Public Comment
Bay-Delta Plan Supplemental NOP
Deadline: 04/25/12 by 12 noon

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Via Electronic Mail and Hand Delivery

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State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814
commentletters@waterboards.ca.gov

Re: Sacramento Valley Water Users' Comment Letter – Bay-Delta Plan Supplemental Notice of Preparation – Comprehensive Review

Dear Ms. Townsend:

These comments are submitted on behalf of the parties listed on Exhibit 1 attached hereto, and collectively referred to herein as the Sacramento Valley Water Users or SVWU. The SVWU appreciate this opportunity to provide these comments pursuant to the State Water Resources Control Board's (SWRCB) January 24, 2012 Supplemental Notice of Preparation (NOP) and Notice of Scoping Meeting for the Update and Implementation of the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan): Comprehensive Review.

A. *General Background*

The NOP explains that the "Bay-Delta Plan identifies beneficial uses of the Bay-Delta, water quality objectives for the *reasonable protection* of those beneficial uses, and a program of implementation for achieving the water quality objectives." (NOP at p. 2, emphasis added.) One of the purposes of the NOP is to "seek input on significant environmental issues, reasonable alternatives, and mitigation measures that should be addressed in the SED [Substitute Environmental Document] . . . ." (*Id*. at p. 4.) The NOP includes a Project Description, which states as follows:

> The proposed Project includes review of potential modifications to current objectives included in the 2006 Bay-Delta Plan, the potential establishment of new objectives, and modifications to the program of implementation for those objectives. The proposed project also includes potential changes to the monitoring and special studies program included in the 2006 Bay-Delta Plan. *The*

> *proposed Project does not include amendments to water rights and other measures to implement a revised Bay-Delta Plan. A separate Environmental Impact Report will be prepared for these actions.* As noted above, a separate SED is being prepared to address updates to the water quality objectives for the protection of southern Delta agricultural beneficial uses; San Joaquin River flow objectives for the protection of fish and wildlife beneficial uses; and the program of implementation for those objectives. (*Id.* at p. 6, emphasis added.)

According to the SWRCB, its issuance of the NOP "starts the process of soliciting information to inform the next phase of the State Water Board's comprehensive Bay-Delta Plan update." (See SWRCB's January 27, 2012 Fact Sheet.) The SVWU submit these comments based upon this characterization of the process by the SWRCB.

B. *Summary of Key Comments*

As a fundamental premise, the SWRCB's development of any new water quality objectives for its Bay-Delta Plan update must be reasonable. As detailed below, implementing water quality objectives for Delta outflow and Sacramento River inflows based on 40% or 50% of unimpaired flows would be unreasonable because implementing such objectives would cause severe hydrologic, environmental and water supply impacts. If the SWRCB were to propose new Bay-Delta water quality objectives based upon such percentages of unimpaired flows, then the California Environmental Quality Act (CEQA) would require the SWRCB to analyze many significant environmental impacts that would occur in numerous resource categories. Moreover, state-of-the-art streamflow requirements already govern the major rivers in the Sacramento Valley. Because these streamflow requirements have been developed largely to integrate fishery protection and water supplies, CEQA would require the SWRCB to at least analyze a reasonable alternative of establishing any new water quality objectives concerning Bay-Delta streamflows based upon the Delta inflows produced by existing streamflow requirements for the Sacramento Valley's rivers.

C. *California Environmental Quality Act Compliance Issues*

1. *Environmental Review of the Proposed Bay-Delta Plan Update Is Premature Because the SWRCB Has Not Adequately Defined the Project*

CEQA requires that an NOP include a description of the project that will be the subject of environmental review, as well as a summary of the probable environmental effects of the project. (CEQA Guidelines, § 15082 subds. (a)(1)(A),(C).) The purpose of soliciting comments on an NOP is to receive input regarding the significant environmental issues, alternatives, mitigation measures and range of actions that need to be explored in the environmental document, and to bring together and resolve the concerns of affected federal, state, and local agencies. (CEQA Guidelines, § 15083 subd. (a).) In order for the public to provide meaningful comments on the scope of the environmental document, the project description must provide an adequate explanation of what the project is intended to do, and what changes the public can expect as a result of adopting the project. An "accurate, stable and finite project description is the sine qua non of an informative and legally sufficient EIR." (*San Joaquin Raptor/Wildlife Rescue Center v. County of Stanislaus* (1994) 27 Cal.App.4th 713, 730.)

Contrary to this requirement, the proposed project has not been fully or clearly defined in the NOP. For example, the NOP states:

> Specifically, the State Water Board seeks input and information to support whether the water quality objectives and associated program of implementation discussed above should be modified or whether they should remain the same. In particular, the State Water Board seeks input and information to support whether Delta outflows, Delta inflows, and water project operational constraints should be increased, decreased, or remain the same. (NOP at p. 4.)

The NOP also states,

> In addition to the issues identified in the 2009 Staff Report, the State Water Board will also consider other potential changes to the Bay-Delta Plan that were not specifically addressed in the report, including issues that are identified through the scoping process. The State Water Board may also consider information that is produced as part of the Bay Delta Conservation Plan (BDCP) currently being developed. (*Id.* at p. 3.)

It is unclear, however, what specific information from the BDCP the SWRCB intends to consider regarding potential changes to the Bay-Delta Plan. It appears the SWRCB is using the NOP, as well as the ongoing BDCP process, to develop the project description for its update to the Bay-Delta Plan. Without complete and accurate information about the project now, it is very difficult for the public to provide meaningful and complete comments about the range of issues that must be evaluated, especially alternatives and mitigation measures. As a result, it is premature for the SWRCB to request comments on the scope and content of an environmental document for the Bay-Delta Plan update. After the project is adequately defined and described, the SWRCB should issue a new NOP. The SWRCB should, therefore, treat the current NOP as only the first step towards developing a project description that will be circulated to the public by means of a second – and legally adequate – NOP that will properly commence the CEQA process.

2. *The SWRCB's Approach to Updating the Plan and Associated Environmental Review Improperly Segments the Analysis of Environmental Effects*

On February 13, 2009 the SWRCB issued its initial, underlying NOP for this proceeding to update the Bay-Delta Plan. In the February 13, 2009 notice, the SWRCB stated that it would stage components of its environmental review of the Bay-Delta Plan, and the environmental review for potential changes to water rights and other measures needed to implement any revisions to the Bay-Delta Plan, by preparing more than one environmental document. That earlier NOP indicated the work could be completed in four stages:

1. Bay-Delta Plan review and update of the San Joaquin River flow and southern Delta salinity objectives and their program of implementation;

2. Amendment of water rights and other measures to implement the San Joaquin River flow and southern Delta salinity objectives;

3. Review and update of other components of the Bay-Delta Plan and their program of implementation;

4. Amendment of water rights and other measures to implement other components of the Bay-Delta Plan.

The February 2009 notice stated that the proposed Project would include both: 1) the review and update of water quality objectives, including flow objectives, and the program of implementation in the Bay-Delta Plan; and 2) changes to water rights and water quality regulation consistent with the program of implementation. However, at that time, the SWRCB only requested comments from responsible and trustee agencies and interested persons concerning the scope and content of the environmental information to be included in the environmental evaluation of the documentation relating to the southern Delta salinity and San Joaquin River flow objectives and their implementation. A separate environmental document is being prepared for that element of the Bay-Delta Plan update. Now, the latest supplemental NOP states that the SWRCB will defer consideration of changes to water rights and other unidentified measures necessary to implement the project.[1] This piecemeal approach to environmental review of the Bay-Delta Plan update is flawed, and precludes meaningful analysis or consideration of the potential range of environmental effects associated with the Plan.

CEQA defines "project" as "the whole of an action, which has a potential for resulting in a physical change in the environment . . . ." (CEQA Guidelines, § 15378 subd. (a).) CEQA does not permit an agency to conceal potential environmental impacts by focusing separately on isolated parts of an overall action. (*Ibid.*; *City of Sacramento v. State Water Resources Control Bd.* (1992) 2 Cal.App.4th 960, 969 [water board's consideration of rice pesticide plan must address environmental effects of steps required to implement plan]; *Bozung v. Local Agency Formation Comm'n* (1975) 13 Cal.3d 263, 283.) Here, the project is the entire process required to develop and implement flow criteria, including changes to water rights identified in the NOP. (*City of Sacramento v. State Water Resources Control Bd*, *supra*; see also *City of Arcadia v. State Water Resources Control Bd.* (2006) 135 Cal.App.4th 1392, 1395-1396 [rejecting water board's functional equivalent document for water quality regulatory plan for failure to consider reasonably foreseeable environmental effects of actions required to implement plan].)

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[1] The NOP states: "The proposed Project includes review of potential modifications to current objectives included in the 2006 Bay-Delta Plan, the potential establishment of new objectives, and modifications to the program of implementation for those objectives. The proposed project also includes potential changes to the monitoring and special studies program included in the 2006 Bay-Delta Plan. *The proposed Project does not include amendments to water rights and other measures to implement a revised Bay-Delta Plan*." (NOP at p. 6, emphasis added.)

The decision to segregate environmental review of the various elements of the Plan violates CEQA's mandate that an EIR evaluate the whole of an action that is likely to have environmental effects, including action that is a reasonably foreseeable consequence of the initial project, if the subsequent phases of the project or other action will change the scope or nature of the project's environmental effects. (*Laurel Heights Improvement Assn v. Regents of Univ. of Cal.* (1988) 47 Cal.3d 376, 396.) Here, the NOP describes several processes to update the Plan, each of which tackles part of the Plan update, and improperly proposes to conduct separate environmental review of the various elements of the Plan.

One of CEQA's basic purposes is to inform government decision-makers and the public about the potential significant environmental effects of proposed projects. (CEQA Guidelines, § 15002(A)(1); *Citizens of Goleta Valley v. Board of Supervisors* (1990) 532 Cal.3d 553; *Laurel Heights Improvement Assn v. Regents of Univ. of Cal.*, *supra*.) "[A] paramount consideration is the right of the public to be informed in such a way that it can intelligently weigh the environmental consequences of any contemplated action and have an appropriate voice in the formulation of any decision." (*Environmental Planning and Information Center v. County of El Dorado* (1982) 131 CalApp.3d 350, 354.) Without a clear description of the range of activities that are reasonably foreseeable and necessary to implement the Plan update, it is impossible to adequately assess the range of potential environmental effects. Accordingly, the SWRCB's proposed phased environmental review for its Bay-Delta Plan update would not comply with CEQA.

D. *The SWRCB's Development of Water Quality Objectives Must Be Reasonable*

Protection of water quality in California is governed by the Porter-Cologne Water Quality Control Act, Water Code section 13000 et seq. (Porter-Cologne). A fundamental premise of Porter-Cologne is that water quality regulation must be reasonable. (See, e.g., Wat. Code, § 13000.) The SWRCB is empowered to adopt Water Quality Control Plans (also known as Basin Plans), which must include: beneficial uses of the waterbodies in the region; water quality objectives (WQOs) to reasonably protect the beneficial uses; and a program of implementation for the WQOs. (Wat. Code, §§ 13050(h), (j), 13170, 13241, 13242.) In formulating a water quality control plan, the SWRCB seeks "to attain the highest water quality which is *reasonable*, considering all demands being made and to be made on waters of the state and the values involved." (Wat. Code, § 13000, emphasis added.)

