow During the Spring
As discussed in the Sacramento River inflow section, it is important to preserve the general attributes of the natural hydrograph to which the various salmon runs adapted to over time, including variations in flows and continuity of flows. Accordingly, as with the Sacramento River flow criteria, the State Water Board developed flow criteria for San Joaquin River inflows to protect emigrating juvenile Chinook salmon intended to mimic the natural hydrograph during the peak emigration period of February through June. This period may also cover a portion of the rearing period for juveniles as well. As with the Sacramento River flow criteria, to achieve the attributes of a natural hydrograph, the criteria are advanced as a percentage of unimpaired flow on a 14-day average, to be achieved on a proportional basis from each of the tributaries to the San Joaquin River. The unimpaired estimates from which the 60% criterion is calculated are monthly estimates. Estimates of 14-day unimpaired flow have not been published, but the exceedance curve is likely similar to one generated with monthly estimates. The appropriateness of this time-step and the percentage of unimpaired flows should be further evaluated.

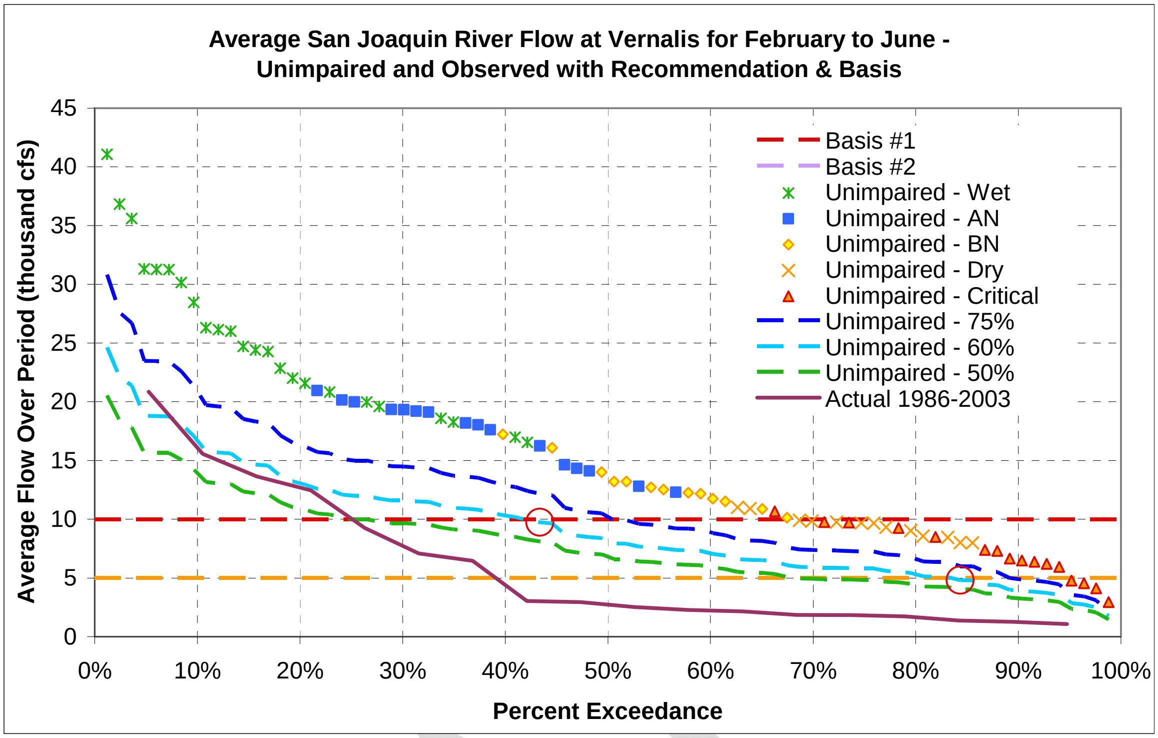
To determine the percentage of unimpaired flow needed to protect Chinook salmon, the State Water Board reviewed flow exceedance information to determine what percentage of flow would be needed to achieve various flows. The analysis in section 4.2.3 indicates that increasing spring flows on the San Joaquin River and its tributaries is needed to protect Chinook salmon in the San Joaquin River basin. The TBI/NRDC analyses of temperatures and population growth indicate that there is a threshold response of salmon survival to flows above 5,000 cfs during the spring period and that average flows of 10,000 cfs during this same period may provide adequate flows to achieve doubling. Both the AFRP and DFG modeling analyses also seem to support these flows. However, the time periods for the AFRP recommended flows is from February through May and the time period for the DFG recommended flows is from March 15 through June 15. AFRP, DFG, and TBI/NRDC provide different recommendations for how to distribute flows during the spring period in different years, with increasing flows in increasingly wet years. All are generally consistent with an approach that mimics the natural flow regime to which these fish were adapted. Other analyses speak to the validity of this approach. (Propst and Gido, 2004 and Marchetti and Moyle, 2001, as cited in DOI 1, p. 25.) San Joaquin River flow criteria for the February through June period are determined to be 60% of unimpaired flows. Figure 20b shows that if 60% of unimpaired flows of the San Joaquin River at Vernalis were provided, average March through June flows would meet or exceed 5,000 cfs in over 85% of years (shown by red circle). An unimpaired flow of 60% during this period would also meet or exceed 10,000 cfs during the March through June time period in approximately 45% of years. The exceedance rates are not significantly different if applied to the February through June period as shown in Figure 20a. Additional information should be developed to determine whether these flows could be lower or higher and still meet the Chinook salmon doubling goal in the long term.

San Joaquin River Fall Flows

In addition to spring flows, 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. Analyses support a range of flows from 3,000 to 3,600 cfs for 10 to 14 days during mid to late October. Absent additional information, the State Water Board determines flow criteria for late fall to be 3,600 cfs for a minimum of 10 days in mid to late October. Providing these flows from the tributaries to the San Joaquin River that support fall-run Chinook salmon appears to be a critical factor to achieve homing fidelity and continuity of flows from the tributaries to the mainstem and Delta. Until additional information is developed regarding the need to maintain the 2006 Bay-Delta Plan October flow objective, these flows supplement and do not replace the 2006 Bay-Delta Plan October flow requirements such that flows do not drop below historic conditions during the remainder of October when the pulse flow criteria would not apply. Additional analyses should be conducted to determine the need to expand the pulse flow time period and modify the criteria to better mimic the natural hydrograph by coinciding pulse flows with natural storm events in order to potentially improve protection by mimicking the natural hydrograph.

Given that salmon and steelhead may be present in the San Joaquin River and its tributaries for all or most of the year (including spring-run in the future) and that the Bay-Delta plan does not currently include any flow requirements from July through September and November through January additional flow criteria for the remainder of the year may be needed to protect Chinook salmon and their habitat. Specifically, additional criteria for spawning, egg incubation, rearing and riparian vegetation recruitment may be needed. However, adequate information is not available in the record for this proceeding upon which to base such criteria at this time. Additional information, building on the AFRP and other analyses, should be developed to determine needed flows for the remainder of the year.

a)



b)

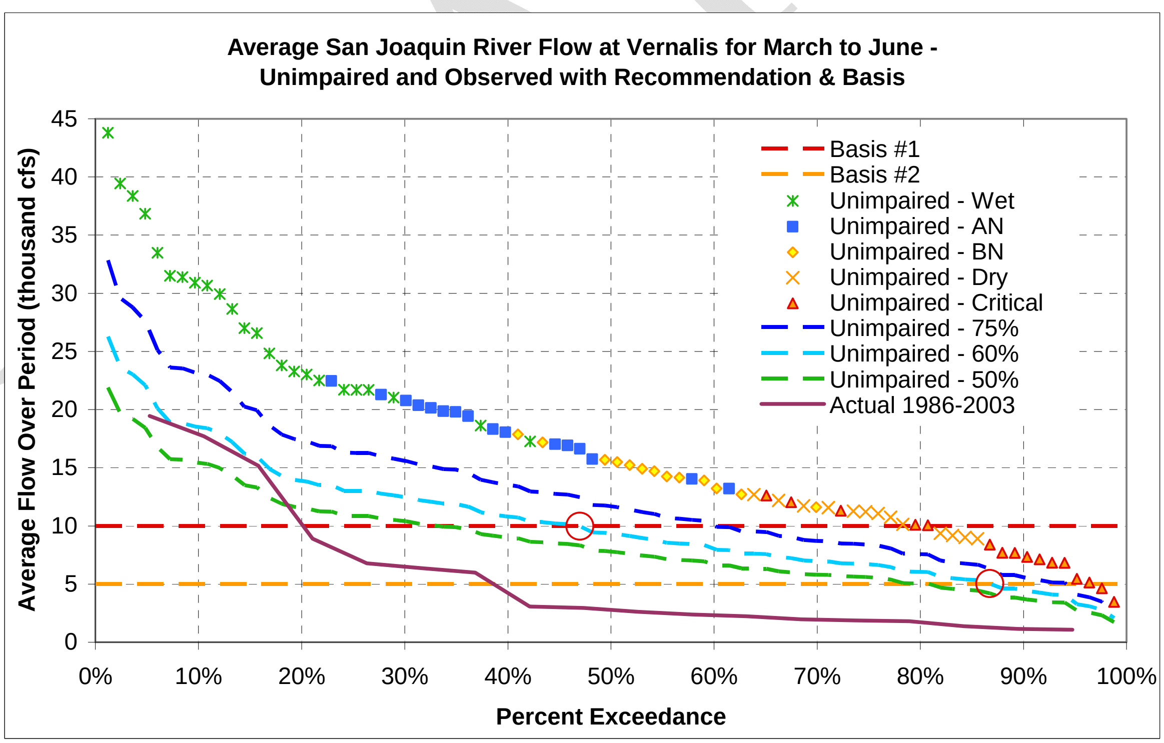


Figure 20. San Joaquin River Flow Exceedance Plot - February through June

The specific San Joaquin River flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water and tributary specific flows in the San Joaquin River basin. It may not be possible to attain both the flow criteria and meet the thermal and tributary specific flow needs of steelhead, fall-run Chinook salmon, and other sensitive species in the San Joaquin River basin. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

5.4 Hydrodynamics

The following hydrodynamic related criteria have been developed based on analysis of the species-specific flow criteria and other measures discussed above:

1) San Joaquin River Flow to Export Ratio: Vernalis flows to exports great than .33 during the 10 day San Joaquin River pulse flow in October
2) Old and Middle River Flows: greater than -1,500 cfs in March and June of Critical and Dry water years
3) Old and Middle River Flows: greater than 0 or -1,500 cfs in April and May of Critical and Dry water years, when FMWT index for longfin smelt is less than 500, or greater than 500, respectively
4) Old and Middle River Flows: greater than -5,000 cfs from December through February in all water year types
5) Old and Middle River Flows: greater than -2,500 when salmon smolts are determined to be present in the Delta from November through June
6) San Joaquin River flow to export ratio: Vernalis flow to exports greater than 4.0 when juvenile San Joaquin River salmon are migrating in the mainstem San Joaquin River from March through June
7) San Joaquin River at Jersey Point Flows: Positive flows when salmon are present in the Delta from November through June
8) 2006 Bay-Delta Plan Exports to Delta Inflow Limits for the Entire Year

Hydrodynamic criteria 1 is a Category A criterion because it is supported by more robust scientific information. Hydrodynamic criteria 2-7 are Category B criteria because there is less scientific information, with more uncertainty, to support the specific numeric criteria. The 2006 Bay-Delta Plan exports to Delta inflow criteria (criteria 8) are offered as a Category B criteria as a minimal level of protection when the other criteria above do not apply. However, the validity of the specific export restrictions included in the 2006 Bay-Delta Plan were not specifically reevaluated. Category A and B criteria are both equally important for protection of the public trust resource, but there is more uncertainty about the appropriate volume of flow required to achieve the goals of the Category B criteria. Following is discussion and rationale for these criteria.

