Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta

DRAFT DOCUMENT

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D R A F T

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Preface

DFG is required by Water Code section 85084.5 to develop quantifiable biological objectives and flow criteria for species of concern dependent on the Delta. These objectives and criteria are to be submitted to the Water Board by November 2010.

This document contains the methodology and rationale for the development of

- recommendations for biological goals
- recommendations for management goals
- recommendations to ensure biological objectives remain relevant
- findings
- biological objectives
- flow criteria

Executive Summary

The Sacramento-San Joaquin Delta (Delta) is the largest estuary on the west coast of North America. It is home to hundreds of bird, mammal, and fish species. Populations of many ecologically and commercially important species (public trust resources) have declined substantially over the past decade. These declines are related, among other factors, to increased diversions of water that have occurred since 1985 (Fleenor et al. 2010). Changes in Delta flows resulting from upstream diversions and operations of the State and federal water projects upstream of and in the Delta have resulted in modification of the hydrologic and physical habitat of the Delta system which in turn has altered the Delta ecosystem (Healey et al. 2008).

Fish population declines coupled with these hydrologic and physical changes suggest that current Delta water flows for environmental resources are not adequate to maintain, recover, or restore the functions and processes that support native Delta fish. Salmon in the Central Valley are also in decline. Two of the four races of Chinook salmon are listed under the federal Endangered Species Act (FESA) and California Endangered Species Act (CESA) and fall-run Chinook salmon, a species of concern, is at historic low abundance. Delta smelt is listed under both FESA and CESA and longfin smelt is listed under the CESA reflecting their precipitous declines in abundance.

Water flow through the Delta is one of the primary drivers of ecosystem function. The timing, magnitude, quality of flows, and way in which water is diverted all influence habitat features such as temperature, turbidity, transport, nutrient loadings, pollutant dispersal, and other factors. Each native Delta fish species is adapted to the habitat conditions characteristic of the ecosystem. As natural flows and the patterns of those flows have been reduced or altered, flow conditions have become more favorable for nonnative species. However, flow is not the only factor affecting ecosystem health and the decline of fish populations in the Delta. Other factors such as non-native clams, habitat loss, and contaminants can adversely affect the ecosystem by reducing overall productivity and affecting nutrient dynamics and the base of the foodweb.

It is not the purpose of this document to address all of these issues. Factors other than flow will have to be taken into account and made a part of any comprehensive solution that addresses Delta environmental problems. A highly adaptive decision making process will be an essential characteristic of any process adopted as a result of the current Delta planning efforts. As new information is developed, biological objectives and flow criteria must be re-evaluated and adjusted as necessary to reflect our best understanding of the affect water flow and other factors has on species of concern and the Bay Delta ecosystem.

The recommendations in this report represent the current understanding of the needs of the individual species identified in light of current conditions and the objectives described. Several factors outside the scope of this legislative mandate would need to be considered and modeled or analyzed more fully (e.g., cold water pool management in upstream reservoirs, operational constraints, habitat restoration, and the relationship between flow criteria and unimpaired flow) before any flow standards are set. In addition, capital facility improvements, such as an alternative conveyance system, relocated water intakes, enhancement of floodplain and tidal wetlands, and additional fish screening may serve to improve conservation in the Delta. Flows by themselves are not the only consideration when the goal is the overall health of the estuary.

The mission of DFG is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. As trustee agency for the fishery resources in the State, the Department of Fish and Game (DFG) has an interest in assuring that water flow into and out of the Delta is maintained at levels which are adequate for long-term viability of native fish and the aquatic resources they depend on.

Legislative Mandate

In November 2009 the Legislature passed several bills focused on better protecting Delta resources. Senate Bill No. 1 (SB 1) (Stats. 2009 (7th Ex. Sess.) ch 5, § 39) contains the Delta Reform Act of 2009 (Delta Reform Act) which establishes and requires the Delta Stewardship Council (DSC) to develop, adopt, and commence implementation of a comprehensive management plan for the Delta (Delta Plan) on or before January 1, 2012. To inform the planning processes of the Delta Plan and the Bay Delta Conservation Plan (BDCP), the Delta Reform Act requires that the State Water Resources Control Board (SWRCB) develop new flow criteria for the Delta ecosystem and that DFG identify quantifiable biological objectives and flow criteria for the species of concern in the Delta.

In August 2010, the SWRCB completed a report identifying flow criteria for the Delta ecosystem. The report was developed using information on unimpaired flows, historical impaired inflows that supported more desirable ecological conditions, statistical relationships between flow and native species abundance, and an ecological functions-based analysis for desirable species and ecosystem attributes. While the summary recommendations found in the SWRCB report focus on a percentage of unimpaired flow, the report contains a comprehensive summary of the specific flow needs for the species identified that is based on the most recent and available science.

The biological objectives and flow criteria contained in this report rely on the data and information submitted as part of the SWRCB's informational proceeding and the SWRCB's report (SWRCB, 2010).

To comply with the legislative mandates of the Delta Reform Act and develop quantifiable biological objectives and flow criteria, DFG first developed a set of biological goals for terrestrial and aquatic species of concern in the Delta:

Terrestrial Species Biological Goals

- Achieve, first, recovery and then self-sustaining populations of the following at-risk native species dependent on the Delta, Suisun Bay and Suisun Marsh, with emphasis on valley elderberry longhorn beetle, Suisun ornate shrew, Suisun song sparrow, soft bird's-beak, Suisun thistle, Mason's lilaeopsis, Lange's metalmark butterfly, Antioch Dunes evening primrose, Contra Costa wallflower, and Suisun marsh aster.

- Contribute to the recovery of the following at-risk native species in the Bay-Delta estuary and its watershed: delta green ground beetle, giant garter snake, riparian brush rabbit, least Bell's vireo, California black rail, California clapper rail, bank swallow, western yellow-billed cuckoo, greater sandhill crane, Swainson's hawk, California yellow warbler, delta tule pea, delta mudwort, and delta coyote thistle.

- Protect and/or restore natural communities in the Bay-Delta Estuary and its watershed for ecological values such as supporting species and functional habitat types, and ecological processes.

Aquatic Species Biological Goals

- Halt species population declines and increase populations of ecologically important native species, as well as species of commercial and recreational importance, by providing sufficient water flow and water quality at appropriate times to propagate species life stages that use the Delta.

- Establish water flows through the Delta that will likely benefit particular species or ecosystem functions in a manner that is: (1) comprehensive, (2) not overly complex, and (3) encourages production. Functional flow criteria shall be established for at least:

  Yolo Bypass
  Sacramento River and its basin
  San Joaquin River and its basin
  Eastside streams and their basins
  Interior Delta including Old and Middle rivers
  Delta outflow

- Establish an adaptive management process to review and modify flow criteria in the Delta that is: (1) responsive to scientific advances, changing environmental conditions including a warming climate and change in sea level, and changes in conveyance and water operations, and (2) implemented on a time scale needed to realistically manage desirable species.

With these goals in mind, a set of biological objectives were developed (Section 8.2) that contain 27 terrestrial species biological objectives and 20 aquatic species biological objectives. Additionally, flow criteria (Section 8.3) are recommended that pertain to the timing, magnitude (in cubic feet per second [cfs]), and quality of flows needed for eight identified species of concern in the Delta. While DFG is required to develop only quantifiable biological objectives and flow criteria, management goals are also needed to ensure that the objectives and criteria remain relevant and scientifically supportable. These two management goals address the importance of adaptive management and the need for continued evaluation of objectives and criteria developed for the Delta.

Management Goals

- Integrate all flow measures needed to protect species and ecosystem functions in a manner that is comprehensive, does not double count flows, uses a justified time step, and is documented in peer reviewed or otherwise vetted literature.

- Establish an adaptive management process to evaluate Delta environmental conditions, periodically review the scientific underpinnings of the biological objectives and flow criteria, and change biological objectives and flow criteria when warranted.

Delta outflow needs are a continuum of conditions that begin in upstream riverine habitats and progress through the Sacramento-San Joaquin Delta. The effect of inflow and Delta outflow on several native, recreational, and commercial species that live in or pass through the Sacramento-San Joaquin Delta were used in the development of this report. Data and information used include: species life history requirements; season and time periods of flow importance; relationships of species abundance and habitat, invasive species, and survival; species environmental requirements; and factors influencing and limiting population trends. Additionally, consideration was given to the role of Delta water project operations, habitat, water diversions, cold water pool, tidal influence, and hydrodynamics.

DFG encourages the SWRCB's continued commitment to ensure impacts on beneficial uses of the Delta are comprehensively addressed when balancing environmental protection and water supply reliability. The SWRCB's flow criteria report along with DFG's biological objectives and flow criteria will serve an important role in providing the scientific foundation for future water quality control planning activities, water rights proceedings, and Comprehensive Delta Plan and BDCP development. The balancing of needs in these regulatory efforts can only take place when the proposed projects are fully described and presented in the context of the available scientific understanding provided in the flow criteria documents. These reports serve to inform the BDCP goals and objectives and help to ensure the BDCP Conservation Strategy includes measures that will provide for the conservation of terrestrial and aquatic species and natural communities while achieving water supply and water quality goals for the Delta.

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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	Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary
BDCP	Bay Delta Conservation Plan
CA	California
CCWD	Contra Costa Water District
CVJV	Central Valley Joint Venture
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
CESA	California Endangered Species Act
cfs	cubic feet per second
CSC	California species of concern
CSPA	California Sportfishing Protection Alliance
CVP	Central Valley Project
CWIN	California Water Impact Network
Delta	Confluence of the Sacramento River and San Joaquin River (as defined in Water Code section 12220)
Delta Reform Act	Sacramento-San Joaquin Delta Reform Act of 2009
DFG	California Department of Fish and Game
DO	dissolved oxygen
DOI	United States Department of the Interior
DSM2	Delta Simulation Model
DWR	California Department of Water Resources
DVC	Delta Vision Committee
EC	Electrical Conductivity
EDF	Environmental Defense Fund
ERP	Ecosystem Restoration Program
ERPP	Ecosystem Restoration Program Plan
FERC	Federal Energy Regulatory Commission
FESA	Federal Endangered Species Act
FMWT	Fall mid-water trawl
IEP	Interagency Ecological Program
LSZ	Low Salinity Zone
mg/L	milligrams per liter
NAS	National Academy of Sciences
NCCP	Natural Community Conservation Plan
NCCPA	State Natural Community Conservation Planning Act
NDOI	Net Delta Outflow Index
NHI	Natural Heritage Institute

NMFS	National Marine Fisheries Service
NRDC	Natural Resources Defense Council
OCAP	Long-Term Operations Criteria and Plan for Coordination of the Central Valley Project and the State Water Project
OMR	Old and Middle Rivers
PCFFA	Pacific Coast Federation of Fishermen's Associations
POD	Pelagic Organism Decline
PPIC	Public Policy Institute of California
ppt	parts per thousand
psu	practical salinity unit
PTM	Particle Tracking Model
RPA	Reasonable and Prudent Alternatives
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
SJRGA	San Joaquin River Group Authority
SJRRP	San Joaquin River Restoration Program
SWP	State Water Project
SWRCB	State Water Resources Control Board
Task Force	Delta Vision Blue Ribbon Task Force
TBI	The Bay Institute
TNC	The Nature Conservancy
USACE	U.S. Army Corps of Engineers
USBR	United States Bureau of Reclamation
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan
Water Year Type	
C	Critical
D	Dry
BN	Below normal
AN	Above normal
W	Wet
X2	Distance in kilometers along the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical salinity units
7DADM	7-Day Average Daily Maximum

Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta

1 Introduction

This document presents the recommendations, rationale, and justification for: (1) biological objectives to protect aquatic and terrestrial species of concern that are dependent on the Delta and (2) flow criteria that would benefit aquatic species of concern. This report contains sections describing: background on the decline of fish populations, planning efforts, and legal mandates; methodology for developing the biological objectives and flow criteria; rationale for the biological objectives and flow criteria; findings; and a summary list of biological goals and objectives and a range of flow criteria for the Delta.

2 Background

The Sacramento-San Joaquin Delta (Delta) is the largest estuary on the west coast of North America. The Delta is home to a great diversity of bird, mammal, and fish species. Populations of many ecologically and commercially important species (public trust resources) have declined substantially over the past decade. These declines, among other factors, are related to increased diversions of water that have occurred since 1985 (Fleenor et al. 2010). Changes in Delta flows have resulted in modification of the hydrologic and physical habitat of the Delta system which in turn has altered the Delta ecosystem (Healey et al. 2008).

Fish declines coupled with hydrologic and physical changes in the Delta suggest that the current water flow available for environmental resources is not adequate to maintain, recover, or restore the functions and processes that support native Delta fishes. Salmon in the Central Valley are also in decline. Two of the four runs of Chinook salmon are listed under the State and federal Endangered Species Act and fall-run Chinook salmon is at historic low abundance. Delta smelt is both State and federally listed as threatened and longfin smelt is listed under the California Endangered Species Act reflecting their precipitous declines in abundance.

Water flow through the Delta is one of the primary drivers of ecosystem function. The timing, magnitude, and quality of flows all influence habitat features such as temperature, turbidity, transport, nutrient loadings, pollutant dispersal, and other factors. Each native Delta fish species is adapted to a set of unique natural habitat conditions. As natural flows have been reduced flow conditions have become more favorable for nonnative species.

2.1 Legislative Order

In November 2009, a Comprehensive Water Package was passed consisting of four policy bills. Efforts enacted through the Water Package were crafted to help achieve two coequal goals of providing a more reliable water supply for California, and protecting, restoring, and enhancing the Delta ecosystem. Among the efforts planned in the water package are the assurances of better groundwater monitoring, funding for enforcement of illegal water diversions, setting of water conservation policy, and the creation the Delta Stewardship Council.

Senate Bill No. 1 (SB1) (Stats. 2009 (7th Ex. Sess.) Ch 5, 39) of the water package contains the Delta Reform Act (Delta Reform Act) which establishes the Delta Stewardship Council and requires it to develop, adopt, and commence implementation of a comprehensive management plan for the Delta (Delta Plan) on or before January 1, 2012. To address and identified water flow-related problems in the Delta and to inform the planning processes of the Delta Plan and the Bay Delta Conservation Plan, SB1 requires that the SWRCB develop new flow criteria for of the Delta ecosystem and that DFG identify quantifiable biological objectives and flow criteria needs for the species of concern in the Delta, respectively. Specifically, the Water Code states:

85084.5: The Department of Fish and Game in consultation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service and based on the best available science, shall develop and recommend to the board Delta flow criteria and quantifiable biological objectives for aquatic and terrestrial species of concern dependent on the Delta. The recommendations shall be developed no later than 12 months after the date of enactment of this division.

85086(b): It is the intent of the Legislature to establish an accelerated process to determine instream flow needs of the Delta for the purposes of facilitating the planning decisions that are required to achieve the objectives of the Delta Plan.

(c) (1) For the purpose of informing planning decisions for the Delta Plan and the Bay Delta Conservation Plan, the board shall pursuant to its public trust obligations, develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. In carrying out this section, the board shall review existing water quality objectives and use the best available scientific information. The flow criteria for the Delta ecosystem shall include volume, quality, and timing of water necessary for the Delta ecosystem under different conditions. The flow criteria shall be developed in a public process by the board within nine months of the enactment of this division.

2.2 DFG Public Trust Responsibilities

The mission of DFG is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. As trustee agency for the fishery resources in the State, the Department of Fish and Game (DFG) has an interest in assuring water flow into and out of the Delta is maintained at levels which are adequate for long-term viability of native fish and the aquatic resources they depend on.

3 Planning Efforts

Many programs, plans, and processes have been developed to address issues facing the Delta and help guide and implement restoration activities. The following sections represent an overview of the programs and information used to develop the biological objectives and criteria found in this report

3.1 Ecosystem Restoration Program

CALFED began in 1994 with the signing of the Bay-Delta Accord. Over the next six years, the program wrote a Programmatic Environmental Impact Statement/Environmental Impact Report and the Record of Decision (ROD) (CALFED 2000a). One major goal was to improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species. The Ecosystem Restoration Program (ERP) was established as a component of the ROD to accomplish this goal. The ERP is intended to restore the ecological health of the Bay-Delta ecosystem, and support the objective of improving water management for beneficial uses of the Bay-Delta system. To achieve this, the ERP approach is to restore or mimic ecological processes and to increase and improve aquatic and terrestrial habitats to support stable, self-sustaining populations of diverse and valuable species.

The Ecosystem Restoration Program Plan (ERPP**)** (CALFED 2000b) presents visions for the ecosystem elements in the Central Valley that serve as the ERP's foundation and scientific basis. The ERPP also contains restoration targets, programmatic actions, the rationale for targets and actions, and conservation measures.

The ERPP also contains the ERP Strategic Plan (CALFED 200c). The Strategic Plan lists ERP goals and objectives and provides the scientific and practical framework for implementing restoration in the Bay-Delta watershed. The six strategic goals that define the scope of ERP are further divided into more specific objectives, each of which are intended to help determine whether or not progress is being made toward achieving the respective goal (http://www.dfg.ca.gov/ERP). Specific actions based on the ERPP Volumes 1 and 2 also are identified in the ERP Strategic Plan.

3.2 Delta Vision

The Delta Vision process began in 2006 in response to Executive Order S-17-06 (Schwarzenegger 2006). That Executive Order set up the Delta Vision Committee, the Delta Vision Blue Ribbon Task Force (Task Force), and the establishment of a timeline for the vision document and strategic plan to be completed. The goal of the Delta Vision process was to "develop a durable vision for sustainable management of the Delta." The seven-member Task Force completed their vision in 2007(DVBRTF 2007) and their strategic plan in 2008 (DVBRTF 2008). In December 2008, recommendations on how to implement the Delta Vision Strategic Plan were submitted to the Governor and

Legislature by the Delta Vision Committee (DVC). The DVC was comprised of the secretaries for The Resources Agency; Business, Transportation, and Housing; California Environmental Protection Agency; Department of Food and Agriculture, and the President of the Public Utilities Commission.

The Delta Vision effort had a broad focus. The Task Force members issued their recommendations that addressed an array of natural resources, infrastructure, land use, and governance issues necessary to achieve a sustainable Delta. The Delta Vision effort began with the consensus that the current mix of uses, resources, and ecosystem of the Sacramento-San Joaquin Delta estuary, including the Suisun Bay and Marsh, is unsustainable over the long-term. The process took into consideration changing climatic, hydrologic, environmental, seismic, and land use conditions that can jeopardize the Delta's natural and human infrastructure.

In *Our Vision for the California Delta,* the Task Force made 12 integrated and linked recommendations, the key one being "The Delta ecosystem and a reliable water supply for California are the co-equal goals for sustainable management of the Delta" (DVBRTF 2007). These co-equal goals became focal points for the Delta Vision Strategic Plan, which listed seven goals and strategies to achieving those goals (DVBRTF 2008). Goal 3 in their strategic plan is to restore the Delta ecosystem as the heart of a healthy estuary, and includes five strategies and twenty associated actions to achieve that goal. Among the other recommendations the DVC made is for an inclusive Delta Plan to be written. For more information, go to www.deltavision.ca.gov.

The (2008) DVC noted several important actions required to carry out many of its recommended actions toward achieving the two co-equal goals. In addition to continued implementation of the ERP, these included: completion of the Bay-Delta Conservation Plan (BDCP); updating of Bay-Delta regulatory flow and water quality standards; evaluation and initial construction of gates and barriers in the Delta; development and implementation of instream flow recommendations; control of aquatic invasive species; evaluation of other potential stressors to ecological processes, habitats, and species; and initiation of comprehensive monitoring of Delta water quality and fish and wildlife health.

3.3 State of Bay-Delta Science report

The CALFED Science Program in 2008 released a report synthesizing the state of knowledge about ecological processes, habitats, stressors, and species in the Delta, as well as about other CALFED program elements (levees and water quality and supply) (Healy et al 2008). Much of the information in that report is consistent with findings from ERP implementation during Stage 1 (and with ongoing research and data collection efforts separate from the CALFED Program), and has been incorporated into this conservation strategy.

The report offered perspectives on the Delta derived from recent science which have been integrated into this conservation strategy, including:

- The Delta is continually changing, so uncontrolled drivers of change (such as population growth, land subsidence, and seismicity) mean the Delta will look very different in the future;
- Because of this continuous change, consequences of management solutions cannot be predicted, so solutions will need to be robust but provisional, and responsive and adaptive to future changes;
- It is neither possible nor desirable to "freeze" the Delta in its present or any other form, so strengthening of levees will not be a sustainable solution for all Delta islands;
- The problems of water and environmental management are interlinked, requiring the strong integration of science, knowledge, and management methods;
- The capacity of the system to deliver human, economic, and environmental services is likely at its limit, so tradeoffs must be made – fulfilling more of one water-using service means accepting less of another;
- Good science provides knowledge for decision-making, but for complex environmental problems, new areas of uncertainty will continue to arise as learning continues; and
- Climate change dictates that species conservation is no longer simply a local habitat problem, so conservation approaches need to include a broad range of management tools other than habitat restoration. (Healy et al. 2008).

3.4 Bay-Delta Conservation Plan (BDCP)

The BDCP is an applicant-driven process through which certain activities (i.e., water export operations of the State Water Project (SWP) and Central Valley Project (CVP) and power plant operations of Mirant Energy in the Pittsburg/Antioch area) would be authorized under federal Endangered Species Act (FESA), California Endangered Species Act (CESA), and Natural Community Conservation Planning Act (NCCPA) in the context of an overall conservation strategy for the covered natural communities and listed species. A Steering Committee is guiding BDCP development; committee members represent Department of Water Resources and the Bureau of Reclamation seeking incidental take coverage, water contractors as well as State and federal fisheries agencies, nonprofit groups, and other interested stakeholders. The intent is to develop a joint NCCP and federal Habitat Conservation Plan (HCP).

The BDCP Steering Committee members signed a Planning Agreement in 2006, in accordance with the NCCPA, that included preliminary identification of the planning area, covered activities, covered species, and natural communities that would be included in the conservation plan. A goal of the BDCP is ecosystem and species recovery and restoration of a reliable water supply.

In the first half of 2007, the Steering Committee identified a number of stressors affecting the aquatic species listed in the Planning Agreement, and came up with four conceptual options for water conveyance through or around the Delta to address those stressors. In late 2007, an initial evaluation of the four conveyance options was completed. Based on that evaluation, the Steering Committee agreed that the Dual Conveyance Option provided the best opportunity to meet the objectives of the Planning

Agreement. During 2008 and 2009, modeling to evaluate conveyance operations of the options and a detailed draft conservation strategy is due in the Fall of 2010. NEPA and CEQA environmental documentation began in early 2009, and the final environmental document is expected to be certified and all necessary permits in hand by the end of 2012. For more information, go to www.baydeltaconservationplan.org.

3.5 Public Policy Institute of California (PPIC) reports

PPIC and experts from the University of California wrote two reports evaluating the vulnerability of the Sacramento–San Joaquin Delta to a variety of risk factors and describing options for addressing current and likely future problems. The first report, *Envisioning Futures for the Sacramento–San Joaquin Delta* (Lund et al. 2007), describes why the Delta matters to Californians and why the region is currently in a state of crisis. The report concludes with recommendations for several actions, some regarding technical and scientific knowledge, and others regarding governance and finance policies.

The second report, *Comparing Futures for the Sacramento-San Joaquin Delta* (Lund et al. 2008), continued their analysis of future changes to the Delta, and the system's potential responses to those changes. That report focused on which water management strategies would best meet the co-equal goals of environmental sustainability and water supply reliability established by the Delta Vision Blue Ribbon Task Force. In comparing different water management alternatives, this report concludes that an isolated conveyance facility is the best option of all the export alternatives for achieving the co-equal goals.

3.6 Pelagic Organism Decline (POD) studies

Abundance indices calculated by the Interagency Ecological Program (IEP) through 2005 suggest recent, marked declines in numerous pelagic fishes in the Delta and Suisun Bay (IEP 2007a). Although several species show evidence of long-term declines, recent low levels were unexpected given the relatively moderate winter-spring flows of the late 1990s and early 2000s.

In response to these changes, the IEP formed a POD work team to evaluate the potential causes of the decline. Issues emerging from POD studies, most of which were already identified in ERP documents, emphasize a subset of stressors, namely ecological foodweb declines and invasive species, toxic pollution, and water operations (IEP 2007b). The POD work team is conducting multiple investigations, including the effects of exotic species on food web dynamics, contaminants, water project operations, and stock recruitment.