WQOs are defined as, "the limits or levels of water quality constituents or characteristics which are established for the *reasonable protection of beneficial uses* of water or the prevention of nuisance within a specific area."[2] (Wat. Code, § 13050(h), emphasis added.) When establishing WQOs, the state must consider a series of factors, including economics, attainability, and other public interest factors. (See Wat. Code, § 13241.) As the SWRCB's

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[2] Beneficial uses may include, but are not limited to, "domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves." (Wat. Code, § 13050(f).)

Chief Counsel has previously explained, Porter-Cologne requires that "*objectives must be reasonable,* and economic considerations are a necessary part of the determination of reasonableness." (*Memorandum to Regional Water Board Executive Officers from William R. Attwater, Chief Counsel, State Water Resources Control Board* (Jan. 4, 1994), at p. 3, emphasis added.) In adopting WQOs, the SWRCB must ensure that the WQOs provide for the reasonable protection of beneficial uses after considering the factors required by Water Code section 13241, including economics and attainability. (See *United States v. State Water Resources Control Bd.* (1986) 182 Cal.App.3d 82, 109-110 [the SWRCB "is required to 'establish such water quality objectives . . . as in its judgment will ensure the reasonable protection of beneficial uses . . .'"] (citing Wat. Code, § 13241); *id.* at p. 118 [the SWRCB shall consider "all competing demands for water in determining what is a reasonable level of water quality protection."].)

E. Hydrologic Modeling Using the Best Available Information Indicates That Implementation of New January-June Delta Water Quality Objectives Reflecting 50% Or 40% of Unimpaired Flows Would Have Severe Hydrologic Impacts

The 2010 Delta Flow Criteria report issued by the SWRCB suggested that current levels of Delta flows are inadequate to protect aquatic public trust resources in the Delta, and that flows in the Delta should approximate 75% of unimpaired Delta outflow from January through June, and 75% of unimpaired Sacramento River inflow from November through June. The SWRCB stated, at the time that it released the Delta Flow Criteria report, that the report should not be used for regulatory purposes, but nevertheless indicated that it would develop future "Delta flow objectives with regulatory effect." (See 2010 Delta Flow Report, at p. 16.) In addition, numerous parties – including the SWRCB itself – have embraced the basic concepts that there should be additional flows in the Delta, and that such flows should based on a percentage of unimpaired flows.

Since the SWRCB, and other parties, have conceived of developing water quality objectives using the metric of unimpaired flows, the SVWU retained Walter Bourez, of MBK Engineers, to analyze the potential effect of a flow regime based on a percentage of unimpaired flows. Mr. Bourez's report is attached as Exhibit 2 (hereafter MBK Report), and incorporated herein by reference.

Mr. Bourez's analysis began with determining the average percentages of unimpaired Delta outflows that would have occurred in different water-year types if Existing Conditions had been in effect during the entire period of historical record. Consistent with standard hydrological modeling practice, Existing Conditions are defined by today's regulatory requirements, land use, water demands, and facilities and are used to establish how the CVP/SWP currently operates.[3] This analysis determined that, under Existing Conditions, average January-June Delta outflow

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[3] As explained in the MBK Report at 1, the Existing Conditions percentage of unimpaired Delta outflow is calculated by averaging total modeled Delta outflows for the period of January through June and dividing by the average total unimpaired Delta outflow over that same period. The outflows were not calculated on a month-to-month basis for the initial analysis to determine Existing Conditions percentage of unimpaired Delta outflow.

over the period of record is about 50% of unimpaired flows and the critical year average Delta outflow is about 40% of unimpaired flows.

These average percentages of 50% and 40% of unimpaired flows then were modeled, in separate analyses, as minimum *monthly* Delta flow requirements, for each month in the January through June period, to estimate the hydrological and related impacts that would result from implementation of such minimum requirements. As such, the MBK Report presents the estimated impacts that would occur if the existing average and average critical year percentages of unimpaired Delta outflows during the January through June period – 50% and 40%, respectively – were imposed as regulatory minimum Delta outflow requirements *for each separate month* from January through June. This approach of applying a constant percentage of unimpaired flow as a requirement for each month from January through June is consistent with the SWRCB August 2010 Delta Flow Criteria report and recent analysis performed by the SWRCB on certain tributaries to the San Joaquin River as part of its update to the Bay-Delta Plan

The overall conclusions regarding the estimated effects of implementing January-June minimum monthly Delta outflow requirements of 50% and 40% of unimpaired flows are as follows:

- Effects to the water system would be severe and would result in the inability to maintain viable water system operations.

- Increase in average annual Delta outflow
    - 50% unimpaired requirement: 1.1 MAF
    - 40% unimpaired requirement: 480 TAF

- Decrease in Sacramento Basin project reservoir carryover storage
    - Significant reductions in cold water pools under both analysis
    - 50% unimpaired requirement: 2.2 MAF average reduction
    - 40% unimpaired requirement: 1.1 MAF average reduction

- Increase in Sacramento Basin groundwater pumping
    - Groundwater pumping in the 50% scenario: 250 TAF average annual, 1 MAF average in Critical years
    - Groundwater pumping in the 40% scenario: 100 TAF average annual, 400 TAF average in Critical years

- Neither of these estimated pumping amounts could be sustained, so reductions in irrigated acreages would have to occur.

- Increased groundwater overdraft in export service area

- Seasonal changes in river flow and Delta outflow
    - Increases in March through June
    - Decreases in July through December
    - Impacts to key instream temperature and habitat

- Regular and multiple violations in existing SWRCB standards and ESA Biological Opinion requirements.

- Severe water supply impacts
    - Impacts to diversions by Central Valley Project (CVP) settlement and exchange contractors, and State Water Project (SWP) settlement agreement holders
    - Inability to meet public health and safety water deliveries
    - Refuge delivery reductions

F. Under Porter-Cologne and CEQA, the SWRCB Must Analyze the Numerous Impacts That Would Occur if the SWRCB Were to Adopt New Delta Water Quality Objectives Based on 50% or 40% of Unimpaired Flows

MBK's analysis demonstrates that implementation of new Delta water quality objectives based on 50% or 40% of January-June unimpaired flows would have very significant hydrological impacts, because implementation of such objectives would significantly reduce storage in the Sacramento Valley's reservoirs, cause significant shifts in streamflow in the Valley's rivers, and significantly reduce water-supply deliveries both in the Sacramento Valley and in export areas.

Accordingly, if the SWRCB were to consider new Delta water quality objectives based on 50% or 40% of unimpaired flows, Porter-Cologne and CEQA would require the SWRCB to consider numerous significant impacts that implementation of such objectives would cause. (See Pub. Resources Code, § 21080.5, subds. (d)(2)(A), (d)(3)(A); Wat. Code, § 13241; Cal. Code Regs., tit. 14, §§ 15250, 15252.) The significant impacts that Porter-Cologne and CEQA require the SWRCB to analyze would include impacts in the following categories:

- <u>Special-status and migratory fisheries</u> – MBK's analysis demonstrates that implementing Delta water quality objectives based on 50% or 40% of January-June unimpaired flows would substantially reduce cold-water storage in the Sacramento Valley's reservoirs. As a result, summer and fall water temperatures in the Sacramento Valley's rivers likely would increase significantly, probably resulting in significant impacts on rearing and spawning salmonids, including at least winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, late fall-run Chinook salmon and steelhead. As the SWRCB is aware, winter-run Chinook salmon, spring-run Chinook salmon and steelhead are listed under the federal Endangered Species Act, as is green sturgeon. The impacts on these species would be particularly severe in multi-year droughts because, as MBK's analysis demonstrates, implementation of Delta water quality objectives based on 50% or 40% of unimpaired flows would cause reservoir storage to be severely reduced – indeed, completely depleted – for many months during such droughts. (MBK Report Figs., 14-17.) For example, MBK's analysis shows that, in a repeat of the 1987-1992 drought, Shasta and Folsom Reservoirs would reach dead pool in the summers and falls of multiple years of that drought. (MBK Report Figs. 15, 17.) The resulting temperature impacts on multiple cohorts of Central Valley salmon would be devastating if such a scenario were to actually occur.

In addition, MBK's analysis demonstrates that implementing Delta water quality objectives based on 50% or 40% of unimpaired flows would cause significant shifts of streamflows in the Sacramento Valley's rivers from the summer and fall months to the spring months. These shifts would also probably cause significant impacts on rearing and spawning salmonids, including at least winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, late fall-run Chinook salmon and steelhead.

Furthermore, an April 2011 report, prepared by the highly respected fisheries biologist David Vogel of Natural Resources Scientists, Inc., and entitled, *Insights into the Problems, Progress, and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration,*[4] reveals that implementing these types of unimpaired flow based objectives could undermine 20 years of work to improve conditions for salmon in the Sacramento Valley.

Such significant impacts on special-status and migratory species require analysis under CEQA. (See Cal. Code Regs., tit. 14, Appendix G, items IV.a) and IV.d).) These impacts will reach levels that mandate a finding of significance. (See Cal. Code Regs., tit. 14, Appendix G, item XVIII.a).)

- Water supplies – As demonstrated by MBK's analysis, implementation of Delta water quality objectives based on 50% or 40% of January-June unimpaired flows would substantially reduce reservoir storage and summer and fall streamflows in the Sacramento Valley. Because California's climate generally is dry in the summer and fall, these hydrological impacts probably would result in significant water-supply shortages for all consumptive uses in many years, and particularly in dry cycles. The water-supply impacts would not be limited to those caused by the fact that streamflows and bypass-flow requirements would be increased and reservoir storage to meet dry-season demands would be decreased. For example, the significant impacts on water storage in Folsom Reservoir could cause the reservoir's level to drop below public water suppliers' intakes in many years, and for multiple months during dry cycles. In such cases, implementing water quality objectives based on 50% or 40% of unimpaired flows could have serious impacts on public health and safety because it would not be physically possible to draw water from Folsom Reservoir. Such effects would trigger a mandatory finding of significance. (See Cal. Code Regs., tit. 14, Appendix G, item XVIII.c).) Porter-Cologne requires that the SWRCB consider all water-supply impacts because it requires the

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[4] This document is attached hereto as Exhibit 3, and incorporated herein by reference.

SWRCB to consider, in developing water quality objectives, "[p]ast, present, and probable future beneficial uses of water" and "economic considerations," among other factors. (Wat. Code, § 13241, subds. (a), (d).)

- Groundwater supplies and contamination – As MBK's report discusses, the loss of surface water supplies as the result of implementing water quality objectives based on 50% or 40% of January-June unimpaired flows would have significant impacts on groundwater resources. These impacts would occur for multiple reasons.

  First, in order to attempt to maintain economically viable communities and operations, Sacramento Valley water users would have to pump significantly more groundwater. For example, modeling of the effects of implementing objectives reflecting 50% of unimpaired flows causes CalSim II to model that 997,000 acre-feet of groundwater would be pumped in the Sacramento Valley in critical years. (MBK Report Figs. 8, 10.) While this level of groundwater pumping would be unsustainable, it demonstrates that implementing water quality objectives based on 50% or 40% of unimpaired flows would result in severe groundwater impacts. If the SWRCB considers adopting and implementing such water quality objectives, then it must analyze the resulting significant impacts on groundwater supplies. (See Cal. Code Regs., tit. 14, Appendix G, item IX.b).)