<u>Pelagic Species Flow Recommendations</u>

Old and Middle River reverse flows have increased in both magnitude and frequency with the development of the California water projects (Figure 6) and are having a detrimental effect on biotic resources in the Delta (Brown *et al*. 1996). It is also clear that the negative impact of Old and Middle River reverse flows increases as Sacramento River and net Delta outflow decreases (Grimaldo *et al*. 2009; Kimmerer 2008; USFWS 2008; NMFS, 2009). Old and Middle River flow restrictions for the protection of longfin and Delta smelt are only recommended for dry and critically dry water years when less Delta outflow may be available (Table 22, criteria 2 and 3). No spring restrictions for the protection of longfin and Delta smelt are proposed for other water year types if the higher net Delta outflow recommendations are met. If higher outflows are not provided in wetter years, then restrictions on OMR may be needed in these years as well. The State Water Board determines thatOld and Middle River flow criteria of greater than -5,000 cfs, from December through February in all water year types, to protect upstream migrating adult smelt are needed. The -5,000 cfs recommendation may need to be made more protective if a large portion of the smelt population moves into the Central Delta. The additional restrictions would be recommended after consultation with the U.S. Fish and Wildlife Service (2008) Smelt Working Group. Spring and fall Old and Middle River flow criteria for the protection of longfin and Delta smelt are classified as Category B because, as noted by the National Academy of Sciences (2010), "***…** the data do not permit a confident identification of the threshold (OMR) values to use … and … do not permit a confident assessment of the benefits to the population… As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management and additional analyses that permit regular review and adjustment of strategies as knowledge improves*…

<u>Salmon Related Flow Recommendations</u>

Salmon must migrate through the Delta past the effects of the south Delta export facilities and the associated inhospitable conditions in the central Delta, first as juveniles on their way to the ocean, and later as adults returning to spawn. Exports change the hydrodynamic patterns in the Delta, drawing water across the Delta rather than allowing water to flow out of the Delta in a natural pattern. Over the years, different criteria have been developed to attempt to protect migrating salmon from the adverse hydrodynamic conditions caused by the south Delta export facilities in order to preserve the functional flows needed for migration that could be used to protect public trust resources. Old and Middle river flows, Jersey Point flows, and Vernalis flow to export ratios are all criteria that can be used to protect migrating salmon. The State Water Board recommends a combination of these criteria be used to protect migrating salmon from export effects.

Increasingly negative Old and Middle river flows have been shown to increase particle entrainment, particularly beginning at flows between -2,500 and -3,500 cfs. While juvenile salmon do not necessarily behave like particles, the particle entrainment estimates are a useful guide until additional information can be developed using evolving acoustic tracking methods and other appropriate techniques. Reduced negative Old and Middle river flows should also provide some level of protection from the indirect reverse flow effects related to fish entering the central Delta where predation and other sources of mortality are higher. Based on the above, the State Water Board determines criteria for net Old and Middle River flow should be for greater than -2,500 cfs when salmon are present in the Delta during the peak juvenile outmigration period of November through June, for the protection of Chinook salmon. This is a Category B criterion because there is limited information upon which to base a specific numeric criteria at this time. Such information should be developed to better understand the relationship between salmon survival and Old and Middle river flows to determine more specific criteria that would protect against entrainment and other factors leading to indirect mortality.

Increased reverse flows at Jersey Point have also been shown to decrease survival of salmon smolts migrating through the lower San Joaquin River. However, the precise Jersey Point flow that is necessary to protect migrating salmon is unclear. In addition, it is unclear whether the same functions of such a flow could be better met using different criteria such as Old and Middle river flows or San Joaquin River flow to export ratios.

The State Water Board therefore advances positive Jersey Point flows when salmon are present in the Delta during the peak juvenile salmon outmigration period of November through June. Again, this is a Category B criterion because there is limited information upon which to base a specific numeric criteria at this time.

Increased San Joaquin River flow to export ratios appear to improve survival for San Joaquin River salmon, though the exact ratio that is needed to protect public trust resources is not well understood. A San Joaquin River flow to export ratio of greater than 4.0 is recommended as a Category B criterion when San Joaquin River juvenile salmon are outmigrating from the San Joaquin River from March through June. There is, however, sufficient information in the record to support a Category A criterion for exports to be kept to less than 300% of San Joaquin River flows (equal to a San Joaquin River flow to export ratio of more than 0.33) at the same time that the recommended San Joaquin River pulse flows are provided. Additional analyses should be conducted to determine if this time frame should be extended to capture more of the San Joaquin River adult Chinook salmon return period between October and January.

The NAS review concerning OMR restrictions for salmon concluded "…*that the strategy of limiting net tidal flows toward the pump facilities is sound, but the support for the specific flows targets is less certain. In the near-term telemetry-based smolt migration and survival studies (e.g, Perry and Skalski, 2009) should be used to improve our understanding of smolt responses to OMR flow levels*." (NAS 2010, p. 44.) Much additional work is needed to better understand the magnitude and timing of the recommended criteria and how OMR criteria should be integrated with other criteria for San Joaquin River flows, San Joaquin River flows to export ratios, Sacramento River flows, and OMR restrictions for the protection of pelagic species. For all of the OMR, Jersey Point, and Vernalis Flows to export ratio recommendations, further analysis and consideration is needed to determine: 1) how salmon presence should be measured and the information used to temper the criteria; 2) an appropriate averaging period; and 3) how to adaptively manage to assure that flows are sufficiently but not overly protective.

The October San Joaquin River flow to export ratio criteria is a Category A criterion since the basis for this minimum recommendation is sufficiently understood to develop a quantitative criteria. Additional analyses should still, however, be conducted to determine if this criteria could be refined to provide better protection for migrating adult San Joaquin River Chinook salmon. All of the other hydrodynamic recommendations for the protection of salmon are Category B criteria.

The San Joaquin River flow to export criterion during the spring is also Category B criteria due to a lack of certainty regarding the needed protection level. Regarding this issue, the NAS concluded that "…*the rationale for increasing San Joaquin River flows has a stronger foundation than the prescribed action of concurrently managing inflows and exports. We further conclude that the implementation of the 6-year steelhead smolt survival study (action IV.2.2) could provide useful insight as to the actual effectiveness of the proposed flow management actions as a long-term solution.*" (NAS 2010, p. 45.)

In addition, based on similar uncertainty regarding needed protection levels and interaction between OMR and San Joaquin River flows to export ratios, the San Joaquin River at Jersey Point criteria is also a Category B criteria. More work is needed to develop a suite of operational tools and an operational strategy for applying those tools to protect public trust resources in the Delta from the adverse hydrodynamic effects of water diversions, channel configurations, reduced flows, and other effects.

2006 Bay-Delta Plan Export Objectives
The 2006 Bay-Delta Plan includes export limitations for the entire year. From February through June exports are limited to 35-45% of Delta inflow. (State Water Board 2006a, pp. 184-187.) From July through January, exports are limited to 65% of Delta inflow. (*id.)* The export to Delta inflow restrictions are intended to protect the habitat of estuarine-dependent species. (State Water Board 2006b, pp. 46-47.) These export restrictions provide a minimum level of protection for public trust uses and should be maintained to the extent that the other recommended criteria do not override them.

For all of the hydrodynamic criteria, biologically appropriate averaging periods need to be developed. Averaging periods may need to include a two-step approach whereby a shorter averaging period is included that allows for some divergence from the criteria and a longer averaging period is included that does not.

5.5 Other Inflows - Eastside Rivers and Streams

The Cosumnes and Mokelumne rivers, and smaller streams such as the Calaveras River, Bear Creek, Dry Creek, Stockton Diversion Channel, French Camp Slough, Marsh Creek and Morrison Creek are all tributary to the Delta. Flow should generally be provided from tributaries in proportion to their contribution to unimpaired flow.

5.6 Other Measures

5.6.1 Variability, Flow Paths, and the Hydrograph

Criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the criteria specified herein are expressed as a percentage of the unimpaired hydrograph rather than as a single number or range of numbers that vary by water year type. Additional efforts should focus on restoring habitat complexity. Inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow in order to assure connection between Delta flows and upstream tributaries, to the extent that such connections are beneficial to protecting public trust resources. Flows should be at levels that maintain flow paths and positive salinity gradients through the Delta. This concept is reflected in the specific determinations made above. More study is needed to determine to which tributaries such criteria should apply. For example, since the percent of unimpaired flow criteria determined to protect public trust uses for San Joaquin River inflows is at times lower than the criteria determined for Delta outflow, more study is needed to determine the appropriate source of such flows to protect the public trust. All determined flow criteria must also be tempered by the need to protect health and safety. No flow criteria, for example, should be in excess of flows that would lead to flooding. For all of the flow criteria, there may be a need to reshape the specified flows to better protect public trust resources based on real-time considerations. All of the criteria should be implemented adaptively to allow for such appropriate reshaping to improve biological and geomorphological processes.

Moyle *et al* (2010) concluded, however, that there is a fundamental conflict between restoring variability and maintaining the current Delta: “restoring environmental variability in the Delta is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export. The drinking and agricultural water quality requirements of through-Delta exports, and perhaps even some current in-Delta uses, are at odds with the water quality and variability needs of desirable Delta species."

5.6.2 Floodplain Activation and Other Habitat Improvements

Activated floodplains stimulate food web activity and provide spawning and rearing habitat for floodplain adapted fish. The frequency of low-magnitude floods that occurred historically has been reduced, primarily by low water control levees. The record supports the conclusion that topography changes associated with future floodplain restoration will provide improved ecosystem function with less water. Studies and demonstration projects for, and implementation of, floodplain restoration projects should therefore proceed to allow for the possible reduction of flows required to protect public trust resources in the Delta.

<u>Floodplain Flow Determinations for Protection of Salmon and Splittail</u>:
Floodplain and off-channel inundation are required for splittail spawning and appear to be important in protecting Chinook salmon. At the same time, it is also important how and when such inundation occurs. Due to the effects of levees and dams, natural side channel and floodplain inundating flows have been substantially reduced. As a result, modification to weirs and other changes may be needed to substantially improve floodplain inundation conditions on the Sacramento and San Joaquin rivers. Based on the above, the State Water Board determines that an effort be made to provide appropriate additional seasonal floodplain habitat for salmon, splittail and other species in the Central Valley. The various recommendations the State Water Board received for floodplain inundation are included in Appendix A.1. The State Water Board has no specific flow determinations for floodplain inundation. The State Water Board recommends that BDCP, the Council, and others continue to explore the various issues concerning flood protection, weir modifications, and property rights related to floodplain inundation.

Other future habitat improvements will likely change the response of native fishes to flow and allow flow criteria to be modified. Habitat restoration should proceed to allow for the possible reduction of flows required to protect public trust resources in the Delta. Other future habitat restoration that should be reviewed and implemented include:

- Development of slough networks with natural channel geometry and less diked and rip-rapped channel habitat
- Increased tidal marsh habitat, including shallow (one to two meters) subtidal areas in both fresh and brackish zones of the estuary (in Suisun Marsh, for example)
- Create large expanses of low salinity open water habitat in the Delta

5.6.3 Water Quality and Contaminants

Any set of flow criteria should include the capacity to readily adjust the flows to adapt to changing future conditions and improved understanding (DEFG 1). As our understanding of the effect of contaminants on primary production and species composition in the Sacramento River and Delta improves, flow criteria may need to be revisited.

The Central Valley and San Francisco Regional Water Quality Control Boards should continue developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions. Specifically, the Central Valley Regional Water Quality Control Board should require additional studies and incorporate discharge limits and other controls into permits, as appropriate, for the control of nutrients, including ammonia.

5.6.4 Coldwater Pool Resources and Instream Flow Needs on Tributaries

The flow criteria contained in this report should be tempered by the need to maintain cold water resources and meet tributary specific flow needs in the Delta watershed. It may not be possible to attain all of the identified flow criteria in all years and meet the tributary flow needs and thermal needs of the various runs of Chinook salmon, steelhead, and other sensitive species. Temperature and water supply modeling analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals. In addition, these flow determinations do not consider the needs of other non-fish species and terrestrial species which should be considered before any implementation of these criteria.

5.6.5 Adaptive Management

The numeric criteria are all short term criteria that are only appropriate for the current physical system and climate. There is uncertainty in these criteria even for the current physical system and climate, and therefore for the short term. Long term numeric criteria, beyond five years, for example, and assuming a modified physical system, are highly speculative. Only the underlying principles for the proposed numeric criteria and the other measures are advanced as long term determinations.

The information received in this proceeding suggests that the relationships between hydrology, hydrodynamics, water quality, and the abundance of desirable species are often unclear. In preparing for the long term, resources should be directed toward better understanding these relationships. In particular, there is significant uncertainty associated with Category B numeric criteria advcanced in this report. Category B criteria should therefore be high priority candidates for grant funded research.

A strong science program and a flexible management regime are critical to improving flow criteria. The relationship between flow, habitat, and abundance is not well enough understood to recommend flows in the Delta ecosystem without some reliance on adaptive management to better manage these flows. The State Water Board intends to work with the Council, the Delta Science Program, IEP, and others to develop the framework for adaptive management that could be relied upon for the management and regulation of flows in the Delta. The State Water Board will consider supporting and incorporating into its regulations greater reliance upon adaptive management in its flow regulations.