3.7 State Water Resources Control Board's Bay-Delta Strategic Workplan

The State Water Resources Control Board (SWRCB) and the Central Valley and San Francisco Regional Water Quality Control Boards completed a *Strategic Workplan for Activities in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* in July 2008. The workplan was written in response to two SWRCB resolutions directing the

Water Boards to describe the actions they will complete in order to protect the beneficial uses of water in the Bay-Delta estuary. The workplan activities are divided into nine broad elements:

- Water Quality and Contaminant Control
- Comprehensive Delta Monitoring Program
- Southern Delta Salinity and San Joaquin River Flow Objectives
- Suisun Marsh Objectives
- Comprehensive Review of the Bay-Delta Plan, Water Rights, and Other Requirements to Protect Fish and Wildlife Beneficial Uses and the Public Trust
- Methods of Diversion of the State Water Project and the Central Valley Project
- Water Right Compliance, Enforcement, and Other Activities to Ensure Adequate Flows to Meet Water Quality Objectives
- Water Use Efficiency for Urban and Agricultural Water Users
- Other Actions

These actions fall within the SWRCB's existing responsibilities and authorities. The actions also are responsive to the priorities identified in the Delta Vision documents and build upon planning processes such as the BDCP. The workplan identifies activities that will need to be coordinated with other efforts including the development of flow criteria. For more information, go to www.waterrights.ca.gov/baydelta/strategic_workplan.htm.

3.8 Suisun Marsh Plan

The Habitat Management, Preservation, and Restoration Plan for Suisun Marsh (Suisun Marsh Plan) is being developed by The Suisun Marsh Charter Group Principal Agencies, a team of local, State, and federal agencies. The Suisun Marsh Plan is focused on protecting and enhancing Suisun Marsh's contributions to the Pacific Flyway and existing wildlife and endangered species' habitats, maintaining and improving strategic exterior levees, and restoring tidal marsh and other habitats. A draft programmatic EIS/EIR is anticipated in 2010 and will include action-specific elements (Suisun Marsh Charter Principal Agencies 2007). The authors of the Suisun Marsh Plan anticipate that it can be implemented as a distinct element in any future vision, conservation strategy, or implementation plan for the Delta and Suisun. For more information, go to www.delta.dfg.ca.gov/suisunmarsh/charter/.

3.9 Central Valley Project Improvement Act (CVPIA) programs

The CVPIA was enacted in 1992 and mandated changes in management of the CVP, particularly for the protection, restoration, and enhancement of fish and wildlife. Among other provisions relating to water transfers and contracts, CVPIA calls for: 800,000 acre-feet of water dedicated to fish and wildlife annually; special efforts to restore anadromous fish populations by 2002; a restoration fund financed by water and power users for habitat restoration and enhancement and water and land acquisitions; and firm water supplies for Central Valley wildlife refuges.

3.10 Federal Biological Opinions and Recovery Plans

In response to the POD, court-mandated restrictions in the amount of water pumped by the SWP and CVP were implemented in late 2007, while the USFWS and NOAA Fisheries developed new Biological Opinions on the coordinated operations of the State and federal water projects. The USFWS Biological Opinion for delta smelt was completed in December 2008, and the NOAA Fisheries Biological Opinion for salmonids and green sturgeon was completed in June 2009. In combination, these two Biological Opinions include Reasonable and Prudent Alternative actions that restrict the amount of reverse flows (and thus the amount of water that can be exported by the projects) in Old and Middle rivers during certain times of the year, provide for new X_2 requirements in fall of some years, and require modified operation of Delta Cross Channel gates in late fall and early winter. These Biological Opinions are now important influences on operations of the SWP and CVP, and provide the current regulatory baseline for export operations from the Delta.

To view the two Biological Opinions: http://swr.nmfs.noaa.gov/ocap.htm (NMFS 2009a), and www.fws.gov/sacramento/es/documents/SWP-CVP_OPs_BO_12-15_final_OCR.pdf (USFWS 2008).

For the purposes of setting goals and objectives for species and their habitats in the Delta, there are a number of species recovery plans that are integrated with this conservation strategy. Two recovery plans of particular note include:

U.S. Fish and Wildlife Service (USFWS) Delta Native Fishes Recovery Plan

Significant new information regarding status, biology, and threats to Delta native species has emerged since USFWS originally released its recovery plan in 1996 (USFWS 1996). The plan is currently under revision. The information is being used to develop a strategy for the conservation and restoration of Sacramento-San Joaquin Delta native fishes. Species covered by this plan are delta smelt, longfin smelt, Sacramento splittail, and Sacramento perch.

The goal of the Delta Native Fishes Recovery Plan is to establish self-sustaining populations of these species. To be effective, recovery planning must consider not only species or assemblages of species but also habitat components, specifically, their structure, function and change processes. Restoration actions may also include establishing genetic refugia for delta smelt. The recovery plan adopted in 1996 is available from ecos.fws.gov/docs/recovery_plan/961126.pdf.

NOAA Fisheries Central Valley Recovery Plan

The NOAA Fisheries Technical Recovery Team produced four documents about (1) current and historical population distributions of winter-run and spring-run Chinook salmon, (2) historical population distribution of Central Valley steelhead, (3) population viability, and (4) research and monitoring needs. These documents provide the foundation for the draft Central Valley Recovery Plan (2009). Species addressed in the draft Recovery Plan include Sacramento River winter-run and Central Valley spring-run Chinook salmon and Central Valley steelhead. Initial reviews of the draft Recovery Plan include a detailed and prioritized list of threats and a lengthy list of recovery actions to respond to the prioritized threats. The draft Recovery Plan was released in October 2009. For more information, go to swr.nmfs.noaa.gov/recovery/centralvalleyplan.htm

3.11 California Wildlife Action Plan

DFG with the University of California, Davis Wildlife Health Center developed the California Wildlife Action Plan to identify the State's species and habitats that are of greatest conservation need, the major stressors affecting native wildlife and habitats, and actions needed to restore and conserve wildlife to reduce the likelihood of more species becoming threatened or endangered.

This report contains recommendations on monitoring and adaptive management to achieve conservation objectives, based on a publication formulated in 2004 through a joint effort of the U.S. Geological Survey, the USFWS, and DFG (Atkinson et al. 2004). The information contained in that publication provides guidance on implementing adaptive management for conservation plans that address multiple species, and this information has been incorporated into the conservation strategy mainly to provide context as to what ERP has achieved to date within that framework and next steps. For more information, go to www.dfg.ca.gov/wildlife/wap/report.html.

3.12 Central Valley Joint Venture (CVJV) 2006 Implementation Plan

The Central Valley Joint Venture (CVJV) was formed to protect, restore, and enhance wetlands and associated habitats for waterfowl, shorebirds, waterbirds, and riparian songbirds through partnerships with conservation organizations, public agencies, private landowners, and others interested in Central Valley bird habitat conservation. The *CVJV 2006 Implementation Plan* incorporates new information and broadens the scope of conservation activities to include objectives for breeding waterfowl, breeding and non-breeding shorebirds, waterbirds, and riparian-dependent songbirds. It lists specific goals and objectives for these species, and considered both-biological and non-biological factors in establishing bird-group conservation objectives. The *CVJV 2006 Implementation Plan* also contains Central Valley-wide objectives for protecting, restoring, or enhancing seasonal and semi-permanent wetlands, riparian areas, rice cropland, and waterfowl-friendly agricultural crops; it also includes basin-specific recommendations for the Delta, the Yolo Basin, and the Suisun Marsh (CVJV 2006).

Ducks Unlimited, one of the partners in the CVJV, has completed 46 wetland restoration and protection projects benefiting migratory birds and other wildlife on approximately 20,000 acres in the Delta, in accordance with the recommendations in the CVJV Implementation Plan. ERP Implementing Agencies anticipate that these efforts to benefit waterfowl and other avian and terrestrial species will continue to enhance ecosystem function and survival of those species. Although the initial focus of the ERP conservation strategy will be on actions contributing to the recovery of pelagic fish species and enhancement of aquatic resources in the Delta, actions benefiting waterfowl and terrestrial species in the CVJV 2006 Implementation Plan are consistent with this conservation strategy and are expected to be funded by ERP in accordance with its desires to protect and enhance terrestrial resources. For more information, go to www.centralvalleyjointventure.org/plans/.

3.13 Regional Habitat Conservation Plans (HCPs)

There are a number of HCPs (some of which will also meet the standard of an NCCP) for the five Delta counties; the HCP's listed below are in different stages of development or have been completed:

- ***South Sacramento County HCP.*** This HCP is under development. The focus of the HCP is to protect vernal pool and upland habitats that are being diminished by vineyards and housing development, and on several special status terrestrial species including Swainson's hawk and burrowing owl. The geographic scope of this HCP generally does not include the Sacramento-San Joaquin Delta portions of Sacramento County; the westernmost boundary of the planning area is Interstate 5. Aquatic species are not addressed by this HCP, and have historically been covered by U.S. Army Corps of Engineers' (USACE) 404 permits and DFG Streambed Alteration Agreements. Sacramento County is working with the USACE, U.S. Environmental Protection Agency, and DFG to develop programmatic permits that may be incorporated into the HCP. Sacramento County expects draft environmental documentation and implementing agreement for this HCP to be completed in 2010, and to have all permits in place by 2011. More information is available from the website: www.planning.saccounty.net/SSHCP/toc.html.
- ***Eastern Contra Costa County HCP/NCCP*.** This is an approved HCP/NCCP. It was developed, in part, to address indirect and cumulative impacts to terrestrial species from development supported by increases in water supply provided by the Contra Costa Water District. Although the HCP/NCCP plan area includes land areas within the Legal Delta, the highest priority area for acquisition include some lands just west of the Byron Highway; the Dutch Slough/Big Break area, lower Marsh Creek, and lower Kellogg Creek are identified as key restoration priorities. Investments in land acquisition and habitat improvements are otherwise focused outside of the Legal Delta. Fish species, including salmonids, were not covered in the HCP/NCCP. Impacts to fisheries are addressed through separate consultation and permitting. For more information: www.co.contra-costa.ca.us/depart/cd/water/HCP/documents.html.
- ***Yolo County HCP/NCCP.*** This county-wide HCP/NCCP is under development. It will provide for the conservation of between 70-80 species in five habitat types: wetland, riparian, oak woodland, grassland and agriculture. No aquatic species are being addressed in this HCP; project-specific mitigation will be developed for projects affecting aquatic resources. Some initial draft chapters are available, and environmental documentation is expected to be initiated in 2010. For more information, go to www.yoloconservationplan.org/.
- ***Solano County HCP***. The Solano HCP is under development; a final administrative draft was released in June 2009. It will address species conservation in conjunction with urban development and flood control and infrastructure improvement activities. Covered species will include federally- and State-listed fish species and other species of concern. The geographic scope

includes lands within the Legal Delta. Solano County expects to have permits in place by 2010. To view the administrative draft: www.scwa2.com/Conservation_Habitat_FinalAdminDraft.aspx.

- ***San Joaquin County Multi-Species Conservation Plan.*** This HCP was approved in 2001. This plan was developed to provide guidelines for converting open space to other land uses, preserving agriculture, and protecting species. The geographic scope includes lands within the legal Delta. For more information, click on the "Habitat" link on www.sjcog.org.

Integration with these programs may provide opportunities to pursue floodplain habitat restoration projects that have the mutual benefit of controlling the risks and consequences of flooding. Some opportunity areas in the Delta in which such activities could occur include the Yolo Bypass, the Cosumnes/Mokelumne confluence, and along the lower San Joaquin River.

3.14 SWRCB Flow Criteria

The SWRCB held an Informational Proceeding for the development of flow criteria. Several parties submitted data and information regarding Delta hydrology, hydrodynamics, anadromous fish that pass through the Delta, and pelagic fish inhabiting the Delta. DFG participated in the proceeding and provided several exhibits describing the relationship between water flow and species abundance, the effect of inflows on salmon emigration, effects of water temperature on salmon in streams tributary to the Delta, and methodology for developing flow criteria (DFG 2010a, 2010b). The Water Board's flow criteria were completed in August 2010 (SWRCB 2010).

4 Methodology

This section provides a description of the approach used to develop biological goals, objectives, and flow criteria.

4.1 Definitions

As used in this document, "goals" are defined as a future desired outcome or state. Goals provide direction and focus on ends rather than means.

"Objectives" are statements of action that are clear, realistic, specific, and measurable. While DFG is required to develop only biological objectives and flow criteria, management objectives are also needed to ensure that the biological objectives and flow criteria remain relevant and scientifically supportable (please refer to sections 5, 6 and 7).

Notwithstanding the descriptions of "flow criteria" in the Delta Reform Act, flow criteria are considered to be equivalent to performance measures. Performance measures are indicators of progress toward meeting prescribed objectives.

4.2 Principles for Developing DFG Biological Objectives and Flow Criteria

DFG used the following principles to guide the development of the Delta goals, objectives, and flow criteria:

1. Flow criteria and biological objectives should be based on best available data and information contained in existing recovery plans, publications, reports, journal articles, etc. To the extent possible, DFG will use the flow criteria record developed by the Water Board during their 2010 Informational Proceeding.
2. In developing flow criteria, DFG recommendations will follow guidance in Water Code sections 85084.5 and 85086(c)(1).
3. Species to be covered by the biological objectives and flow criteria may include federal and State listed species in the Delta (e.g., delta smelt, longfin smelt, etc.), salmon, other commercial/recreational fish species, and other species or habitats known to be influenced by both Delta inflow and outflow and which contribute to the heterogeneity and sustainability of the Delta ecosystem.

4.3 Data and Information Used to Develop Biological Objectives

DFG used several lines of evidence to develop the recommended biological objectives. Lines of evidence included data or information linking aspects of Delta flow to important species processes:

1. Life history information.
2. Season or time period when flow characteristics are most important to sensitive or important species life stages.
3. Relationships of species abundance or habitat to Delta outflow, Delta inflow, water quality parameters linked to water flow, etc.
4. Species environmental requirements (e.g., dissolved oxygen, temperature tolerances, salinity, X_2 location, turbidity, etc.)
5. Relationship of species survival dependent upon Delta inflow, interior Delta flow, and Delta outflow.
6. Factors influencing and limiting population trends.
7. Ecological standards (e.g. measures of population viability).

This line of evidence approach considers a fundamental, mechanistic, and process-based view of how changes in freshwater flow may interact with components of Delta habitat, ecosystem, and management actions to support desirable fish populations (as described in more detail by Fleenor et al. 2010). The approach will ultimately be used to estimate the water flows needed to sustain Delta fishes of concern and to support specific life stages and preferred habitat for fish.

The steps for developing the necessary data and information are:

1. Identify species of concern to include based on listing status, ecological, recreational, or commercial importance.
2. Identify species with a survival or abundance relationship to flow.

3. Identify critical time(s) of year or seasons when species are most affected by flow characteristics. Identify key quantifiable population response or habitat characteristics linked to water flow.
4. Identify mechanisms or hypotheses about mechanisms that link species abundance, habitat, etc. with water flow and water quality variables.
5. Establish goals for protection of species of concern in the Delta.
6. Establish biological objectives for priority species. To the extent possible, biological objectives will be quantitative.
7. Identify performance measures for management and biological goals/objectives.
8. Develop management goals to ensure the relevance of the biological objectives and flow criteria.
9. Assemble evidence in order to establish a range of flow criteria needed to meet biological objectives. This should include all data, information, and analysis that could assist in developing the weight of evidence that would lead to flow criteria.
10. Organize conclusions, relationships, and numerical/narrative recommendations (based on evidence) into a range of values that provide criteria to be considered in future proceedings.
11. Identify, to the extent possible, the assumptions and judgments inherent in each flow criterion (endpoint) and the concurrence (i.e., overlap) or lack of concurrence between endpoints.
12. Accumulate flows (without double counting) using justifiable time step(s).
13. Establish a process to understand the underlying mechanisms in order to refine biological objectives and flow criteria over time (e.g., research, monitoring, and adaptive management).

4.4 Limitations of DFG Approach to Developing Flow Criteria

Delta outflow needs are a continuum of conditions that begin in upstream riverine habitats and progress through the Sacramento-San Joaquin Estuary. This report presents the effects of inflow and Delta outflow on several native, recreational, and commercial species that live in or pass through the Sacramento-San Joaquin River Delta. It takes into consideration the role of water project operations, water diversions, cold water pools above dams, tidal influence, and hydrodynamics of the Delta. Much of the report relies on information submitted as part of the SWRCB's informational proceeding (SWRCB, 2010).

Understanding flow and species needs in the Delta is a complex and difficult task. Several interrelated factors must be balanced in order to comprehensively manage water resources in the Delta. These factors include: Delta outflows, Delta inflows, in-Delta water diversions, water quality, coldwater pool management, hydrology, hydrodynamics, tidal action, and project operations. The recommendations in this report represent DFG's current understanding of the flow needs of the individual species identified in order to meet DFG's biological objectives. Several factors outside the scope of this legislative mandate must be considered and modeled more fully (e.g., cold water pool management in upstream reservoirs, operational constraints, and the relationship between flow criteria and unimpaired flow) before any flow standards are set.

5 Goals Needed to Protect Species of Concern in the Delta

This section describes the rationale for more focused flow-related biological goals that will serve as the foundation for biological objectives.

5.1 Ecosystem Restoration Program Goals and Objectives

Of the many programs discussed in section 3, the ERP goals and objectives found in the ERP Strategic Plan, Volume 3, provide the most scientific and practical framework for implementing restoration in the Bay-Delta watershed, meet the requirements of the Delta Reform Act, and serve as the foundation for DFG's goals.

The six strategic goals that define the scope of ERP are further divided into more specific objectives, each of which are intended to help determine whether or not progress is being made toward achieving the respective goal. Specific actions based on the ERPP Volumes I (CALFED 2000a) and II (CALFED 2000b) also are identified in the ERP Strategic Plan. The ERP goals are:

> GOAL 1. ENDANGERED AND OTHER AT-RISK SPECIES AND NATIVE BIOTIC COMMUNITIES: Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species. Support similar recover of at-risk native species in San Francisco Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.
>
> GOAL 2. ECOLOGICAL PROCESSES: Rehabilitate natural processes in the Bay-Delta estuary and its watershed to fully support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities.
>
> GOAL 3. HARVESTED SPECIES: Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with the other ERP strategic goals.
>
> GOAL 4. HABITATS: Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics.
>
> GOAL 5. NONNATIVE INVASIVE SPECIES: Prevent the establishment of additional non-native invasive species and reduce the negative ecological and economic impacts of established non-native species in the Bay-Delta estuary and its watershed.
>
> GOAL 6. WATER AND SEDIMENT QUALITY: Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic

ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.

Goals 1, 2, 3, and 6 serve as the foundation for more specific biological goals related to water flow and the protection of Delta public trust resources as described in the Delta Reform Act. Goal 1, 4, and the following two objectives taken from ERP serve as the foundation for goals related to terrestrial species of concern:

> OBJECTIVE 1: Achieve, first, recovery and then large self-sustaining populations of the following at-risk native species dependent on the Delta, Suisun Bay and Suisun Marsh, with emphasis on Central Valley winter-, spring- and fall/late fall-run Chinook salmon ESUs, Central Valley steelhead ESU, delta smelt, longfin smelt, Sacramento splittail, green sturgeon, valley elderberry longhorn beetle, Suisun ornate shrew, Suisun song sparrow, soft bird's-beak, Suisun thistle, Mason's lilaeopsis, San Pablo song sparrow, Lange's metalmark butterfly, Antioch Dunes evening primrose, Contra Costa wallflower, and Suisun marsh aster.
>
> OBJECTIVE 2: Contribute to the recovery of the following at-risk native species in the Bay-Delta estuary and its watershed: Sacramento perch, delta green ground beetle, giant garter snake, salt marsh harvest mouse, riparian brush rabbit, San Pablo California vole, San Joaquin Valley woodrat, least Bell's vireo, California clapper rail, California black rail, little willow flycatcher, bank swallow, western yellow-billed cuckoo, greater sandhill crane, Swainson's hawk, California yellow warbler, salt marsh common yellowthroat, Crampton's tuctoria, Northern California black walnut, delta tule pea, delta mudwort, bristly sedge, delta coyote thistle, alkali milk-vetch, and Point Reyes bird's-beak.

5.2 Delta Vision: Water Supply and Ecological Resources are Indispensable

In 2008, Delta Vision, a blue-ribbon task force established by the Governor (DVBRTF 2007) found that the Delta ecosystem and a reliable water supply for California are the primary, co-equal goals for sustainable management of the Delta (DVBRTF 2007). Delta Vision found that:

> *Both California's water supply and the ecological resources of the Delta are of paramount importance. They are co-equal: each is indispensable to California as a whole, and our actions must secure the future of both.*
>
> *Current uses of Delta water—including diversions upstream and within the Delta as well as exports—are a major barrier to a "durable vision for sustainable management of the Delta."*
>
> *But problems in the Delta can be solved only as part of a comprehensive effort to improve statewide water management and ecosystem management. Failure to protect the estuary could result in an inland salt sea or the collapse of an estuarine ecosystem with loss of protected and desired species. The*

consequences for statewide water supply would be unacceptable. The loss of a reliable supply of water from the Delta could lead to substantial economic hardships because large fractions of the state's water supply must come from the Delta watershed. Some of this water must be exported from the Delta to other parts of the state.

As the vision is achieved, the two co-equal values of ecosystem function and water provision are deeply woven into the institutions and policies through which California has mobilized public resources to achieve that vision. This principle of equality does not mean that these two values will somehow be precisely balanced in every policy or management decision. Rather, it means that each is indispensable to the whole state and that each must be advanced in any decision. The sum of our actions must secure the future of both, ideally through choices which integrate the two values. This will result in change in current ways of using the Delta and its watershed.

In response to Delta Vision, the Delta Reform Act acknowledges the concept of co-equal goals and sets in motion efforts to develop flow criteria and biological objectives in the Delta to meet them. To support these efforts, goals are needed to protect ecological resources of the Delta dependent on water flow and to improve on current conditions to enhance protection of public trust resources. The goals should:

1. Address species of ecological, recreational, and commercial importance.
2. Halt and reverse observed declines as described in the ERP goals.
3. Focus on those life stages that live in or pass through the Delta.

This report addresses only the goals for protection of public trust resources. As decisions for allocating water are identified and proposed, the necessary balancing must be completed as required by the Water Code.

5.3 Comprehensive Flow Criteria: "Bottom Up" Accumulation of Functional Flows

Fleenor et al. (2010) have suggested using an approach for establishing flow criteria that does not rely on past flow conditions that might not be representative of current conditions. Rather they suggested using an approach that focuses on the mechanisms and processes influenced by freshwater flow and flow interaction with landscape, ecosystem, and management actions.

This "bottom-up" strategy would itemize and estimate specific functional flows needed to support fish habitat and successful transitions of fish species from one life stage to the next. To make this work, the flow estimates would be based on scientific literature and other technical information that describes important effects of season and between year variability.

Key features of this approach are the modification of flow estimates as new scientific information is developed and the flexibility to include a variety of methods, approaches, and lines of evidence. This functional flow approach fosters a much more scientific view of the fish species-flow interactions.

Process or management goals and objectives should be established to:

1. Acknowledge the salient points of the functional flows approach (Fleenor et al. 2010) and encourage the need to be comprehensive yet not overly complex. The goal should identify general geographic locations throughout the Delta and its watershed in need of flow criteria.
2. Identify generally the areas of the Delta where flow-related biological objectives and flow criteria are needed.
3. Build in flexibility to review and modify flow criteria as new data and information comes to light.
4. Make sure review and modifications occur on a time frame to realistically manage desirable species.

5.4 Goals for the Protection of Terrestrial and Aquatic Species of Concern

Based on the foregoing discussion with focus on addressing Delta-related species, both biological and management goals are recommended as follows:

5.4.1 Terrestrial species biological goals

- Achieve, first, recovery and then self-sustaining populations of the following at-risk native species dependent on the Delta, Suisun Bay and Suisun Marsh, with emphasis on valley elderberry longhorn beetle, Suisun ornate shrew, Suisun song sparrow, soft bird's-beak, Suisun thistle, Mason's lilaeopsis, Lange's metalmark butterfly, Antioch Dunes evening primrose, Contra Costa wallflower, and Suisun Marsh aster.

- Contribute to the recovery of the following at-risk native species in the Bay-Delta estuary and its watershed: delta green ground beetle, giant garter snake, riparian brush rabbit, least Bell's vireo, California black rail, California clapper rail, bank swallow, western yellow-billed cuckoo, greater sandhill crane, Swainson's hawk, California yellow warbler, delta tule pea, delta mudwort, and delta coyote thistle.

- Protect and/or restore functional habitat types in the Bay-Delta Estuary and its watershed for ecological and public values such as supporting species and functional habitat types, and ecological processes.

5.4.2 Aquatic species biological goals

- Halt species population declines and increase populations of ecologically important native aquatic species, as well as species of commercial and recreational importance, by providing sufficient water flow and water quality at appropriate times to propagate species life stages that use the Delta.

- Establish water flows through the Delta that will likely benefit particular species or ecosystem functions in a manner that is: (1) comprehensive, (2) not overly complex, and (3) encourages production. Functional flow criteria shall be established for at least: (1)Yolo Bypass, (2) Sacramento River and its basin, (3) San Joaquin River and its basin, (4) Eastside streams and their basins, (5) Interior Delta including Old and Middle rivers, and (6) Delta outflow.

- Establish an adaptive management process to review and modify flow criteria in the Delta that is: (1) responsive to scientific advances, changing environmental conditions including a warming climate and change in sea level, and changes in conveyance and water operations, and (2) implemented on a time scale needed to realistically manage desirable species.