  Second, the reduced amount of surface deliveries would reduce the amount of groundwater recharge that currently occurs from the application of surface water to beneficial uses, and also from the planned percolation of surface water through earthen conveyance systems as part of conjunctive use programs. (See Cal. Code Regs., tit. 14, Appendix G, item IX.b).)

  Third, the increased groundwater pumping that would be triggered by the reductions in surface supplies likely would cause existing contamination plumes to expand and migrate. There are a number of such plumes in the Sacramento metropolitan area associated with former military and aerospace facilities. The expansion and migration of these plumes would be a significant impact. (See Cal. Code Regs., tit. 14, Appendix G, items IX.a), IX.f).)

- Farmland and Associated Terrestrial and Migratory Bird Species – The water-supply reductions resulting from any implementation of Delta water quality objectives based on 50% or 40% of January-June unimpaired flows would result in significant environmental impacts to farmland. If such objectives were implemented, it would not be possible to sustain the levels of groundwater pumping that would be necessary to replace the lost surface supplies. For example, MBK's analysis indicates that an unsustainable 997,000 acre-feet of pumping would be necessary in the Sacramento Valley in critical years to replace the lost surface supplies. (MBK Report Figs. 8, 10.) A great deal of farmland therefore would be lost, which would be a significant environmental impact. (See Cal. Code Regs., tit. 14, Appendix G, item II.a).)

The loss of this farmland would result in the loss of habitat for terrestrial species that currently occupy irrigated farmland. The impacts on these terrestrial species and their habitats likely would be significant and potentially would reach levels that mandate a finding of significance. (See Cal. Code Regs., tit. 14, Appendix G, items IV.a), IV.b), XVIII.a).)

The loss of farmland in the Sacramento Valley also would impact migratory bird species that use the irrigated lands for habitat as part of the Pacific Flyway. The habitat values created by these irrigated lands are described in detail in the Central Valley Joint Venture 2006 Implementation Plan (www.centralvalleyjointventure.org/science). Such impacts would be significant. (See Cal. Code Regs., tit. 14, Appendix G, items IV.a), IV.b), IV.d).)

- Wildlife Refuges – There are numerous wildlife refuges in the Sacramento Valley that are supplied with surface water. Reduced surface-water supplies would reduce the amount of water available for those refuges. The species that use the refuges as habitat would be impacted by the implementation of Delta water quality objectives based on 50% or 40% of January-June unimpaired flows. Such impacts would be significant. (See Cal. Code Regs., tit. 14, Appendix G, items IV.a), IV.b), IV.d).)

- Hydroelectric generation, air quality and greenhouse gasses – The reduced reservoir storage and significant seasonal shifts in streamflows resulting from any implementation of water quality objectives based on 50% or 40% of January-June unimpaired flows would significantly impact hydroelectric generation. There would be at least two significant impacts on hydroelectric generation. First, generation would be shifted from the high-demand summer and fall months to the low-demand spring months. Second, lost storage would reduce the amount of water available to generate electricity to meet temporary demand peaks, such as during weekday summer afternoons. The SWRCB must consider such impacts under Porter-Cologne. (See Wat. Code, § 13241, subds. (a), (d).) Because this lost generation would have to be replaced by new facilities, this impact also must be considered under CEQA. (See Cal. Code Regs., tit. 14, Appendix G, item XIV.a).)

  Because lost hydroelectric generation likely would be replaced by generation with the same operating characteristics as hydro power, the SWRCB also must consider the potential air quality and greenhouse-gas impacts that would be associated with the required replacement generation. (See Cal. Code Regs., tit. 14, Appendix G, items III.a)-c), VII.a)-b).) In light of these potential impacts, the California Global Warming Solutions Act of 2006 – AB 32 – also would require the SWRCB to consider the greenhouse-gas impacts of implementing water quality objectives based on 50% or 40% of unimpaired flows. (Health & Saf. Code, § 38592, subd. (a).)

  Finally, because groundwater pumping would increase significantly under both the 50% and the 40% scenario, there would be either more use of diesel-fueled groundwater pumps or increased electrical demand because of increased pumping using electrical pumps. In either case, there would be air quality impacts because more fossil fuels would need to be burned to meet the additional pumping demands.

- Riparian Habitat – The dramatic hydrologic changes that implementing water quality objectives based on 50% or 40% of January-June unimpaired flows would cause, and the resulting increased groundwater pumping, would cause soils and groundwater aquifers to be drier, increasing induced recharge from streambeds and causing drier conditions in the Sacramento Valley's riparian habitat. Implementing such objectives therefore would adversely impact the Sacramento Valley's riparian habitat and that impact could be significant. (See Cal. Code Regs., tit. 14, Appendix G, item IV.b).)

- Aesthetics, Recreation and Lake Fisheries – The Sacramento Valley's reservoirs provide aesthetic enjoyment for the communities that have grown around them, and for people who use them for recreation. The severe impacts on reservoir storage resulting from implementing water quality objectives based on 50% or 40% of January-June unimpaired flows would cause those reservoirs to become much less pleasing aesthetically as they would feature large "bathtub rings" much more often. In addition, the significant shift of streamflows in the Sacramento Valley's rivers from the high-recreation summer months to the low-recreation spring months would cause those rivers to become much less attractive to the public during the time of maximum exposure. These aesthetic impacts would be significant. (See Cal. Code Regs., tit. 14, Appendix G, items I.a), I.b), I.c).) These impacts also would reduce the value of numerous recreational resources, including the Sacramento Valley's whitewater rafting streams as well as its reservoirs. These impacts also would be significant, partly because there would be an indirect impact of shifting recreational demands to other resources that presumably would have to be expanded. (See Wat. Code, § 13241, subds. (a), (d); Cal. Code Regs., tit. 14, Appendix G, item XV.b).) Finally, the severe reservoir storage impacts would affect the habitat for lake fish, which impact could be significant. (See Cal. Code Regs., tit. 14, Appendix G, item IV.d).)

- Population – Reliable and affordable water supplies are a key economic asset of the Sacramento Valley. Due to the significant impacts throughout the Sacramento Valley that would result from implementing water quality objectives based on 50% or 40% of unimpaired flows, the value of this key asset would be reduced, and there likely would be at least some shift of population out of the Valley to other areas of California. This population shift would be a significant impact that CEQA would require the SWRCB to analyze. (See Cal. Code Regs., tit. 14, Appendix G, items XIII.a), XIII.c).)

G. *The SWRCB Must Analyze the Reasonable Alternative of Establishing Any New Water Quality Objectives Concerning Delta Streamflows, Based on the Accumulation of Existing State-of-the-Art Streamflow Requirements in the Sacramento Valley*

The baseline for CEQA analysis normally is the physical environmental conditions existing when the NOP is published. (Cal. Code Regs., tit. 14, § 15125, subd. (a).) In addition, under CEQA, the lead agency must consider project alternatives that would avoid or reduce significant or potentially significant environmental impacts. (Pub. Resources Code, §§ 21001, subd. (g); 21002; 21002.1, subd. (a); 21061; 21080.5, subds. (d)(2)(A), (d)(3)(A); Cal. Code Regs., tit. 14, §§ 15126.6(a); 15252, subd. (a)(2)(A).) In light of the numerous significant environmental impacts that would result from implementing water quality objectives based on 50% or 40% of January-June unimpaired flows, the SWRCB must consider project alternatives.

The baseline for the SWRCB's CEQA document must include the Delta inflows from the Sacramento River that presently occur as a result of recently-adopted streamflow requirements on Sacramento Valley rivers. In addition, a reasonable project alternative that must be evaluated would base any new water quality objectives for Delta streamflows on such inflows from the Sacramento River. In this regard, and as described in more detail in the September 2011 document entitled *Instream Flow Requirements in the Sacramento River Hydrologic Region*,[5] major rivers in the Sacramento River basin already are governed by streamflow requirements that state and federal regulatory agencies believe protect beneficial uses and that are based on the best available science. In summary, the applicable requirements are as follows:

- American River – Implementation of the streamflow standards stated in the Water Forum's 2006 flow management standard (FMS) through those standards' incorporation by the National Marine Fisheries Service (NMFS) into NMFS's 2009 biological opinion for the operation of the CVP and the SWP;

- Bear River – The SWRCB approved, in Order WR 2000-10, water-right changes necessary to implement a settlement agreement among the Department of Water Resources, South Sutter Water District and Camp Far West Irrigation District concerning the responsibility of water users on the Bear River for contributing to meeting Delta flow objectives;

- Feather River – Streamflow requirements adopted by the SWRCB in the 2010 water quality certification for the relicensing of the Department of Water Resources' Oroville facilities;

- Sacramento River – Streamflow standards including those stated in the SWRCB's Orders 90-05 and 91-01 and in NMFS's 2009 biological opinion for the CVP and the SWP; and

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[5] This document is attached hereto as Exhibit 4, and incorporated herein by reference.

- Yuba River – The Lower Yuba River Accord's streamflows standards, as implemented by the SWRCB in its Corrected Order 2008-0014.

These current streamflow requirements generally reflect substantial collaborative work among water users, fishery agencies and environmental groups to simultaneously meet the streamflow needs of sensitive fisheries, and the water-supply needs of the Sacramento Valley's communities. In addition, these streamflow requirements generally have taken effect since the recognition of the Delta's pelagic organism decline and, in most cases, have taken effect since 2006.

The Sacramento Valley's existing streamflow requirements, therefore, reflect very recent science to support salmonids. Also, as discussed above and in detail in the MBK report regarding Delta outflow requirements that would be based on 40% and 50% of unimpaired flows, any such requirements would have significant adverse impacts on river flows and water temperatures. This, in turn, would significantly and adversely impact salmonids. Furthermore, there is no indication that the Sacramento Valley's existing streamflow requirements together do not produce sufficient Sacramento River inflows to the Delta to support the Delta's pelagic fish. This latter point is demonstrated both by MBK's above-referenced April 2012 report, and the December 2011 report entitled, *Relating Delta Smelt Index to X2 Position, Delta Flows, and Water Use*.[6] MBK's April 2012 report demonstrates that there has been no significant change in January-June Sacramento River inflows to the Delta, as a percentage of unimpaired flows, since 1944. (MBK Report Fig. 5.) As the SWRCB is aware, the Delta's pelagic fisheries were healthy for much of the post-1944 period. The December 2011 report summarizes available data, which indicates that there is no correlation between Sacramento Valley water use and the decline of the Delta's pelagic fisheries. Given this information, and the fact that existing Sacramento Valley streamflow requirements are recent and generally reflect extensive collaborative efforts to improve conditions for salmonids, a reasonable project alternative would be to base any new flow-related Delta water quality objectives on the Sacramento River inflows to the Delta resulting from operations under those existing streamflow requirements. The SWRCB must consider this project alternative because CEQA requires that a lead agency consider all reasonable project alternatives. (*Citizens of Goleta Valley*, *supra*, 52 Cal.3d, at pp. 564-566; *In re Bay-Delta Programmatic Environmental Impact Report Coordinated Proceedings* (2008) 43 Cal.4th 1143, 1162-1163.)[7]

Finally, as noted above, Porter-Cologne requires that the SWRCB establish WQOs that provide reasonable protection to beneficial uses. In most of the above-referenced collaborative processes, state and federal agencies focused their attention on protecting a broad range of beneficial uses, from recreation to fisheries to terrestrial species. Those judgments, based on

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[6] This document is attached hereto as Exhibit 5, and incorporated herein by reference.