5.7 Summary Determinations

Table 20 through Table 23 provide summary determinations for Delta Outflow, Sacramento Inflow, San Joaquin River Inflow, and Reverse flows on Old and Middle River (including inflow-export ratios), respectively. Each table shows various numbered criteria, applicable to the shaded range of months. Criteria fall into two categories. Category “A” criteria have more robust scientific information to support specific numeric criteria than do Category “B” criteria. Both categories of criteria are considered equally important for protection of public trust resources in the Delta ecosystem, and are supported by scientific information on function-based species or ecosystem needs. The basis and explanation for each criterion is provided. Each table is appended with the following notes to explain the limitations and constraints of how the criteria should be considered:

- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources
- These flow criteria should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria have been determined or where Bay-Delta Plan flow objectives are advanced, but adequate information is not available at this time to determine such flows

These criteria are made specifically to achieve the stated goal of halting the population decline and increase populations of native species as well as species of commercial and recreational importance. Additionally, positive changes in the Delta ecosystem resulting from improved flow or flow patterns will benefit humans as well as fish and wildlife, especially when accompanied by large-scale habitat restoration and pollution reduction (Moyle *et al*, 2010)

In addition Table 24 contains a summary of other issues and concepts that should be considered in conjunction the numeric criteria. These other measures are also based on a synthesis of the best scientific information submitted by participants in the Water Board's Informational Proceeding. These criteria and other measures, however, must be further qualified as to their limitations. The limitations of this and any other flow prescription are described at the end of the Fleenor *et al*. (2010) "flow prescriptions" report as a "further note of caution":

> "How much water do fish need?" has been a common refrain in Delta water management for many years… it is highly unlikely that any fixed or predetermined prescription will be a "silver bullet". The performance of native and desirable fish populations in the Delta requires much more than fresh water flows. Fish need enough water of appropriate quality over the temporal and spatial extent of habitats to which they adapted their life history strategies. Typically, this requires habitat having a particular range of physical characteristics, appropriate variability, adequate food supply and a diminished set of invasive species. While folks ask "How much water do fish need?" they might well also ask, "How much habitat of different types and locations, suitable water quality, improved food supply and fewer invasive species that is maintained by better governance institutions, competent implementation and directed research do fish need?" The answers to these questions are interdependent. We cannot know all of this now, perhaps ever, but we do know things that should help us move in a better direction, especially the urgency for being proactive. We do know that current policies have been

> disastrous for desirable fish. It took over a century to change the Delta's ecosystem to a less desirable state; it will take many decades to put it back together again with a different physical, biological, economic, and institutional environment."

The State Water Board concurs with this cautionary note and recommends the flow criteria and other conclusions advanced in this report be used to inform the planning efforts for the Delta Plan and BDCP and as a report that can be used to guide needed research by the Delta Science Program and other research institutions.

Table 20. Delta Outflow Summary Criteria

Delta Outflow Recommendations												
Category A												
Water Year												**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S	
			■	■	■	■	■	■				1) Net Delta Outflow: 75 percent of 14-day average unimpaired flow
Category B												
Water Year												**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S	
■	■										■	2) Delta Smelt Fall X2 a. Wet years X2 less than 74 km (greater than approximately 12,400 cfs) b. Above normal years X2 less than 81 km (greater than approximately 7,100 cfs)
■	■								■	■	■	3) 2006 Bay-Delta Plan Delta Outflow Objectives (critical, dry and below normal years)
Basis for Criteria and Explanation												

1) Promote increased abundance and improved productivity (positive population growth) for Longfin Smelt and other desirable estuarine species
2) Increase quantity and quality of habitat for Delta Smelt; Fall X2 requirement limited to above normal and wet years to reduce potential conflicts with cold water pool storage, while promoting variability with respect to fall flows and habitat conditions in above normal and wet water year types; expected to result in improved conditions for Delta Smelt, however, the statistical relationship between Fall X2 and abundance is not strong; note 2) above regarding need for improved understanding concerning the Fall X2 action also applies
3) Fish and wildlife beneficial use protection

Notes:

- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow recommendations should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

Table 21. Sacramento River Inflow Summary Criteria

Sacramento River

Category A

O	N	D	J	F	M	A	M	J	J	A	S	Criteria
						■	■	■				1) Rio Vista: 75 percent of 14-day average unimpaired flow

Category B

O	N	D	J	F	M	A	M	J	J	A	S	Criteria
	■	■	■	■	■							2) Rio Vista: 75 percent of 14-day average unimpaired flow to support same functions as #1 for other runs of Chinook salmon
	■	■	■									3) Wilkins Slough: Provide pulse flows of 20,000 cfs for 7 days starting in November coinciding with storm events producing unimpaired flows at Wilkins Slough above 20,000 cfs until monitoring indicates that majority of smolts have moved downstream
	■	■	■	■	■	■	■	■				4) Freeport: Positive flows in Sacramento River downstream of confluence with Georgiana Slough while juvenile salmon are present (approximately 13,000 to 17,000 cfs)
■											■	5) Sacramento River at Rio Vista: 2006 Bay-Delta Plan flow objectives

Basis for Criteria and Explanation, and Notes

1) Increases juvenile salmon outmigration survival for fall-run Chinook salmon
2) Promote juvenile salmon emigration for other runs of Chinook salmon
3) Increases juvenile salmon outmigration survival by reducing diversion into Georgiana Slough and the central Delta
4) Increases juvenile salmon outmigration survival
5) Fall adult Chinook salmon attraction flows

Notes:

- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow recommendations should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

[1] Definition of storm, number of storms, and how to determine when the majority of juveniles have outmigrated needs to be determined.

Table 22. San Joaquin River Inflow Summary Criteria

San Joaquin River

Category A

O	N	D	J	F	M	A	M	J	J	A	S	Criteria
				■	■	■	■	■				1) Vernalis: 60 percent of 14-day average unimpaired flow
■												2) Vernalis: 10 day minimum pulse of 3,600 cfs in late October (e.g., October 15 to 26)

Category B

O	N	D	J	F	M	A	M	J	J	A	S	Criteria
■												3) 2006 Bay-Delta Plan October pulse flow

Basis for Criteria and Explanation, and Notes

1) Increase juvenile Chinook salmon outmigration survival and provide conditions that will generally produce positive population growth in most years and achieve the doubling goal in more than half of years
2) Minimum adult Chinook salmon attraction flows to decrease straying, increase DO, reduce temperatures, and improve olfactory homing fidelity
3) Adult Chinook salmon attraction flows

Notes:

- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow recommendations should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

Table 23. Hydrodynamics Summary Criteria

Hydrodynamics: Old and Middle River, Inflow-Export Ratios, and Jersey Point												
Category A												
Water Year												**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S	
X												1) San Joaquin River Flow to Export Ratio: Vernalis flows to exports greater than 0.33 during fall pulse flow (e.g., October 15 – 26); complementary action to San Joaquin River Inflow recommendation #2
Category B												
Water Year												**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S	
					X			X				2) Old and Middle River Flows: greater than -1,500 cfs in Critical and Dry water years
						X	X					3) Old and Middle River Flows: greater than 0 or -1,500 cfs in Critical and Dry water years, when FMWT index for longfin smelt is less than 500, or greater than 500, respectively
		X	X	X								4) Old and Middle River Flows: greater than -5,000 cfs in all water year types
	X	X	X	X	X	X	X	X				5) Old and Middle River Flows: greater than -2,500 when salmon smolts are determined to be present in the Delta
					X	X	X	X				6) San Joaquin River Flow to Export Ratio: Vernalis flows to exports greater than 4.0 when juvenile San Joaquin River salmon are migrating in mainstem San Joaquin River
	X	X	X	X	X	X	X	X				7) Jersey Point: Positive flows when salmon present in the Delta
X	X	X	X	X	X	X	X	X	X	X	X	8) 2006 Bay-Delta Plan Exports to Delta Inflows
Basis for Criteria and Explanation												

1) Reduce straying and improve homing fidelity for San Joaquin basin adult salmon
2) Reduce entrainment of larval / juvenile delta smelt, longfin smelt, and provide benefits to other desirable species
3) Same as number 2), but if the previous FMWT index for longfin smelt is less than 500, then OMR must be greater than 0 (to reduce entrainment losses when abundance is low), or greater than -1,500 if the previous FMWT index for longfin smelt is greater than 500
4) Reduce entrainment of adult delta smelt, longfin smelt, and other species; less negative flows may be warranted during periods when significant portions of the adult smelt population migrate into the south or central Delta; thresholds for such flows need to be determined
5) Reduce risk of juvenile salmon entrainment and straying to central Delta at times when juveniles are present in the Delta; will also provide associated benefits for adult migration
6) Improve survival of San Joaquin River juvenile salmon emigrating down the San Joaquin River and improve subsequent escapement 2.5 years later
7) Increase survival of outmigrating smolts, decrease diversion of smolts into central Delta where survival is low, and provide attraction flows for adult returns
8) Protection of estuarine dependent species

(cont.)

Notes:

- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow recommendations should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

Table 24. Other Summary Determinations

Variability and the Natural Hydrograph:

- Criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the criteria specified above are expressed as a percentage of the unimpaired hydrograph
- Inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow unless otherwise indicated. This concept is reflected in the specific criteria made above.

Floodplain Activation and Other Habitat Improvements:

- Studies and demonstration projects for, and implementation of, floodplain restoration, improved connectivity and passage, and other habitat improvements should proceed to provide additional protection of public trust uses and potentially allow for the reduction of flows otherwise needed to protect public trust resources in the Delta.

Water Quality and Contaminants:

- The Central Valley and San Francisco Regional Water Quality Control Boards should continue developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions.
- The Central Valley Regional Water Quality Control Board should require additional studies and incorporate discharge limits and other controls into permits, as appropriate, for the control of nutrients and ammonia.

Coldwater Pool Resources and Instream Flow Needs on Tributaries:

- Temperature and water supply modeling and analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

Adaptive Management:

- A strong science program and a flexible management regime are critical to improving flow criteria. The State Water Board should work with the Delta Stewardship Council, the Delta Science Program, Interagency Ecological Program, and others to develop the framework for adaptive management that could be relied upon for the management and regulation of Delta flows.
- The numeric criteria in this report are all short term recommendations that are only appropriate for the current physical system and climate; actual flows should be informed by adaptive management
- Only the underlying principles for the numeric criteria and these other measures are advanced as long term recommendations.

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7. Appendices

Appendix A: Summary of Participant Recommendations

Appendix A, Table 1. Delta outflow recommendations summary table (cfs unless otherwise noted).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
Unimpaired Flow 1956-2003	C	16092	23292	31045	29103	27552	15301	5974	3880	4096	8167	8372	12531	
	D	24670	37460	52907	45810	39512	18994	6801	4759	5180	7221	16635	19339	
	BN	32402	63985	52056	53471	49644	25325	9091	5683	6004	7027	12842	16911	
	AN	88051	99722	86990	69589	78076	50019	18214	7932	7862	8162	13980	26763	
	W	113261	114512	103250	92975	96911	68197	27987	11354	8717	11804	30357	77204	
Historical Flow 1956-2003	C / D	14117	17916	17597	9193	7367	4504	3952	3334	4285	6896	9663	12734	87
	BN	27274	48832	32673	14991	10100	4336	3952	5025	7798	12116	15192	18996	
	AN	61801	70133	70404	32283	27876	13444	7172	5985	7865	6766	10940	17093	
	W	94930	111565	87497	67642	46530	29897	14279	10588	15545	13385	23024	60061	
D1641	C	4500 (1)	7100 - 29200 (2)					4000	3000	3000	3000	3500		1, 2
	D	4500	7100 - 29200					5000	3500	3000	4000	4500		
	BN	4500	7100 - 29200					6500	4000	3000	4000	4500		
	AN	4500	7100 - 29200					8000	4000	3000	4000	4500		
	W	4500	7100 - 29200					8000	4000	3000	4000	4500		
Draft D1630	All				6700									3
	C					3300	3100	2900						4
	D					4300	3600	3200						
	BN					11400	9500	6500						
	AN					14000	10700	7700						
	W					14000	14000	10000						
	W		10000											5
	BN & AN	12000												6
	All	6600 (if > flow not required by other standards)												7
TBI / NRDC / AR / NHI / EDF	81-100% (driest years)	14000 - 21000			10000 - 17500		3000 - 4200			5750 - 7500				8
	61-80%	21000 - 35000			17500 - 29000		4200 - 5000			7500 - 9000				
	41-60%	35200 - 55000			29000 - 42500		5000 - 8500			9700 - 12400				
	21-40%	55000 - 87500			42500 - 62500		8500 - 25000			12400 - 16100				
	0-20% (wettest years)	87500 - 140000			62500 - 110000		25000 - 50000			16100 - 19000				
CSPA / C-WIN	C	4100	9100		6700				4100					9
	D	9200	23500		10800				9200					
	BN	12100	41000		14400				12100					
	AN	14600	90800		23000				14600					
	W	29000	91800		43000				29000					
EDF / Stillwater (monthly average)	C	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	10, 11, 12
	D	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	
	BN	26800	26800	26800	26800	26800	11500	7500	7500	7500	7500	7500	11500	
	AN	26800	26800	26800	26800	26800	11500	11500	11500	11500	11500	11500	17500	
	W	26800	26800	26800	26800	26800	17500	17500	17500	17500	17500	17500	26800	
EDF / Stillwater (peak flows)	C	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	13
	D	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	
	BN	26800	90800 (14)	90800 (15)	26800	26800	11500	7500	7500	7500	7500	7500	11500	14, 15
	AN	26800	105600 (16)	105600 (17)	26800	26800	11500	11500	11500	11500	11500	11500	17500	16, 17
	W	26800	105600 (18)	105600 (19)	26800	26800	17500	17500	17500	17500	17500	17500	26800	18, 19
USFWS - OCAP Bio Op	AN									X2 ≤ 81 km (approx. 7000)		X2 ≤ 81 km		20
	W									X2 ≤ 74 km (approx. 12400)		X2 ≤ 74 km		