5.4.3 Management goals

- Integrate all flow measures needed to protect species and ecosystem functions in a manner that is comprehensive, does not double count flows, uses a justified time step, and is documented in peer reviewed or otherwise vetted literature.

- Establish an adaptive management process to evaluate Delta environmental conditions, periodically review the scientific underpinnings of the biological objectives and flow criteria, and change biological objectives and flow criteria when warranted.

6 Biological Objectives for Terrestrial Species of Concern

A large number of terrestrial species are identified for consideration in Habitat Conservation Plans and NCCPs developed for or being developed in the Delta region (Table 1). Volume 2 of the Ecosystem Restoration Program Plan contains restoration targets, programmatic actions, the rationale for targets and actions, and conservation measures.

Table 1: Species considered for NCCP/NCCPs in the Delta and Suisun Planning Area

	Common Name/Scientific Name	**Solano**	**Natomas Basin**	**San Joaquin**	**East Contra Costa**	**South Sacramento**	**Yolo**	**Rarity/Status**
PLANTS	Suisun Marsh Aster, *Symphyotrichum lentum* (*Aster lentus*)	**X**		**X**				**CNPS 1B.2**
	Ferris's Milk-vetch, *Astragalus tener* var. *ferrisiae*	**X**						**CNPS 1B**
	Alkali Milk-vetch, *Astragalus tener* var. *tener*	**X**		**X**			**X**	**CNPS 1B.1**
	Heartscale, *Atriplex cordulata*	**X**		**X**			**X**	**CNPS 1B.2**
	Brittlescale, *Atriplex depressa*	**X**		**X**	**X**		**X**	**CNPS 1B.2**

	Common Name/Scientific Name	Solano	Natomas Basin	San Joaquin	East Contra Costa	South Sacramento	Yolo	Rarity/Status
	San Joaquin Spearscale, *Atriplex joaquiniana*	X			X		X	**CNPS 1B.2**
	Vernal Pool Smallscale, *Atriplex persistens*	X						**CNPS 1B.2**
	Big Tarplant, *Blepharizonia plumosa*	X		X	X			**CNPS 1B.1**
	Bristly Sedge, *Carex comosa*			X	X			**CNPS 2.1**
	Succulent Owl's Clover aka Fleshy Owl's Clover, *Castilleja campestris ssp. succulenta*			X				**Fed Threat CA Endang CNPS 1B.2**
	Slough Thistle, *Cirsium crassicaule*			X				**CNPS 1B.1**
	Suisun Thistle, *Cirsium hydrophilum* var. *hydrophilum*	X						**Fed Endang CNPS 1B.1**
	Soft Bird's-beak, *Cordylanthus mollis* ssp. *mollis*	X			X	X		**Fed Endang CA Rare CNPS 1B.2**
	Palmate-bracted Birds Beak, *Cordylanthus palmatus*			X			X	**Fed Endang CA Endang CNPS 1B.1**
	Recurved Larkspur, *Delphinium recurvatum*	X		X	X			**CNPS 1B.2**
	Dwarf Downingia, *Downingia pusilla*	X		X		X		**CNPS 2.2**
	Delta Button-celery/Delta Coyote Thistle, *Eryngium racemosum*			X	X			**CA Endang CNPS 1B.1**
	Diamond-petaled (California) Poppy, *Eschscholzia rhombipetala*			X	X			**CNPS 1B.1**
	Fragrant Fritillary, *Fritillaria liliacea*	X			X			**CNPS 1B.2**
	Boggs Lake Hedge-hyssop, *Gratiola heterosepala*	X		X		X		**CA Endang CNPS 1B.2**
	Hogwallow Starfish, *Hesperevax caulescens*	X						**CNPS 4.2**
	Wooly Rose-mallow, *Hibiscus lasiocarpus* var. *occidentalis*	X		X	X	X	X	**CNPS 2.2**
	Carquinez Goldenbush, *Isocoma arguta*	X						**CNPS 1B.1**
	Ahart's Dwarf Rush, *Juncus leiospermus* var. *ahartii*					X		**CNPS 1B.2**
	Ferris's Goldfields, *Lasthenia ferrisiae*	X		X	X	X	X	**CNPS 4.2**
	Delta Tule Pea, *Lathyrus jepsonii* var. *jepsonii*	X	X	X	X	X		**CNPS 1B.2**
	Legenere, *Legenere limosa*	X	X	X		X		**CNPS 1B.1**
	Heckard's Pepper-grass, *Lepidium latipes var. heckardii*	X					X	**CNPS 1B.2**
	Mason's Lilaeopsis, *Lilaeopsis masonii*	X		X				**CA Rare CNPS 1B.1**
	Delta Mudwort, *Limosella subulata*	X		X				**CNPS 2.1**
	Showy Madia, *Madia radiata*			X	X			**CNPS 1B.1**

	Common Name/Scientific Name	Solano	Natomas Basin	San Joaquin	East Contra Costa	South Sacramento	Yolo	Rarity/Status
	Cotula Navarretia, *Navarretia cotulifolia*	X						CNPS 4.2
	Baker's Navarretia, *Navarretia leucocephala* ssp. *bakeri*	X						CNPS 1B.1
	Pincushion Navarretia, *Navarretia myersii* spp. *myersii*					X		CNPS 1B.1
	Adobe Navarretia *Navarretia nigelliformis* ssp. *nigelliformis*				X			CNPS 4.2
	Colusa Grass, *Neostapfia colusana*	X	X				X	Fed Threat CA Endang CNPS 1B.1
	Slender Orcutt Grass, *Orcuttia tenuis*		X			X		Fed Threat CA End CNPS 1B.1
	Sacramento Orcutt Grass, *Orcuttia viscida*		X			X		Fed Endang CA Endang CNPS 1B.1
	San Joaquin Valley Orcutt Grass, *Orcuttia inaequalis*	X						Fed Threat CA Endang CNPS G2/S2.1
	Gairdner's Yampah, *Perideridia gairdneri* ssp. *gairdneri*	X						CNPS 4.2
	Marin Knotweed, *Polygonum marinense*	X						CNPS 3.1
	Delta Woolly-marbles, *Psilocarphus brevissimus* var. *multiflorus*	X						CNPS 4.2
	Lobb's Aquatic Buttercup, *Ranunculus lobbii*	X						CNPS 4.2
	Sanford's Arrowhead (Sagittaria), *Sagittaria sanfordii*		X	X		X		CNPS 1B.2
	Side-flowering Skullcap, *Scutellaria lateriflora*			X				CNPS 2.2
	Rayless Ragwort, *Senecio aphanactis*	X						CNPS 2.2
	Wright's Trichocoronis, *Trichocoronis wrightii* var. *wrightii*			X				CNPS 2.1
	Saline Clover, *Trifolium depauperatum* var. *hydrophilum*	X						CNPS 1B.2
	Caper-fruited Tropidocarpum, *Tropidocarpum capparideum*			X				CNPS 1B.1
	Greene's Tuctoria, *Tuctoria greenei*			X				Fed Endang CA Rare CNPS 1B.1
	Crampton's Tuctoria (Solano Grass), *Tuctoria mucronata*	X					X	Fed Endang CA Endang CNPS 1B.1
ANIMALS	BIRDS							

	Common Name/Scientific Name	Solano	Natomas Basin	San Joaquin	East Contra Costa	South Sacramento	Yolo	Rarity/Status
	Cooper's Hawk, *Accipiter cooperii*	X		X		X	X	CA CSC
	Sharp-shinned Hawk, *Accipiter striatus*	X		X		X		CA CSC
	Western Grebe, *Aechmophorus occidentalis*			X				CA FGC
	Tricolored Blackbird *Agelaius tricolor*	X	X	X	X	X	X	CA CSC
	Bell's sage sparrow, *Amphispiza belli belli*			X				CA CSC
	Golden Eagle, *Aquila chrysaetos*	X		X	X	X		CA CSC
	Great Egret, *Ardea alba* (rookery)			X				CA FGC
	Great blue Heron, *Ardea herodias* (rookery)			X				CA FGC
	Short-eared Owl *Asio flammeus*	X				X	X	CA CSC
	Long-eared Owl, *Asio otus*					X		CA CSC
	Burrowing Owl, *Athene cunicularia*	X	X		X	X	X	CA CSC
	Aleutian Canada Goose, *Branta hutchinsii leucopareia*		X	X				
	Ferruginous Hawk, *Buteo regalis*					X		CA CSC
	Swainson's Hawk, *Buteo swainsoni*	X	X	X	X	X	X	CA Threat
	Northern Harrier, *Circus cyaneus*	X				X	X	CA CSC
	Mountain Plover *Charadrius montanus*	X		X				Fed Candit CA CSC
	Western Yellow-billed Cuckoo, *Coccyzus americanus occidentalis*			X			X	Fed Candit CA Endang
	California Yellow Warbler, *Dendroica petechia*						X	CA CSC
	White-tailed Kite, *Elanus leucurus*					X		CA FP
	Merlin, *Falco columbarius*					X		
	American Peregrine Falcon, *Falco peregrinus anatum*		X			X		CA FP
	Salt Marsh Common Yellowthroat, *Geothlypis trichas sinuosa*	X						CA CSC
	Greater Sandhill Crane, *Grus canadensis tabida*		X	X		X		CA Threat CA FP
	Bald Eagle, *Haliaeetus leucocephalus*					X		Fed Threat CA Endang
	Yellow-breasted Chat, *Icteria virens*	X				X		CA CSC
	Loggerhead Shrike, *Lanius ludovicianus*		X			X	X	CA FP
	California Black Rail *Laterallus jamaicensis coturniculus*	X		X				CA Threat CA FP
	Suisun Song Sparrow, *Melospiza melodia maxillaris*	X						CA CSC
	White-faced Ibis, *Plegadis chihi*		X			X	X	CA CSC
	California Clapper Rail, *Rallus longirostris obsoletus*	X						CA Threat CA FP
	Bank swallow, *Riparia riparia*		X	X			X	CA Threat
	AMPHIBIANS							
	California Tiger Salamander, *Ambystoma californiense*	X	X	X	X	X	X	Fed Endang CA Threat
	Foothill Yellow-legged Frog, *Rana boylii*	X		X	X		X	CA CSC

	Common Name/Scientific Name	Solano	Natomas Basin	San Joaquin	East Contra Costa	South Sacramento	Yolo	Rarity/Status
	Western Spadefoot, *Spea hammondii*		X			X	X	**CA CSC**
	REPTILES							
	Western Pond Turtle, *Actinemys marmorata*	X	X	X	X	X	X	**CA CSC**
	Silvery Legless Lizard, *Anniella pulchra pulchra*				X			**CA SCS**
	San Joaquin Whipsnake, *Masticophis flagellum ruddocki*			X				**CA CSC**
	Alameda Whipsnake, *Masticophis lateralis euryxanthus*				X			**Fed Threat CA Threat**
	Giant Garter Snake, *Thamnophis gigas*	X	X	X	X	X	X	**CA Threat**
	MAMMALS							
	Pallid bat, *Antrozous pallidus*					X		**CA CSC**
	Ringtail, *Bassariscus astutus*					X		**CA FP**
	Townsend's Western Big-eared Bat, *Corynorhinus townsendii townsendii*				X			**CA CSC**
	Western Red Bat, *Lasiurus blossevillii*					X		**CA CSC**
	Yuma Myotis Bat, *Myotis yumanensis*					X		**CA CSC**
	Riparian Woodrat, *Neotoma fuscipes riparia*			X				**Fed Endang CA CSC**
	Salt Marsh Harvest Mouse, *Reithrodontomys raviventris halicoetes*	X						**Fed Endang CA Endang CA FP**
	Suisun Shrew, *Sorex ornatus sinuosus*	X						**CA CSC**
	Riparian Brush Rabbit, *Sylvilagus bachmani riparius*			X				**Fed Endang CA Endang**
	American Badger, *Taxidea taxus*					X		
	San Joaquin Kit Fox, *Vulpes macrotis mutica*			X	X			**Fed Endang CA Threat**
	INVERTEBRATES							
	Ciervo Aegialian Scarab Beetle, *Aegialia concinna*			X				**G1 S1**
	Conservancy Fairy Shrimp *Branchinecta conservatio*	X	X	X	X		X	**Fed End**
	Vernal Pool Fairy Shrimp, *Branchinecta lynchi*	X		X	X	X	X	**Fed Threat**
	Longhorn Fairy Shrimp, *Branchinecta longiantenna*		X	X	X			**Fed Endang**
	Mid Valley Fairy Shrimp *Branchinecta mesovallensis*	X	X	X	X	X	X	**G2 S2**
	Valley Elderberry Longhorn Beetle *Desmocerus californicus dimorphus*	X	X	X		X	X	**Fed Threat**
	Delta Green Ground Beetle, *Elaphrus viridis*	X						**Fed Threat**
	Curved-foot Diving Beetle, *Hygrotus curvipes*			X				**G1 S1**
	Ricksecker's Water Beetle, *Hydrochara rickseckeri*	X				X		**G1G2 S1S2**

	Common Name/Scientific Name	Solano	Natomas Basin	San Joaquin	East Contra Costa	South Sacramento	Yolo	Rarity/Status
	Vernal Pool Tadpole Shrimp, *Lepidurus packardi*	X	X	X	X	X	X	**Fed Endang**
	Callippe Silverspot Butterfly, *Speyeria callippe callippe*	X						**Fed Endang CA Endang**

From: DFG's Ecosystem Restoration Program

Of the several species identified for recovery in the Delta, the following objectives are recommended for the selected species. Much of the information has been excerpted and summarized from the ERP Plan (http://www.dfg.ca.gov/ERP/reports_docs.asp)

6.1 Mason's Lilaeopsis

Mason's lilaeopsis is dependent on saturated clay soils that are regularly inundated by waves and tidal action. Habitat restoration action in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Management Zones will contribute to the recovery of this species. Objective:

- Expand suitable and occupied habitat for Mason's lilaeopsis by 100 linear miles and protect at least 90 percent of the currently occupied habitat including 90 percent of high quality habitat occurrences in the North, South, and East Delta and Napa River Ecological Management Units.

6.2 Suisun Marsh Aster

Suisun Marsh aster has habitat requirements similar to those described for Mason's lilaeopsis. Habitat restoration action in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Management Zones will contribute to the recovery of this species. Objective:

- Expand suitable and occupied habitat for Suisun marsh aster by 100 linear miles and protect at least 90 percent of the currently occupied habitat including 90 percent of high quality habitat occurrences in the North, South, and East Delta and Napa River Ecological Management Units.

6.3 Suisun Thistle

Suisun thistle is known from only two locations in Suisun Marsh. It occurs on the edges of salt and brackish marsh habitat that are periodically inundated during high tides. Proposed habitat restoration action in the Suisun Marsh/North San Francisco Bay Ecological Management Zone will contribute to the recovery of this species. Objective:

- Maintain the current distribution and existing populations of Suisun thistle, establish 10 new populations, and increase overall population size tenfold.

6.4 Soft-Bird’s Beak

Soft bird’s-beak inhabits the upper reaches of salt grass-pickleweed marshes at or near the limit of tidal action. Proposed habitat restoration action in the Suisun Marsh/North San Francisco Bay Ecological Management Zone will contribute to the recovery of this species. Objective:

- Maintain the current distribution and existing populations of soft bird’s-beak and reestablish and maintain viable populations throughout its historic range.

6.5 Antioch Dunes Evening-Primrose and Contra Costa Wallflower

Protection and restoration of these two species at the Antioch Dunes is a major objective of efforts to improve and expand suitable dune habitat. Although the species distribution is limited, the species appear stable. Objective:

- Continue protection of and expand the size of Antioch Dunes evening-primrose and Contra Costa wallflower populations; enhance and restore suitable habitat at and in the vicinity of the Antioch Dunes; and achieve recovery goals identified in the USFWS recovery plan for these species.

6.6 Lange’s Metalmark Butterfly

Protection and restoration of Lange’s metalmark habitat at the Antioch Dunes is a major objective of the USFWS species recovery plan (U.S. Fish and Wildlife Service 1984). Objective:

- Continue protection of and expand the site of the Antioch Dunes population of the Lange’s metalmark butterfly; enhance and restore suitable habitat at and in the vicinity of the Antioch Dunes; and achieve recovery goals identified in the USFWS recovery plan.

6.7 Valley Elderberry Longhorn Beetle

The primary reason attributable to the decline in numbers and distribution of the valley elderberry longhorn beetle populations is the extensive loss or degradation of its historical riparian habitats in the Central Valley to urban and agricultural uses, and flood control and water supply projects to support those uses (U.S. Fish and Wildlife Service 1984b). Protection, restoration, and enhancement of large expanses of suitable riparian habitat within the species historical and current range, therefore, will protect existing populations from future decline and provide habitat area necessary for existing populations to expand. Objective:

- Maintain and restore connectivity among riparian habitats occupied by the valley elderberry longhorn beetle and within its historic range along the Sacramento and San Joaquin rivers and their major tributaries.

6.8 Salt Marsh Harvest Mouse

The salt marsh harvest mouse is listed as a federal endangered species and a fully protected species in California. Typically nesting is found above ground in grasses, shrubs, or small trees within tidal and diked salt marshes. Declines in population can be attributed to urban development over marshlands and an increase in invasive species, decreasing native habitat availability.

- Reestablish and maintain viable populations of the salt marsh harvest mouse throughout its historical range in the portion of the Bay-Delta located within the ERP Focus Area.

6.9 Suisun Ornate Shrew

The Suisun ornate shrew is a listed as a species of special concern by DFG. Long-term survival of this subspecies is dependent upon tidal wetland, as opposed to diked wetlands; it has to have adequate physical structures and plant communities for survival. Its tidal marsh habitat has to have adjacent upland habitat for survival of the species during periods when the marsh is inundated. Restoring habitat would not only benefit the Suisun ornate shrew but other species, such as the salt marsh harvest mouse, that also use tidal marsh and upland marsh habitats. Objective:

- Maintain current distribution and existing populations of the Suisun ornate shrew and reestablish and maintain viable species' populations throughout its historic range in the portion of the Bay Region within the ERP focus area.

6.10 San Joaquin Valley Woodrat

Once occupying a larger range, the San Joaquin Valley Woodrat (riparian woodrat) is now confined to the lower portions of the San Joaquin County (Williams 1986, 1993, USFWS 1998). Habitat loss and fragmentation along streams in the San Joaquin Valley due to farm land conversion and canal and dam construction are considered the main attributable reason for the decline in numbers and distribution of the riparian woodrat. Objective:

- Protect the Caswell Memorial State Park population of the San Joaquin Valley Woodrat; protect, enhance, and expand the species' population in Caswell Memorial State Park; and improve habitat connectivity and genetic interchange among isolated populations.

6.11 Suisun Song Sparrow

The Suisun song sparrow occurs only in and near Suisun Marsh, in about 13 isolated populations. Populations of this unusual subspecies are declining for a variety of reasons, but mainly the degradation of their habitat. Reductions in fresh water outflow from the Sacramento-San Joaquin Rivers and diking and channelization of marsh lands have contributed to their decline. Restoration of their populations is likely to be a good indicator of the success of restoration of brackish tidal marshes in the Suisun Marsh area. Objective:

- Maintain the current distribution and existing populations of the Suisun song sparrow and reestablish and maintain viable species' populations throughout its historic range in portions of the Bay and Delta Regions within the ERP focus areas.

6.12 California Black Rail

The primary reason attributable to the decline in California black rail populations is the extensive loss of its historical tidal marsh habitat to urban, industrial, and agricultural uses. Restoration of large expanses of suitable tidal marsh habitat within the species historical and current range, therefore, will provide habitat area necessary for populations to expand. Objective:

- Maintain the current distribution and existing populations of the California black rail and reestablish and maintain viable populations throughout its historic range in portions of the Delta.

6.13 California Clapper Rail

The California clapper rail resides in salt and brackish marshes. Declines in clapper rail numbers continue to be attributed to a decline in habitat. Native channel edge habitat is quickly being displaced by the introduction of *Spartina* species; and altering sloping channel flats to steep sided channels. As a result, protection from predators and forage benefits that native high marsh pickleweed (*Salicornia virginica*) and gum plant (*Grindelia stricta*) habitat offer is also diminishing. Objective:

- Maintain the current distribution and existing populations of the California clapper rail, and reestablish and maintain viable populations throughout its historical range in the portion of the Bay Region within the ERP Focus Area.

6.14 Swainson's Hawk

Historically, Swainson's hawk foraging habitat consisted of large expanses of open grasslands that supported abundant prey species. Swainson's hawks typically nest in riparian forests, small groves of trees, or lone trees within open habitats. As a result of conversion of large expanses of historic grassland to urban, industrial, and agricultural uses, agricultural lands are now major foraging habitat areas for Swainson's hawks. Some types of agriculture, however, are unsuitable because they do not support sufficient prey populations or because prey is unavailable as a result of dense vegetation (safflower). Over 85 percent of nesting territories in the Central Valley are associated with riparian systems adjacent to suitable foraging habitats (DFG 1992). Consequently, improving prey abundance and availability on agricultural lands adjacent to restored riparian habitats will provide important elements of the species' habitat necessary for the population to expand. Objective:

- Protect, enhance, and increase habitat sufficient to support a viable breeding population of Swainson's hawk. The interim prescription is to increase the current estimated population of 1,000 breeding pairs in the Central Valley to 2,000 breeding pairs.

6.15 Riparian-Brush Rabbit

Protection and restoration of existing occupied riparian brush rabbit habitat at Caswell Memorial State Park and actions to reduce the probability for mortality as a result of flooding, fire, and predation are major objectives of the species recovery plan (U.S. Fish and Wildlife Service 1997). Objective:

- Protect the population of riparian-brush rabbit in Caswell Memorial State Park; protect, enhance, and expand the species' Caswell Memorial Park population; and restore four additional self-sustaining populations in the Delta and along the San Joaquin River by 2020.

6.16 Greater Sandhill Crane

Suitable shallow-water roosting habitat used by greater sandhill cranes during winter in the Delta is limited. Restoration and management of seasonal wetlands specifically to provide suitable roosting habitat free from disturbance near suitable foraging habitats will increase the area of available roosting habitat and may improve distribution of wintering cranes. Increases in food availability and abundance on agricultural lands will also be likely to improve distribution and winter survival of cranes in the Delta. Objective:

- Achieve recovery objectives identified in the Pacific Flyway Management Plan for the Central Valley population of greater sandhill cranes and Assembly Bill (AB) 1280.

6.17 California Yellow Warbler

Neotropical migratory birds constitute a diverse group of largely passerine songbirds that overwinter in the tropics but breed in or migrate through the Central Valley and Bay-Delta region. As a group, they are in decline because of loss of habitat on their breeding grounds, in their migratory corridors, and in their wintering grounds. The species within this group are good indicators of habitat quality and diversity and their popularity with birders means that populations are tracked and have high public interest. They can also be good indicators of contaminant levels, by monitoring reproductive success and survival in areas near sources of contamination. Riparian forests are particularly important to this group because they are major migration corridors and breeding habitat for many species. By providing improved nesting and migratory habitat, it may be possible to partially compensate for increased mortality rates in wintering grounds.

Improved habitat for songbirds also provides habitat for many other species of animals and plants. Objective:

- Maintain and enhance suitable riparian corridor migration habitats and restore suitable breeding habitat within the historic breeding range of California yellow warbler in the Central Valley.

6.18 Least Bell's Vireo

A major reason attributable to the extirpation of the least Bell's vireo from its historical range in the Central Valley is the extensive loss and fragmentation of historical riparian habitats to urban and agricultural uses, and flood control and water supply projects to support those uses (U.S. Fish and Wildlife Service 1998). Protection, restoration, and enhancement of large expanses of suitable riparian habitat within the species historical range is an objective of the least Bell's vireo recovery plan (U.S. Fish and Wildlife Service 1998) and will provide habitat area necessary for existing populations to expand. Objective:

- Achieve recovery objectives identified in the least Bell's vireo recovery plan in the Delta and ERP focus area.

6.19 Western Yellow-Billed Cuckoo

The primary reason attributable to the decline in numbers and distribution of the western yellow-billed cuckoo is the extensive loss or degradation of its historical riparian forest habitats in the Central Valley to urban and agricultural uses, and flood control and water supply projects to support those uses (DFG 1992). Protection, restoration, and enhancement of large expanses of suitable riparian habitat within the species historical and current range, therefore, will protect existing populations from future decline and provide habitat area necessary for existing populations to expand. Objective:

- Protect existing suitable riparian forest habitat areas within the western yellow-billed cuckoo historic range and increase the areas of suitable riparian forest habitat sufficiently to allow the natural expansion of the Sacramento Valley population.

6.20 Bank Swallow

The decline in numbers and distribution of bank swallow populations is attributable to the loss of the natural depositional and erosional processes of rivers that create and sustain the types of channel bank nesting substrates required by the species. These nesting habitats have disappeared largely as a result of flood control projects that have impeded the ability of rivers to erode their banks (DFG 1992). Restoration of the ability of channels of major rivers in the Central Valley to erode their banks will increase the availability of suitable nesting habitat, providing the additional habitat area necessary for existing populations to expand. Objective:

- For bank swallow, allow reaches of the Sacramento River and its tributaries that are unconfined by flood control structures (e.g., bank revetment and levees) to continue to meander freely, thereby creating suitable bank nesting substrates through bank erosion.