[7] Similarly, Mr. Vogel's above-referenced and attached report (see Exh. 3), recommends numerous actions that could be undertaken to reduce mortality to anadromous fish in the Delta by fixing the serious predation and site-specific habitat problems in the Delta. This alternative for protecting these beneficial uses would not cause the severe and unreasonable impacts resulting from any new objectives based upon a percentage of unimpaired flows. As such, the SWRCB must analyze this approach as an alternative.

current science, should only be modified by the SWRCB if it is clear, based on the record in front of the SWRCB, that these settlements do not protect beneficial uses. To use the example of delta smelt and X2, it would not be appropriate for the SWRCB to conclude that Sacramento River inflows to the Delta must be increased to move X2 closer to the Golden Gate Bridge, in light of the data presented by the above-referenced December 2011 report (Exhibit 5 hereto), which shows no correlation between delta smelt abundance and water use in the Sacramento Valley. Moreover, because most of these settlements and the associated regulatory regimes have only been in place for a few years (mostly during the 2007-2009 drought), it would be inappropriate and premature for the SWRCB to conclude – at the present time – that these regulatory standards have failed to protect beneficial uses.[8]

We appreciate the SWRCB's consideration of these comments, and look forward to participating in the scoping meeting on May 26, 2012.

Sincerely,

SOMACH SIMMONS & DUNN

By Andrew M. Hitchings
Andrew M. Hitchings, Attorneys for
Glenn-Colusa Irrigation District

DOWNEY BRAND LLP

By__________________________
David R.E. Aladjem, Attorneys for
Reclamation District 108, Calaveras County Water District, Meridian Farms Water Company, Natomas Central Mutual Water Company, Pelger Mutual Water Company, River Garden Farms Company, South Sutter Water District, Sutter Extension Water District, Sutter Mutual Water Company and Sacramento Municipal Utility District

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[8] In particular, the currently controlling NMFS Biological Opinion for the CVP and SWP operations was not adopted until June 4, 2009. As such, there have been less than three full irrigation seasons to assess its efficacy.

BARTKIEWICZ, KRONICK & SHANAHAN

By____________________________________
Alan B. Lilly, Attorneys for
Browns Valley Irrigation District, City of Folsom, City of Roseville, Sacramento Suburban Water District, San Juan Water District, Yolo County Flood Control & Water Conservation District, and Yuba County Water Agency

MINASIAN, MEITH, SOARES, SEXTON & COOPER, LLP

By____________________________________
Jeffrey Meith, Attorneys for
Western Canal Water District, Richvale Irrigation District and Biggs-West Gridley Water District

Attachments
cc: *(via email w/o attachments)*
Charles R. Hoppin, SWRCB Chair
Frances Spivy-Weber, SWRCB Vice Chair
Tam M. Doduc
John Laird
Dr. Jerry Meral
Matthew Rodriquez
AMH:cr

EXHIBIT 1

PARTIES

Biggs-West Gridley Water District

Browns Valley Irrigation District

Calaveras County Water District

City of Folsom

City of Roseville

Glenn-Colusa Irrigation District

Meridian Farms Water Company

Natomas Central Mutual Water Company

Pelger Mutual Water Company

Reclamation District 108

Richvale Irrigation District

River Garden Farms Company

Sacramento Municipal Utility District

Sacramento Suburban Water District

San Juan Water District

South Sutter Water District

Sutter Extension Water District

Sutter Mutual Water Company

Western Canal Water District

Yolo County Flood Control & Water Conservation District

Yuba County Water Agency

EXHIBIT 1

EXHIBIT 2

Evaluation
Of
Potential
State Water Resources Control Board
Unimpaired
Flow
Objectives

April 25, 2012

Prepared for: Sacramento Valley Water Users Group
Prepared by: MBK Engineers

EXECUTIVE SUMMARY

This report was prepared to support the Sacramento Valley Water Users in submitting comments to the State Water Resources Control Board (SWRCB) regarding proposed Delta outflow and Sacramento River flow requirements that would be based on percentages of unimpaired flows, and potentially included as water quality objectives in the SWRCB's update and implementation of the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). This report summarizes the results of a reconnaissance level analysis of the estimated effects that implementation of such requirements would have on water users in the Sacramento River Basin and on CVP/SWP reservoirs and operations.

Initially, an analysis was performed to determine the average percentages of unimpaired Delta outflows that would have occurred in different water-year types if Existing Conditions had been in effect during the entire period of historical record. Consistent with standard hydrological modeling practice, Existing Conditions are defined by today's regulatory requirements, land use, water demands, and facilities and are used to establish how the CVP/SWP currently operates. Existing Conditions percentage of unimpaired Delta outflow is calculated by averaging total modeled Delta outflows for the period of January through June and dividing by the average total unimpaired Delta outflow over that same period. The outflows were not calculated on a month-to-month basis for the initial analysis to determine Existing Conditions percentage of unimpaired Delta outflow. This analysis determined that, under Existing Conditions, average January-June Delta outflow over the period of record is about 50% of unimpaired flows and the critical year average Delta outflow is about 40% of unimpaired flows.

These average percentages of 50% and 40% of unimpaired flows then were modeled, in separate analyses, as minimum monthly Delta flow requirements for each month in the January through June period to estimate the hydrological and related impacts that would result from implementation of such minimum requirements. In other words, this report presents the estimated impacts that would occur if the existing average and average critical year percentages of unimpaired Delta outflows during the January through June period – 50% and 40%, respectively – were imposed as regulatory minimum Delta outflow requirements for each separate month from January through June. The approach of applying a constant percentage of unimpaired flow as a requirement for each month from January through June is consistent with the SWRCB August 2010 Delta flow criteria report and recent analysis performed by SWRCB on certain tributaries to the San Joaquin River as part of its update to the Bay-Delta Plan

The overall conclusions are summarized in the following list, and the detailed analytical results are summarized in this report. The overall conclusions regarding the estimated effects of implementing January-June minimum monthly Delta outflow requirements of 50% and 40% of unimpaired flows are as follows:

- Effects to the CVP and SWP reservoirs and operations would be severe and would result in the inability to maintain viable operations
- Increases in average annual Delta outflows would be:
    - 1,100,000 acre-feet for a 50% of unimpaired flows requirement; and
    - 480,000 acre-feet a 40% of unimpaired flows requirement
- The following reductions and decreases in Sacramento Basin CVP and SWP reservoir carryover storage would occur:

  - Significant reductions in cold water pools would occur under both the 50% and the 40% of unimpaired flows scenarios
  - An average reduction of 2,200,000 acre-feet in reservoir carryover storage would occur under the 50% of unimpaired flows scenario
  - An average reduction of 1,000,000 acre-feet in reservoir carryover storage would occur under the 40% of unimpaired flows scenario
- The following increases in Sacramento Basin groundwater pumping to meet reductions in surface-water deliveries would be necessary:
  - For the 50% of unimpaired flows scenario, groundwater pumping in the Sacramento Basin would have to increase by 250,000 acre-feet per year on average annual basis , and by an average of 1,000,000 acre-feet per year in Critical years
  - For the 40% of unimpaired flows scenarios, groundwater pumping in the Sacramento Basin would have to increase by 100,000 acre-feet per year on average annual, and by an average of 400,000 acre-feet per year in Critical years
- Such increases in groundwater pumping would not be realistic and therefore would not actually occur. Instead, there would have to be reductions in irrigated acreage
- Under both scenarios, there would be increased groundwater overdrafts in the export service area
- The following seasonal changes in river flows and Delta outflows and impacts would occur:
  - Increases in March through June
  - Decreases in July through December
  - Impacts to key instream temperature and habitat
- There would be regular and multiple violations of existing SWRCB standards and ESA Biological Opinion requirements
- There would be severe water supply impacts, including the following:
  - Water-supply impacts to CVP settlement and exchange contractors, and SWP settlement agreement holders, which have water rights senior to the CVP and the SWP
  - Significant reductions in north-of-Delta CVP and SWP water-service contract deliveries.
  - Inability to meet public health and safety water deliveries
  - Reductions in water deliveries to wildlife refuges

UNIMPAIRED FLOW

For hydrological analyses, unimpaired flows are the calculated flows that the Department of Water Resources (DWR) has developed to estimate the flow conditions that would have occurred in the absence of any human alterations of flows. These estimated unimpaired flows have been calculated by taking the stream flow conditions that actually occurred and by subtracting the effects of reservoir storage, water diversions, resulting return flows, and other factors that were caused by human influences on flows.

Unimpaired flow data used for this evaluation were provided by DWR and published in the 2006 report titled: *California Central Valley Unimpaired Flow Data, Fourth Edition*. DWR defines unimpaired flow on page 1 of this report as:

> *"Unimpaired flow is runoff that would have occurred had water flow remained unaltered in rivers and streams instead of stored in reservoirs, imported, exported, or diverted. The data is a measure of the total water supply available for all uses after removing the impacts of most upstream alterations as they occurred over the years. Alterations such as channel improvements, levees, and flood bypasses are assumed to exist."*

The State Water Resources Control Board (SWRCB) has suggested that it may establish new Delta outflow and Sacramento River flow requirements that are based on specified percentages of unimpaired flows. The SWRCB's August 2010 Delta Flow Criteria report suggested that in order to protect aquatic public trust resources in the Delta, 75% of unimpaired Delta outflow would be necessary from January through June, and that 75% of unimpaired Sacramento River flow would be needed for these months, as well as for November and December. The SWRCB has also analyzed the potential imposition of 20%, 40% and 60% unimpaired flow requirements on certain tributaries to the San Joaquin River as part of its update to the Bay-Delta Plan.

The percentages of unimpaired flow that flow into and out of the Delta are highly variable and are influenced by hydrologic conditions, historical development, and regulatory requirements. Fluctuating hydrologic conditions are the dominant factor contributing to variations in the percentages of unimpaired flow that occur over time at various locations in the Delta watershed. Historical development has influenced the percentages of unimpaired flows that have occurred as project reservoirs have been developed. However, it is not possible to ascertain the precise effects of these developments by analyzing historical data, because these data are heavily influenced by changes in hydrologic conditions. Regulatory conditions have also influenced the percentages of unimpaired flow that have occurred, particularly during summer and fall months where regulatory minimum river flow and Delta outflow requirements are greater than the corresponding unimpaired flows.

Because current operating requirements have only been in place for a short period of time, there is not enough available historical data to estimate the Existing Conditions percentage of unimpaired Delta outflow. Therefore standard hydrological modeling practice is to analyze the hydrologic impacts that would occur when current cultural and regulatory conditions – Existing Conditions – are applied to the variable hydrology that has occurred over a period of record. This approach enables projections about what effects existing requirements, or possible new requirements, will have going forward. In this report, to determine the average percentage of unimpaired Delta outflows that would occur, Existing Conditions are applied to a long-term hydrologic period, CalSim II is used to depict streamflows and those modeled streamflows then are compared to DWR's unimpaired flow data to estimate the Existing Conditions percentage of unimpaired Delta outflow. Actual historical flow data are included in this report to provide a historical perspective on the modeled percentages of unimpaired flow over the period of record under Existing Conditions. That comparison demonstrates that the modeled data is sufficiently reliable for analytical purposes.