Appendix A, Table 1. Delta outflow recommendations summary table - con't. (p. 2 of 2)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
CDFG	All	Recommendation in X2 format: 64 - 75 km (approx. 29200 - 11400 cfs)												21
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22
The following is from Fleenor et al. 2010 (Preliminary Draft) - Functional flow approach with exports occurring via a peripheral canal, tunnel, or other alternative form of conveyance.														
Delta Solutions Group	5 of 10 yrs			48000										23

Appendix A, Table 2. Sacramento River inflow recommendations (cfs unless noted otherwise).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
D1641	C									3000		3500		
	D									3000	4000	4500		
	BN									3000	4000	4500		
	AN									3000	4000	4500		
	W									3000	4000	4500		
Draft D1630	All				$\geq$18000									24
	All				$\geq$13000 (14-day running average) and $\geq$9000 (min mean daily flow)									25
	C	1500	2500			2000		1000	1000	1500				26
	D	1500	2500			2500		1000	1000	1500				
	BN	2500	2500			3000		2000	1000	2500				
	AN	2500	2500			3000		2000	1000	2500				
	W	2500	3000			5000		3000	1000	5000				
CDFG	All		6000 (base flows)											27
	All				20000 - 30000 (pulse flows @ Rio Vista)									
C-WIN / CSPA	All		6000 (minimum base flows, measured @ Rio Vista)											28
	All				30000 (Freeport to Chipps Island)									29
PCFFA	All				25000 (Hood to Chipps Island)									30
USFWS					The catch of juvenile salmon at Chipps Island between April and June is correlated to flow at Rio Vista. The highest abundance leaving the Delta has been observed when flows at Rio Vista between April and June averaged above 20000 cfs..."									31
AR / NHI	All	Sac Riv at Bend Bridge - Pulse flows continuously exceed 8000, periodically exceed 12000, for a duration exceeding 2 weeks										See Jan - May		32
	All	Sac Riv at Wilkins Slough and Freeport - Pulse flows of 15000 at Wilkins Slough, and up to 20000 at Freeport, should occur for a duration of 7 days or longer. There should be at least 5 such events in dry years and more in wet years											See Jan - May	33
TBI / NRDC / AR / NHI	C (0-20 percentile)		27500 for 15 cont days											34
	D (20-40 percentile)			27500 for 30 cont days										
	BN		30000 for 60 cont days											
	AN		32500 for 90 continous days											
	W	35000 for 120 continuous days												
NMFS	AN & W		$\geq$ 17700 (at Grimes RM125)											35
	AN & W		$\geq$ 31100 (at Verona RM80)											
	All	Provide pulse flows $\geq$ 20000 cfs, measured at Freeport periodically during winter-run emigration season to facilitate outmigration past Chipps Island (ie, Dec-Apr)											See Jan-Apr	36

Appendix A, Table 2. Sacramento River inflow recommendations - con't. (p. 2 of 2)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
EDF / Stillwater	C	3500		10000			Determined based on Delta outflows ([38])			3000 - 3500 ([39])			3500	37, 38, 39
	D	4500		10000						3000 - 4500			4500	
	BN	4500		10000						3000 - 4500			4500	
		64000 (pulse flow, 21 consecutive days)												
	AN	4500		10000						3000 - 4500			4500	
		64000 (pulse flow, 35 consecutive days)												
	W	4500		10000						3000 - 4500			4500	
		64000 (pulse flow, 49 consecutive days)												
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22
The following is from Fleenor et al. 2010 (Preliminary Draft) - Functional flow approach with exports occurring via a peripheral canal, tunnel, or other alternative form of conveyance.														
Delta Solutions Group	6 of 10 yrs	10000									10000			40
	6 of 10 yrs			25000										
	1 of 10 yrs	70000												41
	8 of 10 yrs		Yolo Bypass 2500 (Sac Riv ~45750)											42
	6 of 10 yrs			Yolo Bypass 4000 (pulse) (Sac Riv ~ 50150)										

Appendix A, Table 3. San Joaquin River inflow recommendations summary table (cfs unless noted otherwise).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
D1641	C		710 or 1140 ([43])		3110 or 3540 ([44])	710 or 1140 ([43])					1000 ([45])			43, 44, 45
	D		1420 or 2280		4020 or 4880	1420 or 2280					1000			
	BN		1420 or 2280		4620 or 5480	1420 or 2280					1000			
	AN		2130 or 3420		5730 or 7020	2130 or 3420					1000			
	W		2130 or 3420		7330 or 8620	2130 or 3420					1000			
Draft D1630	C				2000 ([46])						≥2000 ([47])			46, 47
	D				4000						≥2000			
	BN				6000						≥2000			
	AN				8000						≥2000			
	W				10000						≥2000			
CDFG	C			1500 (Base)	5500 (Pulse) (4/15-5/15) (Total 7000)									48
	D			2125 (Base)	4875 (Pulse) (4/11-5/20) (Total 7000)									
	BN			2258 (Base)	6242 (Pulse) (4/6-5/25) (Total 8500)									
	AN			4339 (Base)	5661 (Pulse) (4/1-5/30) (Total 10000)									
	W			6315 (Base)	8685 (Pulse) (3/27-6/4) (Total 15000)									
C-WIN / CSPA	C		13400	4500	6700 / 8900	1200					5400			49
	D		13400 (2 days)	4500	6700 / 8900	1200					5400			
	BN		13400 (16 days), 26800 (2 days)	4500	6700 / 8900	11200 / 1200					5400			
	AN		13400 (13 days), 26800 (5 days)	4500	6700 / 8900	11200 / 1200					5400			
	W		13400 (17 days), 26800 (5 days)	13400		14900					5400			
TBI / NRDC	100% of years (all yrs)	2000			5000		2000							50
	80% (D yrs)	2000			5000 / 10000	7000 / 5000	2000							
	60% (BN yrs)	2000			20000 / 10000	7000 / 5000	2000							
	40% (AN yrs)	2000		5000	20000	7000	2000							
	20% (W yrs)	2000		5000	20000	7000	2000							

Appendix A, Table 3. San Joaquin River inflow recommendations summary table - con't. (p. 2 of 3)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
AR / NHI	100% of years (all yrs)			3000 | 4000	5000		2000							51
	80% (D yrs)			3000 | 4000	5000 | 10000	7000 | 5000	2000							
	60% (BN yrs)			3000 | 5000	20000 | 10000	7000 | 5000	2000							
	40% (AN yrs)			3000 | 5000	20000	7000	2000							
	20% (W yrs)			3000 | 5000	20000		7000 | 2000							
	All			Flows of approx. 10000 cfs should occur at Vernalis for ≥5 days. There should be at least 2 such events in dry years, and more in wetter years.										
EDF / Stillwater	All									> 1800 in DWSC				52
	All			Discuss USFWS (1995) and D-1641, no clear recommendation (55)			Determined based on Delta outflows (38)				3500 (10-14 days) (54)	FERC (53)		38, 53, 54, 55
	C & D	1000 (positive flows at Jersey Pt)											See Jan-Feb	56
	BN & AN	2000 (positive flows at Jersey Pt)											See Jan-Feb	
	W	3000 (positive flows at Jersey Pt)											See Jan-Feb	
	AN	14800 (pulse flow, ≥ 21 consecutive days)												57
	W	14800 (pulse flow, ≥ 35 consecutive days)												
USFWS			"...the Board should consider the Vernalis flows contained in USFWS (2005) [AFRP] and DFG's San Joaquin Escapement Model as a starting point for establishing flow for the protection of salmon and steelhead migrating from the San Joaquin basin"											58
AFRP (salmon doubling)	C		1744	2832	4912	5665								59
	D		1784	3146	5883	7787								
	BN		1809	3481	6721	9912								
	AN		2581	5162	8151	13732								
	W		4433	8866	10487	17369								
AFRP (53% Increase in Salmon Production)	C		1250	1665	2888	3331								60
	D		1350	1850	3459	4579								
	BN		1450	1933	3733	5505								
	AN		1638	2703	4266	7194								
	W		2333	4667	5520	9142								
NMFS OCAP Bio Op					Interim Operations in 2010-2011, min flows at Vernalis ranging from 1500 - 6000 based on New Melones Index									61
		In addition, USBR/DWR shall seek supplemental agreement with SJRGA as soon as possible to achieve the min flows listed below at Vernalis												
	C				1500									
	D				3000									
	BN				4500									
	AN				6000									
	W				6000									

Appendix A, Table 3. San Joaquin River inflow recommendations summary table - con't. (p. 3 of 3)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
NMFS	AN & W AN & W		≥ 14000 (at Vernalis) ≥ 7000 (at Newman)											62
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22
The following is from Fleenor et al. 2010 (Preliminary Draft) - Functional flow approach with exports occurring via a peripheral canal, tunnel, or other alternative form of conveyance.														
Delta Solutions Group	C	2000			5000	2000								63
	D	2000			7000	2000								
	BN	2000			10000		2000							
	AN	2000			15000		2000							
	W	2000			20000			2000						

Appendix A, Table 4. Old and Middle River flow, export restriction, San Joaquin River flows at Jersey Point (e.g., QWEST) recommendations summary table (cfs unless noted otherwise).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
D1641	All	See Jul-Dec	Export/Inflow Ratio: 35% of Delta Inflow ([64])					Export/Inflow Ratio: 65% of Delta Inflow						64
D1641	All				Export Limit: > of 1500 or 100% of 3-day avg. Vernalis flow									65
Draft D1630	All	QWEST > -2000	No reverse flow for all year types on a 14-day running average in the Western Delta (QWEST > 0 cfs, as calculated in Dayflow)					QWEST > -1000	QWEST > -2000					66
Draft D1630	C & D				14-day running average combined export rate for Tracy, Banks, and Contra Costa pumping plants shall be $\leq$ 4000 cfs									
Draft D1630	BN, AN, W				14-day running average combined export rate for Tracy, Banks, and Contra Costa pumping plants shall be $\leq$ 6000 cfs									
CSPA / C-WIN	All			Combined Export Rates = 0										67
CSPA / C-WIN	All			2000 cfs daily flow in Old and Middle Rivers										68
CSPA / C-WIN	C	1000 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			69
CSPA / C-WIN	D	1500 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			69
CSPA / C-WIN	BN	2000 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			69
CSPA / C-WIN	AN	2500 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			69
CSPA / C-WIN	W	3000 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			69
TBI / NRDC		Sac Salmonids, Delta Smelt, Longfin Smelt*		Sac & SJR Salmonids, D. Smelt, L. Smelt*	Sac & SJR Salmonids, D. Smelt, L. Smelt (C & D yrs)		Sac & SJR Salmonids, D. Smelt				Sac Basin Salmon		Sac Salmon, D. Smelt	70
TBI / NRDC	C	-1500 or >0*	-1500 or >0*	-1500 or >0*	>0	>0	-1500				-2000	-2000	-1500	
TBI / NRDC	D	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
TBI / NRDC	BN	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
TBI / NRDC	AN	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
TBI / NRDC	W	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
AFRP	C / D	1000 (net seaward flows at Jersey Pt)									See Jan-June			71
AFRP	BN / AN	2000 (net seaward flows at Jersey Pt)									See Jan-June			71
AFRP	W	3000 (net seaward flows at Jersey Pt)									See Jan-June			71
NMFS - OCAP Bio Op	All	Limit negative flows to -2000 to -5000 cfs in Old and Middle Rivers, depending on the presence of salmonids (see decision tree upon which the negative flow objective w/in the range shall be determined)												72
NMFS - OCAP Bio Op	All				Export restrictions based on Vernalis flow: <6000 cfs = 1500 cfs export limit 6000-21750 cfs = 4:1 (Vernalis flow:export ratio) >21750 = Unrestricted									

Appendix A, Table 4. Old and Middle River flow, export restriction, San Joaquin River flows at Jersey Point (e.g., QWEST) recommendations summary table - con't. (p. 2 of 2)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
USFWS	All	Board should develop reverse flow criteria that would maintain Old and Middle River flow positive during key months (Jan - Jun)												73
USFWS	All	"...the AFRP Working Paper (USFWS, 1995) Restoration Action #3 calls for maintaining positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point... Higher flow at Jersey Point has been provided during the VAMP period (mid-April to mid-May) with the adoption of VAMP flows and exports. We encourage the Board to retain or expand this type of action to assure the contribution of downstream flow from the San Joaquin Basin to Delta outflow..."									See Jan - June			74
USFWS - OCAP Bio Op	All	Action 1: -2000 cfs for 14 days once turbidity or salvage trigger has been met. Action 2: range btw -1250 and -5000 cfs ([75])			Range between -1250 and -5000 ([76])								See Jan-Mar	75, 76
CDFG Longfin Smelt Incidental Take Permit	All	Condition 5.1 (Dec - Feb): >-5000 ([77]) Condition 5.2 (Jan - June): OMR flow between -1250 and -5000 cfs ([78])											Condition 5.1 (Dec-Feb)	77, 78
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22

Appendix A, Table 5. Floodplain inundation flow recommendations summary table.