6.21 Giant Garter Snake

The giant garter snake is listed by both state and federal agencies as a threatened species. Most of the original giant garter snake habitat, freshwater marshes, has been lost to agriculture. This snake resides in marsh habitat where there are pools and sloughs that exist year round to provide the frogs and invertebrates on which they feed. This snake survives today because small numbers live in rice fields and along irrigation ditches. Survival of the species, however, is likely to depend upon increasing its natural habitat through marsh restoration combined with special protection measures on the agricultural land it currently inhabits. Objective:

- Protect the existing population and habitat of giant garter snake within the Delta Region and restore, enhance, and manage suitable habitat areas adjacent to known populations to encourage, the natural expansion of the species.

6.22 Delta Green Ground Beetle

The delta green ground beetle is federally listed as a threatened species that is currently known only from Jepson Prairie Preserve (Solano County). Habitat requirements for this species are not well understood but the beetles seem to require open places near vernal pools. A better understanding of the beetle and its ecological needs would help restoration efforts. Objective:

- For delta green ground beetle, protect all known occupied habitat areas from potential adverse effects associated with current and potential future land uses and establish three additional populations of the delta green ground beetle within its current and/or historic range.

6.23 Delta Mudwort and Delta Tule Pea

These two species inhabit freshwater and brackish marshes. Actions to enhance existing marsh habitats and to restore tidal marsh areas will contribute to the recovery of delta tule pea and delta mudwort. Objective:

- For delta mudwort and delta tule pea, protect at least 90 percent of occupied habitat including 90 percent of high quality habitat throughout the range of these species to protect geographic diversity, and expand suitable and occupied habitat by 100 linear miles.

6.24 Delta Coyote-Thistle

Delta coyote-thistle occurs on clay soils on sparsely vegetated margins of seasonally flooded floodplains and swales, freshwater marshes and riparian areas. Actions to enhance and restore these habitat types will contribute to the recovery of delta coyote-thistle. Objective:

- Bring at least 10 of the largest extant, naturally occurring delta coyote-thistle populations found during surveys into permanent protected status and bring at least 50 percent of all extant populations and individuals under permanent protected status.

- Increase delta coyote-thistle habitat by 50 percent over existing extent. Increase individual populations by 25 percent over present existing conditions.

6.25 Waterfowl

- Protect, enhance, and restore the habitat functions and values of tidal, permanent, and seasonal wetlands and agricultural lands within the Bay-Delta for waterfowl, shorebirds, and waterbirds. For managed seasonal wetlands and agricultural lands, see objectives in the 2006 Central Valley Joint Venture Implementation Plan

6.26 Intertidal Habitat

Intertidal habitats are highly variable environments that endure regular periods of immersion and emersion and are important to many different species. Intertidal habitats include beaches, mudflats, salt, brackish and freshwater tidal marshes. While loss of habitat can mostly be attributed to urban, industrial, and agricultural development, climate change has the potential to threaten the location and dynamic of these habitats. This habitat type has been reduced by 95% in the Delta nd 80% in the Suisun Marsh. Actions to enhance and restore these habitats will benefit many of the species identified in the ERP Plan.

- Protect, enhance, restore, and develop intertidal habitat and associated sub-tidal habitat within the Bay-Delta to improve habitat and food web support for species of concern.

7 Biological Objectives and Flow Criteria for Aquatic Species of Concern

This section describes the rationale for the aquatic species biological objectives and flow criteria needed to achieve the flow-specific biological goals. Much of what is presented in this section has been excerpted from the SWRCB Delta Flows Report (SWRCB 2010) and DFG testimony on the SWRCB’s Informational Proceeding (DFG 2010a, 2010b). When referencing information in the SWRCB flows report in most case the source of the information is identified by exhibit in the SWRCB record (e.g., DOI 1 as cited in SWRCB, 2010).

7.1 Priority Species

Several species are of priority concern and will benefit by improving water flow conditions. The following table lists the species identified of priority concern based on ecological, commercial, or recreational importance and that are influenced by Delta inflow (including mainstem river tributaries) or Delta outflow. Table 2 identifies the priority species life stage most affected by water flow, the mechanism most affected by flow, and the time when water flow is most important to the species (updated from DFG 2010a).

Table 2: Priority species

Priority Species	Life Stage(s)	Mechanism	Time When Water Flows are Most Important
Chinook salmon (San Joaquin River basin)	Smolt	Outmigration	March – June
Chinook salmon (San Joaquin River basin)	Adult	Immigration & Egg Viability	Sept – December
Chinook salmon (Sacramento River basin)	Juvenile	Outmigration	November – June
Chinook salmon (San Joaquin River tributaries)	Adults (Egg)/fry	Temperature, dissolved oxygen	September – March
Steelhead Rainbow Trout (San Joaquin River basin)	Smolt	Outmigration	March – May
Steehead Rainbow Trout (San Joaquin River basin)	Adult	Immigration & Egg Viability	Sept – April
Longfin smelt	Egg	Freshwater-brackish habitat	December – April
Longfin smelt	Larvae	Freshwater-brackish habitat; transport; turbidity	December – May
Splittail	Adults	Floodplain inundating flows	January – April
Splittail	Eggs and larvae	Floodplain habitat persistence	January – May
Delta smelt	Larvae, juvenile, and pre-adult	Transport; low salinity zone habitat suitability	March – November September – November
Starry flounder	Settled juvenile; Juvenile-2 yr old	Estuary attraction; habitat	February – May
Bay shrimp	Late-stage larvae and small juveniles	Transport	February – June
Bay shrimp	Juveniles	Nursery habitat	April – June
Mysid shrimp (zooplankton)	All	Habitat	March – November
Eurytemora affinis (zooplankton)	All	Habitat	March – May
American shad	Egg/larvae	Transport; dispersal; habitat	April – June

While many species found in the Delta are of ecological, commercial, and recreational interest, specific flow needs for some of those species may not be directly addressed in this report because they: (1) overlap with the needs of more sensitive species already addressed in this report, (2) the relationships between flow and abundance of those species are not well understood, or (3) the needs of those species may be outside the scope of this report.

For example, placement of X_2 at certain locations in the Delta to protect species like longfin smelt or starry flounder will also provide habitat for striped bass. Striped bass survival from egg to 38mm is significantly increased as X_2 shifts downstream in the estuary (Kimmerer 2002a). Kimmerer et al. (2009) showed that as X_2 location moved downstream several measures of striped bass survival and abundance significantly increased, as did several measures of striped bass habitat. Increases were also shown for striped bass with improved delta smelt fall stream flow conditions (Feyrer et al. 2007).

Similarly, it is assumed that improved stream flow conditions for fall-run Chinook salmon will benefit juvenile or some life stages 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, McEwan and Jackson 1996, 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, in: McEwan and Jackson 1996). Additional information is needed to develop objectives and flow criteria that protect steelhead at times when flows are not specifically recommended for salmon protection. Additional flow criteria may also be needed to protect various runs and life stages of salmon but adequate information is not presently available to support run-specific flow criteria.

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

7.2 Species Status, Life History, and Relationship to Flow

This section provides an assessment of the effect of inflow and Delta outflow on the selected priority native, recreational, and commercial species of concern for which live in or pass through the Delta. For each species, DFG scientists have summarized the available scientific data and information related to life stage, mechanism of the relationship between water flow and species abundance or habitat, the type of relationship, and the months of the year when flows are most critical to various life stages (Table 3).

Data and information are not generally available for all species that inhabit the Delta. The following sections focus on those species that DFG has the best understanding. Most of the information presented below was provided to the SWRCB in February 2010 as part of DFG's exhibits for the SWRCB's March 2010 informational proceeding on flow criteria to protect public trust resources in the Delta (DFG 2010a, 2010b). DFG scientists have also reviewed the SWRCB's informational proceeding record and Delta Flows Report (SWRCB 2010). Much of this section is excerpted and adapted from DFG (2010a, 2010b) and SWRCB (2010).

Table 3: Timing of important species and life stage specific flow/outflows and the mechanisms of action on survival or abundance.

Species			Water Year Months[1]											
Name	**Life Stage**	**Mechanism(s)**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
Native														
Chinook salmon	egg	Temperature Scouring	●	●●	●									
	fry			●	●	●								
	smolt			●	●	●	●	●	●	●●	●			
Longfin smelt	egg	Freshwater-Brackish habitat		●?	●	●●	●●	●	●					
	larvae	Freshwater-Brackish habitat; transport; turbidity			●	●	●●	●●	●●	●●	●?			
Splittail	adults	Flood plain inundating flows (can be short)				●	●	●	●					
	eggs and larvae	Flood plain habitat persistence				●	●	●●	●●	●●	●?			
Delta smelt	pre-adult	Transport; habitat	●	●				●	●●	●●	●	●		●

[1] ● = Flow timing important during this month, ●● = flow timing very important during this month, ●? = flow timing may be important but the need is uncertain.

Species			Water Year Months[1]											
Name	**Life Stage**	**Mechanism(s)**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
Starry Flounder	settled juvenile/juvenile-2yr old	Estuary attraction; habitat					●	●	●	●				
Bay Shrimp, *Crangon franciscorum*	late-stage larvae and small juveniles	Transport					●	●	●●	●●	●●			
	juveniles	Nursery habitat							●●	●●	●●			
Mysid shrimp, *Neomysis mercedis*	all	habitat	●	●				●	●	●	●	●	●	●
Eurytemora affinis	all	habitat						●●	●●	●●				
American Shad	egg/larvae	Transport; dispersal; habitat						●	●●	●●	●			

Source: CDFG 2010a

7.2.1 Chinook Salmon

Status

Sacramento River winter-run Chinook salmon – Endangered (FESA and CESA)
Central Valley spring-run Chinook – Threatened (FESA and CESA)
Central Valley fall/late fall-run Chinook salmon – Species of Special Concern (FESA)

Life History

Chinook salmon are philopatric semelparous anadromous species (i.e., adult species return to their natal sites to spawn then die soon after spawning). They exhibit two generalized freshwater life history types (Healey 1991). Adult "stream-type" Chinook salmon enters freshwater up to several months before spawning, and juveniles reside in freshwater for a year or more (e.g., winter and spring-run), while "ocean-type" Chinook salmon spawn soon after entering freshwater. The eggs are deposited via redd and hatch as alevins. The alevins emerge from the redd and become free swimming once the yolksac are fully absorbed. The fry develop parr marks on the flanks of their body after several months. The parr undergoes smoltification (i.e., physiological changes of osmoregulatory mechanism that promote seawater tolerance) before migrating to the ocean within their first year (e.g., fall and late fall-run)(Table 4). Adequate instream flows and cool water temperatures are critical for longer periods of time to support the survival of Chinook salmon exhibiting a stream-type life history due to over-summering by adults and/or juveniles.

Chinook salmon mature between 2 and 6 years of age (Myers et al. 1998). The return to freshwater and timing of spawning generally is thought to be related to adaptation to local water temperature and flow regimes, but might also be connected to ocean conditions which influence prey availability and growth rates (Wells et.al. 2007). Runs are identified by adult migration timing. However, runs also differ in the maturity 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 advanced 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 adequate streamflows sufficient to provide olfactory and other orientation cues to quickly 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 (3°C to 13°C) (Bell 1991, DFG 1998). Boles (1988) recommends water temperatures below 65ºF (18°C) for adult Chinook salmon migration, and Lindley et al. (2004) report that adult migration is completely blocked when temperatures reach 70ºF (21°C), and that fish can become stressed as temperatures approach 70ºF (21°C). The 7DADM chronic population criteria for adult migration is 64°F (18°C) EPA (2003).

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 km per day (6.2 miles) to greater than 35 km per day (21.7 miles) 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 km to 32 km per day (18 miles to 19.8 miles) in the Snake River.

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 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 (13°C to 14°C) (Chambers 1956, Smith 1973, Bjornn and Reiser 1991, and Snider 2001). The 7DADM criteria for spawning, egg incubation, and fry emergence is 55°F (13°C) EPA (2003).

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 percent of fry emerged successfully from large gravel with adequate subgravel flow. The optimal water temperature for egg incubation ranges from 41ºF to 56ºF (5°C to 13°C) [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 (14°C) and total embryo mortality can occur at temperatures above 62ºF (17°C)(NMFS 1997). Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50 percent pre-hatch mortality were 61ºF (16° C) and 37ºF (3° C), 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 fungal 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. 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 feeding in the 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). Shallow water habitats have been found to be more productive for salmon rearing 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). Juveniles are essentially committed to outmigration when they begin to undergo smoltification. Smoltification is the physiological process that increases salinity tolerance and preference, endocrine activity, and gill Na^+-K^+ ATPase activity. It usually begins when the juveniles reach between three to four inches (76 to 102 millimeters) fork length (FL); however, some fish delay smoltification until they are about 12 months old (yearlings) when they reach four to nine inches (102 to 229 millimeters) FL (SJRRP 2009, Appendix A). Environmental factors, such as streamflow, water temperature, photoperiod, lunar phase, and pollution, can affect the onset of smoltification (Rich and Loudermilk 1991). The 7DADM criteria for smoltification is 59°F (15°C) (EPA 2003).

As fish begin their outmigration, they are displaced by the river's current downstream of their natal reaches. Similar to adult movement, juvenile salmonid downstream movement is primarily during twilight. 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 are between 54ºF to 57ºF (12°C to 14°C) (Brett 1952). In Suisun and San Pablo bays, water temperatures reach 54ºF (12°C) by February in a typical year. Other portions of the Delta (e.g*.,* South Delta and Central Delta) can reach 70ºF (21°C) by February in a dry year. However, cooler temperatures are usually the norm until after the spring runoff has ended. The 7DADM criteria for juvenile rearing in the lower part of river basins is 64°F (18°C) and for the upper basin is 61°C (16°C) (EPA 2003).

Within estuarine habitats, juvenile Chinook salmon movements are dictated by 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 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 smolts 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 ocean-type 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.

Table 4: 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	September-early January	November	Late October-January	November	December-April	1-5 months

Source: adapted from Yoshiyama *et al*. (1998) as cited in Moyle 2002

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). The runs are named after the season during the upstream migration of the adults such as; 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). 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). 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 lifecycle timing are summarized in Table 3 and described in more detail below.

Winter-run - 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 as cited in SWRCB 2010). 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 (NMFS 5 as cited in SWRCB 2010). Currently, winter-run habitat is likely limited to the Sacramento River reach between Keswick Dam to just downstream of the Red Bluff Diversion Dam. The winter-run population is currently very vulnerable due to its low population numbers and the fact that only one population exists (NMFS 5 as cited in SWRCB 2010). In the late

1960s escapement was near 100,000 fish declining to fewer than 200 fish in the 1990s. Recent escapement estimates from 2004 to 2006 averaged 13,700 fish (DFG Website 2007). 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 (NMFS 5 as cited in SWRCB 2010). In addition, a temperature control device was installed on Shasta Dam in 1997 likely improving conditions for winter-run.

Spring-run - 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 as cited in SWRCB 2010). Since the 1880s, construction of dams and other factors have significantly reduced the numbers and range of spring-run in the Central Valley. Currently, the only viable populations occur on Mill, Deer, and Butte creeks, but those populations are small and isolated. 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 as cited in SWRCB 2010).

Historically, Central Valley spring-run numbers were estimated to be as large as 600,000 fish (NMFS 5 as cited in SWRCB 2010). Nearly 50,000 spring-run adults were counted on the San Joaquin River prior to construction of Friant Dam. Shortly after construction of Friant Dam, spring-run were extirpated on the San Joaquin River. 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.

Fall-Run - 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). 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 (Yoshiyama et. al 2001).

Currently, fall-run Chinook inhabit both the Sacramento and San Joaquin river basins and are the most abundant of the Central Valley races, contributing to large commercial and recreational fisheries in the ocean and popular sport fisheries in the freshwater streams. Fall-run Chinook are raised at five major Central Valley hatcheries 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 88,000 and 66,000 fish in 2007 and 2008 (NMFS 2009). NMFS concluded that the recent declines were likely primarily due to poor ocean conditions in 2005 and 2006. 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, elevated water temperature conditions, introduced species, altered sediment dynamics, hatchery practices, degraded water quality, and loss of riparian and estuarine nursery habitat.

Late-Fall Run - Historically, late-fall run probably spawned in the mainstem Sacramento River and major tributary reaches and possibly in the upstream San Joaquin River and it's tributaries (Hatton and Clark 1942; Van Cleve 1945; Fisher 1994 as cited in Yoshiyama et. al 2001).

At present, 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). The late-fall run has continued low, but potentially stable abundance (NMFS 2009). 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.

Population Abundance and Relationship to Flow

In the Sacramento-San Joaquin 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 as cited in SWRCB 2010). Decreased flows may decrease migration rates and increase exposure to unsuitable water quality and temperature conditions, predators, and entrainment at water diversion facilities (DFG 2010a). 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 as cited in SWRCB 2010). Prior to development and channelization, the Delta provided hospitable habitat for salmon. With channelization and other development, the Delta environment is no longer as hospitable for salmon. As a result, the most beneficial Delta outflow pattern for salmon may be flows that move salmon through the Delta quickly. Salmon respond behaviorally to variations in flows. Juvenile and adult salmon begin migrating during the rising limb of the hydrograph (DOI 1 as cited in SWRCB 2010). For juveniles, pulse flows appear to be more important than for adults. For adults, continuous flows through the Delta and up to each of the natal tributaries appear to be more important. 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 outmigration from redds, increased flows provide improved transport downstream and improved rearing habitat, and for salmonids that stay in the rivers to rear, increased flows provide for increased habitat and food production.

Sacramento River Inflow

The 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 (SWRCB, 2006). These objectives range from 3,000 to 4,500 cfs and are in part intended to provide attraction flows, outmigration flows and suitable habitat conditions for Chinook salmon. The Bay-Delta Plan does not include any specific Sacramento River flow requirements for the remainder of the year, including the spring.

Sacramento River salmon production is limited by habitat alterations in the Delta primarily through reduced survival during smolt outmigration. 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 juvenile fall-run Sacramento River salmon (DOI 1 as cited in SWRCB 2010). The USFWS (Kjelson 1987, Kjelson et al. 1981, 1982) reported that flow was positively correlated with juvenile fall-run Chinook salmon survival through the Delta and that temperature was negatively correlated with survival. 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. This relationship did not exist at flows between 7,000 and 19,000 cfs, suggesting a potential threshold response to flow. Smolt survival was also found to be highest when water temperatures were below 66ºF (19°C).

In addition to increased survival, juvenile abundance has also been found to be higher with greater Sacramento River flow. 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. Dettman et al. (1987) reanalyzed data from the 1987 Kjelson experiments and found a positive correlation between an index of spawning returns and both June and July outflow from the Delta. 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. 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 as cited in SWRCB 2010). In 2001, Brandes and McLain confirmed the relationships between water temperature and flow and the increase in juvenile salmonid survival. 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.

In addition to the flow versus juvenile fall-run Chinook salmon survival relationships, 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 NOAA 3 as cited in SWRCB 2010). 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 reduce the number of fish that enter the interior Delta and will improve survival (DOI 1 as cited in SWRCB 2010). To achieve no bidirectional flow in the mainstem Sacramento River near Georgiana Slough, flow levels of 13,000 (SWRCB 2010) to 17,000 cfs at Freeport are needed.

Juvenile Chinook salmon outmigration on the lower Sacramento River near Knights Landing also shows 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 2010a). Outmigration 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). Sacramento River flows at Wilkins Slough of 15,000 to 20,000 cfs following major precipitation events are associated with increased outmigration (DFG 2010a, NMFS 7 as cited in SWRCB 2010).

Delays in precipitation producing flows result in delayed outmigration which may result in increased susceptibility to in-river mortality from predation and poor water quality conditions (DFG 2010a). Allen and Titus (2004) suggest that the longer the delay in migration, the lower the survival of juvenile salmon to the Delta. To encourage and support outmigration, 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 2010a). 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 that hide young salmon from predators (AR/NHI 1 as cited in SWRCB 2010).

San Joaquin River Inflow

Tributaries to the San Joaquin River (the Merced, Tuolumne, and Stanislaus rivers) support fall-run Chinook salmon and steelhead. Since the 1980s (1980-1989) San Joaquin River 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 as cited in SWRCB 2010). Flow related conditions are likely to be a major cause of this decline. Additionally, the limited information available on steelhead abundance indicates that the tributaries support small, self-sustaining populations.

The Bay-Delta Plan includes flow objectives for the San Joaquin River at Vernalis that are aimed at protecting 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 of X_2. 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. These flow objectives have never been implemented. The Vernalis Adaptive Management Plan (VAMP) flow targets for the past 10 years have been used to provide flows intended to protect salmon outmigration. VAMP flows are lower than the Bay-Delta Plan's pulse flow objectives and vary between 2,000 and 7,000 cfs (SWRCB 2006). The 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.

Inflows from the San Joaquin River affect various life stages of Chinook salmon including adult migration, spawning, egg incubation, juvenile rearing, and juvenile outmigration to the ocean. Using the Tuolumne River as an example, in order to maintain a viable Chinook salmon population, per NMFS guidelines (Lindley et. al. 2007), 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 in spawning runs should be reduced to no more than 10 percent (Lindley and others 2007, as cited in CSPA 14, p. 3-4). At present, the Tuolumne River population is at a high risk of extinction (Mesick 2009). It is also possible that the Stanislaus River and Merced River populations will soon be at a high risk of extinction due to the influence of high percentages of hatchery fish (CSPA 7 as cited in SWRCB 2010) in proportion to naturally produced fish, especially in drier (lower stream flow) water year type fish production years.

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 as cited in SWRCB 2010). 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. Spawner abundance, spawning habitat degradation, and reduced flows have caused the decline in escapement. The decline of Tuolumne River adult production, and both Merced and Stanislaus River, began well before the 2005 downturn in ocean conditions (Marston 2007).

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 2010a, CSPA 7 as cited in SWRCB 2010, Hallock et al. 1970). Analyses of flow needs for the protection of adult fall-run migration 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 (DOI 1 as cited in SWRCB 2010). These analyses also show that reverse flows on the San Joaquin River delay and potentially hinder migration. In addition, 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). Delayed migration may result in reduced gamete viability under elevated temperatures and mortality to adults prior to spawning (AFRP 2005). Up to 58 percent 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 percent when flows were at least 3,500 cfs (CSPA 14 and CSPA 7 as cited in SWRCB 2010). Flows of 1,200 cfs from the Merced, Tuolumne, and Stanislaus rivers to the San Joaquin River for ten days in late October increases escapement by an average of 10 percent (CSPA 7 as cited in SWRCB 2010).

The 2005 AFRP report includes similar recommendations for flows of 1,000 cfs from each of the San Joaquin River tributaries. 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, EDF 1 as cited in SWRCB 2010). It is necessary for the scent of the San Joaquin basin watershed to enter the Bay in order for adult salmonids to find their way back to their natal river (EDF 1 as cited in SWRCB 2010).

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, DOI 1 as cited in SWRCB 2010). 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) (DOI 1 as cited in SWRCB 2010). A positive relationship has also been shown between salmon survival indices and flow at Jersey Point for fish released at Jersey Point (DOI 1 as cited in SWRCB 2010). Maximum San Joaquin basin adult fall-run Chinook salmon escapement may be achieved with flows exceeding 20,000 cfs at Vernalis during the smolt outmigration period of April 15 through June 15 (DOI 1 as cited in SWRCB 2010). Higher 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. The primary mechanism needed to substantially produce more smolts at Jersey Point is to increase the spring Vernalis flow level (magnitude, duration, and frequency) which will increase the survival of smolts leaving the San Joaquin River tributaries, and produce more smolts surviving to, and through, the South Delta (DFG 2010a, b; Figure 1). Random rare and unpredictable poor ocean conditions may cause stochastic high mortality of juvenile salmon entering the ocean, but the overwhelming evidence is that more spring flow results in higher smolt abundance, and higher smolt abundance equates to higher adult production (DFG 2010a).