Figure 1 is a plot of historical average monthly Delta outflows as percentages of average monthly unimpaired Delta outflows for the following periods:

- 1930-1943: Pre-Shasta Reservoir
- 1944-1955: Pre-Folsom Reservoir
- 1956-1968: Pre-Oroville Reservoir
- 1969-2003: Post Sacramento Basin Project Reservoirs
- All years: 1930-2003

During 1969 through 2003, hydrologic conditions varied significantly and regulatory standards became more stringent. Figure 2 is a plot showing average January through June historical Delta outflows during the 1969-2003 period as percentages of unimpaired Delta outflows for the same period of each year. Each data point is labeled with the Sacramento River Basin 40-30-30 index water year type. The average percentages of unimpaired flow for each water year type during the 1969-2003 period are listed in Table 1. Values in Table 1 are calculated by taking the average of total January through June historical flows divided by average total January through June unimpaired flows and is expressed in the following equation:

$$\mathit{Average}\left(\sum \mathit{January\ through\ June\ historical\ flow}\right) \div \mathit{Average}\left(\sum \mathit{January\ through\ June\ unimpaired\ flow}\right)$$

This equation can be used to calculate:(1)average percentage of unimpaired flow for all years; (2) percentages for each year type, as displayed in Table 1; and (3) average percentages based on a comparison of modeled flows over the period of record and DWR's calculated unimpaired flows. As indicated by this table, Delta outflows in wetter years tend to be higher percentages of unimpaired outflows, while Delta outflows in drier years tend to be lower percentages of unimpaired outflows. These differences generally occur because reservoir storage capacity does not change with changes in water year types, and reservoirs therefore are capable of storing a greater percentage of unimpaired flows in drier years than in wetter years.

Figure 1 – Average Historical Delta Outflow as a Percentage of Unimpaired Delta Outflow

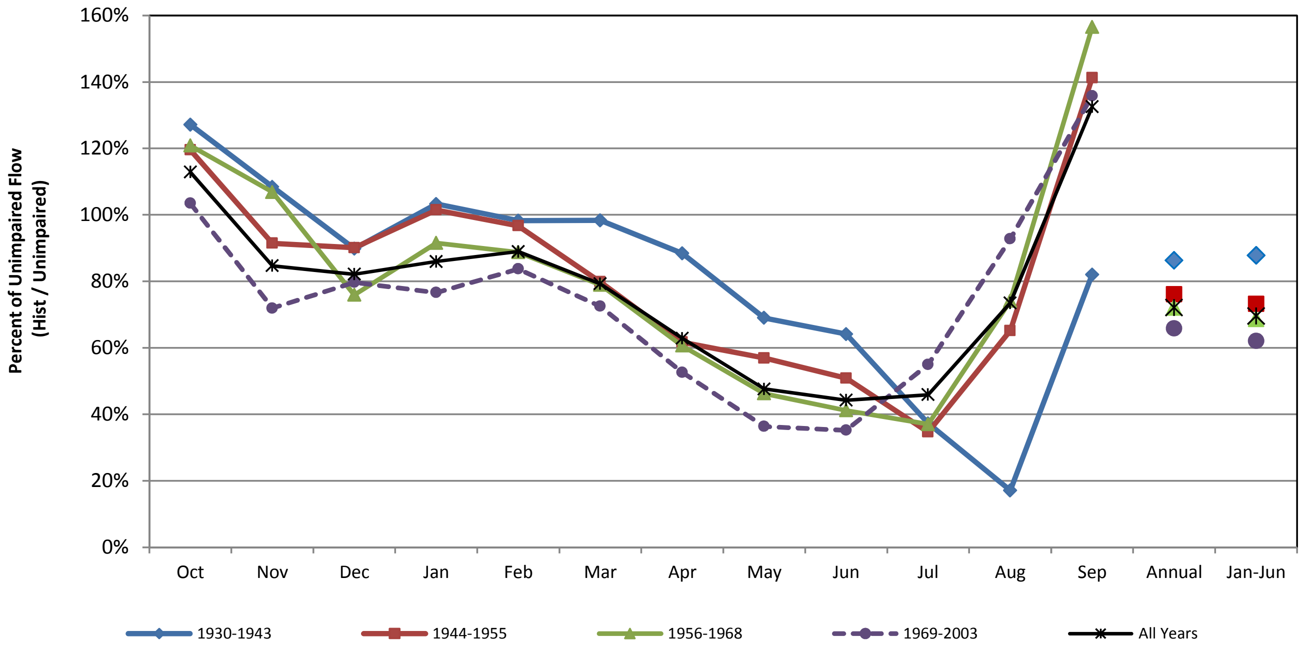


Figure 2 - Historical 1969-2003 Average January through June Historical Delta Outflow as a Percentage of Unimpaired Delta Outflow

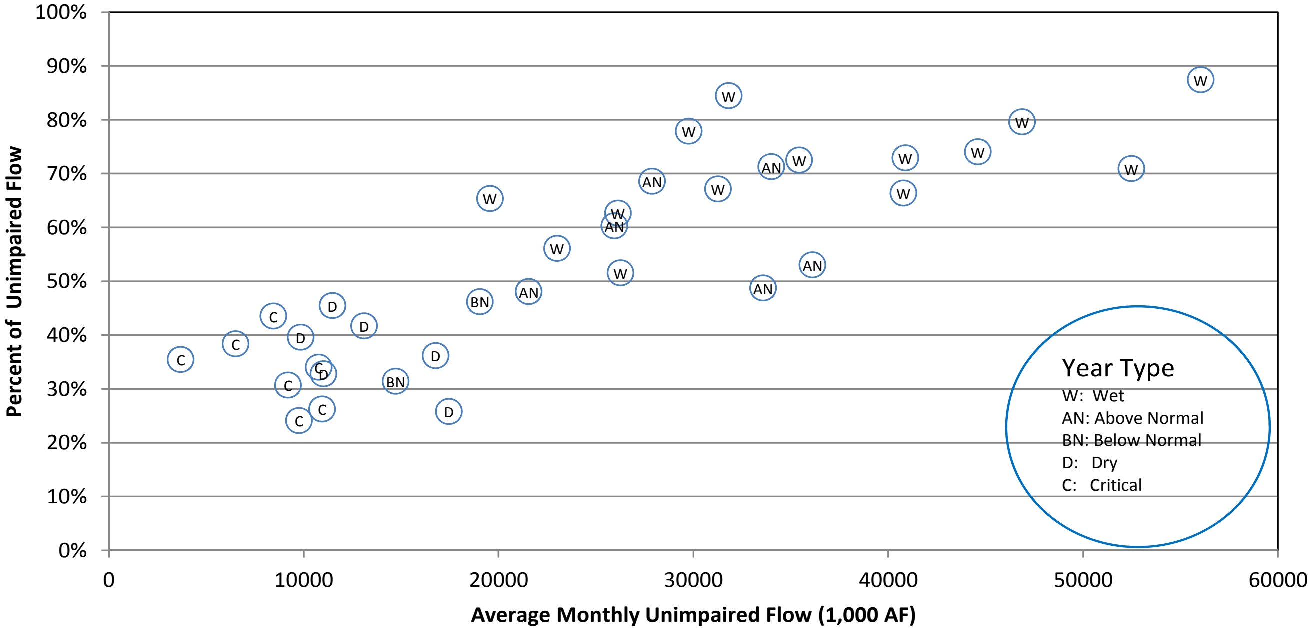


Table 1 - Historical 1969-2003 Average January through June Historical Delta Outflow as a Percentage of Unimpaired Delta Outflow by SRI Water Year Type

Wet	Above Normal	Below Normal	Dry	Critical	All Years
72%	59%	40%	36%	32%	62%

Due to the difficulties in using historical records to determine the average percentage of unimpaired flows that flow into and out of the Delta under Existing Conditions, an evaluation of CalSim II results was performed to estimate what Delta outflows would occur as percentages of unimpaired flows under Existing Conditions, under the variable hydrology that occurred during the 1922-2003 period of record. CalSim II is designed to represent existing CVP/SWP operating and system conditions by using existing operating criteria, facilities, and land use to model the CVP/SWP system and Delta for the 1922-2003 hydrologic period. Using CalSim II to determine the percentage of unimpaired Delta outflows that occur under this Existing Conditions scenario, and then using the average unimpaired outflow percentage developed from this scenario to create new model runs with these average percentage as minimum monthly Delta outflow requirements is the best available method of estimating what might happen if one of these existing percentages were implemented as a minimum Delta outflow requirement.

Figure 3 is a plot showing, by water year type, the monthly average modeled Delta outflows for the 1922-2003 period of record as percentages of monthly average unimpaired Delta outflows over the same period. Because Existing Conditions operating criteria are the same in every year of this CalSim II simulation, variations due to fluctuating hydrologic conditions can be more easily identified under this approach. For example, the percentages that modeled Delta outflows are of unimpaired flows for March vary from 40% in dry years to 78% in wet years. Figure 4 is a plot showing the average January through June modeled Delta outflow percentages of unimpaired Delta outflows for each year. Each data point is labeled with its water year type in this figure. The average percentages that modeled Delta outflows are of unimpaired flows for each water year type are listed in Table 2. In wetter years, modeled Delta outflows tend to be higher percentage of unimpaired outflows, averaging 65%, while in drier years modeled Delta outflows tend to be lower percentage of unimpaired outflow, averaging 40%.

The CalSim II modeling results indicate that over the 1922-2003 period of record, the average modeled Delta outflows under Existing Conditions is 53% of unimpaired outflows for the January through June period; the average percentage for critical years is 40%. To estimate the effects of imposing the existing average January through June percentage of unimpaired flow as a Delta outflow requirement, the value of 50% (rounded down from 53% to ensure that the effects are not overestimated) then is used as a minimum monthly regulatory requirement in further analysis. For the purpose of this further analysis, it is assumed that the 50% of unimpaired flow requirement is applied on a monthly basis from January through June, i.e., for each month from January through June, Delta outflow must be equal to or greater than 50% of unimpaired Delta outflow for that month. A second stage in the further analysis then was performed to estimate the effects of imposing the average January through June critical year Delta outflow percentage of unimpaired flows, 40%, as a minimum monthly regulatory requirement.