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
CDFG	AN & W	$\geq$ 30 day floodplain inundation												79
EDF / Stillwater	BN	64000 (pulse flow, 21 consecutive days)												37 Sacr Riv - Yolo Byp
	AN	64000 (pulse flow, 35 consecutive days)												
	W	64000 (pulse flow, 49 consecutive days)												
TBI / NRDC / AR / NHI	C (0-20 percentile)			27500 for 15 cont days										34 Sac Riv - Yolo Byp
	D (20-40 percentile)			27500 for 30 cont days										
	BN		30000 for 60 cont days											
	AN		32500 for 90 continous days											
	W	35000 for 120 continuous days												
AR / NHI	All	Sac Riv at Bend Bridge - Pulse flows continuously exceed 8000, periodically exceed 12000, for a duration exceeding 2 weeks										See Jan - May		32
USFWS	6 of 10 yrs	"The Board should consider the importance of more frequent floodplain inundation (especially Yolo Bypass flows) when determining the Delta outflows..."												80
NMFS - OCAP Bio Op	All	"...Reclamation and DWR shall, to the maximum extent of their authorities, provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type."											See Jan-Apr	81
NMFS - Recovery Plan	All	"Enhance the Yolo Bypass by re-configuring Fremont and Sacramento weirs to: ... and (6) create annual spring inundation of at least 8000 cfs to fully activate the Yolo Bypass floodplain."												82
Delta Solutions Group	8 of 10 yrs		Yolo Bypass 2500 (Sac Riv ~ 45750)											42
	6 of 10 yrs			Yolo Bypass 4000 (pulse) (Sac Riv ~ 50150)										
San Joaquin River														
EDF / Stillwater	AN	14800 (pulse flow, $\geq$ 21 consecutive days)												57
	W	14800 (pulse flow, $\geq$ 35 consecutive days)												
See TBI / NRDC and AR / NHI SJ River Inflow recommendations, flows >20000 cfs to trigger floodplain inundation														

Appendix A, Table 6. Delta Cross Channel closures summary table.

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Notes
D-1641		see Nov	Gates Closed			Close for 14 days ([83])						Nov-Jan - gates may be closed for up to total of 45 days		83
Draft D-1630	All	Closed if daily DOI >12000	Operated based on results of real-time monitoring											84
CSPA / C-WIN	All		Gates Closed											85
	All		Acoustic Barrier at head of Georgiana Slough at Sacramento River											
NMFS - OCAP Bio Op	All	Dec 15 - Jan 31 Gates closed	Gates Closed per D1641			Gates closed up to 14 days per D1641					Gates closed if fish are present		Gates closed except for experiments/water quality Dec 15 Jan 31 Gates closed	86

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
1	D1641	Outflow	All water year types - Increase to 6000 if the Dec 8RI is > than 800 TAF
2	D1641	Outflow	Habitat Protection Flows, minimum Delta outflow calculated from a series of rules that are described in Tables 3 and 4 of D1641
3	Draft D1630	Outflow	Striped Bass, Antioch spawning - Delta outflow index, Sac Riv at Chipps Island, average for the period not less than value shown (cfs).
4	Draft D1630	Outflow	Striped Bass, general - Delta outflow index, Sac River at Chipps Island - average for period not less than value shown (cfs), May period = May 6-31
5	Draft D1630	Outflow	Suisun Marsh - Delta outflow index at Sac River at Chipps Island - average of daily DOI for each month, not less than value shown (cfs)
6	Draft D1630	Outflow	Suisun Marsh - Delta outlflow index, Sac River at Chipps Island - minimum daily DOI for 60 consecutive days in the period
7	Draft D1630	Outflow	Suisun Marsh - Delta outflow index, Sac River at Chipps Island - average of daily DOI for each month, not less than value shown, in cfs: applies whenever storage is at or above minimum level in flood control reservation envelope at two of the following - Shasta Reservoir, Oroville Reservoir, and CVP storage on the American River
8	TBI et al	Outflow	Water year categories represent exceedance frequencies for the 8-river index, they are not equivalent to the DWR "water year types" (which account for storage and other conditions). TBI_Exhibit 2 (Outlfow). References for correlation btw winter-spring outlfow and abundance of numerous species on p.3. Winter-spring Delta outflow criteria approximate the frequence distribution of outflow levels, i.e., the relationship btw outflow and the 8 River Index, for the 1956-1987 period. Winter and spring outlfow recommendations to benefit public trust uses of pelagic species (as represented by abundance and productivity of longfin smelt, Crangon shrimp, and starry flounder and spatial distribution of longfin smelt) (see TBI Exhibit 2, pp 21-25). Two methods were used to develop outflow criteria: an analysis of historical flow-abundance relationships that corresponded to recovery targets for longfin smelt abundance (Native Fishes Recovery Plan, USFWS 1995), and an analysis of population growth response to outflows in order to identify outflows that produced population growth more than 50% of the time. Applying these
8 cont	TBI et al	Outflow	two methods produces very similar results regarding desirable outflow levels. Break in summary table at mid-Mar is artificial, original table included Mar under both Winter and Spring, so for simplicity, it was split at 15 Mar. Fall outflows (TBI Exhibit 2, p. 35, Table 1 and Fig 27) - analyzed emerging statistical evidence of relationship btw outlfow and abundance and distribution of delta smelt and striped bass (Feyrer et al 2007; Feyrer et al In Review; DSWG notes, Aug 21, 2006), in order to develop recommendations. Recommendations occassionaly exceed unimpaired outflow in limited cases (would require reservoir releases in fall independent of antecedent conditions).

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
9	CSPA / C-WIN	Outflow	Net Delta Outflow, as a 14-day running average - Source WRINT-DFG Exh 8 (1992). Feb-Mar - flows correspond to Table 8 (p.23), Alternative C (Estuarine species - target mean monthly flows based on data from DWR's 1995 Level of Development + 50% increase). Orig. recommendations by month, C-WIN/CSPA took average of Feb and Mar, and reported as such. Apr-July - flows correspond to Table 2 (p16), Alternative C (mean Delta outflows required to maintain populations of 1.7 million adult striped bass). Aug-Jan - based on Alt C (discussed above), in combination with flow recommendations developed by C-WIN for Jan. DFG identified flows for all months except Jan, C-WIN developed a method for Jan flows from DayFlow information (C-WIN extracted monthly average Delta outflows from DayFlow, sorted them, and then allocated them to water years based on unimpaired runoff data from the California Data Exchange Center. The medians of the water year types were then used as January flows in developing our optimal conditions recommendations for mean Delta outflows in the August 1 through January 31 period).
10	EDF / Stillwater	Outflow	Stillwater Focal Species Approach - Source - EDF closing comments (Table 1), Supporting Info - EDF Exhibit 1 (Winter [Dec-Feb] outflows - p.52-53). A primary objective was to provide enough Delta outflow to maintain X2 westward of 65 km, w/ variations to allow eastward excursion of X2 as far as 80 km in drier water year types. Proximate function is to increasethe westward extent of fresh water into Suisun and San Francisco bays to more closely approximate historical conditions. "This will serve to increase the availability of food resources to larval fish species in late winter as well as improve access to low salinity habitat in the shallows of Grizzly and Honker bays (Feyrer et al 2009)." Flows also designed to limit the eastward distribution and density of overbite clam. "...low salinity may inhibit spawning and subsequent adult recruitment, thereby reducing grazing pressures on phytoplankton and the pelagic food web. Improvements in food resources to the western Delta will serve to increase populations of Delta smelt, striped bass, and other pelagic species that are currently in decline."
11	EDF / Stillwater	Outflow	Stillwater Focal Species Approach - Source - EDF closing comments (Table 1), Supporting Info - EDF Exhibit 1 (Spring [Mar-May] Outlfows - p.55-56). Spring flows primarily based on delta outflows needed to maintain X2 in locations that are beneficial to delta pelagic fish populations as well as the provision of floodplain inundation in the Yolo Bypass during March Primary objective was to provide enough Delta outflow to maintain X2 westward of 65 km, w/ variations to allow eastward excursion of X2 as far as 70 km in drier water year types. References in justification: Feyrer et al. In Revision, Bennett et al 2005. Herbold 1994, Hobbs et al 2004, Bennett et al. 2008, and others). Secondary goal is to provide sufficient flows to maintain inundated season floodplain habitat in Yolo Bypass and lower SJ Riv for varying periods in March based on water year type. These floodplain inundation flows should be coordinated with flows in late winter to provide prolonged periods of inundation.
12	EDF / Stillwater	Outflow	Stillwater Focal Species Approach - Source - EDF closing comments (Table 1), Supporting Info - EDF Exhibit 1 (Fall [Sept-Nov] - pp.49-50; Summer - pp.57-58) Summer (Jun-Aug) and Fall flows based primarily on Delta outflows needed to maintain X2 in the shallow-water habitats of Suisun Bay. Secondary objective for Fall outflows from the Delta were to provide attraction flows for upstream-migrating salmonids and to maintain adequate DO concentrations for fall-run chinook salmon within the lower SJ River system. Summer and Fall - in some months and water year types, depending on water year type and month, the projected monthly outflows are higher than the unimpaired and/or current flow ranges. Thus some modification of upstream reservoir release schedules may be required to meet these flows. Fall - references in justification - Feyrer et al 2007; Feyrer et al In revision; Bennet et al 2002; Jassby et al 1995; and others

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
13	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Peak flows required to provide floodplain inundation are assumed to be concurrent between the Sac and SJ River basins as well as the east side tributaries. However, the duration of the peak flows varies by water year (see notes 69-74)
14	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 14 days of floodplain inundation flow of 64000 cfs in the Sac River
15	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 7 days of floodplain inundation flow of 64000 cfs in the Sac River
16	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 21 days of floodplain inundation flow of 64000 cfs in the Sac River and 14 days of floodplain inundation flow of 14800 cfs in the SJ River
17	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 14 days of floodplain inundation flow of 64000 cfs in the Sac River and 7 days of floodplain inundation flow of 14800 cfs in the SJ River.
18	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 28 days of floodplain inundation flow of 64000 cfs in the Sac River and 21 days of floodplain inundation flow if 14800 cfs in the SJ River
19	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 21 days of floodplain inundation flow of 64000 cfs in the Sac River and 14 days of floodplain inundation flow of 14800 cfs in the SJ River
20	USFWS	Outflow	Delta smelt biological opinion (RPA concerning Fall X2 requirements [pp. 282-283] - improve fall habitat [quality and quantity] for DS) (references USFWS 2008, Feyrer et al 2007, Feyrer et al in revision) - Sept-Oct in years when the preceeding precipitation and runoff period was wet or above normal, as defined by the Sacramento Basin 40-30-30 Index, USBR and DWR shall provide sufficient Delta outflow to maintain monthly average X2 no greater than 74 km and 81 km in Wet and Above Normal yrs, respectively. During any November when the preceding water yr was W or AN, as defined by Sac Basin 40-30-30 index, all inflow into the CVP/SWP reservoirs in the Sac Basin shall be added to reservoir releases in Nov to provide additional increment of outflow from Delta to augment Delta outflow up to the fall X2 of 74 km and 81 km for W and AN water yrs, respectively. In the event there is an increase in storage during any Nov this action applies, the increase in reservoir storage shall be released in December to augment the Dec outflow requirements in SWRCB D-1641.
21	CDFG	Outflow	Outflow recommendations from closing comments. Originally provided as X2 recommendations - Source - DFG Exhibit 1 and Exhibit 2 - Consolidates recommendations for American Shad, Longfin Smelt, Starry Flounder, Bay Shrimp, Zooplankton (consistent with D1641 requirements to maintain X2 at one of two compliance points in Suisun Bay [64 km or 75 km] from Feb-June). Longfin smelt = Jan - June; Starry flounder, Bay shrimp, zooplankton = Feb - Jun; and American Shad = April - June.
22	DWR / SFWC	Outflow, SJ Riv Inflow, Sac Riv Inflow, OMR	DWR_closing comments, in response to request for a table identifing recommended flows, DWR submitted summary of D-1641 objectives.