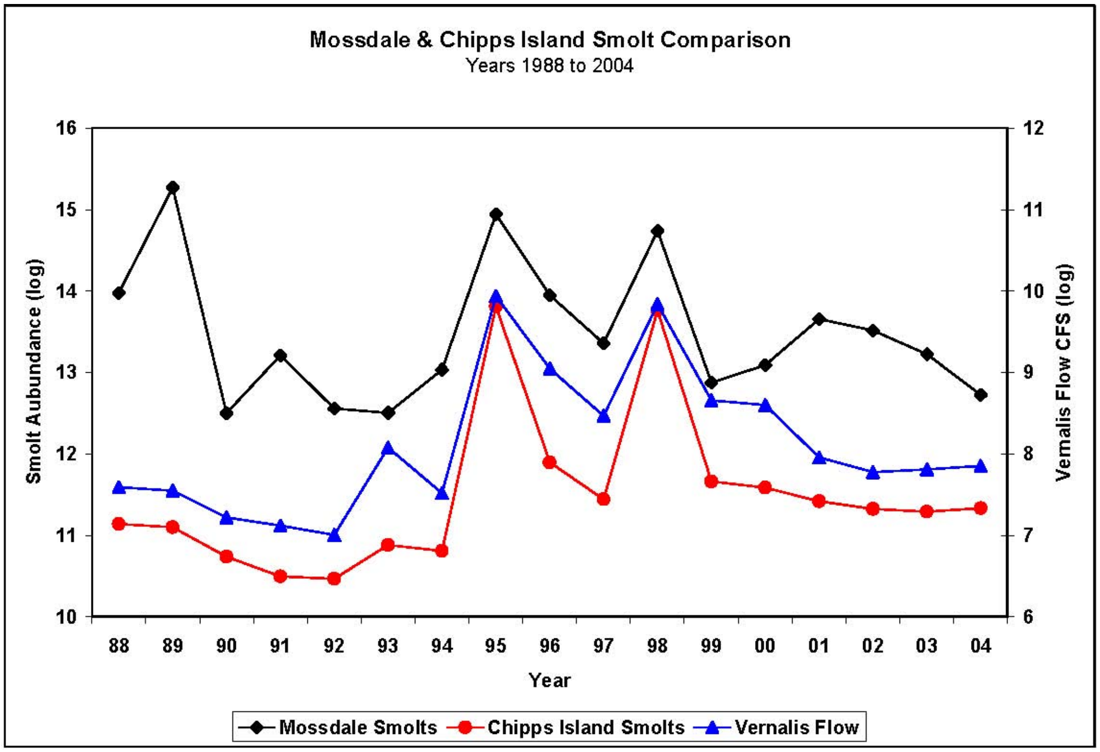

Figure 1: Smolt Survival and San Joaquin River Vernalis Flows

Note: This figure shows the relationship of estimated 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). 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 2010a).

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, dissolved oxygen, and other water quality conditions. All of these functions are impacted on the San Joaquin River (e.g., “Steelhead stressor matrix,” TBI/NRDC 3 as cited in SWRCB 2010). 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. 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 as cited in SWRCB 2010; Bisson et al. 2009). Variable 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.

Water temperature is critical to successful juvenile and adult anadromous salmonid migration. Although salmonid spawning migration may occur throughout the year for all three races (fall, late-fall, winter) of Chinook salmon and steelhead, high water temperature delays migration and/or imposes highly stressful conditions during summer and early fall migration, holding periods, and spawning (Hallock et. al, 1970). Stocks that are subject to longer migration distances to inland spawning grounds during the summer and early fall would be more vulnerable. Furthermore, increased water temperature is reported to create blockages to migration for several species of salmonids (Beschta et al. 1987, Major and Mighell 1967, cited in ODEQ 1995, cited in USEPA issue paper 1, 2001). The AFRP restoration plan (USFWS 2001) recommends that actions be implemented to minimize exposure to elevated temperatures and that suitable water temperatures be maintained for all life stages of Chinook salmon in the San Joaquin River.

Lethal temperature thresholds for Pacific salmon depend, to some extent, on acclimation temperatures (Myrick and Cech 2004). Central Valley salmonids are generally temperature-stressed through at least some portion of their freshwater life-cycle. Lethal temperature effects commence in a range between 71.6° and 75.2°F (TBI/NRDC 3 as citd in SWRCB 2010), 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 as cited in SWRCB 2010). While salmon can show decreased growth, smoltification success, and the ability to still avoid predators at temperatures above 68°F, 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 (TBI/NRDC 3 as cited in SWRCB 2010). These findings are consistent with several studies that suggest optimal growth and survival for Chinook salmon occurs at a temperature range from 53.6°F to 62.6°F (TBI/NRDC 3 as cited in SWRCB 2010). 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 2008).

Temperature is controlled by a number of factors including reservoir releases, channel geometry, riparian cover, groundwater seeps, timing of snow melt, and ambient air temperatures. As a result, a given flow may achieve different water temperatures depending on these factors. Flows over 5,000 cfs in late spring (April to May) generally provide water temperatures (below 65°F) suitable for Chinook salmon, but flows less than 5,000 cfs may not be adequate to provide sufficient temperature conditions (TBI/NRDC 3 as cited in SWRCB 2010). 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 as cited in SWRCB 2010). To maintain average 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, flows need to be increased in response to average air temperature (CSPA 7 as cited in SWRCB 2010).

While several temperature criteria have been proposed, DFG supports the use of the temperature criteria developed by U.S. Environmental Protection Agency (USEPA) (Table 5) (USEPA 2003, DFG 2010a).

Table 5: USEPA temperature thresholds for Pacific migratory salmonid species and life stages.

Salmonid Life History Phase Terminology	EPA-based Recommended Temperature Thresholds to Protect Salmon and Trout[1] (Criteria are based on the 7-day average of the daily maximum values)
Adult migration	<64°F (<18°C) for salmon and trout migration <68°F (<20°C) for salmon and trout migration - generally in the lower part of river basins that likely reach this temperature naturally, if there are cold-water refugia available
Incubation	<55°F (<13°C) for salmon and trout spawning, egg incubation, and fry emergence
Juvenile rearing (early year)	<61°F (<16°C) for salmon "core" juvenile rearing - generally in the mid- to upper part of river basins
Smoltification	<59°F (<15°C) for salmon smoltification <57°F (<14°C) for steelhead smoltification (for composite criteria steelhead conditions are applied)
Juvenile rearing (late year)	<64°F (<18°C) for juvenile salmon and steelhead migration plus non-Core Juvenile Rearing - generally in the lower part of river basins

[1] Water temperature thresholds taken from: United States Environmental Protection Agency (USEPA). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. 49 pp. April. The USEPA identified temperature unit is: Seven day average of the daily maximum water temperature (7DADM).

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. USFWS's 2005 *Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin* (AFRP 2005) 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. 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. 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.

DFG, using a non-linear based regression model founded upon empirical data obtained from the San Joaquin River basin, developed a fall-run Chinook salmon production model that can be used to develop flow recommendations for the San Joaquin River (DFG 2010a). DFG recommends flows from March 15 through June 15 to double

Chinook salmon smolt production. DFG has modeled a variety of 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.

Based on the modeling results, flows needed for the SJR at Vernalis are provided in Table 6 and depicted in Figure 2. The predicted Chipps Island smolt production from this flow schedule (Figure 3) accomplishes the doubling objective (e.g., smolt production as measured at Chipps Island is increased two-fold from 78,210 to more than 156,420).

Table 6: Delta (Vernalis) Flows Needed to Double Smolt Production at Chipps Island (by Water Year Type)

	Water Year Type				
Flow Type	Critical	Dry	Below Normal	Above Normal	Wet
Base (cfs)	1,500	2,125	2,258	4,339	6,315
Pulse (cfs)	5,500	4,875	6,242	5,661	8,685
Pulse Duration (days)	31	40	50	60	70
Total Flow (cfs)	7,000	7,000	8,500	10,000	15,000
Acre-Feet Total	614,885	778,772	1,035,573	1,474,111	2,370,768

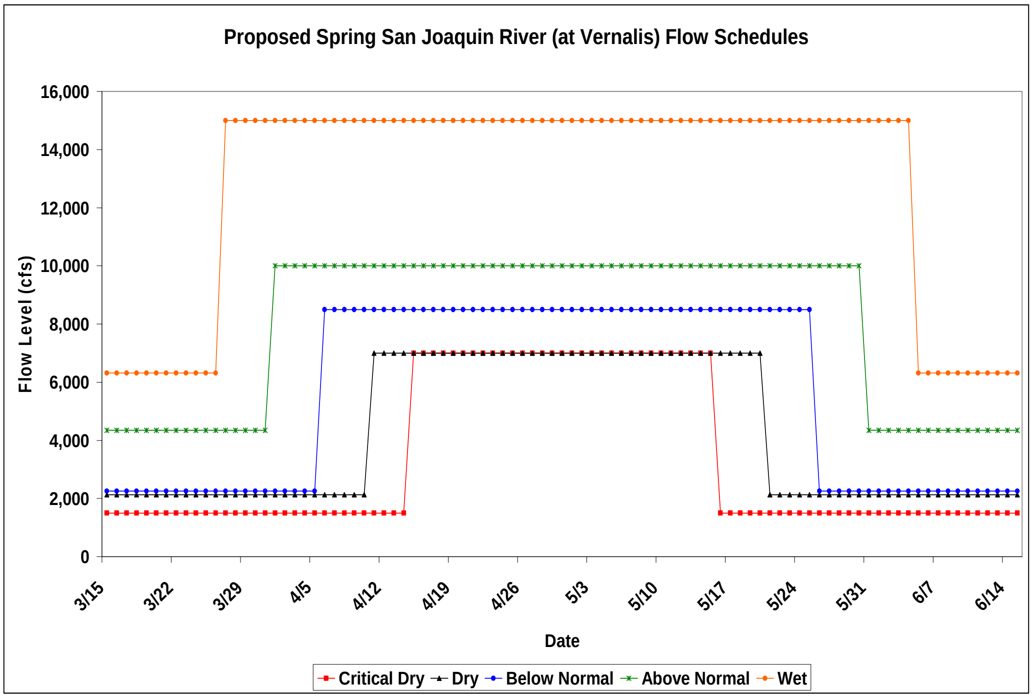

Figure 2: South Delta (Vernalis) Flows Needed to Improve Smolt Production at Chipps Island (by Water Year Type)

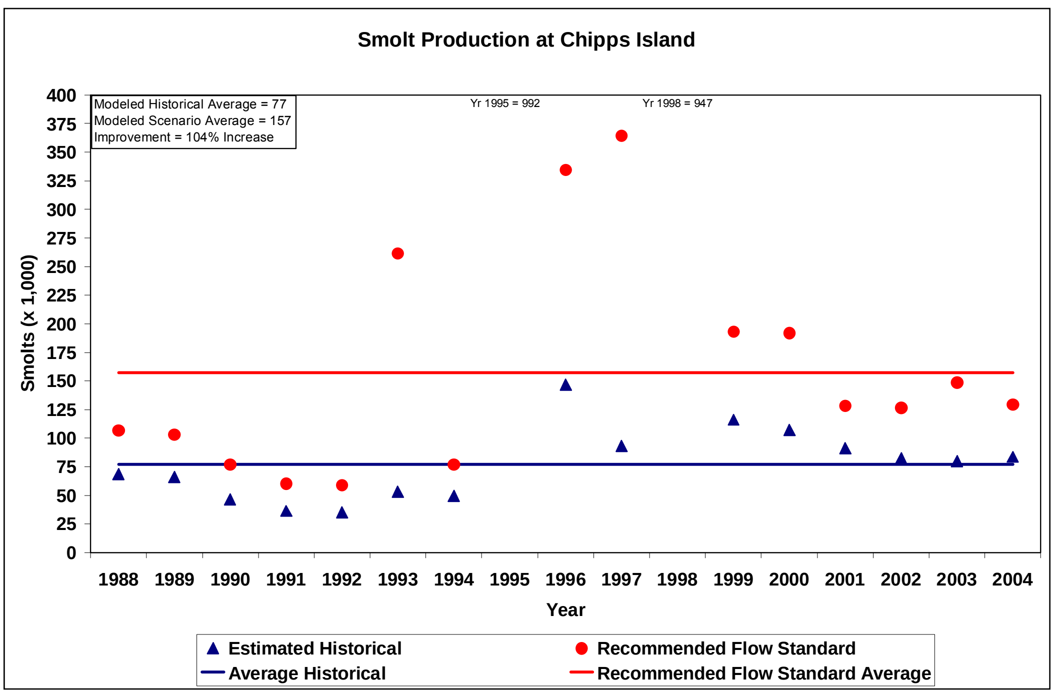

Figure 3: Modeled Chipps Island Salmon Production for Years 1988-2004.

Note: This figure shows the model predicted Chipps Island smolt production for the base (historical-blue diamonds) and recommended Vernalis flow standards (red circles). Smolt production is doubled at the recommended flow levels. The average for both data sets excludes the extremely wet years (and corresponding high smolt production) as these years (1995 and 1998) inflate the average (in both cases), and the spring flows were not changed in the scenarios evaluated.

The smolt production model was used to determine flows to achieve smolt production doubling for the various water-year types for the San Joaquin River near Vernalis. The time period for the modeled flows spans 93 days from March 15 through June 15 for each water-year type, the time period determined from smolt outmigration monitoring that should provide sufficient flows necessary to cover all but the small percentage of unusually early or late migrants.

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 as cited in SWRCB 2010). TBI/NRDC found that average March through June flows exceeding 5,000 cfs resulted in positive population growth in 84 percent of years with only 66 percent growth in years with flows less than 5,000 cfs. TBI/NRDC further 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 percent of years. This analysis suggests that 5,000 cfs may represent an important minimum flow threshold for salmon survival on the San Joaquin River. 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 as cited in SWRCB 2010).

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

Current flow conditions on the San Joaquin River result in DO concentrations 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 as cited in SWRCB 2010) and would have additional benefits by reducing nutrients pollution and biological oxygen demand (TBI/NRDC 3 as cited in SWRCB 2010).

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 2005). Habitat modeling indicates that flows of up to 300 cfs on each of the San Joaquin River tributaries may provide favorable physical habitat during the fall (AFRP 2005). It is noted that crowding of adults during fall spawning infers that spawning superimposition (one female spawning on top of another females already deposited eggs) is producing a population limiting impact (e.g., adult density dependence). The theory of adult density dependence controlling salmon populations in the San Joaquin River has not been substantiated. In fact, data collected to date indicates that lack of spring flows far better explain adult salmon escapement trends in the San Joaquin River basin than does spawner density (DFG 2008).

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). To protect over-summering steelhead and salmon, flows in the San Joaquin River 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).

The magnitude, duration, timing, and source of San Joaquin River inflows are important to San Joaquin River Chinook salmon migrating through the Bay-Delta and several different aspects of their life history. Inflows to the Delta 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, outmigration 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 outmigration 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 Flow recommendations.

In-Delta Flows

All Central Valley Chinook salmon must pass through 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 as cited in SWRCB 2010). Delta exports affect salmon migrating through and rearing in the Delta by modifying tidally-dominated flows in the channels. It is, however, difficult to evaluate quantitatively 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 as cited in SWRCB 2010). 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. Steady flows during drier periods (as opposed to pulse flows that occur during wetter periods) may increase these residence time effects (DOI 1 as cited in SWRCB 2010).

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 as cited in

SWRCB 2010). 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. It is therefore necessary to provide adequate flows in these eastside streams (e.g., the flows suggested in Fleenor et al., 2010).

The 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 as cited in SWRCB 2010). 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, SJRGA 2007, and NMFS 3 as cited in SWRCB 2010). Analyses indicated that tagged fish were 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 as cited in SWRCB 2010). 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, pollutants, and unscreened diversions (NMFS 3 as cited in SWRCB 2010).

As net reverse flows in Old and Middle rivers increase from -2,500 cfs to -3,500 cfs, particle entrainment changes from 10 percent to 20 percent and then increases to 40 percent when flows are -5,000 cfs and 90 percent when flows are -7,000 cfs (NMFS 3 as cited in SWRCB 2010). 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 as cited in SWRCB 2010). 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 have also been completed (USFWS, 1995). Net reverse flows at Jersey Point decrease the survival of smolts migrating through the lower San Joaquin River (AFRP 1995 as cited in SWRCB 2010). 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. 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-normal 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. These flow should be implemented in concert with San Joaquin River flows at Vernalis.

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 salmon. San Joaquin basin Chinook salmon production increases when the ratio of spring flows to exports increases (NMFS 3 as cited in SWRCB 2010).

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. 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 as cited in SWRCB 2010).

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 percent of years (TBI/NRDC 4 as cited in SWRCB 2010). 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 percent of years. TBI/NRDC estimates that Vernalis flows to export ratios of greater than 4.0 would reach population abundance goals (TBI/NRDC 4 as cited in SWRCB 2010). This ratio should be implemented in concert with San Joaquin River flows at Vernalis.

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). As a result, if exports are high, little if any flow from the San Joaquin basin reaches the bay and ocean to help guide San Joaquin basin salmon back to the basin to spawn. Increased straying occurs when south Delta exports exceed 400 percent of the flow at Vernalis (equivalent to a Vernalis flow to export ratio of 0.25). Straying rates have historically decreased substantially when export rates were less than 300 percent of Vernalis flow (Mesick, 2001).

Floodplain Flows

Juvenile salmon can rear on seasonally inundated floodplains when available. Floodplain 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 salmon through the Delta (DOI 1 as cited in SWRCB 2010, NMFS 3 as cited in SWRCB 2010). The increased growth rates are due to the combined effect of increased temperatures (but still below levels causing direct or indirect mortality) and increased food supplies (DFG 2010a, DOI 1 as cited in SWRCB 2010). Floodplain rearing provides conditions that promote larger and faster growth which may improve outmigration, predator avoidance, and ultimately survival (DFG 2010a). 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 temporary flooded areas (DOI 1 as cited in SWRCB 2010, DFG 2010a). The improved growing conditions provided by floodplain habitat are also believed to improve ocean survival resulting in higher adult return rates (Healy 1982, DOI 1 as cited in SWRCB 2010). It is noted that floodplain flows have several highly advantageous juvenile salmon habitat rearing conditions associated with them. For instance entire river length floodplain flows occur typically when reservoir releases are elevated which produces both lower water temperatures and lower out-migration rates. Reduced water temperatures decrease both the likelihood of direct mortality, fish dying from elevated water temperature, and in-direct mortality, predation lessened due to predators not needing to feed as much. Lowered migration rates occur due to higher flows which increase water velocities resulting in shorter travel times for out-migrating salmon (which also reduces predation potential).

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 (DOI 1 as cited in SWRCB 2010). In addition, high temperatures, low dissolved oxygen, and other water quality conditions that may occur on floodplains may adversely affect salmon (DFG 2010a). Reduced depth may also make salmon more susceptible to predation. Water depths of 30 cm or more are believed to reduce the risk of avian predation (DFG 2010a). Further, the most successful native fish are those that use the floodplain for rearing, but leave before the floodplain becomes disconnected to the river (DFG 2010a). From a restoration perspective, projects should be designed to drain completely to minimize formation of ponds in order to avoid stranding (DOI 1 as cited in SWRCB 2010). 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 2010).

The timing of floodplain inundation for the protection of 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)(AR/NHI 1 as cited in SWRCB 2010). The benefits of floodplain inundation generally increase with increasing duration, with even relatively short periods of two-weeks providing potential feeding benefits to salmon (AR/NHI 1 as cited in SWRCB 2010). 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.

DFG Recommended Biological Objectives for Salmon

Based on the forgoing information for salmon, the following biological objectives are proposed:

- For the San Joaquin River basin, provide sufficient water flow depending on year type to transport salmon smolts through the Delta during spring in order to contribute to attainment of the salmon protection water quality objective[1].

[1] Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Water Board Resolution No. 2006-0098. Table 3. Page 14.

- For the Sacramento River basin, provide sufficient water flow to transport salmon smolts through the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective[1].

- For eastside streams that flow to the Delta including the Mokelumne and Consumes River basins, provide sufficient water flow to transport salmon smolts through the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective[1].

- To favor salmon smolts rearing in the Delta, during above normal and wet years, provide floodplain inundation flows for at least a 10 consecutive day period between January and May, maintain continuous inundation for at least 30 days in the Yolo Bypass and at suitable locations in the Sacramento River or in the San Joaquin River.

- For mainstem rivers that flow into the Delta and their tributaries, maintain water temperatures and dissolved oxygen at levels that will support adult migration, egg incubation, smolting, and early-year and late-year juvenile rearing at levels that facilitate attainment of specified life-history stage production goals.

[1] Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Water Board Resolution No. 2006-0098. Table 3. Page 14.

DFG Recommended Flow Criteria for Salmon

Category	Function	Flow (cfs)	Year Type	Months												Citation
				O	N	D	J	F	M	A	M	J	J	A	S	
San Joaquin River	Increase juvenile Chinook salmon outmigration survival and abundance and provide conditions that will generally produce positive population growth in most years and eventually achieve the doubling goal	1500 (Base)	C				1	1	1	1	1	½				DFG (2010a)
		5500 (Pulse) (4/15-5/15) (Total 7000)								½	½					
		2125 (Base)	D				1	1	1	1	1	½				DFG (2010a)
		4875 (Pulse) (4/11-5/20) (Total 7000)								½	½					
		2258 (Base)	BN				1	1	1	1	1	½				DFG (2010a)
		6242 (Pulse) (4/6-5/25) (Total 8500)								1	1					
		4339 (Base)	AN				1	1	1	1	1	½				DFG (2010a)
		5661 (Pulse) (4/1-5/30) (Total 10000)								1	1					
		6315 (Base)	W				1	1	1	1	1	½				DFG (2010a)
		8685 (Pulse) (3/27-6/4) (Total 15000)							1	1	1	1				
	Minimum adult Chinook salmon attraction flows to decrease straying, increase DO, reduce temperatures, and improve olfactory homing fidelity	At Vernalis: pulse flow: 1000[2]	All	1												

1 = criteria recommended for the whole month
½ = criteria recommended for half of the month

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[2] 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

Category	Function	Flow (cfs)	Year Type	Months												Citation
				O	N	D	J	F	M	A	M	J	J	A	S	
Eastside Streams	Mokelumne River flows: Juvenile salmon outmigration	1500	All						1	1						From Flennor et al. 2010
	Eastside stream minimum flows	1060	All	1	1	1	1	1	1	1	1	1	1	1	1	From Flennor et al. 2010
Sacramento River	Increase juvenile salmon outmigration survival and abundance for fall-run Chinook salmon. Increases juvenile salmon outmigration survival	At Wilkins Slough: pulse flow: 20,000 cfs for 7 days[3]	All		1	1	1									SWRCB 2010
	Increase juvenile salmon outmigration survival by reducing diversion into Georgiana Slough and the central Delta	At Freeport: 13,000 - 17,000[4]	All		1	1	1	1	1	1	1	1				
	Promote juvenile salmon outmigration	At Rio Vista: 20000 - 30000								1	1	1				DFG (2010a)
Floodplain	Salmon smolts also benefit from increased food in floodplain habitats.	≥ 30 day floodplain inundation[5]	AN W				1	1	1	1	1					DFG (2010a), SWRCB (2010)

1 = criteria recommended for the whole month

[3] Pulse flows should coincide with storm events producing unimpaired flows until monitoring indicates that majority of smolts have moved downstream.
[4] Positive flows are needed downstream of confluence with Georgiana Slough while juvenile salmon are present.
[5] Flows needed to inundate floodplain habitat vary substantially depending on Sacramento River, San Joaquin River, and in-Delta floodplain habitat (e.g., Fremont Weir in the Yolo Bypass flow can range from 56,000 cfs (existing crest) to 23,100 cfs (the proposed notch) (AR/NHI 1 as cited in SWRCB, 2010).

Category	Function	Flow (cfs)	Year Type	Months												Citation
				O	N	D	J	F	M	A	M	J	J	A	S	
Old and Middle Rivers	Reduces straying and improve homing fidelity for San Joaquin basin adult salmon	> -5,000 cfs	All			1	1	1								
	Reduced risk of juvenile salmon entrainment and straying to central Delta	> -2,500 cfs when salmon smolts are in the Delta	All		1	1	1	1	1	1	1	1				
	Improve survival of San Joaquin River juvenile salmon emigrating down the San Joaquin River and improve subsequent escapement	At Jersey Point: Positive flows when salmon are in the Delta	All		1	1	1	1	1	1	1	1				
	Increase survival of outmigrating smolts, decrease diversion of smolts into central Delta where survival is low															

1 = criteria recommended for the whole month

7.2.2 Longfin Smelt

Status

Threatened (CESA)

Life History

The longfin smelt (*Spirinchus thaleichthys*) is a small, native, anadromous member of the true smelt family Osmeridae. Ranging from Alaska to California, the most southern breeding population inhabits the San Francisco Estuary (Moyle 2002).

Toward the end of its primarily 2-year life cycle, maturing adults migrate toward fresh water in late fall and stage in low salinity water, often found in Suisun Bay, before spawning (Rosenfield and Baxter 2007, DFG 2009a and b). Spawning probably takes place in freshwater (Wang 1986, Moyle 2002) where adhesive eggs are scattered on sand substrates from November through April, peaking in January (DFG 2009a). Thus, the geographic regions where adult fish stage and downstream boundary of spawning are both influenced by the prevailing location of X_2 during late fall, winter, and spring. Based on historical larval sampling, Moyle (2002) identified principal spawning regions as the lower Sacramento River from Rio Vista to the confluence and the lower San Joaquin River from Medford Island to the confluence. The Cache Slough complex is also an important spawning area, particularly during low outflow periods (DFG 2009a and b). Longfin smelt hatch into buoyant larvae from December through May, peaking in February (Table 1 in DFG 2009a), and are immediately transported by prevailing currents.