Figure 3 - Modeled with CalSim II: Average Delta Outflow as a Percentage of Unimpaired Delta Outflow

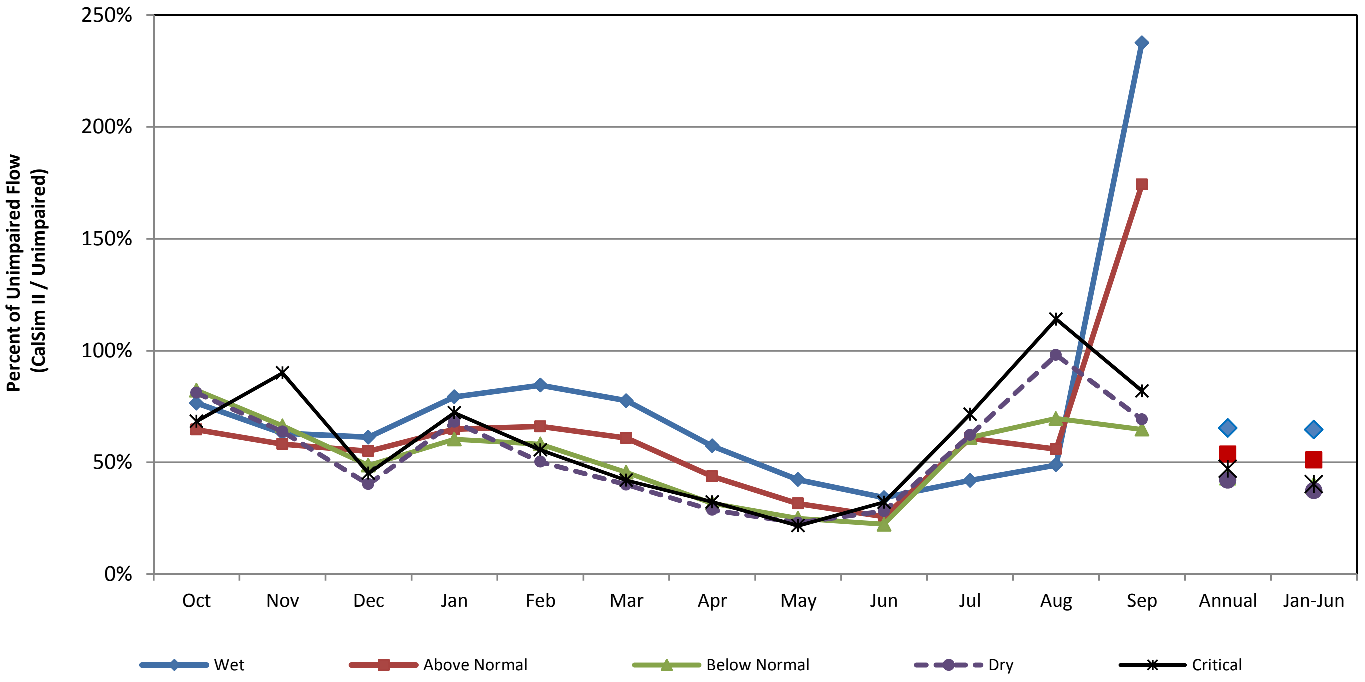


Figure 4 - Modeled with CalSim II: Average January through June Delta Outflow as a Percentage of Unimpaired Delta Outflow

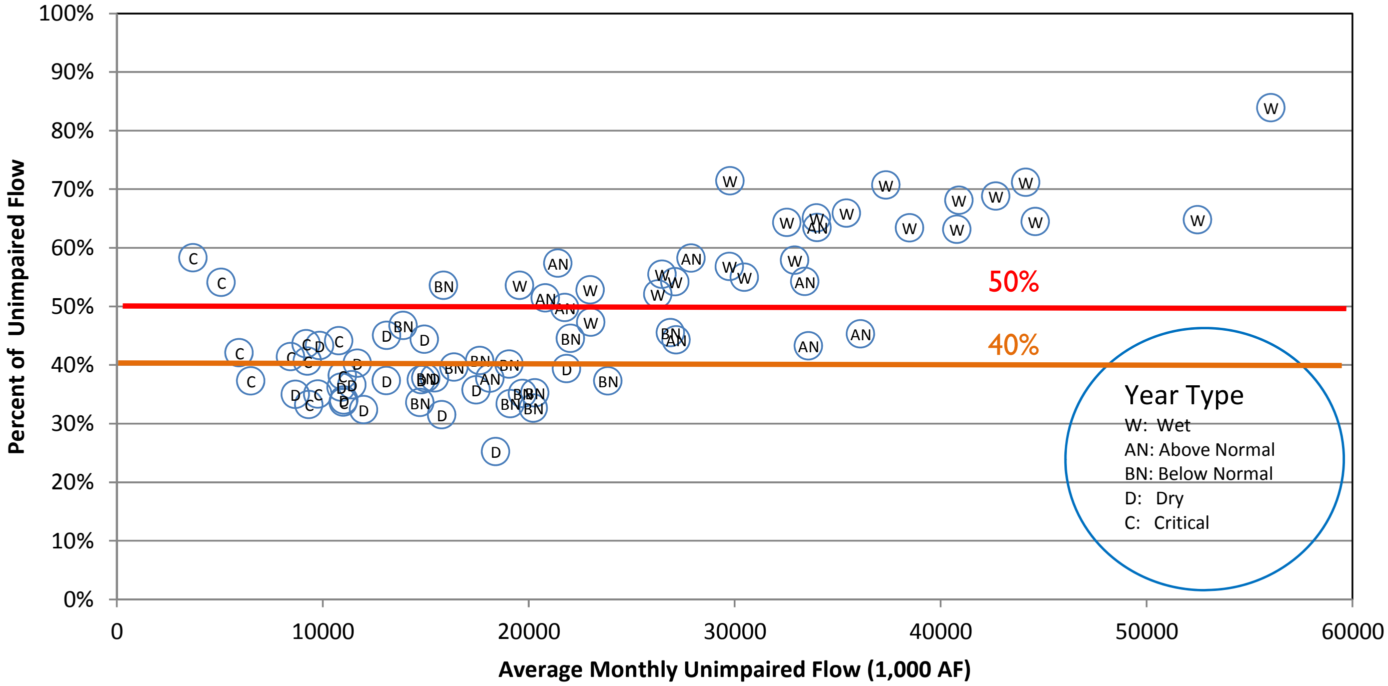


Table 2 - Modeled with CalSim II: Average January through June Delta Outflow as a Percentage of Unimpaired Delta Outflow

Wet	Above Normal	Below Normal	Dry	Critical	All Years
65%	51%	40%	37%	40%	53%

Sacramento River Basin Delta Inflow

Figure 5 is a plot of historical Sacramento River Basin Delta inflows as percentages of unimpaired flows, averaged for the following periods:

- 1930-1943: Pre-Shasta Reservoir
- 1944-1955: Pre-Folsom Reservoir
- 1956-1968: Pre-Oroville Reservoir
- 1969-2003: Post Sacramento Basin Project Reservoirs
- All years: 1930-2003

Although there were hydrologic fluctuations and varying regulatory requirements during the post-1944 period, the January through June averages of Delta inflows as percentages of unimpaired flows into the Delta from the Sacramento River have changed minimally during this almost 70-year period.

During the period from 1969 through 2003, hydrologic conditions varied significantly and regulatory standards became more stringent. The percentage of historical Sacramento River Delta inflows to unimpaired flows for the July through October period have increased through time due to increases in flow and salinity requirements and Delta exports. Figure 6 is a plot showing, for the 1969-2003 period, average January through June historical Sacramento River Basin flows to the Delta as percentage of unimpaired flows for each year. Each data point is labeled with the year type. The average percentages of Sacramento River Delta inflows to unimpaired flows for each water year type are listed in Table 3. In wetter years, Sacramento River inflows tend to be higher percentage of unimpaired outflows, while in drier years these percentage tend to be lower.

Figure 7 contains a chart showing monthly average Sacramento River Basin Delta inflows as percentages of unimpaired flows by water year type for the 1922-2003 period. Based on the CalSim II baseline, the average percentage of Sacramento River Basin Delta inflows to unimpaired flows for the January through June period is 78%; the average of these percentages for critical years is 67%. Although Sacramento River Basin inflows to the Delta are a higher percentage of unimpaired flows (69%) than are Delta outflows (50%), the percentage of Delta outflow to unimpaired flows is applied as a minimum flow requirement for Sacramento River inflows to the Delta for this analysis. This assumption will estimate less adverse effects to the Sacramento River Basin than would occur with a 78% minimum flow requirement.

Figure 5 - Average Historical Sacramento Basin Delta inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow

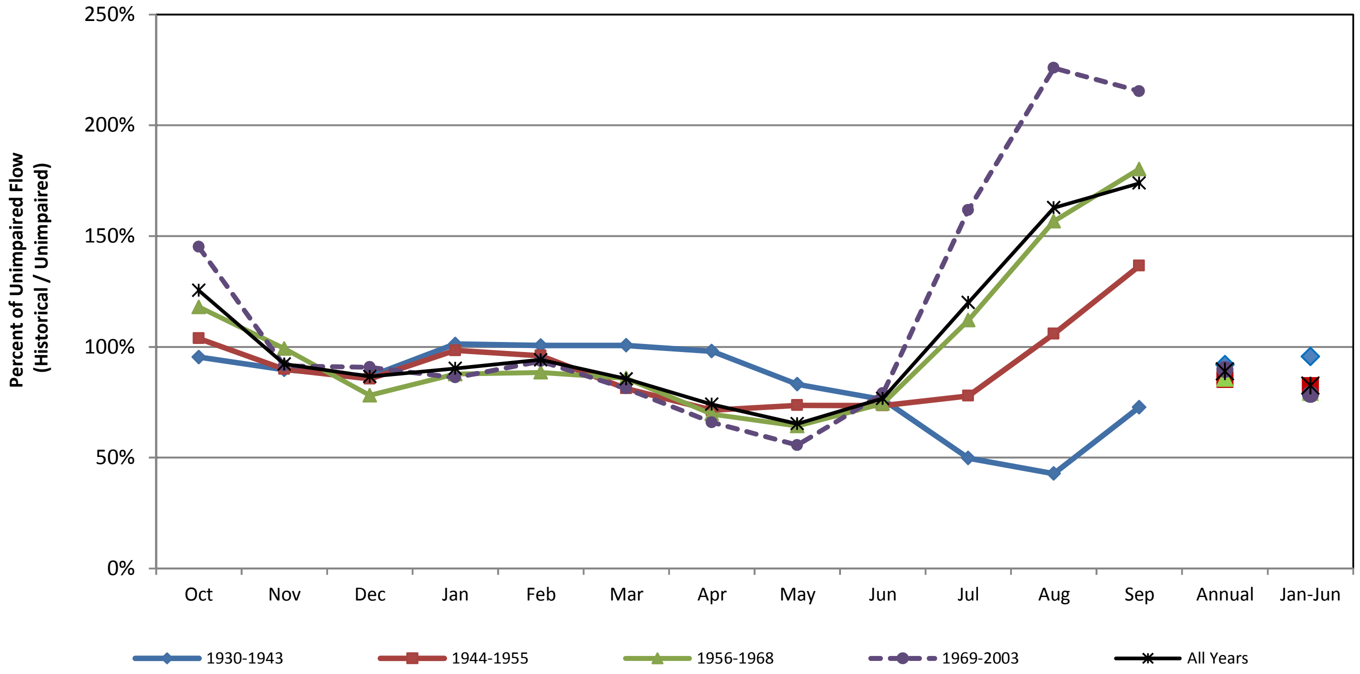


Figure 6 - Historical 1969-2003 Average January through June Sacramento Basin Delta inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow