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
23	UCDavis - Delta Solutions Group	Outflow	Functional Flow 5a - Delta Smelt flows, 48000 cfs, from March through May (5 out of 10 years, every other year). Maintain freshwater to low salinity habitat in the northeastern Delta to Napa River, facilitating a broad spatial and temporal range in spawning and rearing habitat (Bennett 2005, Hobbs et al 2005). Flow recommendation not based on water year type, but rather number of years out of 10. Based on exports through an alternative form of conveyance (e.g., peripheral canal or tunnel).
24	Draft D1630	Sac River Inflow	Function = Chinook salmon. Sac River at Freeport. Average flow at Freeport >18000 cfs for a 14-day continuous period corresponding to release of salmon smolts from Coleman Nat Fish Hatchery. Anticipate to occur in late April or early May. If no fish are released from the hatchery, the Executive Director shall determine the appropriate timing of this pulse flow with advice from CDFG.
25	Draft D1630	Sac River Inflow	Function = striped bass, general; Sac River at Freeport - 14-day running average at Freeport >13000 cfs for a 42-day continuous period, with minimum mean daily flow >9000 cfs. Requirement initiated when real-time monitoring indicates the presence of striped bass eggs and larvae in Sac River below Colusa. This period should begin in late April or early May in most years.
26	Draft D1630	Sac River Inflow	Function = chinook salmon. Sac River at Rio Vista - 14-day running average of minimum daily flow.
27	CDFG	Sac River Inflow	Chinook salmon, smolt outmigration. (1) Feb - Oct base flows. Source - DFG Exhibit 14 (WRINT-DFG-8, p.11). (2) Apr - Jun pulse flows. Source - DFG Exhibit 1, page 1, 6, and USFWS Exhibit 31 (Kjelson).
28	CSPA	Sac River Inflow	CSPA Closing Comments. Source - CDFG_1992_WRINT-DFG-Exhibit #8, p.11. Minimum base flow, measured at Rio Vista. 14-day average flow.
29	CSPA / C-WIN	Sac River Inflow	Sacramento River from Freeport to Chipps Island - Pulse flows - flows needed to sustain viable migration corridor for optimal smolt passage and survival. Source - USFWS Exhibit 31 (Kjelson)
30	PCFFA	Sac River Inflow	Function = salmonid juvenile outmigration. PCFFA closing comments, Source - USFWS Exhibit 31 (Kjelson). Kjelson and Brandes research - found that flows of 20000 to 30000 cfs yield the greatest survival of juvenile salmon during out-migration from Sac River to San Francisco Bay (PCFFA recommends splitting the difference and setting standard at 25000 cfs). Set from Hood to Chipps Island.
31	USFWS	Sac River Inflow	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 25, 54, and 57. "The catch of juvenile salmon at Chipps Island between April and June is correlated to flow at Rio Vista (USFWS, 1987; Brandes and McLain, 2001; Brandes et al., 2006). The highest abundance leaving the Delta has been observed when flows at Rio Vista between April and June averaged above 20,000 cfs which is also the level where we have observed maximum survival in the past (USFWS, 1987)" (p.25).

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No.	Entity	Type	Notes (excerpts from source documents)
32	AR / NHI	Sac River Inflow	AR_NHI_Exh1 (testimony of Cain, Opperman, and Tompkins) and AR_NHI_closing comments. Purpose - interconnect side channels with main channel, contribute to foodweb productivity and rearing habitat for salmon. Inundated off-channel habitat such as high flow channels can also provide rearing habitat for salmon (Peterson and Reid 1984), but regulated spring flows are generally insufficient to inundate these habitats for prolonged periods (30-60 days), A recent study of these habitats in the Sac River determined that a large proportion of secondary channels between Red Bluff and Colusa become fully connected to the river at flows above 12000 cfs (Kondolf 2007). (from AR_NHI_Exh1 p.28)
33	AR / NHI	Sac River Inflow	AR_NHI_Exh1 (Testimony of Cain, Opperman, and Tompkins) and AR_NHI_closing comments - aid migration of winter-run chinook, in later months aid migration of spring and fall-run. Recent analyses indicate that the onset of emigration of winter-run fish to the Delta at Knights Landing is triggered by flow pulses of 15000 cfs at Wilkins Slough, and emigration from the Sac River to Chipps Island follows pulse flows of 20000 cfs at Freeport (del Rosario 2009). Previous studies found that smolt survival increased with increasing Sac River flow at Rio Vista, with maximum survival observed at or above about 20000 and 30000 cfs (USFWS 1987, Exhibit 31). Despite uncertainty about the exact magnitude of flow necessary to initiate substantial bank erosion, there is growing evidence that flows between 20000 and 25000 cfs will erode some banks while flows above 50000 to 60000 cfs are likely to cause widespread bank erosion (Stillwater 2007).
34	TBI / NRDC / AR / NHI	Sac River Inflow	TBI_Exh3 (Inflows - Table 3), TBI_closing comments (Table 3), AR/NHI_Exh1 (Testimony of Cain, Opperman, and Tompkins), AR/NHI closing comments - Table 3. Flows recommended for floodplain inundation (Sutter and Yolo Bypasses) - salmonid rearing, splittail spawning and early rearing. Flows measured at Verona. Flow magnitudes assume structural modifications to the weir to allow inundation at lower flow rates than is currently possible. Reservoir releases should be timed to coincide with and extend duration of high flows that occur naturally on less regulated rivers and creeks. The duration target is fixed for each year type, but actual timing of inundation should vary across the optimal window depending on hydrology and to maintain life history diversity.
35	NMFS	Sac River Inflow	NMFS_Exh9 (from ARFP 1995), Sturgeon (Grn and Wht) - adult migration to spawning and downstream larval transport
36	NMFS	Sac River Inflow	Public Draft Recovery Plan for Central Valley Salmon and Steelhead (October 2009). NMFS_Exhibit_5. Section 6.1.1 Recovery Action Narrative, Action 1.5.9, p.158.
37	EDF / Stillwater	Sac River Inflow	Source: EDF_Exh1 (Stillwater Sciences - Focal Species Approach). Spring flows - Establishing base flows of at least 10000 cfs in the Sac Riv in spring would improve transport of eggs and larval striped bass and other young anadromous fish and to reduce egg settling and mortality at low flows (USFWS 2001, EDF_Exh1, p.53). Proximate function of Delta inflows is to maintain net transport of passively swimming fishes (juv salmonids, larval delta smelt, and striped bass) and nutrients towards Suisun and San Francisco bays (USFWS 2008). Goal of winter and spring floodplain activation flows (managed pulse flows of approx 64000 cfs at Verona) is to maintain inundated seasonal floodplain habitat conditions in much of Yolo Bypass during January and April for a minimum of 21, 35, and 49 days in Below Normal, Above Normal, and Wet water year types, respectively. The NMFS (2009) draft recovery plan for Sac winter-run chinook, CV spring-run chinook, and CV steelhead ESUs calls for an annual spring flow of 8000 cfs (approx 64000 cfs at Verona) above the initial spill level "to fully activate the Yolo Bypass floodplain." For the

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No.	Entity	Type	Notes (excerpts from source documents)
37 cont	EDF / Stillwater	Sac River Inflow	purposes of this assessment, Stillwater allocated the Delta inflows for floodplain inundation to February and March. Summer Delta inflows to be determined by Delta outflows. Fall Inflows - Maintenance of D1641 flow standards in necessary to provide attraction flows for Chinook salmon, although these levels would potentially need to be increased to provide adequate Delta outflows. Winter Inflows - Winter flows primarily designed to provide upstream migration passage for salmonids and striped bass during Dec and Jan, as well as to inundate floodplains such as Yolo Bypass for benefit of rearing juv salmonids and other floodplain associated species (p.50-51). See Spring for discussion of goal of combined winter-spring floodplain activation flows.
38	EDF / Stillwater	Sac Riv Inflow / SJ Riv Inflow	Inflows determined based on Delta outflows (EDF_Exh1 - Stillwater Focal Species)
39	EDF / Stillwater	Sac River Inflow	These levels may need to be increased to provide adequate Delta outflows (EDF_Exh1 - Stillwater Focal Species)
40	UCDavis - Delta Solutions Group	Sac River Inflow	Functional Flow 2a - Sac River adult salmon - 10000 cfs to to occur from Oct - June during 6 out of 10 years (references Newman and Rice 2002, Williams 2006, Harrell et al. 2009, USFWS Exhibit 31 1987, Kjelson and Brandes 1989). Functional Flow 2b - Sac River juvenile salmon migration - 25000 cfs from Mar - June during 6 out of 10 years (references Newman and Rice 2002, Williams 2006, Harrell et al. 2009, USFWS Exhibit 31 1987, Kjelson and Brandes 1989). Flows not based on water year type, but rather number of years out of ten.
41	UCDavis - Delta Solutions Group	Sac River Inflow	Functional Flow 2c - Sacr River adult sturgeon flows - 70000 cfs to occur between Jan and May during 1 out of 10 years (flows for salmon -2a, 2b, and 1a,1b) (Kohlhorst et al 1991 [flow rate], Harrell and Sommer 2003 [passage problems at Fremont Weir]). Flows not based on water year type, but rather number of years out of ten.
42	UCDavis - Delta Solutions Group	Sac River Inflow	Functional Flow 1a - yolo bypass inundation - salmon and splittail (area inundated based on recommended flows BDCP draft rpt 2008) (other references related to flow and corresponding extent of habitat in Yolo Bypass Moyle et al. 2004, Sommer et al. 2004, Harrell and Sommer 2003, Harrell et al. 2009). Functional Flow 1b - yolo bypass pulse - salmon and splittail (area inundated based on recommended flows BDCP draft rpt 2008) (other references related to flow and corresponding extent of habitat in Yolo Bypass Moyle et al. 2004, Sommer et al. 2004, Harrell and Sommer 2003, Harrell et al. 2009). Functional Flows 1a and 1b require flows at Freeport of approx. 45750 and 50150 cfs, respectively, based on regressions of historical data.
43	D1641	SJ River Inflow	Base Vernalis minimum monthly average flow rate in cfs (the 7-day running average shall not be less than 20% below the objective). Take the higher objective if X2 is required to be west of Chipps Island
44	D1641	SJ River Inflow	Pulse Vernalis minimum monthly average flow rate in cfs. Take the higher objective if X2 is required to be west of Chipps Island
45	D1641	SJ River Inflow	Pulse - up to an additional 28 TAF pulse/attraction flow to bring flows up to a monthly average of 2000 cfs except for a critical year following a critical year. Time period based on real-time monitoring and determined by CalFed Op's group

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No.	Entity	Type	Notes (excerpts from source documents)
46	Draft D1630	SJ River Inflow	SJ River at Vernalis. Function = chinook salmon. Minimum daily flow, in cfs, for 21-day continuous period. Start date depends on beginning of chinook salmon smolt out-migration from SJ basin. During this time, water right holders on Mokelumne and Calaveras rivers shall bypass all inflows for 5 consecutive days. Daily mean combined pumping at Tracy, Banks, and Contra Costa pumping plants shall be $\leq$1500 cfs. All pumping restrictions are to be split equally between CVP and SWP. Total annual maximum of 150 TAF for the two salmon flows (these and fall attraction flows) from the SJ Basin reservoirs
47	Draft D1630	SJ River Inflow	SJ River at Vernalis. Function = chinook salmon. Minimum daily flow, for 14-day continuous period. Start date depends upon beginning of chinook salmon adult spawning migration. Attraction flow shall be provided only if water is avaiable from the 150 TAF alloted for the two salmon flows. During this time, water right holders on Mokelumne and Calaveras rivers shall bypass all inflows for 5 consecutive days.
48	CDFG	SJ River Inflow	Source: SJR Salmon Model V.1.6 (CDFG 2009), DFG Exhibit 3 (Flows needed in the Delta to restore anadromous salmonid passage from the SJ River at Vernalis to Chipps Island) - Table 10 - South Delta (Vernalis) flows needed to double smolt production at Chipps Island (by water year type), and CDFG closing comments. Flows to support smolt outmigration.
49	CSPA / C-WIN	SJ River Inflow	CSPA and C-WIN Closing Comments - CSPA Table 2. Based on WRINT-DFG Exhibit 8 (1992) and C. Mesick 2010 (C-Win Exh 19). Pulse flows in all years to attract adult spawning salmonids, Oct 20-29, SJR at Vernalis. To the tributary flows (each measured at their confluence with SJ Riv mainstem (see Mesick 2010), C-WIN / CSPA added in a flow of the SJ Riv below Millerton Lake reflecting that river's fair share unimpaired flow, as well as accretions and other inflows. Combined valley flows at Vernalis assumes tributaries (Mer, Stan, Tuol) are 67.06% of total SJ River flow at Vernalis. Spring - pulse flows for temperature regulation, migration cues, habitat inundation. Oct - pulse flows to attract adult salmonids.
50	TBI / NRDC	SJ River Inflow	TBI Exhibit 3 - Delta Inflows (Table 1, p.28), TBI / NRDC closing comments (Table 3b). Flows >5000 cfs to maintain minimum temperature ($\leq$ 65F) for migrating salmonids in April and May. Flows >20000 to trigger floodplain inundation. Year-round flows should exceed 2000 cfs to alleviate potential for DO problems in DWSC.
51	AR / NHI	SJ River Inflow	AR_NHI_Exh1 (testimony of Cain, Opperman, and Tompkins) and AR_NHI_closing comments (Table 2). SJ River flows to benefit salmon rearing habitat and smolt out-migration (increase flow velocities and turbidity), with focus on temperature (maintain temp at or below 65F) and floodplain inundation. Criteria recommended to be in addition to those stipulated in D1641.
52	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.47-49). Based upon investigations for the SJ River DO TMDL, minimum instream flows at the Stockton DWSC should be maintained in excess of 1,800 cfs during Sept and Oct of each year. Low DO in the lower SJ River has been found to impede upstream salmon migration (NMFS 2009, p.74). Studies by Hallock (1970) indicate that low DO at Stockton delay upmigration and straying rates.
53	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.47-49). Flows during November should correspond to current minimum Federal Energy Regulatory Commission (FERC) spawning flow requirements from the Stanislaus, Tuolumne, Merced, and upper San Joaquin rivers.