Population Abundance and Relationship to Flow

The annual production of longfin smelt is positively correlated with winter-spring Delta outflow and inversely related to Old and Middle River (OMR) winter-spring reverse flows (Figure 4). Larval distribution is related to winter-spring outflow and initially closely associated with the position of X_2 (DFG 1992a, Baxter 1999a, Dege and Brown 2004); that is, larvae are transported farther downstream when outflow increases and X_2 is shifted downstream. Larval and early juvenile longfin smelt habitat is modeled best by salinity and Secchi depth (Kimmerer et al. 2009, Table 3, 20mm Survey), and their habitat selection based on salinity is most narrow among all life stages (Kimmerer et al. 2009, Figure 5f, 20mm Survey). The longfin smelt larva and early juvenile habitat selection function peaks at about 2 parts per thousand (ppt) and declines rapidly to about 12 ppt before tailing off, indicating strong selectivity for low salinity habitat. Both low salinity habitat and increased turbidity are functions of outflow. As fish grow, juveniles disperse more broadly (Baxter 1999a).

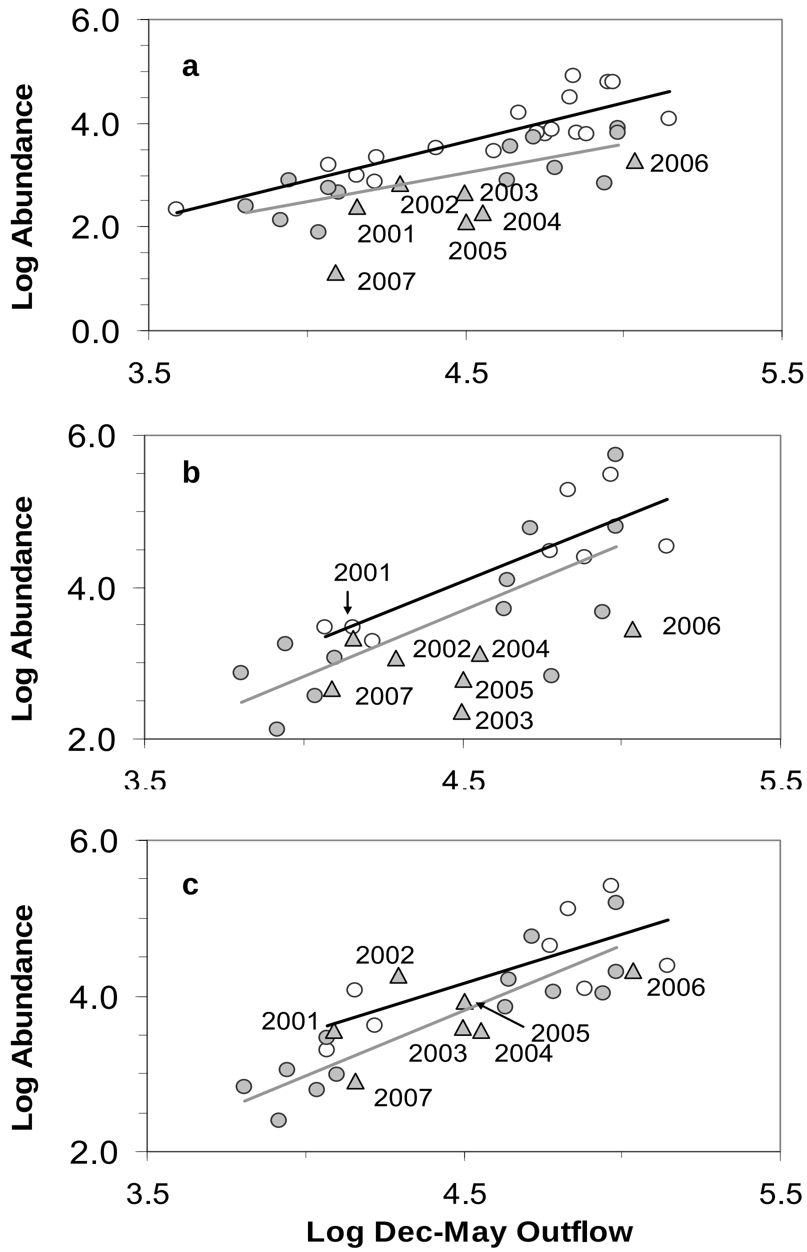

Figure 4: Longfin smelt annual abundance indices plotted on December through May mean monthly delta outflow for a) Fall Midwater Trawl (all ages); b) Bay Study Midwater Trawl Age 0; c) Bay Study Otter Trawl Age 0.

Relationships depicted are pre- *Corbula amurensis* (1967-1987; open circles, black line) and post- *Corbula amurensis* (1988-2000; filled circles, grey line) and more recent years during the Pelagic Organism Decline (POD) (2001- 2007, grey triangles, no line). Lines indicate the relationship is significant, $p < 0.05$. Source DFG 2009a

Rosenfield and Baxter 2007) and inhabit a broader range of salinities (Baxter 1999a, Kimmerer et al. 2009).

In the early 1990s, DFG identified February through May as the most critical period for longfin smelt based upon first feeding and development (DFG 1992a). More recently we hypothesized that freshwater outflow during the incubation and early rearing periods (December through May) had a strong positive affect on longfin smelt recruitment to the juvenile stage (Baxter 1999a, DFG 2009a). Outflow during the December through May period continues to have a significant positive relationship to longfin smelt abundance even though the relationship changed after the introduction of the over-bite clam *Corbula amurensis* (Figure 4, see also Kimmerer 2002a and b). After 2000, the outflow-abundance relationship appeared to change once again, but not consistently across all surveys (c.f., Figure 4a&b and 4c). The relationship did not appear to change for the Bay Study otter trawl sampling (Figure 4c), which samples longfin smelt more effectively in the lower San Francisco Estuary, from San Pablo Bay through Central San Francisco Bay. More importantly the outflow abundance regressions for years 2001-2008 all remain positive, indicating that increasing outflow continues to be beneficial to longfin smelt.

The population abundance of juvenile and adult longfin smelt is also inversely related to the number of fish salvaged at the SWP and CVP facilities (TBI/NRDC 4 as cited in SWRCB 2010). High pumping rates at the facilities cause reverse OMR flows, which passively move all age groups of longfin smelt toward entrainment at the pumps. A subset of juvenile and adult smelt entrained is counted at the pumping facilities. Larval smelt (<20mm) pass through the louvers and are not counted. Peak adult and juvenile smelt entrainment occur in January and April to May, respectively (Baxter et al. 2009).

Entrainment of larval smelt, although not measured, is likely greatest between March and April (TBI/NRDC 4 as cited in SWRCB 2010). Adult and juvenile longfin smelt salvage is an inverse logarithmic function of net OMR flows (Grimaldo et al. 2009a). Increasing OMR reverse flows results in an exponential increase in salvage loss. Juvenile longfin smelt salvage is a negative function of Delta outflow between March and May (TBI/NRDC 4 as cited in SWRCB 2010). 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, and transport flows are not present to move larvae away from the pumps. Also, negative net OMR flows can either passively draw fish, particularly larvae, to the pumps or at high levels miscue adults and juveniles as to the direction downstream. A consequence is that juvenile longfin smelt are mostly in danger of entrainment at the CVP and SWP pumping facilities during low outflow years with high net negative OMR flows.

The OMR flow results discussed above are consistent with the findings of DFG (2009b). The authors used the Delta Simulation Model (DSM2, PTM subroutine) to predict the fate of larval longfin smelt. The PTM predicted that larval entrainment at the SWP might be substantial (2 to10 percent), particularly during the relatively low outflow conditions modeled. DFG (2009b) also identified a significant negative relationship between spring (April to June) net negative OMR flows and the sum of combined SWP and CVP juvenile longfin smelt salvage. Juvenile longfin smelt salvage increased rapidly as OMR became more negative than -2,000 cfs (DFG 2009b). However, as winter-spring or just spring outflows increased, shifting the position of X_2 downstream, the salvage of juvenile longfin smelt decreased significantly. Also, particle entrapment decreased, even with a high negative net 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 as cited in SWRCB 2010) presented a generation to generation population abundance analysis for longfin smelt versus Delta outflow. In this analysis the probability of an increase in the FMWT longfin smelt index was greater than 50 percent of annual production in years when Delta outflow averaged 51,000 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 as cited in SWRCB 2010). 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 two lowest FMWT abundance indices on record occurred during the last three years. 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.

Delta outflow recommendations made to the SWRCB to protect longfin smelt are summarized in Table 7. DFG (2010a) recommends a Delta outflow between 12,400 and 28,000 cfs from January to June of all water year types to help transport larval/juvenile longfin smelt seaward in the estuary. TBI/NRDC (TBI/NRDC 2 as cited in SWRCB 2010) also made spring Delta 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.

Table 7. Summary of the Recommendations for Delta Outflow to Protect Longfin Smelt (SWRCB 2010)

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	X_2 – 64 km to 75 km					

Four sets of OMR recommendations to protect longfin smelt are summarized in Table 8. TBI/NRDC (TBI/NRDC 4 as cited in SWRCB 2010) recommended reducing entrainment losses of longfin smelt in dry years (March to May when outflow is less than 18,000 cfs) and when population abundance is low (FMWT index less than 500) by maintaining positive net OMR flows in April and May. Alternatively, if the index is greater than 500 and Delta outflow is low, then net OMR flows should not be more negative than -1,500 cfs. The DOI (DOI as cited in SWRCB 2010) made a non-species specific recommendation that OMR flows should be positive in all months between January and June. CSPA/CWIN made a non-species specific recommendation that combined export rates equal zero from mid-March through June. (CSPA 1, 2 as cited in SWRCB 2010) DFG has issued an Incidental Take Permit to the State Water Project for longfin smelt (2081-2009-001-03) that restricts net OMR flows in some years based on presence of longfin smelt in the central and south Delta and the recommendations of the Delta Smelt Workgroup (DFG 2009b). Longfin smelt optimally need positive flow on the Sacramento and San Joaquin rivers to move buoyant larvae downstream and away from the influence of the pumps and towards the biologically productive low salinity zone.

Table 8. Summary of the Recommendations for Net OMR Reverse Flows to Protect Longfin Smelt (SWRCB 2010)

<table>
<tr><th>Organization</th><th>Water Year</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sept</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>2006 Bay-Delta Plan</td><td>all</td><td colspan="12">Some restrictions, given in terms of E/I ratios</td></tr>
<tr><td>DFG Take Permit</td><td>all</td><td colspan="5">-1,250 to -5,000[1]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>TBI/NRDC</td><td>C/D</td><td></td><td></td><td></td><td colspan="2">>0[2] or -1,500[3]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>DOI</td><td>all</td><td colspan="6">>0</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CSPA/CWIN</td><td>all</td><td></td><td></td><td colspan="4">Combined export rates = 0</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Organization</td><td>Water Year</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Apr</td><td>May</td><td>Jun</td><td>Jul</td><td>Aug</td><td>Sept</td><td>Oct</td><td>Nov</td><td>Dec</td></tr>
<tr><td colspan="14">[1]This condition is not likely to occur in many years and is based on requirements in the DFG Incidental Take Permit 2081-2009-001-03 and the advice of the Smelt Working Group. The condition is most likely to occur in dry or critical years when longfin smelt 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</td></tr>
</table>

DFG Recommended Biological Objectives for Longfin Smelt

- Provide low salinity habitat for longfin smelt in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between January and June.

- Depending on year type, provide sufficient water flow to increase abundance of longfin smelt to pre-1987 abundance levels.

- At no time should Old and Middle River flows be more negative than -5,000 cfs during the period between December and March.

- During critical and dry years and when longfin FMWT index is more than 500, Old and Middle River flows should be more positive than -1500 cfs during the period between April and May.

- During critical and dry years and when longfin FMWT index is less than 500, Old and Middle River flows should be positive during the period between April and May.

DFG Recommended Flow Criteria for Longfin Smelt

Category	Function	Flow (cfs)	Year Type	Months												Citation
				O	N	D	J	F	M	A	M	J	J	A	S	
Delta Outflow	Promote increased abundance for longfin smelt, starry flounder, zooplankton, American shad, bay shrimp, and other desirable estuarine species	11400 – 29200 (X_2 between 64 km and 75 km)	All				1	1	1	1	1	1				DFG (2010a)
Old and Middle Rivers	Reduces entrainment of larval / juvenile longfin smelt and provide benefits to other desirable species If FMWT index for longfin smelt is low, then OMR should be more positive than 0 or -1500 (depending on prior year population) to reduce entrainment losses when abundance is low. Needed to reduce entrainment of adult 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.	> -1,250 to -5,000 cfs 14-day running average	All						1							DFG take permit
		> 0 or -1,500 cfs, 14-day running average, when FMWT index for longfin smelt is less than 500, or greater than 500, respectively	C, D							1	1					

1 = criteria recommended for the whole month

7.2.3 Delta Smelt

Status

Endangered – CESA
Threatened – FESA

Life History

Delta smelt (*Hypomesus transpacificus*) is a small silvery fish that is slightly translucent with a blue sheen in its sides, and is a true smelt of the family Osmeridae. It is endemic to the upper San Francisco Estuary, where it inhabits low salinity waters in channels and shoals of Suisun Bay, Suisun Marsh, and the Delta (Moyle et al. 1992, Moyle 2002). In high outflow periods they can be transported into San Pablo Bay, but they do not reside there.

Delta smelt is an annual fish and most adults die following spawning in the spring, but a few do survive to a second year (Moyle et al. 1992). Young delta smelt grow rapidly during summer and reach adult lengths (55-70 mm standard length) by September (Moyle 2002). A diffuse upstream migration to spawning areas begins in September and October (Grimaldo et al. 2009). Spawning occurs in freshwater from late January to late June or early July (Wang 2007), with the majority occurring in April and May (Moyle 2002) in temperatures 7-15°C (Wang 1986). 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). At sizes adult delta smelt currently reach, they have a low fecundity. Mager (1996) reported female (56-66 mm fork length (FL)) egg counts ranged 1,190-1,856 and Moyle et al. (1992) reported slightly larger counts 1,247-2,590 for females in a larger size range (59-70 mm FL). However, Bennett (2005) showed that captive two-year females more than 100 mm long could produce up to 12,000 eggs. Eggs are negatively buoyant and adhesive (Wang 1986). Larvae hatch at around 13 days (Mager 1996), although this can vary depending on incubation temperatures (Bennett 2005). Delta smelt at hatch are buoyant, swimming near the surface. Thereafter, they become slightly negatively buoyant and need to swim to remain in the water column until air bladder and swimming ability have developed (Mager et. al 2004). Within a couple of months, larvae develop an air bladder and become pelagic, utilizing vertical movement in the water to better maintain position (Moyle 2002, Bennett et al.2002).

Freshwater outflow during spring (March-June) affects spawning location and the associated distribution of larvae by carrying them to the low salinity habitat (1-7 ppt) (Dege and Brown 2004, Table 3). High spring outflows transport larvae and juveniles farther downstream than low flows, but both life stages are centered well above X_2 in spring and their distributions shift toward X_2 in summer (Dege and Brown 2004). Extremely high outflow events can carry some delta smelt downstream out of rearing areas in the west Delta and Suisun Bay and into San Pablo Bay, such high outflows generally result in lower delta smelt abundance. In reviewing periods of high juvenile abundance, Delta residence time increased, thus prolonging exposure to higher water temperatures and increased risk of entrainment at the State and Federal pumping facilities, when Delta outflow was low (Moyle 2002) (Kimmerer 2002; Kimmerer et al. 2009). Delta smelt are zooplanktivores and calanoid copepods are a major prey type; *Eurytemora affinis* is an important food of larvae and small juveniles in spring, and the introduced *Pseudodiaptomus forbesii* becomes the dominant food in summer (Lott 1998, Nobriga 2002).

Population Abundance and Relationship to Flow

Multiple factors have been identified as potentially responsible for decline in delta smelt abundance including, but not limited to, non-optimal flows, low food supply, and entrainment (DFG, 1992b, Moyle 2002; feyrer et al. 2007). Unlike several other estuarine fishes, Delta smelt abundance does not respond to freshwater outflow during springtime (Stevens and Miller 1983, Kimmerer 2002a). Delta smelt distribution is influenced by outflow through its influence on the location of X_2 (Moyle et al. 1992, Dege and Brown 2004). Their loss of entrainment is also influenced by outflow through its influence on X_2 (Kimmerer 2008). Outflows that locate X_2 in Suisun Bay (mean April through July location) produce the highest delta smelt abundance levels, however, low abundance has also been observed under the same conditions, which indicates several mechanisms must be operating (Jassby et al. 1995). Although outflow did not positively affect delta smelt abundance, outflow did have significant positive effects on several measures of delta smelt habitat (Kimmerer et al. 2009), and spring outflow significantly increased spring abundance of *E. affinis* (Kimmerer 2002a), an important delta smelt prey item.

Delta smelt population abundance is measured in the 20-mm Survey (spring-summer, the Summer Townet Survey, and the FMWT Survey for larval, juvenile, and sub adult fish (Kimmerer et al. 2009.) All three indices indicate that delta 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 the combination of flow (habitat changes), export pumping, food limitation, and introduced species that delta smelt are exposed to.

Three types of flow have been hypothesized to affect delta smelt abundance. These are spring and fall Delta outflow and net OMR reverse flow.

Fall Delta outflow criteria for protection of delta smelt are presented in Table 9. The primary purpose of a fall Delta outflow criterion is to increase the quality and quantity of rearing habitat for delta smelt (Feyrer et al. 2007; Feyrer et al. in revision). Rearing habitat suitability increases when the fall LSZ is downstream of the confluence of the Sacramento and San Joaquin rivers. This corresponds to Delta outflows greater than about 7,500 cfs between September and November, which would have to be achieved by release of water from upstream reservoirs in most years. Grimaldo et al. (2009) found that X_2 was a predictor for salvage of adult delta smelt at the intra-annual scale when net OMR flows were negative. Moving X_2 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 as cited in SWRCB 2010). The USFWS (2008) recommended in their Biological Opinion that the LSZ be maintained in Suisun Bay 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 resources remained for steelhead and salmon and because these are the years in which SWP and CVP operations have most significantly affected fall conditions (USFWS 2008).

The NAS (21010) review panel concluded that the fall X2 criteria is conceptually sound, but expressed concern about the uncertainty associated with its potential benefits. DFG agrees with the USFWS and the NAS review panel 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. Until additional studies are conducted demonstrating the importance of fall X_2 to the survival of delta smelt, additional fall flows, beyond those stipulated in the fall X_2 criteria, for the protection of delta smelt are not recommended if they will compete with preservation of cold water pool resources needed for the protection of winter-run salmon.

Table 9. Summary of the Recommendations for Delta Outflows to Protect Delta Smelt (SWRCB 2010)

	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 Opinion[1]	AN									7000 [4]			
	W									12400			
EDF	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 Opinion flows shown for comparative purposes.

[2] All water year types - Increase to 6000 if the December Eight River Index is > than 800 thousand acre-feet (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] USFWS Opinion (RPA concerning Fall X_2 requirements [pp282-283] - improve fall habitat [quality and quantity] for delta smelt) (references USFWS 2008, Feyrer *et al* 2007, Feyrer *et al* in revision) - September-October in years 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 X_2 no greater than 74 km and 81 km in Wet and Above Normal years, respectively. During any November when the preceding water year was wet or above normal, as defined by Sacramento Basin 40-30-30 index, all inflow into the CVP/SWP reservoirs in the Sacramento Basin shall be added to reservoir releases in November to provide additional increment of outflow from Delta to augment Delta outflow up to the fall X_2 of 74 km and 81 km for wet and above normal water years, respectively. In the event there is an increase in storage during any November 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. Summary of the Recommendations for Net OMR Flows to Protect Delta Smelt (SWRCB 2010)

	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 exports to inflow ratios											
USFWS - Opinion	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 cfs											>-1500 cfs

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

[2] USFWS Opinion - RPA re: net OMR flows. Component 2 - Larvae/juveniles - action starts once temperatures hit 12˚ C at three Delta monitoring stations or when spent female is caught. Net OMR flow range between -1250 and -5000 cfs determined using adaptive process. OMR flow restrictions can begin in late February and continue until June 30 or when Delta water temperatures reach 25˚C, whichever comes first. (pp. 280-282.)

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

Net negative OMR flows can affect delta smelt by pulling them into the central Delta where they are at risk of entrainment in the SWP and CVP pumps. Entrainment of delta smelt and other pelagic species increases as net OMR flows become more negative (Grimaldo et al. 2009; Kimmerer 2008). Delta smelt are at risk as juveniles in the spring and as adults between the fall and early spring as they move upstream to spawn. Salvage of age-0 delta smelt at the SWP/CVP fish collection facilities at the intra-annual scale has been found to be related to the abundance of these fish in the Delta, while net OMR flows 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 net negative OMR flows (Grimaldo et al. 2009). PTM results suggest that entrainment is a function of both river inflows and exports, which are the fundamental variables that deine the hydrodynamic "footprint of the water project (Kimmerer and Nobriga 2008). Particle entrainment increased as a logarithmic function of increasing net negative OMR flows and decreases in river inflows (Kimmerer 2008). The highest entrainment was observed at high net negative OMR flows and low inflows. PTM results suggest that entrainment losses may have been as high as 40 percent of the total delta smelt population in some recent years..

Field investigations support some of the spring PTM results. Gravid females and larvae are present in the Delta as early as February (Bennett 2005). However, analysis of otolith data on individuals collected later in the year by Bennett et al. (unpublished data as cited in SWRCB 2010) show that few of the early progeny survived if spawned prior to the VAMP time period (typically April 15 to May 15). The hydrodynamic data showed high net negative OMR flows in the months preceding and after the VAMP, leading the researchers to conclude that high winter and early spring net negative OMR flows were selectively entraining the early spawning and 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."

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 unimodal, suggesting that migration is a large population-level event, as opposed to being intermittent or random (DOI 1 as cited in SWRCB 2010). 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 identifies turbidity criteria which 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 as cited in SWRCB 2010). Managing OMR flows to thresholds at which entrainment or population losses increase rapidly, represents a strategy for providing additional protection for adult delta smelt in the winter (DOI 1 as cited in SWRCB 2010). The USFWS Biological Opinion identified the lower net OMR flow threshold as negative (-) 5000 cfs based on observed OMR flow 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 flow threshold is appropriate because it is the level where population losses consistently exceed 10 percent (USFWS 2008, DOI 1 as cited in SWRCB 2010). 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 net OMR flows to be more positive than -5000 cfs to reduce high entrainment. If the majority of the population migrates up the lower Sacramento River into the north Delta, a smaller entrainment risk is presumed. This would allow for OMR flows to be more negative than -5000 cfs for an extended period of time, or until conditions warrant a more protective OMR flow (DOI 1 as cited in SWRCB 2010).

The USFWS Biological Opinion for delta smelt also includes net negative OMR flow restrictions to protect both spawning adult and outmigrating young. Component 1 of the Biological 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 delta smelt after migration, but prior to spawning, by restricting net OMR flows to between -1250 and -5,000 cfs based on the recommendations of the Smelt Working Group. Component 2 is to protect larval and juvenile fish. Component 2 actions start once water temperatures reach 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 June 30 or when the 3-day-mean water temperature at Clifton Court Forebay is 25^{o}C. The Smelt Working Group is tasked to make recommendations on the specific OMR flow restrictions between -1250 and -5000 cfs.

The NAS (2010) reviewed the USFWS Biological Opinion OMR flow restrictions 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 negative OMR flows on delta smelt is likely to be greatest during time periods with high negative OMR flows and low Sacramento River outflow (DFG 2009b; Kimmerer and Nobriga 2008). 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.

Minimizing net negative OMR flows during periods when adult delta smelt are migrating into the Delta could also substantially reduce mortality of this 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. 2009a; USFWS Biological Opinion, Component 1, Action 1). This supports a recommendation that net OMR flows be more positive than -5000 cfs during the period between December and March. Additional OMR flow restrictions may be warranted during periods when a significant portion of the adult delta smelt population migrates into the south or central Delta as detected by the Spring Kodiak Trawl (http://www.dfg.ca.gov/delta/projects.asp?ProjectID=SKT). In such instances, the determination of specific thresholds should be made through an adaptive approach involving the Smelt Working Group 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. DFG agrees with the State Water Board and the NAS (2010) that the data, as currently available, do not permit a confident assessment of the threshold OMR flow values nor of the overall benefit to the delta 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, net OMR flow criteria need to be accompanied by a strong monitoring program and adaptive management to adjust OMR flow criteria as more knowledge becomes available.

Like every fish species living in the Delta that has been evaluated, Delta smelt survival is positively correlated with zooplankton abundance (Kimmerer 2008; Grimaldo et al., 2009b). A recent analysis (SFWC 1 as cited in SWRCB 2010) also shows a positive relationship between FMWT delta smelt indices and the previous spring and summer abundance of *Eurytemora* and *Pseudodiaptomus.* There are several hypotheses for the cause of the decline in zooplankton abundance. First, zooplankton abundance in Suisun and Grizzly bays, prime habitat for delta smelt, declined after the introduction of the invasive clam *Corbula. Corbula* is thought to eat copepod nauplii, and compete directly with copepods and other zooplankton for phytoplankton food. A second hypothesis is that changes in nutrient loading and nutrient form in the Delta that result from the SRWTP 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 accepted, both of these hypotheses could indirectly result in slower growth and/or lower densities of delta smelt.