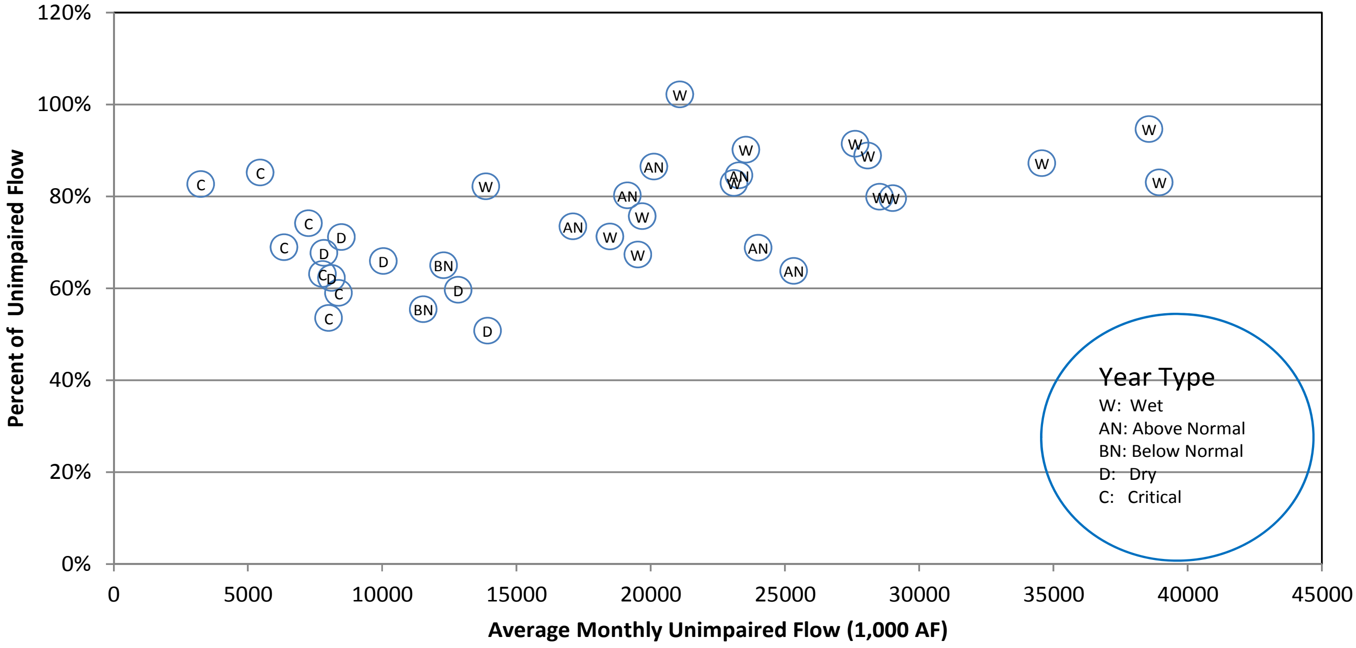


Table 3 - Historical 1969-2003 Average January through June Historical Sacramento Basin Delta Inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow by SRI Water Year Type

Wet	Above Normal	Below Normal	Dry	Critical	All Years
85%	76%	60%	62%	67%	78%

Figure 7 - Modeled with CalSim II: Average Sacramento Basin Delta Inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow

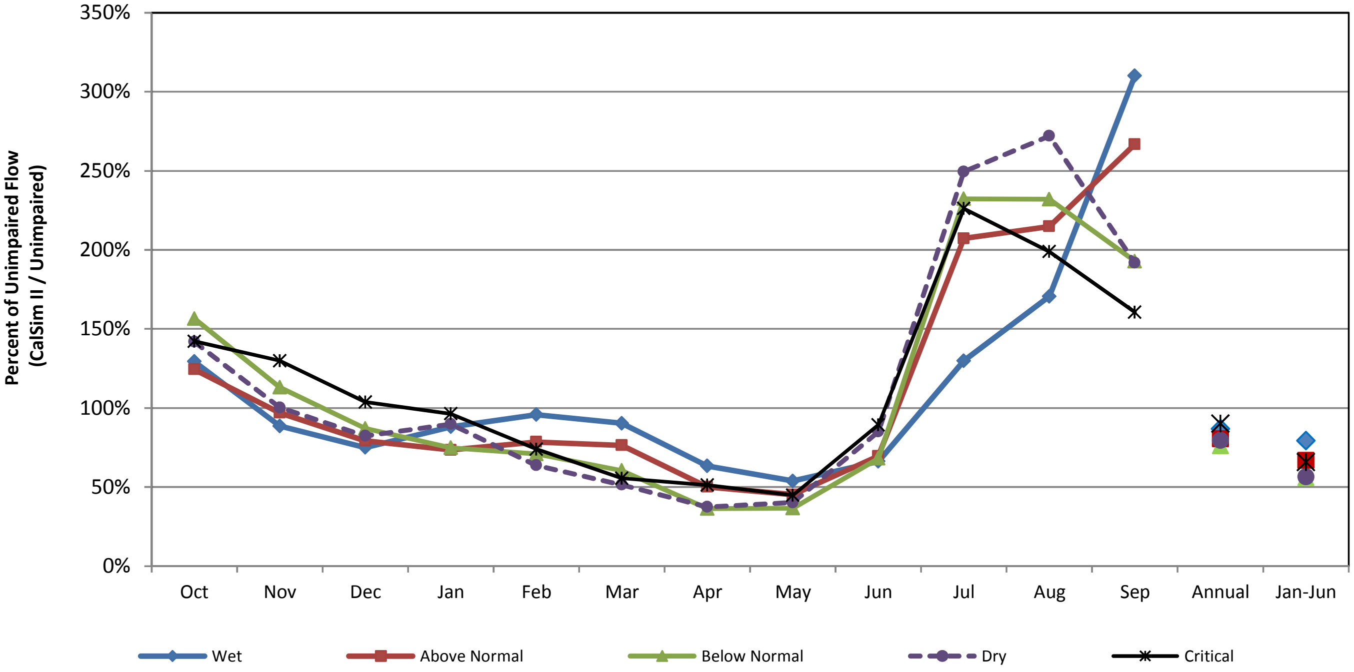


Table 4 - Modeled with CalSim II: Average January through June Sacramento Basin Delta Inflow as a Percentage of Unimpaired Sacramento Basin Delta Inflow

Wet	Above Normal	Below Normal	Dry	Critical	All Years
79%	67%	56%	56%	65%	69%

MODELING ASSUMPTIONS AND LIMITATIONS

The primary analytical tool used for this effort is the latest publically available version of the CalSim II model. The CalSim II model simulation used to support the State Water Project Delivery Reliability Report (SWP DRR) is the best available modeling tool and latest public release of the model. The DRAFT Technical Addendum to SWP DRR 2011, titled January 2012 of the SWP DRR, describes the CalSim II modeling assumptions. For this analysis, CalSim II was used to assess changes in CVP / SWP storage, river flows, water deliveries, and Delta conditions. The SWP DRR may be found at the following web location: http://baydeltaoffice.water.ca.gov/swpreliability/2011DraftDRR012612.pdf.

The Delta outflow requirements based on 50% and 40% of unimpaired flows described above were inputted into the CalSim II Existing Conditions model simulation to develop two new model simulations, which estimate how the system would operate with such Delta outflow requirements. Two CalSim II model simulations were developed to perform this analysis: one with a 50% of unimpaired Delta outflow requirement and a 50% of unimpaired Sacramento River flow requirement from January through June, and the other with a 40% of unimpaired Delta outflow requirement and a 40% of unimpaired Sacramento River flow requirement from January through June. These two model simulations were then compared to Existing Conditions to estimate the changes to the water system that would occur with the new Delta outflow requirements. The applicable Delta outflow requirement for each simulation then was applied as an average monthly net Delta outflow requirement, and the Sacramento River Basin requirement was applied as a minimum requirement for the sum of Sacramento River flow at Freeport plus the Yolo Bypass inflow to the Delta.

The SWRCB’s 2010 Delta flow criteria report suggests that its proposed criteria that are stated in percentages of unimpaired flows could be implemented as 14-day running averages. The CalSim II model, however, simulates on a monthly time step and does not provide daily or hourly results and, therefore, simplifies the hydrologic diversity that exists in reality. Accordingly, when using the CalSim II model – which is the best available model -- it is difficult to predict how requirements that are based on a percentage of the unimpaired flows would be implemented or operated on 14-day average basis. Modeling using the CalSim II model probably understates the real impacts of implementing the proposed Delta outflow and Sacramento River flow requirements as percentage of unimpaired flows on a time-step less than one month, as suggested by the proposed Delta flow criteria in the SWRCB’s 2010 report.

In addition, the CalSim II model primarily simulates operations of the CVP and SWP Systems. The SWRCB’s 2010 Delta flow criteria report suggests that the SWRCB would seek to spread the impacts of implementing the proposed Delta outflow and streamflow requirements over all upstream users, but no integrated model with this capability currently exists. Therefore, the CalSim II model for the SWP/CVP was used for this analysis as a surrogate for the kinds of impacts that may be observed if Delta outflow and Sacramento River flow requirements based on percentage of unimpaired flows were implemented as minimum outflow and flow requirements.

The water supply impacts that would result from 50% and 40% of unimpaired flow requirements for Delta outflow and Sacramento River flow would be extreme and would go far beyond what CalSim II is designed to evaluate. If these requirements were implemented, then SWP and CVP reservoirs would be at the "dead pool" levels by the end of summer in many years, CVP and SWP settlement contracts would be violated due to the lack of adequate water supplies, and existing temperature and water quality standards could not be met much of the time due to exhaustion of water supplies in the reservoirs. None of these events are consistent with how the CVP and SWP actually would be operated. For this reason, to more accurately model the effects of such requirements, a new in-basin depletion analysis would need to be constructed, and this analysis necessarily would have to simulate the additional reductions in water supplies that would result from implementation of such requirements. The CalSim II modeling described in this evaluation was used to evaluate the order of magnitude of water system impacts. However, because of these limitations in the CalSim II model, the results discussed in this evaluation are underestimates of the impacts that actually would occur from implementing these Delta outflow and Sacramento River flow requirements.

OBSERVATIONS

When a 50% of unimpaired Delta outflow requirement and a 50% of unimpaired Sacramento River Basin inflow to the Delta requirement from January through June are imposed on the Existing Conditions scenario, the average annual Delta outflow increases by 1,057,000 AF. The model results show that the 50% of unimpaired flow requirement for Sacramento River inflows to the Delta normally would not govern CVP/SWP operations because the more onerous Delta outflow requirement would control in all but 3 monthly time steps in the 82-year simulation. The model results indicate that, to meet a Delta outflow requirement based on 50% of unimpaired flows, Sacramento River Basin inflows to the Delta would increase by an average of 331,000 AF annually, Delta exports would decrease annually by 703,000 AF, and other Delta diversions (including the North Bay Aqueduct) would decrease by 23,000 AF annually. The CalSim II modeling estimated that the increased Sacramento River Basin inflows to the Delta of 331,000 AF would require increased imports from the Trinity River Basin of 91,000 AF, increased Sacramento River Basin groundwater pumping of an annual average of 248,000 AF, and other average annual changes of 8,000 AF. Figure 8 shows these estimated average annual flow changes by water year type.