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No.	Entity	Type	Notes (excerpts from source documents)
54	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.47-49). Salmonid spawning attraction flows in excess if 3500 cfs at Vernalis should be provided for 10-14 days during October, using coordinated releases from the SJ River and tributaries. For remainder of fall, Delta inflows would be determined by the minimum instream flow requirements of the SJ River basin and east side tributaries. Upstream flow levels would likely be increased to meet the Delta outflow recommendations.
55	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.54). "Although USFWS (1995) previously recommended spring Delta inflows ranging from 4,050 cfs to 15,750 cfs at Vernalis based upon of regression models of Chinook salmon smolt survival. The current D-1641 flow minimums range from 3,110 cfs to 8,620 cfs (Table 1-5), depending upon water year type, have never been fully implemented. In addition to baseline flows, for the benefit of rearing Chinook salmon and other native fishes, floodplain activation flows should be provided..."
56	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.51-52). Winter Inflows - Minimum flows at Vernalis and the eastside tributaries should be coordinated to maintain net seaward flows at Jersey Point of 1000 cfs in Critical and Dry years, 2000 cfs in Below and Above Normal years, and 3000 cfs in Wet years (USFWS 1995 3-Xe-19). Net seaward flows for benefit of outmigrating juvenile salmon.
57	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.54-55). For the benefit of rearing chinook salmon and other native fishes, floodplain activation flows should be provided of 14800 cfs in the lower SJ River in Above Normal and Wet water year types. A series of pulse flows instead of a single extended high flow event might also be used to achieve the desired target of continuous days of inundated floodplain. Goal for combined winter and spring floodplain activation flows is to maintain inundated seasonal floodplain habitat conditions (or the potential for such conditions in sites where floodplain restoration actions may be undertaken in the future) in the lower SJ River during Jan through Apr for a minimum of 21 and 35 consecutive days in Above Normal and Wet water year types, respectively. For the purposes of this assessment, Stillwater allocated the Delta inflows for floodplain inundation to February and March. Also discusses inundation of Cosumnes River floodplain.
58	USFWS	SJ River Inflow	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 56-57 and 25. Quote in table from p.56-57. "The Anadromous Fish Restoration Program has developed estimates of flow levels needed at Vernalis to achieve a 53% increase (page 9) and a doubling (page 10) in predicted Chinook salmon production for the basin (USFWS, 2005). These Vernalis flow criteria vary by water year type and by month between February and May. We recommend these flows as starting point for establishing minimum and maximum volume of flow for increasing juvenile salmon and steelhead survival in the San Joaquin basin." (p.25).
59	AFRP	SJ River Inflow	Anadromous Fish Restoration Program (ARFP). Recommended streamflow schedules to meet the AFRP Doubling Goal in the San Joaquin River Basin (USFWS, 27 Sept 2005). Salmon doubling - total average flow (Stanislaus, Tuolumne, Merced) that would be expected to double the total predicted Chinook salmon production for the basin.

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No.	Entity	Type	Notes (excerpts from source documents)
60	AFRP	SJ River Inflow	Anadromous Fish Restoration Program (ARFP) - Recommended streamflow schedules to meet the AFRP Doubling Goal in the San Joaquin River Basin (USFWS, 27 Sept 2005). Total average flow (Stanislaus, Tuolumne, Merced) that would be expected to achieve a 53% increase in total predicted Chinook salmon production for the basin.
61	NMFS	SJ River Inflow	NMFS OCAP Bio Opinion, Action IV.2.1 (pp.641-644) San Joaquin River Inflow to Export Ratio - both interim (2010-2011) and long-term (beginning in 2012) requirements are stipulated. Interim flows are based on maintaining a minimum status quo for SJ River basin salmonid populations. Long term flow schedules for the SJ River are expected to result from SWRCB proceedings on SJ River flows. Export limitations and flows are also described on pp. 642-644
62	NMFS	SJ River Inflow	NMFS_Exh9 (from AFRP 1995) - Sturgeon (Green and White), mean monthly flows - ensure suitable conditions for sturgeon to migrate and spawn and for progeny to survive.
63	UCDavis - Delta Solutions Group	SJ River Inflow	Functional Flows 3a - transport juvenile salmon (references USFWS Exhibit 31, 1987; Newman and Rice 2002; Williams 2006) - wet years - 20000 cfs, Apr-Jun (2 out of 10 years); AN years - 15000 cfs, April - Jun 15 (4 out of 10 years); BN years - 10000 cfs, Apr-May (6 out of 10 years); Dry years - 7000 cfs, Apr-May 15 (8 out of 10 years); and Critical years - 5000 cfs, Apr (10 out of 10 years). Functional Flows 3c - adult salmon recruitment (reference USFWS Exhibit 31, 1987) - 2000 cfs year round (10 out of 10 years) (flows were not experienced in unimpaired conditions, but likely result from the disturbed conditions). Functional Flows 3b - Improve DO conditions in DWSC (2000 cfs, July-Oct, all years) (Lehman et al 2004, Jassby and VanNieuwenhuyse 2005).
64	D1641	OMR	Export/Inflow ratio - the maximum percent Delta inflow diverted for Feb may vary depending on the Jan 8RI (see D1641)
65	D1641	OMR	SWP/CVP Export Limit - All water year types, Apr 15 - May 15, the greater of 1500 cfs or 100% of 3-day avg. Vernalis flow. Maximum 3-day average of combined export rate (cfs), which includes Tracy Pumping Plant and Clifton Court Forebay Inflow less Byron-Bethany pumping. The time period may need to be adjusted to coincide with fish migration. Maximum export rate may be varied by CalFed Ops Group.
66	Draft D1630	OMR	Reverse flow restrictions for all year types are relaxed when combined CVP and SWP exports are < 2000 cfs. Export pumping restriction is relaxed for all year types when Delta outflow > 50000 cfs, except for the export pumping restriction during the SJ River pulse period. July 1 - Jan 31 - 14-day running average flow (as calculated in DAYFLOW), these restrictions do not apply whenever the EC at the Mallard Slough monitoring station is < 3 mmhos/cm. QWEST standards in 1630 discussed in DOI submittal, p.53, section concerning reverse flows.
67	CSPA / C-WIN	OMR	CSPA closing comments, C-WIN closing comments, CSPA_Exh1_Jennings. Combined export rates would be 0 cfs in all years from March 16 through June 30. Prevent entrainment and keep migration corridors open to maximize salmon juvenile and smolt survival. Facilitate SJ River salmonid migration down Old River.
68	CSPA / C-WIN	OMR	CSPA and C-WIN closing comments - flow direction, entrainment protection and provision of migration corridors

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No.	Entity	Type	Notes (excerpts from source documents)
69	CSPA / C-WIN	OMR	SJ River at Jersey Point flow recommendations (positive 14-day mean flows). Source: CSPA_exh1_Jennings_test; CDFG_1992_WRINT-DFG-Exhibit #8, Alt C (p.11, flows at Jersey Pt from Apr 1 through June 30, salmon); AFRP Working Paper, 1995, p. 3-Xe-19 (salmon). Function maintain positive flow for salmonid smolt outmigration and protect Delta smelt, originally two separate recommendations. DS - Feb 1 - Jun 30, Salmon - Oct 1 - Jun 30, only difference between flow recommendations where overlap occurred was DS in AN years = 2500 cfs, salmon in AN years = 2000. For this table, recommendations merged and 2500 cfs used for AN years (+DFG Exh 8 recommends 2500 cfs in AN years)
70	TBI / NRDC	OMR	TBI/NRDC closing comments (Table 4). The hydrodynamic recommendations expressed as Vernalis flow and/or export to inflow ratios in TBI/NRDC Exh4 (Delta Hydrodynamics, p.30) were converted to OMR flows, using the San Joaquin flow recommendations as described in TBI/NRDC Exh 3 (Delta Inflows), for inclusion in Table 4. Note: recommended OMR flows assume SJ River flows recommended in TBI Exhibit 3 are also implemented. (*) - when the previous longin smelt FMWT index <500, OMR flows in Jan-Mar are >0. This corrects a typographical error in the table on p.30 of TBI Exhibit 4
71	AFRP	OMR	Anadromous Fish Restoration Program (ARFP) (Working Paper on Restoration Needs, Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California, Volume 3, 1995, p. 3-Xe-19). Action 3 - Maintain positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1000 cfs in Critical and Dry years, 2000 cfs in below- and above normal years, and 3000 cfs in wet years from Oct 1 through June 30. Objective - Increase survival of smolts migrating down the mainstem rivers, decrease the number of smolts diverted into the central Delta, increase the survival of smolts diverted into the central Delta, and provide attraction flows for San Joaquin Basin adults (Oct - Dec).
72	NMFS	OMR	NMFS OCAP Bio Opinion, Action IV.2.3 - Old and Middle River Flow Management (pp. 648-652). See action triggers on pp. 648-650. Actions will be taken in coordination with USFWS RPA for Delta Smelt and State-listed longfin smelt 2081 incidental take permit. During the Jan 1 - Jun 15 period, the most restrictive export reduction shall be implemented.
73	USFWS	OMR	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 50, 53, and 24-25 (references USFWS 1992; AFRP Working Paper p.3-Xe-19, USFWS 2005, Restoration Action #3; D-1630, pp44-47). "Based on the scientific information we reviewed, the Board should develop reverse flow criteria that would maintain the Old and Middle river flow positive during key months (January through June) of the year to protect important public trust resources in the Delta" (p.53).

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
74	USFWS	OMR	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 24,25, and 53. "In a previous Board exhibit (USFWS, 1992), we showed a positive relationship between temperature corrected juvenile survival indices and flow at Jersey Point for marked fish released at Jersey Point (QWEST) (USFWS, 1992, p.21). In addition, the AFRP Working Paper (USFWS, 1995) Restoration Action #3 calls for maintaining positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1000 cfs in critical and dry years, 2000 cfs in below- and above-normal years, and 3000 cfs in wet years from Oct 1 through June 30. Higher flow at Jersey Point has been provided during the VAMP period (mid-April to mid-May) with the adoption of VAMP flows and exports. We encourage the Board to retain or expand this
74 cont	USFWS	OMR	type of action to assure the contribution of downstream flow from the San Joaquin Basin to Delta outflow for the protection of juvenile and adult salmonids migrating from the San Joaquin basin."
75	USFWS	OMR	USFWS OCAP Bio Opinion - RPA re: OMR flows. Component 1 - Adults (Dec - Mar) - Action 1 (protect upmigrating delta smelt) - once turbidity or salvage trigger has been met, -2000 cfs OMR for 14 days to reduce flows towards the pumps. Action 2 (protect delta smelt after migration prior to spawning) - OMR range between -1250 and -5000 cfs determined using adaptive process until spawning detected. pp.280-282
76	USFWS	OMR	USFWS OCAP Bio Opinion - RPA re: OMR flows. Component 2 - Larvae/Juveniles - action starts once temperatures hit 12 degrees C at three delta monitoring stations or when spent female is caught. OMR range between -1250 and -5000 cfs determined using adaptive process. OMR flows continue until June 30 or when Delta water temperatures reach 25 degrees C, whichever comes first. pp. 280-282
77	CDFG	OMR	Longfin Smelt Incidental Take Permit (2009), p. 9-10, Condition 5.1. This Condition is not likely to occur in many years. To protect adult longfin smelt migration and spawning during December through February period, the Smelt Working Group (SWG) or DFG SWG personnel staff shall provide OMR flow advice to the Water Operations Management Team (WOMT) and to Director of DFG weekly. The SWG will provide the advice when either: 1) the cumulative salvage index (defined as the total longfin smelt salvage at the CVP and SWP in the December through February period divided by the immediately previous FMWT longfin smelt annual abundance index) exceeds five (5); or 2) when a review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt indicate OMR flow advise is warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average is no more negative than -5000 cfs and the initial 5-day running average is not more negative than -6250 cfs. During any time OMR flow restrictions for
77 cont	CDFG	OMR	the FWS's 2008 Biological Opinion for delta smelt are being implemented, this condition (5.1) shall not result in additional OMR flow requirements for protection of adult longfin smelt. Once spawning has been detected in the system, this Condition terminates and 5.2 begins. Condition 5.1 is not required or would cease if previously required when river flows are 1) > 55000 cfs in the Sac River at Rio Vista; or 2) > 8000 cfs in the SJ River at Vernalis. If flows go below 40000 cfs in the Sac River at Rio Vista or 5000 cfs in the SJ River at Vernalis, the OMR flow in Condition 5.1 shall resume if triggered previously. Review of survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt may result in a recommendation to relax or cease an OMR flow requirement.