OMR flow criteria are presented 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 Delta outflow. The OMR flow restrictions are an extension of the criteria for longfin smelt. In addition, criteria for OMR flows are also recommended to be more positive than -5,000 cfs between December and February of all water year types to protect upstream migrating adult delta smelt. The -5,000 cfs criteria may need to be made more protective in years when delta smelt move into the central or south Delta to spawn. The more restrictive OMR flows would be recommended after consultation with the USFWS's Smelt Working Group. In the absence of any other specific information, the existing 2006 Bay-Delta Plan Delta outflow objectives for July through December are needed to protect delta smelt.

Table 11. Net OMR Flows for the Protection of Delta Smelt (SWRCB 2010)

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

DFG Recommended Biological Objectives for Delta Smelt

- Provide low salinity habitat for delta smelt in Suisun Bay by maintaining X_2 between 74 km and 81 km between September and November in wet and above normal years.

- At no time should Old and Middle River flows be more negative than -5,000 cfs between December and February.

- For critical and dry years, at no time should Old and Middle River flows be more negative than -1,500 cfs between March and June.

- Develop a comprehensive life-cycle model for delta smelt that would allow for assessment of population level impacts associated with entrainment.

DFG Recommended Flow Criteria for Delta Smelt

Category	Function	Flow (cfs)	Year Type	Months												Citation
				O	N	D	J	F	M	A	M	J	J	A	S	
Delta Outflow	Increase quantity and quality of habitat for delta smelt promotes variability of fall flows and habitat conditions in above normal and wet water year types; may result in improved conditions for delta smelt	7100 ($X_2 \leq$ 81 km) to 12400 ($X_2 \leq$ 74 km)	AN W	1	1										1	
Old and Middle Rivers	Reduces entrainment of larval / juvenile delta smelt and provide benefits to other desirable species	> -1,500 cfs	C, D						1	1	1	1				
	Needed to reduce entrainment of adult delta 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.	> -5,000 cfs	All			1	1	1	1	1	1	1				

1 = criteria recommended for the whole month

7.2.4 Starry Flounder

Status

Not listed – CESA and FESA

Life History

Starry flounder (*Platichthys stellatus*) is native to the San Francisco Estuary and ranges from Santa Barbara, California northward to Arctic Alaska and in the western Pacific south to the Sea of Japan (Miller and Lea 1972). Within that range juvenile and adult habitats are segregated, with juveniles seeking shallow, fresh to brackish water of bays and estuaries to rear, and adults primarily inhabiting coastal marine waters (Haertel and Osterberg 1967, Bottom et al. 1984, Wang 1986, Baxter 1999c). The starry flounder, though not targeted, shows up commonly in both recreational and commercial fisheries in central and northern California (Haugen 1992, Karpov et al. 1995).

Spawning occurs between November and February and generally takes place over shallow coastal marine areas, often near river and slough mouths (Orcutt 1950). Eggs and larvae are pelagic and found high in the water column (Orcutt 1950, Wang 1986). Larvae are pelagic for about 2 months before settling to the bottom at about 7 mm standard length (see Baxter 1999c). During this pelagic period, larvae depend upon favorable ocean currents to transport them to or keep them near their estuarine nursery areas prior to settlement. Transforming larvae and small juveniles migrate from coastal marine waters to brackish and fresh waters where they rear for their first 1-3 years of life (Haertel and Osterberg 1967, Bottom et al. 1984, Wang 1986, Baxter 1999c). Juveniles initially seek shallow, relatively warm brackish and freshwaters to rear, and move to more saline water as they grow, but generally remain within estuaries through at least their second year of life (Haertel and Osterberg 1967, Bottom et al. 1984, Wang 1986, Baxter 1999c). Maturity is reached at the end of their 2nd (males) or 3rd- 4th years of life (females) (Orcutt 1950) by which time starry flounder is at most a seasonal visitor to the San Francisco Estuary. The starry flounder is believed to be an estuarine dependent species (Emmett et al. 1991).

Population Abundance and Relationship to Flow

Starry flounder abundance in the estuary is significantly and positively correlated to March through June (or a subset of months) outflow, when larvae and juveniles are locating the estuary, immigrating and beginning to rear (DFG 1992a, Jassby et al. 1995, Kimmerer 2002a and 2002b, Kimmerer et al. 2009). There are several direct mechanisms by which outflows can enhance starry flounder abundance: (1) outflows can provide chemical cues to larvae and juveniles to facilitate locating estuarine nursery habitat; (2) high outflows generate bottom-oriented upstream-directed gravitational currents that assist immigration; (3) flows enhance the area of low salinity habitat selected by young starry flounder (see DFG 1992a). Indirectly, high river flows strongly correlate with the abundance of the bay shrimp, *Crangon franciscorum*, which is an important food source for starry flounder (DFG 1992a).

DFG recommends maintaining X_2 between 64 and 75 km between March and June. This corresponds to an average outflow of 11,400 to 26,815 cfs (DFG 2010a, b). This net Delta outflow criterion is similar to those proposed for the protection of longfin smelt, delta smelt, and *Crangon franciscorum.*

DFG Recommended Biological Objectives for Starry Flounder

- Provide low salinity habitat for starry flounder in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between March and June.

- Depending on year type, provide sufficient water flow to increase abundance of starry flounder to pre-1987 abundance levels.

DFG Recommended Flow Criteria for Starry Flounder

Category	Function	Flow (cfs)	Year Type	Months					
				J	F	M	A	M	J
Delta Outflow	Promote increased abundance for starry flounder	11400 – 29200 (X_2 between 64 km and 75 km)	All			1	1	1	1

1 = criteria recommended for the whole month

7.2.5 American Shad

Status

Not listed – CESA and FESA

Life History

The American shad (*Alosa sapidissima*) is an anadromous fish, introduced into California in the late 1870's, that has become an important sport fish within the San Francisco Estuary watershed. American shad range from Alaska to Mexico and use major rivers between British Columbia and the Sacramento watershed for spawning (Moyle 2002).

American shad adults, at 3-5 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 7 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 3-12 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 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 Relationship to Flow

American shad year class strength correlates positively with freshwater outflow during spawning and nursery periods April through August with the highest correlations April through June (Steven and Miller 1983). This relationship has continued into recent years (Kimmerer 2002a, Kimmerer et al. 2009). Although the outflow abundance relationship is based on Delta outflow, and transport to and through the Delta comprise important components of the relationship, actual flows in spawning tributaries are also important for both attraction flow (Stevens et al. 1987) and for proper incubation and early rearing conditions.

In addition, Kimmerer et al. (2009) found that American shad had a habitat relationship (defined by salinity and Secchi depth) to X_2 that appeared consistent with its relationship of abundance to X_2 (i.e., slopes for abundance versus X_2 and habitat versus X_2 were similar), which provides some support for the idea that increasing quantity of habitat could explain the X_2 relationship for this species (a possible causal mechanism for the abundance versus X_2 relationship). Stevens and Miller (1983) determined that the apparent general effect of high flow on all of the species they examined, including American shad, was to increase the quality and quantity of nursery habitat and more widely disperse the young fish, thus reducing density-dependent mortality.

Table 12: 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	--	--	--	X_2[1] –64 km to 75 km (~11400 – 29200 cfs)			--	--	--	--	--	--

[1] For this species, X_2 is a surrogate for tributary and mainstem river inflows to the Delta that support egg and larval survival. Source: DFG 2010a.

DFG Recommended Biological Objective for American Shad

- Provide low salinity habitat for American shad in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between April and June.

DFG Recommended Flow Criteria for American Shad

Category	Function	Flow (cfs)	Year Type	Months					
				J	F	M	A	M	J
Delta Outflow	Promote increased abundance for American shad	11400 – 29200 (X_2 between 64 km and 75 km)	All				1	1	1

1 = criteria recommended for the whole month

7.2.6 Bay Shrimp

Status

Not listed – CESA and FESA

Life History

Six species of Caridean shrimp are common in the San Francisco Estuary: *Crangon franciscorum, C. nigricauda, C. nigromaculata, Heptacarpus stimpsoni, Palaemon macrodactylus, and Exopalaemon modestus*. The 3 species of *Crangon* and *Heptacarpus* are native while *Palaemon* and *Exopalaemon* are introduced. The life histories, predators, prey, and salinity and temperature preferences of *Crangon*, *Heptacarpus*, and *Palaemon* were reviewed in DFG (1987a) and Hieb (1999).

Crangon spp. are commonly referred to as "Bay shrimp" or "grass shrimp" and are fished commercially by trawl fishermen in the lower estuary, downstream of Suisun Bay. Bay shrimp are primarily sold as bait for sport fishermen and *C. franciscorum* is targeted because of its relatively large size. Earlier in this century, when there was a large market for dried shrimp, over 3 million pounds per year were landed (Reilly et al. 2001). Landings have declined over the past 3 decades, averaging 140,000 pounds per year in the 1980s but only 65,000 pounds from 2000-2008 (Reilly et al. 2001, DFG 2000-2008 California Commercial Landings).

Crangon franciscorum ranges from southeastern Alaska to San Diego and is the dominant caridean shrimp in most Pacific coast estuaries. It is an estuary-dependent species that does not rear in the ocean. Larvae hatch from eggs carried by the females in the higher salinity waters of the lower estuary in winter. Small juveniles (5-10 mm total length) migrate upstream to the shallow brackish water nursery area in spring, where they grow for 4 to 6 months, and mature shrimp migrate downstream to higher salinity waters to complete the life cycle (Hatfield 1985). *C. franciscorum* mature at one year and have a short life span, with males living one to 1.5 years and females 1.5 to two years. Some females hatch more than one brood of eggs during a breeding season.

Juvenile *C. franciscorum* were most common in San Pablo and Suisun Bays during years with high freshwater outflow and their center of distribution moved upstream to Honker Bay and the lower portions of the Sacramento and San Joaquin rivers during low outflow years (DFG 1992a, Hieb 1999) (Figure 5). In the past 3 decades, the abundance of juvenile *C. franciscorum* was lowest in 1992, at the end of a prolonged drought, and highest in the late 1990s (Figure 5).

Population Abundance and Relationship to Flow

There is a strong positive relationship between the abundance of juvenile *C. franciscorum* and spring Delta outflow (Hatfield 1985, DFG 1992a, Kimmerer 2002a, Hieb 2008) that has continued in recent years (Figure 6).

Freshwater outflow from the Delta affects *C. franciscorum* at every life stage. With higher outflows, mature shrimp move further downstream and early stage larvae are transported to Central Bay and the nearshore coastal area. We hypothesize that freshwater outflow creates salinity gradients that are used by late-stage larvae and small juveniles to identify the mouth of the estuary and cue their upstream migration from the nearshore coastal area to the brackish-water nursery area (DFG 1992a, Kimmerer 2002a, Kimmerer et al. 2009). Tidal and non-tidal landward bottom currents aid this migration to the nursery area and one of the non-tidal components, gravitational circulation, increases with increased freshwater outflow (Smith 1987, Monismith et al. 2002). Freshwater outflow also affects the size and location of the nursery area, the abundance of predators and food organisms, and the timing of the downstream movement of mature shrimp.

The period from March to May was selected as the time when freshwater outflow is most critical in the establishment of a strong year class of *C. franciscorum* in the estuary. Most late-stage larval and small juvenile *C. franciscorum* migrate into the estuary and upstream to the nursery area between April and June and then begin a period of rapid growth. In years with low freshwater outflow the salinity gradient moves upstream and there is much less shallow brackish-water habitat then in high outflow years (DFG 1992a). The size of the brackish-water nursery area is important to juvenile

C. franciscorum for several reasons, including increased food and space, reduced inter- and intra-specific competition, and reduced predation (DFG 1992a).

Crangon franciscorum has evolved to use San Francisco Estuary as a nursery area in the spring and early summer when freshwater outflow results in a salinity gradient that helps immigrating late-stage larvae and small juveniles identify the mouth of the estuary and cues their upstream migration. Freshwater outflow also produces strong landward bottom (gravitational) currents that aids this upstream migration and creates a large area of shallow brackish water in San Pablo and Suisun bays used for rearing (DFG 1992a).

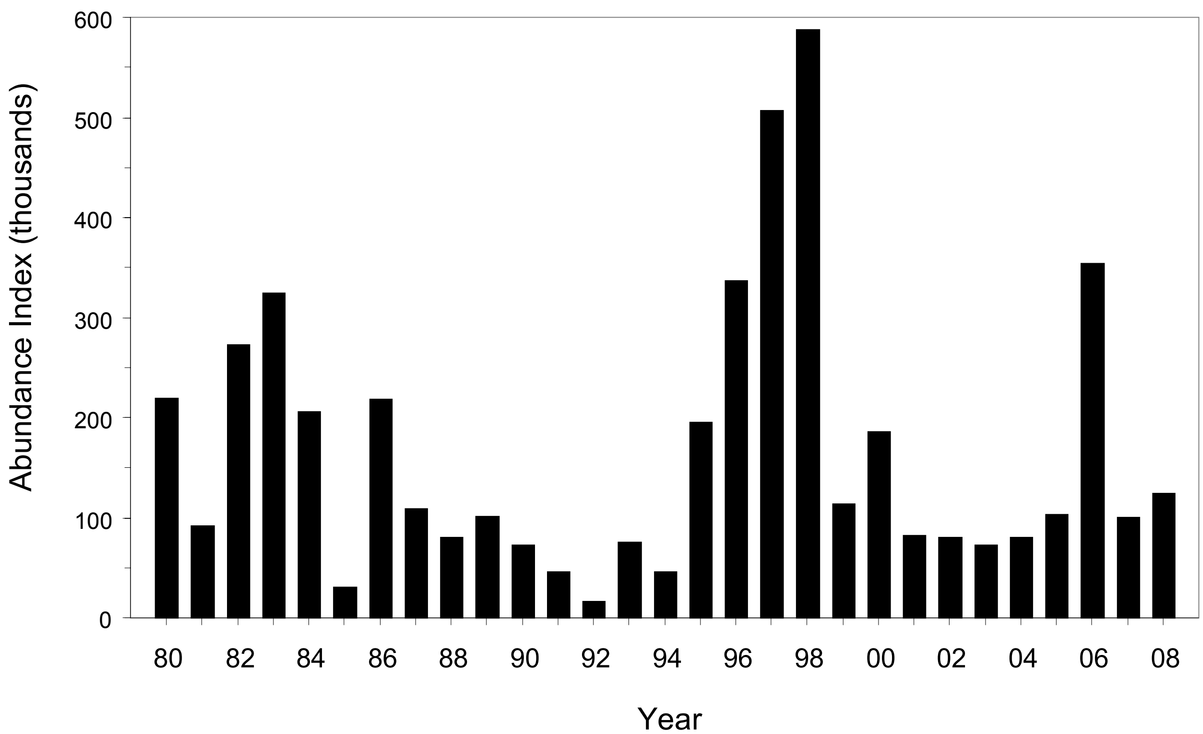

Figure 5: Annual abundance of juvenile *Crangon franciscorum* from DFG's San Francisco Bay Study, 1980-2008.

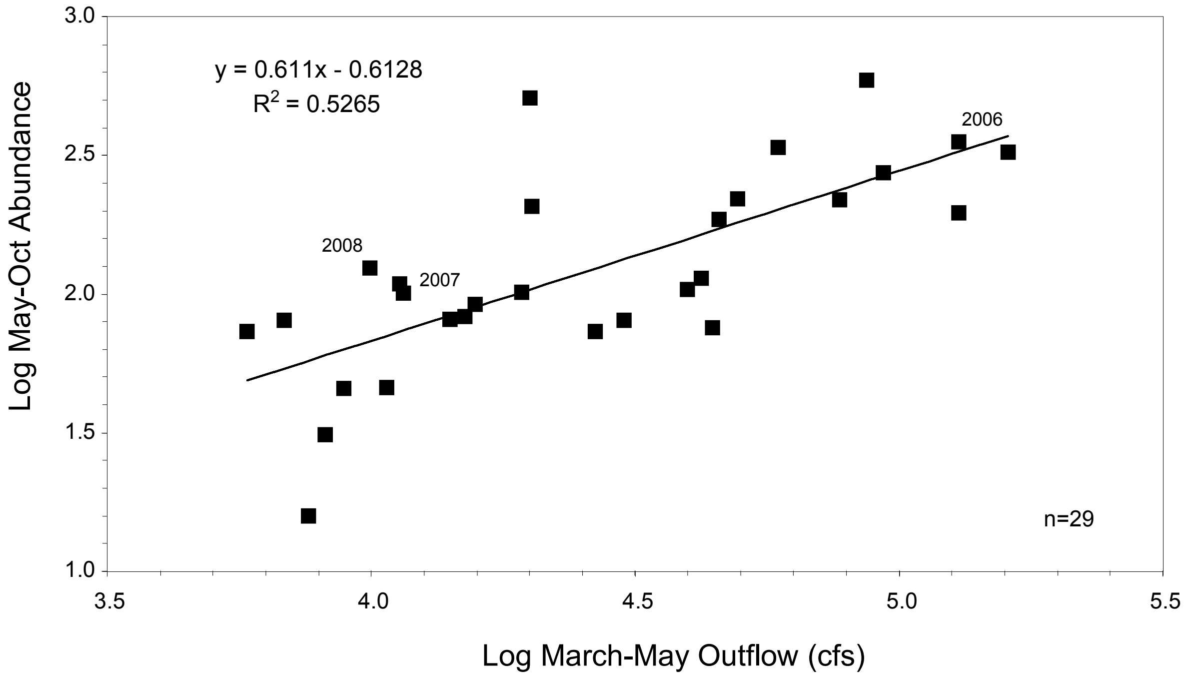

Figure 6: Annual abundance index of juvenile *Crangon franciscorum* from DFG's San Francisco Bay Study vs. mean March to May monthly outflow at Chipps Island, 1980-2008.

TBI/NRDC analyzed the productivity of *C. franciscorum* as a function of net Delta outflow between March and May (TBI/NRDC 2 as cited in SWRCB 2010). The analysis suggests that estuary populations increased in about half of all years when flows between March and May were approximately 5 million acre-feet (MAF), 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. DFG recommends net Delta outflow criterion is 11,400 to 29,200 cfs between March and May of all water years to aid immigration of late stage larvae and small juveniles.

Table 13. Summary of the Recommendations for Delta Outflows to Protect Bay Shrimp (SWRCB 2010)

	Water Year	Feb	Mar	Apr	May	Jun
TBI/NRDC	Most years		28,000			
DFG	all		11,400 to 29,200			

DFG Recommended Biological Objective for Bay Shrimp

- Provide shallow water habitat for bay shrimp in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between March and May.

DFG Recommended Flow Criteria for Bay Shrimp

Category	Function	Flow (cfs)	Year Type	Months					
				J	F	M	A	M	J
Delta Outflow	Promote increased abundance of Crangon franciscorum (bay shrimp)	11400 – 29200 (X_2 between 64 km and 75 km)	All			1	1	1	

1 = criteria recommended for the whole month

7.2.7 Zooplankton

Status

Not listed – CESA and FESA

Life History

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-October) increased significantly as X_2 moved downstream (mean March-November location, Kimmerer 2002a. Table 3). 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 ppt) 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 dramatically in summer and fall (Hennessy 2009). After 1987, *E. affinis* spring abundance (March-

May) has significantly increased as spring X_2 has moved downstream (Kimmerer 2002a). Relative abundance in recent years is highest in spring and persistence of abundance is related to spring outflow. As flows decrease in late spring, abundance decreases to extremely low levels throughout the Estuary (Hennessey 2009).

Placement of X_2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry (DFG 2010a). Maintaining X_2 between 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 14).

Table 14. Summary of the Delta Outflow Recommendations to Protect Zooplankton Species Including *E. affinis* (TBI/NRDC 2 as cited in SWRCB 2010)

Species	Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun
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

DFG Recommended Biological Objective for Zooplankton

- Provide low salinity habitat for zooplankton in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between January and June.

DFG Recommended Flow Criteria for Zooplankton

Category	Function	Flow (cfs)	Year Type	Months					
				J	F	M	A	M	J
Delta Outflow	Promote increased abundance of zooplankton, specifically calanoid copepods	11400 – 29200 (X_2 between 64 km and 75 km)	All	1	1	1	1	1	1

1 = criteria recommended for the whole month

7.2.8 Sacramento Splittail

Status

Species of Special Concern – DFG
Candidate Threatened – FESA (Under review)

Life History

The Sacramento splittail (*Pogonichthys macrolepidotus*) is a cyprinid native to California that can live 7-9 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). 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). 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). After spawning the adult fish move back downstream. 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 (Moyle et al. 2004, Ribeiro et al.2004).

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 2 to 3 years. In the Yolo Bypass, two flow components appeared necessary for substantial splittail production (Feyrer et al. 2006a): (1) inundating flows in winter (January-February) to stimulate and attract migrating adults; and (2) sustained floodplain inundation for 30 or more days March through May or June to allow successful incubation through hatching (3-7 days, see Moyle 2002) and extended rearing until larvae are competent swimmers (10-14 days; Sommer et al. 1997) and beyond to maximize recruitment (see Table 2).

Large-scale spawning and juvenile recruitment occurs only in years with significant protracted (≥30 days) floodplain inundation, particularly in the Sutter and Yolo bypasses (Meng and Moyle 1995, Sommer et al. 1997, Feyrer et al. 2006a). 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).

Population Abundance and 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). Splittail abundance was highest when the Yolo Bypass remained flooded for 50 days or more (Meng and Moyle 1995). Since Feyrer et al. (2006a) observed adult migrations stimulated by flow and estimated spawning could occur as early as January, January is included in recommendations for outflow (Table 2). Floodplain inundation during the months of March, April, and May appears to be most important (see Wang 1986 and 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. PWA and Opperman (2006) have defined a floodplain activation flow on the Sacramento River.

Age-0 splittail 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 X_2 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 X_2 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 X_2 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 X_2 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 X_2 -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).

<u>Delta Inflow</u> – Splittail depends on inundation of off-channel areas for successful spawning and recruitment. 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.

Yolo Bypass Inundation – 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, EDF 1, TBI/NRDC 3 as cited in SWRCB 2010; 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 percent of years (DOI 1 as cited in SWRCB 2010, Sommer et al. 2001a, Feyrer et al. 2006a) with inundation occurring as early as October and as late as June, with a 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 enhance 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 (Sommer et al. 2001b), though the Sutter Bypass and river margin flood terraces remain connected in reaches upstream of the Delta (see Feyrer et al. 2005).

Many recommendations concerning the magnitude and duration of floodplain inundation along the Sacramento River, lower San Joaquin River, and within the Yolo and Sutter bypasses are available (AR/NHI 1, DOI 1, EDF 1, SFWC closing comments, TBI/NRDC 3 as cited in SWRCB 2010; DFG 2010). 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 as cited in SWRCB 2010).

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 huge flows given the typical runoff patterns during those year types (AR/NHI 1 as cited in SWRCB 2010). It is probably 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 as cited in SWRCB 2010).

The BDCP is evaluating structural modifications to the Fremont Weir (e.g., notch the 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 as cited in SWRCB 2010) and AR/NHI (AR/NHI 1 as cited in SWRCB 2010) have developed 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 as well as the resulting spawning and rearing of splittail and rearing of juvenile spring-run Chinook salmon migrating out of Butte Creek.

The NMFS 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 as cited in SWRCB 2010).

OMR 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 are intended to protect salmon, delta smelt, and longfin smelt populations, as well as restrictions stipulated in the Opinions (NMFS 3 as cited in SWRCB 2010; USFWS 2008), by reducing the number of splittail entrained at the export facilities.

Table 15. 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				--	--	--	--	--	--	--

DFG Recommended Biological Objective for Sacramento Splittail

Based on the forgoing information for splittail, the following biological objective is proposed:

- To favor Sacramento splittail recruitment, during above normal and wet years, once floodplain inundation has been achieved based on runoff and discharge for 10 days between March and May, maintain continuous inundation for at least 30 days in the Yolo Bypass and at suitable locations in the Sacramento River or in the San Joaquin River.

DFG Recommended Flow Criteria for Sacramento Splittail

Category	Function	Flow (cfs)	Year Type	Months				
				J	F	M	A	M
Floodplain	Salmon smolts also benefit from increased food in floodplain habitats.	≥ 30 day floodplain inundation[6]	AN W			1	1	1

1 = criteria recommended for the whole month

7.3 Other Factors

7.3.1 The Natural Hydrograph

Water flow into and through the Delta should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the flow criteria expressed in cfs should be implemented recognizing the within and between year variability inherent in the natural flow conditions. 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. Flows should be at levels that maintain flow paths and east-west salinity gradients through the Delta. 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.

DFG Recommended Biological Objective

Based on the forgoing, the following biological objectives are recommended:

- To the extent possible, flow criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes.
- Delta inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow unless otherwise necessary.

7.3.2 The Effect of Contaminants on Fish

It has been hypothesized that ammonia discharged from wastewater treatment facilities and other sources might be responsible for declines in delta smelt by causing acute toxicity. The following is summarized from Foe (2009).

Acute toxicity tests have been completed with delta smelt (Werner et al. 2009). The results of these tests show that ammonia levels in the Sacramento River below the

[6] Flows needed to inundate floodplain habitat vary substantially depending on Sacramento River, San Joaquin River, and in-Delta floodplain habitat (e.g., Fremont Weir in the Yolo Bypass flow can range from 56,000 cfs (existing crest) to 23,100 cfs (the proposed notch) (AR/NHI 1 as cited in SWRCB, 2010)).

SRWTP are not acutely toxic to delta smelt. Ammonia concentrations in the Sacramento River do not exceed the chronic concentrations in U.S. EPA ammonia toxicity criteria (Engle et al. 2009).

Ammonia concentrations are higher in the Sacramento River below the SRWTP and in the Delta than in Suisun Bay. Research by Dugdale, Wilkerson, and Parker of SFSU Romberg Tiburon Center showed that ammonia from the SRWTP reduces phytoplankton nitrate uptake. In contrast to Suisun Bay, however, it appears that river algae are able to take up and grow on ammonia downstream of the SRWTP. Algae in the Sacramento River upstream of Rio Vista can grow equally well on ammonia or nitrate. In contrast, it appears algal growth in Suisun Bay is suppressed by ammonia and phytoplankton biomass never surpasses the range associated with zooplankton food limitation.

In Foe's (2009) summary, no evidence is available demonstrating that ammonia concentrations are causing beneficial use impairments in the Sacramento River or Delta. Ammonia concentrations in the River and Delta appear to be too low to produce acute toxicity to delta smelt or the invertebrate copepods *E. affinis* and *P. forbesi*.

Recent new work (Glibert, 2010) shows correlations between nutrient concentrations and zooplankton, nutrients and fish abundance, and other relationships. These correlations were developed using cumulative summation-converted data (a statistical approach that compares a stable average to observed deviations from that average). Glibert (2010) concludes that nutrients are a major factor in controlling ecosystem function in the Delta. At present, a specific biological objective for nutrients that impacts ecosystem function is not proposed.

DFG Recommended Biological Objective

Based on the forgoing information for nutrients, the following biological objective is recommended:

- Prevent the discharge of pollutants at concentrations that are acutely or chronically toxic to aquatic life.

7.3.3 Cold Water Pool

The criteria contained in this report should be balanced by the 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. 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 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 species of concern, especially in the face of future climate change.

DFG Recommended biological objective

Based on the forgoing information for cold water pool, the following biological objective is recommended:

- Balance the need for cold water storage for upstream salmon habitat protection with the need for Delta outflow in late winter through spring.

8 Biological Goals and Objectives Comparison

This section presents a comparison on the proposed biological goals and objectives with goals and objective developed for or being developed by other projects.

8.1 Ecosystem Restoration Program

The ERP Conservation Strategy (Administrative Draft) provides a comprehensive series of goals and objectives to restore, enhance, and protect terrestrial and aquatic resources of the Delta. These goals are general in scope and were used to form the foundation of the flow-related biological goals presented in this report. The flow-related goals and objectives presented in this report augment the ERP goals and objectives.

8.2 BDCP and the Logic Chain

As described in the background section, the Bay Delta Conservation Plan (BDCP) is intended to increase water supply reliability while contributing to the recovery of threatened, endangered, and otherwise covered species that occur in the Delta. It has been proposed that to capture the underlying rationale and assumptions of the conservation measure included in BDCP that a “Logic Chain” (BDCP 2010) be used. The logic chain would establish goals, specific objectives, and benchmarks against which progress of BDCP could be assessed. The idea is that if the goals and objectives of BDCP can be clearly articulated then there would be greater likelihood of success.

The Logic Chain has been peer reviewed (Dahm et al. 2010) and, as part of the peer review, suggestions are made for improving the approach. One major comment was that BDCP’s contribution to species recovery must be linked clearly to the needs of listed species. When available, recovery plans provide the needed goals and objectives but in the absence of these plans agencies should provide the needed goals and objectives. As described in Dahm et al. (2010), the contribution to recovery by BDCP should be directed toward meeting the recovery or species goals.

So far, draft goals and objective for BDCP specifically have been developed for two covered species: winter-run Chinook salmon and longfin smelt. These objectives will provide more specificity on expectations for species recovery. The goals and objectives presented in this report are less specific than the draft goals and objectives being discussed in the BDCP process.

9 Summary

9.1 Findings

9.1.1 Water flow is a major determinant of species abundance and fish production

In general, the data and information available indicates:

1. Recent Delta flows are insufficient the support native Delta fishes in habitats that now exist in the Delta.

2. Water flow stabilization harms native species and encourages non-native species.

3. For many species, abundance is related to water flow timing and quantity (or the placement of X_2).

4. For many species, more water flow translates into greater species production or abundance.

5. Species are adapted to use the water resources of the Delta during all seasons of the year, yet for many, important life history stages or processes consistently coincide with the winter-spring seasons and associated increased flows because this is the reproductive season for most native fishes and the timing of outmigration of most salmonid fishes. Examples:

   A. Propagation of splittail depends on the annual winter-spring flooding of the floodplains.
   B. Salmon life stages in the Sacramento River depend on certain base and pulse flows.
   C. Salmon life stages in the San Joaquin River need spring outflow to transport smolts through the Delta.
   D. Spring pulse flows in the Mokelumne River and other eastside streams are needed to support localized in-Delta water quality, salmon migration, and floodplain inundation.
   E. Winter Delta outflow has a positive effect on delta smelt.
   F. Fish species are dependent on adequate water temperature in spawning and rearing areas upstream of the Delta and sufficient dissolved oxygen for egg incubation, juvenile development, rearing, smolting, and migration.

6. The source, quantity, quality, and timing of Central Valley tributary outflow affects the same characteristics of mainstem river flow to the Delta and interior Delta water flows. Flows in all three of these areas influence production and survival of Chinook salmon in both the San Joaquin River and Sacramento River basins.

7. Some invasive species negatively influence native species abundance. The best evidence is the negative effects of overbite clam and several species of aquatic plants. Certain flows in and through the Delta may influence these undesirable species.

8. Ammonia does not appear to be acutely or chronically toxic to delta smelt and other species. More research is needed on the effects of nutrients on Delta ecosystem and its foodweb.

9. The biological goals and objectives of ERP can serve as comprehensive goals and objectives for the environmental resources of the Delta.

9.2 Biological Goals and Objectives for Terrestrial and Aquatic Species

Recommended biological goals and objectives to protect terrestrial and aquatic species of concern in the Delta are listed below.

9.2.1 Terrestrial Species Biological Goals

- Achieve, first, recovery and then self-sustaining populations of the following at-risk native species dependent on the Delta, Suisun Bay and Suisun Marsh, with emphasis on valley elderberry longhorn beetle, Suisun ornate shrew, Suisun song sparrow, soft bird's-beak, Suisun thistle, Mason's lilaeopsis, Lange's metalmark butterfly, Antioch Dunes evening primrose, Contra Costa wallflower, and Suisun marsh aster.

- Contribute to the recovery of the following at-risk native species in the Bay-Delta estuary and its watershed: delta green ground beetle, giant garter snake, riparian brush rabbit, least Bell's vireo, California black rail, California clapper rail, bank swallow, western yellow-billed cuckoo, greater sandhill crane, Swainson's hawk, California yellow warbler, delta tule pea, delta mudwort, and delta coyote thistle.

- Protect and/or restore natural communities in the Bay-Delta Estuary and its watershed for ecological values such as supporting species and functional habitat types, and ecological processes.

9.2.2 Terrestrial Species Biological Objectives

- Expand suitable and occupied habitat for Mason's lilaeopsis by 100 linear miles and protect at least 90 percent of the currently occupied habitat including 90 percent of high quality habitat occurrences in the North, South, and East Delta and Napa River Ecological Management Units.

- Expand suitable and occupied habitat for Suisun marsh aster by 100 linear miles and protect at least 90 percent of the currently occupied habitat including 90 percent of high quality habitat occurrences in the North, South, and East Delta and Napa River Ecological Management Units.

- Maintain the current distribution and existing populations of Suisun thistle, establish 10 new populations, and increase overall population size tenfold.

- Maintain the current distribution and existing populations of soft bird's-beak and reestablish and maintain viable populations throughout its historic range.

- Continue protection of and expand the size of Antioch Dunes evening-primrose and Contra Costa wallflower populations; enhance and restore suitable habitat at and in the vicinity of the Antioch Dunes; and achieve recovery goals identified in the USFWS recovery plan for these species.

- Continue protection of and expand the site of the Antioch Dunes population of the Lange's metalmark butterfly; enhance and restore suitable habitat at and in the vicinity of the Antioch Dunes; and achieve recovery goals identified in the USFWS recovery plan.

- Maintain and restore connectivity among riparian habitats occupied by the valley elderberry longhorn beetle and within its historic range along the Sacramento and San Joaquin rivers and their major tributaries.

- Reestablish and maintain viable populations of the salt marsh harvest mouse throughout its historical range in the portion of the Bay-Delta located within the ERP Focus Area.

- Maintain current distribution and existing populations of the Suisun ornate shrew and reestablish and maintain viable species' populations throughout its historic range in the portion of the Bay Region within the ERP focus area.

- Protect the Caswell Memorial State Park population of the San Joaquin Valley Woodrat; protect, enhance, and expand the species' population in Caswell Memorial State Park; and improve habitat connectivity and genetic interchange among isolated populations.

- Maintain the current distribution and existing populations of the Suisun song sparrow and reestablish and maintain viable species' populations throughout its historic range in portions of the Bay and Delta Regions within the ERP focus areas.

- Maintain the current distribution and existing populations of the California black rail and reestablish and maintain viable populations throughout its historic range in portions of the Delta.

- Maintain the current distribution and existing populations of the California clapper rail, and reestablish and maintain viable populations throughout its historical range in the portion of the Bay Region within the ERP Focus Area.

- Protect, enhance, and increase habitat sufficient to support a viable breeding population of Swainson's hawk. The interim prescription is to increase the current estimated population of 1,000 breeding pairs in the Central Valley to 2,000 breeding pairs.

- Protect the population of riparian-brush rabbit in Caswell Memorial State Park; protect, enhance, and expand the species' Caswell Memorial Park population; and restore four additional self-sustaining populations in the Delta and along the San Joaquin River by 2020.

- Achieve recovery objectives identified in the Pacific Flyway Management Plan for the Central Valley population of greater sandhill cranes and Assembly Bill (AB) 1280.

- Maintain and enhance suitable riparian corridor migration habitats and restore suitable breeding habitat within the historic breeding range of California yellow warbler in the Central Valley.

- Achieve recovery objectives identified in the least Bell's vireo recovery plan in the Delta and ERP focus area.

- Protect existing suitable riparian forest habitat areas within the western yellow-billed cuckoo historic range and increase the areas of suitable riparian forest habitat sufficiently to allow the natural expansion of the Sacramento Valley population.

- For bank swallow, allow reaches of the Sacramento River and its tributaries that are unconfined by flood control structures (e.g., bank revetment and levees) to continue to meander freely, thereby creating suitable bank nesting substrates through bank erosion.

- Protect the existing population and habitat of giant garter snake within the Delta Region and restore, enhance, and manage suitable habitat areas adjacent to known populations to encourage, the natural expansion of the species.

- For delta green ground beetle, protect all known occupied habitat areas from potential adverse effects associated with current and potential future land uses and establish three additional populations of the delta green ground beetle within its current and/or historic range.

- For delta mudwort and delta tule pea, protect at least 90 percent of occupied habitat including 90 percent of high quality habitat throughout the range of these species to protect geographic diversity, and expand suitable and occupied habitat by 100 linear miles.

- Bring at least 10 of the largest extant, naturally occurring delta coyote-thistle populations found during surveys into permanent protected status and bring at least 50 percent of all extant populations and individuals under permanent protected status.

- Increase delta coyote-thistle habitat by 50 percent over existing extent. Increase individual populations by 25 percent over present existing conditions.

- Protect, enhance, and restore the habitat functions and values of wetlands and agricultural lands within the Delta and Suisun Marsh for waterfowl, shorebirds, and waterbirds as described in the 2006 Central Valley Joint Venture Implementation Plan.

- Protect, enhance, restore, and develop intertidal habitat and associated sub-tidal habitat within the Bay-Delta to improve habitat and food web support for species of concern.

9.2.3 Aquatic Species Biological Goals

- Halt species population declines and increase populations of ecologically important native species, as well as species of commercial and recreational importance, by providing sufficient water flow and water quality at appropriate times to propagate species life stages that use the Delta.

- Establish water flows through the Delta that will likely benefit particular species or ecosystem functions in a manner that is: (1) comprehensive, (2) not overly complex, and (3) encourages production. Functional flow criteria shall be established for at least:

  Yolo Bypass
  Sacramento River and its basin
  San Joaquin River and its basin
  Eastside streams and their basins
  Interior Delta including Old and Middle rivers
  Delta outflow

- Establish an adaptive management process to review and modify flow criteria in the Delta that is: (1) responsive to scientific advances, changing environmental conditions including a warming climate and change in sea level, and changes in conveyance and water operations, and (2) implemented on a time scale needed to realistically manage desirable species.

9.2.4 Aquatic Species Biological Objectives

Salmon

- For the San Joaquin River basin, provide sufficient water flow depending on year type to transport salmon smolts through the Delta during spring in order to contribute to attainment of the salmon protection water quality objective[1].

- For the Sacramento River basin, provide sufficient water flow to transport salmon smolts through the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective[1].

- For eastside streams that flow to the Delta including the Mokelumne and Consumes River basins, provide sufficient water flow to transport salmon smolts through the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective[1].

- To favor salmon smolts rearing in the Delta, during above normal and wet years, provide floodplain inundation flows for at least a 10 consecutive day period between January and May, maintain continuous inundation for at least 30 days in the Yolo Bypass and at suitable locations in the Sacramento River or in the San Joaquin River.

- For mainstem rivers that flow into the Delta and their tributaries, maintain water temperatures and dissolved oxygen at levels that will support adult migration, egg incubation, smolting, and early-year and late-year juvenile rearing at levels that facilitate attainment of specified life-history stage production goals.

Longfin Smelt

- Provide low salinity habitat for longfin smelt in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between January and June.

- Depending on year type, provide sufficient water flow to increase abundance of longfin smelt to pre-1987 abundance levels.

- At no time should Old and Middle River flows be more negative than -5,000 cfs during the period between December and March.

[1] Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Water Board Resolution No. 2006-0098. Table 3. Page 14.

- During critical and dry years and when longfin FMWT index is more than 500, Old and Middle River flows should be more positive than -1500 cfs during the period between April and May.

- During critical and dry years and when longfin FMWT index is less than 500, Old and Middle River flows should be positive during the period between April and May.

Delta Smelt

- Provide low salinity habitat for delta smelt in Suisun Bay by maintaining X_2 between 74 km and 81 km between September and November in wet and above normal years.

- At no time should Old and Middle River flows be more negative than -5,000 cfs between December and February.

- For critical and dry years, at no time should Old and Middle River flows be more negative than -1,500 cfs between March and June.

- Develop a comprehensive life-cycle model for delta smelt that would allow for assessment of population level impacts associated with entrainment.

Starry Flounder

- Provide low salinity habitat for starry flounder in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between March and June.

- Depending on year type, provide sufficient water flow to increase abundance of starry flounder to pre-1987 abundance levels.

American Shad

- Provide low salinity habitat for American shad in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between April and June.

Bay Shrimp

- Create shallow water habitat for bay shrimp in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between March and May.

Zooplankton

- Provide low salinity habitat for zooplankton in Suisun Bay (and farther downstream) by maintaining X_2 between 64 km and 75 km between January and June.

Sacramento Splittail

- To favor Sacramento splittail recruitment, during above normal and wet years, once floodplain inundation has been achieved based on runoff and discharge for 10 days between March and May, maintain continuous inundation for at least 30 days in the Yolo Bypass and at suitable locations in the Sacramento River or in the San Joaquin River.

9.2.5 Management Goals

To help ensure that the objectives and criteria identified in this report remain relevant and scientifically supportable, management goals have been developed to address the importance of adaptive management and the need for continued evaluation of objectives and criteria developed for the Delta. An adaptive management approach will help improve current understandings while allowing for flexibility in management decisions.

- Integrate all flow measures needed to protect species and ecosystem functions in a manner that is comprehensive, does not double count flows, uses a justified time step, and is documented in peer reviewed or otherwise vetted literature.

- Establish an adaptive management process to evaluate Delta environmental conditions, periodically review the scientific underpinnings of the biological objectives and flow criteria, and change biological objectives and flow criteria when warranted.

Other Factors

Natural Hydrograph

- To the extent possible, flow criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes.

- Delta inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow unless otherwise necessary.

Nutrients and other pollutants

- Prevent the discharge of pollutants at concentrations that are acutely or chronically toxic to aquatic life..

Cold Water Pool

- Balance the need for cold water storage for upstream salmon habitat protection with the need for Delta outflow in late winter through spring.

9.3 Flow Criteria

DFG's recommended flow criteria are presented in Table 16. These flows can be used as the performance criteria to achieve aquatic species biological objectives and serve as the scientific foundation for future water quality control planning activities, water rights proceedings, and the BDCP development. Management of the Delta and its tributaries cannot be separated. If upstream water quality, water quantity, and fisheries problems are addressed, similar impacts in the Delta may be lessened, but this will only occur if upstream water needs are balanced with the needs of the Delta. Before any specific flow criteria are implemented, the following should be considered:

1. Balancing of the need to protect the Delta's aquatic and terrestrial ecosystem with the need for reliable water supply.
2. The proposed project description as presented in the context of the available scientific understanding provided in this document.
3. New research and monitoring not available when this report was completed that may better protect species of concern.

Table 16: DFG Flow Criteria

Category	Function	Flow (cfs)	Year Type	Months: O	N	D	J	F	M	A	M	J	J	A	S	Citation
Delta Outflow	Increase quantity and quality of habitat for delta smelt promotes variability of fall flows and habitat conditions in above normal and wet water year types; may result in improved conditions for delta smelt	7100 ($X_2 \leq$ 81 km) to 12400 ($X_2 \leq$ 74 km)	AN W	1	1										1	SWRCB (2010)
	Promote increased abundance for longfin smelt, starry flounder, zooplankton, American shad, Crangon franciscorum (bay shrimp), and other desirable estuarine species	11400 – 29200 (X_2 between 64 km and 75 km)	All				1	1	1	1	1	1				DFG (2010a)
San Joaquin River	Increase juvenile Chinook salmon outmigration survival and abundance and provide conditions that will generally produce positive population growth in most years and eventually achieve the doubling goal	At Vernalis: 1500 (Base)	C				1	1	1	1	1	½				DFG (2010a)
		5500 (Pulse) (4/15-5/15) (Total 7000)								½	½					
		At Vernalis: 2125 (Base)	D				1	1	1	1	1	½				DFG (2010a)
		4875 (Pulse) (4/11-5/20) (Total 7000)								½	½					
		At Vernalis: 2258 (Base)	BN				1	1	1	1	1	½				DFG (2010a)
		6242 (Pulse) (4/6-5/25) (Total 8500)								1	1					
		At Vernalis: 4339 (Base)	AN				1	1	1	1	1	½				DFG (2010a)
		5661 (Pulse) (4/1-5/30) (Total 10000)								1	1					
		At Vernalis: 6315 (Base)	W				1	1	1	1	1	½				DFG (2010a)
		8685 (Pulse) (3/27-6/4)							1	1	1	1				

Category	Function	Flow (cfs) (Total 15000)	Year Type	Months O	N	D	J	F	M	A	M	J	J	A	S	Citation
	Minimum adult Chinook salmon attraction flows to decrease straying, increase DO, reduce temperatures, and improve olfactory homing fidelity	At Vernalis: pulse flow: 1000[7]	All	1												SWRCB 2006
Eastside Streams	Mokelumne River flows: Juvenilt salmon outmigration	1500	All						1	1						From Flennor et al. 2010
	Eastside stream minimum flows	1060	All	1	1	1	1	1	1	1	1	1	1	1	1	From Flennor et al. 2010
Sacramento River	Increase juvenile salmon outmigration survival and abundance for fall-run Chinook salmon. Increases juvenile salmon outmigration survival	At Wilkins Slough: pulse flow: 20,000 cfs for 7 days[8]	All		1	1	1									SWRCB (2010)
	Increase juvenile salmon outmigration survival by reducing diversion into Georgiana Slough and the central Delta	At Freeport: 13,000 - 17,000[9]	All		1	1	1	1	1	1	1	1				SWRCB (2010)
	Promote juvenile salmon outmigration	At Rio Vista: 20000 – 30000								1	1	1				DFG (2010a)
Floodplain	Inundation of off-channel areas improves spawning and recruitment of Sacramento splittail. Salmon smolts also benefit from increased food in floodplain habitats.	≥ 30 day floodplain inundation[10]	AN W				1	1	1	1	1					DFG (2010a)

[7] 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

[8] Pulse flows should coincide with storm events producing unimpaired flows until monitoring indicates that majority of smolts have moved downstream

[9] Positive flows are needed downstream of confluence with Georgiana Slough while juvenile salmon are present

[10] Flows needed to inundate floodplain habitat vary substantially depending on Sacramento River, San Joaquin River, and in-Delta floodplain habitat (e.g., Fremont Weir in the Yolo Bypass flow can range from 56,000 cfs (existing crest) to 23,100 cfs (the proposed notch) (AR/NHI 1 as cited in SWRCB, 2010)).

Category	Function	Flow (cfs)	Year Type	Months												Citation
				O	N	D	J	F	M	A	M	J	J	A	S	
Old and Middle Rivers	Reduces straying and improve homing fidelity for San Joaquin basin adult salmon Reduces entrainment of larval / juvenile delta smelt, longfin smelt, and provide benefits to other desirable species If FMWT index for longfin smelt is low, then OMR should be more positive than 0 or -1500 (depending on prior year population) to reduce entrainment losses when abundance is low. Needed to 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. Reduced risk of juvenile salmon entrainment and straying to central Delta Improve survival of San Joaquin River juvenile salmon emigrating down the San Joaquin River and improve subsequent escapement Increase survival of outmigrating smolts, decrease diversion of smolts into central Delta where survival is low	> -1,500 cfs 14-day running average	C, D						1	1	1	1				
		> 0 or -1,500 cfs, 14-day running average, when FMWT index for longfin smelt is less than 500, or greater than 500, respectively	C, D							1	1					
		> -5,000 cfs 14-day running average	All			1	1	1	1	1	1	1				
		> -2,500 cfs, 14-day running average, when salmon smolts are in the Delta	All		1	1	1	1	1	1	1	1				
		At Jersey Point: Positive flows when salmon are in the Delta	All		1	1	1	1	1	1	1	1				

1 = criteria recommended for the whole month
½ = criteria recommended for half of the month

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Appendix A: Summary Table of All Flow Recommendations Made During the Water Board's Informational Proceeding (Appendix A in SWRCB (2010))

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 $\leq$ 81 km (approx. 7000)		X2 $\leq$ 81 km		20
	W									X2 $\leq$ 74 km (approx. 12400)		X2 $\leq$ 74 km		

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

<table>
<tr><th></th><th>Water Year</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sept</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Source / Note</th></tr>
<tr><td colspan="15"></td></tr>
<tr><td>CDFG</td><td>All</td><td colspan="6">Recommendation in X2 format: 64 - 75 km (approx. 29200 - 11400 cfs)</td><td colspan="6"></td><td>21</td></tr>
<tr><td colspan="15"></td></tr>
<tr><td>DWR / SFWC</td><td>All</td><td colspan="12">Recommendation to maintain requirements stipulated in D-1641</td><td>22</td></tr>
<tr><td colspan="15"></td></tr>
<tr><td colspan="15">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.</td></tr>
<tr><td>Delta Solutions Group</td><td>5 of 10 yrs</td><td colspan="2"></td><td colspan="3">48000</td><td colspan="7"></td><td>23</td></tr>
</table>

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				≥18000									24
	All				≥13000 (14-day running average) and ≥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		≥ 17700 (at Grimes RM125)											35
	AN & W		≥ 31100 (at Verona RM80)											
	All	Provide pulse flows ≥ 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 otherwis

	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 ≤ 4000 cfs									
Draft D1630	BN, AN, W				14-day running average combined export rate for Tracy, Banks, and Contra Costa pumping plants shall be ≤ 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			
CSPA / C-WIN	BN	2000 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			
CSPA / C-WIN	AN	2500 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			
CSPA / C-WIN	W	3000 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			
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			
AFRP	W	3000 (net seaward flows at Jersey Pt)									See Jan-June			
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	> 30 day floodplain inundation												79
EDF / Stillwater	BN AN W	64000 (pulse flow, 21 consecutive days) 64000 (pulse flow, 35 consecutive days) 64000 (pulse flow, 49 consecutive days)												37 Sacr Riv - Yolo Byp
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 W	14800 (pulse flow, > 21 consecutive days) 14800 (pulse flow, > 35 consecutive days)												57
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).

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

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.

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).

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

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

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 ≤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 (≤ 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.

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.

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

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).

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.

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).

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)