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
78	CDFG	OMR	Longfin Smelt Incidental Take Permit (2009), p. 10-11, Condition 5.2. To protect larval and juvenile longfin smelt during Jan-June period, the SWG or DFG SWG personnel shall provide OMR flow advice to the WOMT and the DFG Director weekly. The OMR flow advice shall be an OMR flow between -1250 and -5000 cfs and be based on review of survey data, including all of the distributional and abundance data, and other pertinent biological factors that influence the entrainment risk of larval and juvenile longfin smelt. When a single Smelt Larval Survey (SLS) or 20 mm Survey sampling period results in: 1) longfin smelt larvae or juveniles found in 8 or more of the 12 SLS or 20mm stations in the central and south Delta (Stations 809, 812, 901, 910, 912, 918, 919) or, 2) catch per tow exceeds 15 longfin smelt larvae or juveniles in 4 or more of the 12 survey stations listed above, OMR flow advice shall be warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average no more negative than the required OMR flow and the 5-day running average is within 25% of the
78 cont	CDFG	OMR	required OMR. This Conditions OMR flow requirement is likely to vary throughout Jan through June. Based on prior analysis, DFG has identified three likely scenarios that illustrate the typical entrainment risk level and protective measures for larval smelt over the period: High Entrainment Risk Period: Jan - Mar OMR range from -1250 to -5000 cfs; Medium Entrainment Risk Period: April and May OMR range from -2000 to -5000 cfs, and Low Entrainment Risk Period: June OMR -5000 cfs. When river flows are: 1) greater than 55000 cfs in the Sac River at Rio Vista; or 2) greater than 8000 cfs in the SJ River at Vernalis, the Condition would not trigger or would be relaxed if triggered previously. Should flows go below 40000 cfs in Sac River at Rio Vista or 5000 cfs in the SJ River at Vernalis, the Condition shall resume if triggered previously. In addition to river flows, the SWG or DFG SWG personnel review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of longfin smelt may result in a recommendation by DFG to WOMT to relax or cease an OMR flow requirement.
79	CDFG	Floodplain	DFG_Closing: DFG Exhibit 1, Page 13. Sacramento Splittail - floodplain inundation (habitat) - incubation, early rearing, egg and larval habitat and survival
80	USFWS	Floodplain	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 28 and 54. "The Board should consider the importance of more frequent floodplain inundation (especially Yolo Bypass flows) when determining the Delta outflows needed to restore the Delta ecosystem pursuant to the Board's public trust responsibilities" (p.28). "The Yolo Bypass floods via the Fremont Weir when flows on the Sacramento River exceed approximately 70,000 cfs, which it currently does in about 60% of years (Feyrer, et al. 2006). Flows on the Sacramento River should therefore exceed 70,000 cfs in at least six out of ten years. Recent historical floodplain inundation events are shown in Figure 4 (Sommer et al., 2001)" (p.54).

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
81	NMFS	Floodplain	NMFS OCAP Bio Opinion, Action I.6.1 - Restoration of Floodplain Rearing Habitat. p.608. " Objective: To restore floodplain rearing habitat for juvenile winter-run, spring-run, and CV steelhead in the lower Sacramento River basin. This objective may be achieved at the Yolo Bypass, and/or through actions in other suitable areas of the lower Sacramento River. Action: In cooperation with CDFG, USFWS, NMFS, and Corps, Reclamation and DWR shall, to the maximum extent of their authorities, provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type. In the event this action conflicts with Shasta Operations Actions I.2.1 to I.2.3., the Shasta Operations Actions shall prevail." By December 31, 2011, Reclamation and DWR shall submit to NMFS a plan to implement this action.
82	NMFS	Floodplain	NMFS - Public Draft Recovery Plan for the ESUs of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the DPS of Central Valley Steelhead (October 2009), Section 1.5.5, p.157. "Enhance the Yolo Bypass by re-configuring Fremont and Sacramento weirs to: (1) all for fish passage through Fremont Weir for multiple species; (2) enhance lower Putah Creek floodplain habitat; (3) improve fish passage along the toe drain/Lisbon weir; (4) enhance floodplain habitat along the toe drain; and (5) eliminate stranding events;and (6) create annual spring inundation of at least 8000 cfs to fully activate the Yolo Bypass floodplain."
83	D1641	DCC	For the May 21 - June 15 period, close the Delta Cross Channel gates for a total of 14 days per CALFED Ops Group. During the period the DCC gates may close 4 consecutive days each week, excluding weekends
84	Draft D1630	DCC	When monitoring indicates that significant numbers of salmon smolts or striped bass eggs and larvae are present or suspected to be present, the Executive Director (ED) or his designee shall order USBR to close the gates. The ED, with advice from other agencies, will develop specific monitoring and density criteria for closing and opening the gates.
85	CSPA / C-WIN	DCC	CSPA_Exh1_Jennings, C-WIN closing comments. Source CDFG_1992_WRINT-DFG-Exhibit #8, Alt C (p10). Function: reduce entrainment of Sacramento salmon smolts into the interior Delta
86	NMFS	DCC	NMFS OCAP Bio Opinion, Action Suite IV.1 (pp. 631-640)
87	EDF / Stillwater	Ouflow	EDF_Closing Comments (Table 1) - Mean Historical Delta Outflow Volumes (TAF) for 1956-2003 by month and water year type. Historical and unimpaired flow values are based on Water Years 1956-2003 using California Central Valley Unimpaired Flow Data, 4th ed. (CDWR 2007). In instances where there was a difference between Dry and Critically Dry years, the value for Critically Dry years was selected. Originally reported as volume (TAF). Conversion calculated as follows: (TAF/month)(1000 AF/TAF)(43560 ft3/AF)(month/X days)(day/86400 sec)

Appendix B: Water Supply Modeling

Background

This appendix provides a rough estimate of the theoretical impact of the flow criteria on water supplies in the Central Valley and Delta. To assist Water Board staff, Department of Water Resources (DWR) Modeling Support Branch staff modeled the criteria using the latest version of the CALSIMII model. The main purpose of this modeling study is to: 1) estimate water supply impacts of meeting the criteria; and 2) determine to what extent the criteria conflict with the needs to preserve cold water in tributaries.

The latest version of the CALSIM model was used as the baseline for this modeling study. A similar version was used in the DWR March 2010 draft *State Water Project Delivery Reliability Report 2009*. Major assumptions for the baseline model run include:

- State Water Board D-1641 (implementing Bay-Delta Plan flow and salinity objectives)
- U.S. Fish and Wildlife Service's Delta Smelt Biological Opinion as released on December 15, 2008.
- National Marine Fisheries Service's (NMFS) Biological Opinion (BO) on the Long-Term Operations of the Central Valley Project and State Water Project as released on June 4, 2009.
- Water Year 2010 Interim Flows Project for San Joaquin River below Friant Dam/Mendota Pool.
- Full entitlements for CVP and SWP contractors.

Modeling Approach

Two model scenarios were performed and results compared with those from the baseline model run. Scenario A applied the Category A criteria to the baseline model, and Scenario B applied both Category A and B criteria to the baseline model. Some simplification of the criteria was required to expedite their representation in the model. The following describes various assumptions included in the two new model scenarios:

- The scenarios were created by superimposing the new criteria on D-1641 and other flow requirements already in the baseline model, with the higher requirement governing. As such, water supply impacts could be slightly less (and flows more variable) if the criteria completely replaced D-1641 flow requirements.
- Flow requirements in the baseline model remain unchanged in months not covered by the proposed criteria. Water quality requirements in the baseline model are not affected by the criteria and remain unchanged in all months.
- CALSIM II does not have the ability to model those criteria that are contingent upon the presence or absence of fish in the system.
- North-of-Delta CVP and SWP settlement contractor surface diversions were manually reduced in the model to provide the additional water needed to satisfy the criteria.

- Agricultural demands were reduced in the two scenarios to compensate for reduced surface diversions. Demands were reduced to levels that maintained groundwater pumping rates similar to those in the baseline.
- SWP and CVP exports to south of the Delta are automatically limited by the model to levels that are available after all flow and other criteria are met (i.e. storage withdrawals are not made from project reservoirs for SWP/CVP export purposes).
- In both scenarios OMR restrictions of >-1,500 cfs supercede the OCAP requirements already in the baseline during March, April, May and June, in Critical and Dry water year types. For other water year types the OCAP OMR requirements remain unchanged.
- The NMFS BO contains Shasta cold water pool storage requirements. The CALSIM II model can determine compliance with these requirements, but cannot use them as constraints for controlling operation of the model.
- CALSIM II limits flows attributable to the criteria to levels that would not cause flooding in the Delta or tributaries.
- The San Joaquin River (SJR) module of CALSIM II could not be modified in time for this study, so inflows to the Delta at Vernalis were developed by manually adding flow to the baseline output from that location as needed to satisfy the criteria. Baseline flows at Vernalis were not modified if they were already above the criteria. (Note: The model was run with the SJR criteria set at 75%, not 60% of unimpaired flow. As such the model results may slightly underestimate CVP/SWP delivery impacts.)

<u>Model Results</u>

The tables and discussion below compare the CALSIM II model results for Scenarios A and B against those for the baseline.

Table 1 presents the required reduction in deliveries in thousands of acre-feet (from the baseline) as needed to satisfy the criteria. Also shown is the effect the criteria would have on San Joaquin River flows at Vernalis. The results in Table 1 are averages over all water years from 1922 to 2003. As discussed further below, even with these delivery reductions, the criteria were not always met.

Table 1. CVP/SWP deliveries and San Joaquin River flows (in thousands of acre-feet) associated with criteria.

Study	Total CVP and SWP north-of-Delta delivery			Total CVP and SWP South-of-Delta delivery			Vernalis Flow		
	Delivery	diff.	pct. diff.	Total	diff.	pct. diff.	flow	diff.	pct. diff.
Baseline	3,355	-	-	4,906	-	-	3,024	-	-
Scenario A	1,109	-2,246	-67%	3,685	-1,221	-25%	4,876	1,852	61%
Scenario B	1,097	-2,258	-67%	3,876	-1,031	-21%	4,633	1,609	53%

When considering dry and critical years only over this same period, flow at Vernalis was increased by 97% on average for both scenarios and CVP/SWP north of Delta deliveries were reduced by 73% for both scenarios, while CVP/SWP south of Delta deliveries remained about the same as shown in Table 1 for both scenarios.

Table 2 presents the effect of the criteria on reservoir storage and compliance with cold water pool requirements. The results in Table 2 are averages over all water years from 1922 to 2003. Nearly all occurrences of dead storage at Trinity, Shasta and Folsom shown in Table 2 happened in association with dry and critical years. Reservoirs reaching dead storage levels also corresponded with criteria not being met. Likewise, compliance with NMFS BO cold water pool storage requirements was not always met.

Table 2. Reservoir storage and cold water pool impacts associated with criteria (in thousands of acre-feet)

Study	End-of-September storage (taf)				Number of months at dead storage (984 months total)				NMFS BO Shasta Cold Water Pool Storage		
	Trinity	Shasta	Oroville	Folsom	Trinity	Shasta	Oroville	Folsom	Req. #1 (87%)	Req. #2 (82%)	Req. #3 (40%)
Baseline	1,393	2,656	1,849	502	3	9	0	13	81%	69%	24%
Scenario A	1,179	2,442	1,674	454	33	40	0	40	67%	20%	21%
Scenario B	1,070	2,203	1,774	417	71	82	0	77	57%	17%	17%

Req. #1 = End of September storage > 2,200 TAF in 87% of years
Req. #2 = Previous end of September storage > 2,200 TAF & end of April > 3,800 TAF in 82% of years
Req. #3 = End of September storage > 3,200 TAF in 40% of years

For comparison, separate CALSIM II model runs of Scenarios A and B were performed with *all* surface water diversions north of the Delta turned off. This reduced occurrences of dead storage in Scenario A to a level similar to the baseline, and reduced them by about a third for Scenario B. Eliminating all diversions also led to 83%, 32%, and 59% compliance with NMFS BO cold water pool requirements #1, #2, and #3 respectively.

Table 3 shows the effect of meeting the criteria on OMR and X2 position. In general, Old and Middle River reverse flows and X2 position were significantly improved by the criteria.

Table 3. Old and Middle River flows and X2 position associated with criteria.

Study	Old and Middle River flow (average monthly cfs)						X2 position (average monthly kilometer)									
	Jan	Feb	Mar	Apr	May	Jun	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Baseline	-3,647	-3,265	-2,848	874	348	-3,769	61	61	64	68	75	80	85	84	84	82
Scenario A	-1,585	71	1,286	2,376	5,458	1,422	58	56	55	56	61	75	86	84	84	82
Scenario B	-2,627	-1,482	-624	2,736	4,471	717	58	56	55	56	61	75	86	84	84	81

Note: For X2 position: Port Chicago = 65km and Chipps Island = 74km