When a 40% of unimpaired Delta outflow requirement and a 40% of unimpaired Sacramento River Basin to Delta flow requirement from January through June are imposed on the Existing Conditions scenario, the average annual Delta outflow increases by 484,000 AF. The model results show that the 40% of unimpaired flow requirement for Sacramento River inflows to the Delta normally would not govern CVP/SWP operations because the more onerous Delta outflow requirement would control in all months of the simulation. The model results indicate that, o meet a Delta outflow requirement based on 40% of unimpaired flows, Sacramento River Basin inflows to the Delta would increase an average of 136,000 AF annually, Delta exports would decrease annually by 333,000 AF, and other Delta diversions (including the North Bay Aqueduct) would decrease by 15,000 AF annually. The CalSim II modeling estimated that the increased Sacramento River Basin inflows to the Delta of 136,000 AF would require increased imports from the Trinity River Basin by 32,000 AF, increased Sacramento River Basin groundwater pumping of an annual average of 99,000 AF, and other changes of 7,000 AF. Figure 9 shows these estimated average annual flow changes by water year type.

Imports from the Trinity River Basin

The requirements of 50% and 40% of unimpaired flows are outside the operational parameters that CalSim II was designed to model. The CalSim II logic that balances Trinity and Shasta Reservoir storage amounts properly for Existing Conditions therefore may not be suitable for modeling the operations that would be necessary to satisfy these outflow and flow requirements. In particular, desired increases in releases from Trinity Reservoir to the Trinity River may be inconsistent with the CalSim II modeled operations that would be triggered by these requirements based on 50% and 40% of unimpaired flows. Additional modeling logic that isolates Trinity operations from the Sacramento River Basin operations therefore may need to be developed. Because imports from the Trinity River Basin actually might not increase as much as is indicated by the CalSim II modeling done for this evaluation, the model results described in this report probably underestimate the impacts within the Sacramento River Basin that actually would occur with implementation of these requirements.

Figure 8 - Annual Average Changes in Flow by Water Year Type
50% Unimpaired Flow Requirement

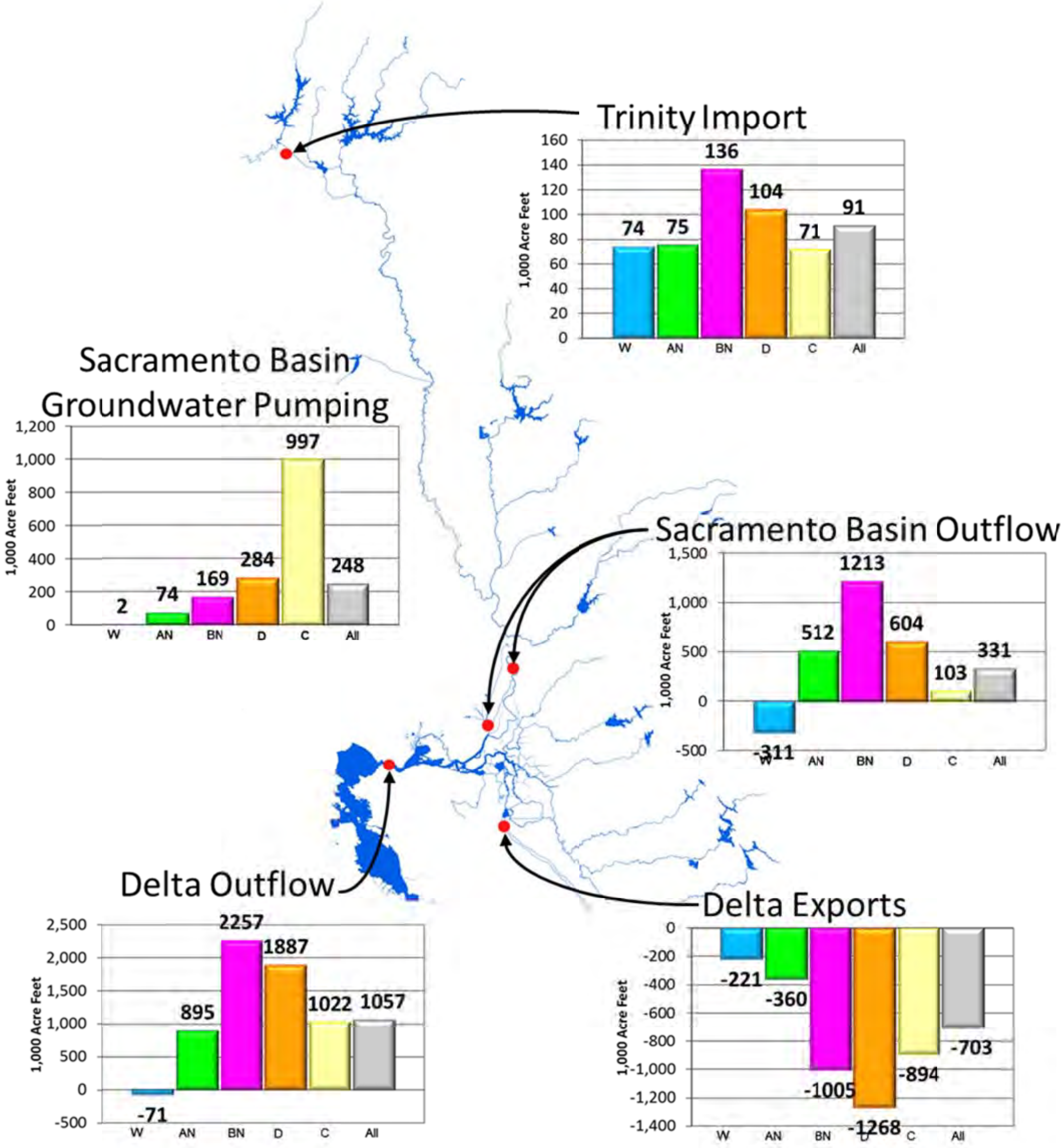
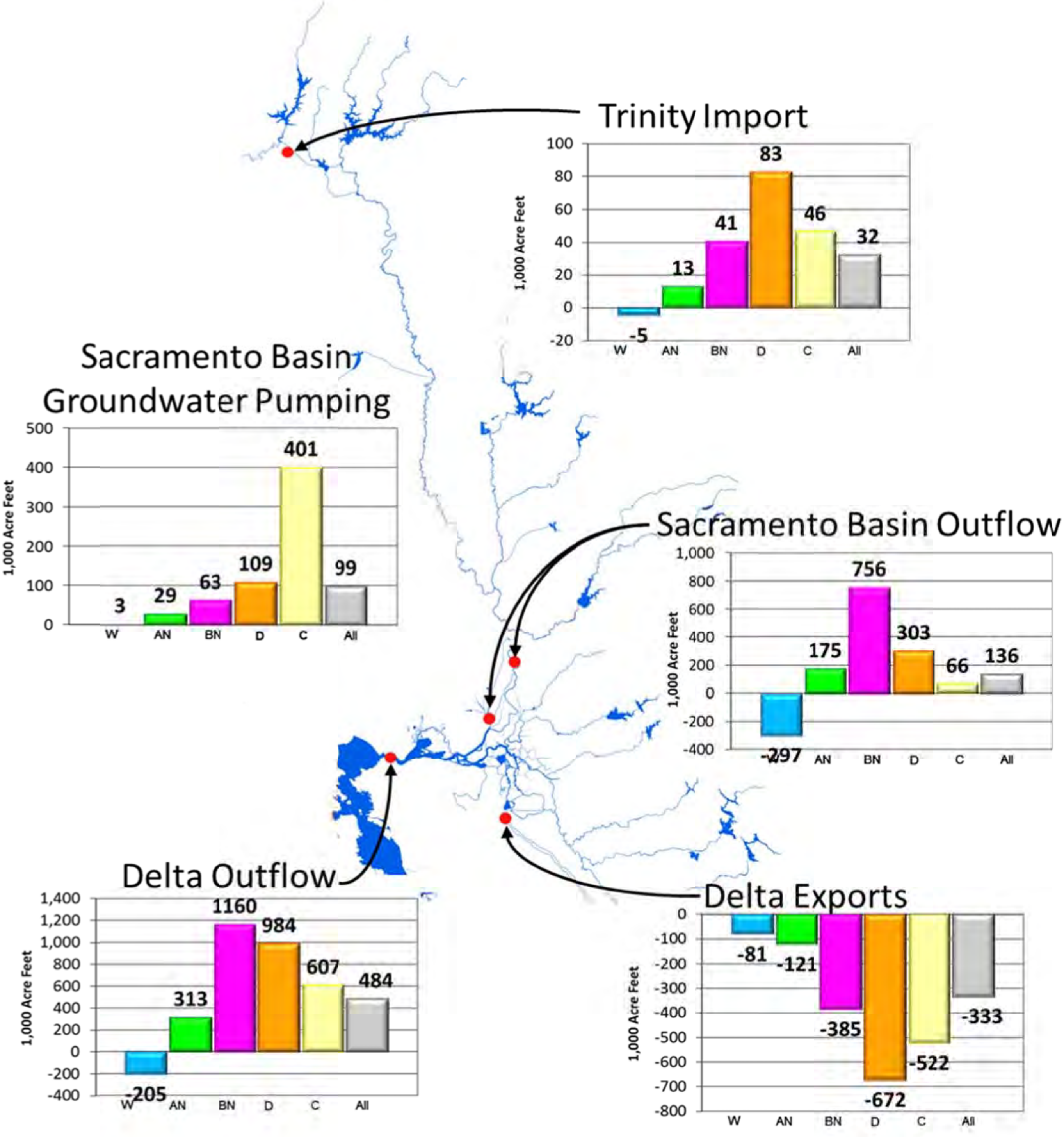


Figure 9 - Annual Average Changes in Flow by Water Year Type
40% Unimpaired Flow Requirement



Groundwater and land fallowing
As noted above, water supply impacts of the requirements that are 50% and 40% of unimpaired flows would exceed what the existing CalSim II model can readily assess. For example, when a CalSim II modeling scenario does not have enough water to meet in-basin demands, the model simply assumes that groundwater in the Sacramento Valley will be pumped to make up the shortage. However, the groundwater pumping that would be necessary to make up for the water supply losses to water users in the Sacramento River Basin with implementation of requirements that are 50% and 40% of unimpaired flows would not be physically possible or sustainable. Figures 10 and 11 show the added groundwater pumping that would be needed to meet in-basin demands that would be necessary to make up for the losses in surface water supplies that would occur with implementation of these requirements.

Although the CalSim II modeling for these requirements assumes that groundwater pumping would increase as necessary to make up for all losses in surface-water supplies in the Sacramento River Basin, in reality this would not be possible, so, in reality, there probably would be reductions in total crop acreage and wildlife refuge water supplies. Also, any increases in actual groundwater pumping probably would result in lower groundwater levels and increases in groundwater recharge (similar in magnitude to the increases in pumping). These increases in recharge would result in decreases in stream flows, which would cause additional needs for groundwater pumping, reservoir releases, and crop fallowing. Decreases in groundwater levels also probably would cause adverse impacts to major surface water systems and ephemeral stream habitat (by inducing greater recharge through streambeds) and to urban wells. There are a large number of factors affecting the interrelationships between groundwater levels and pumping, stream-groundwater interactions, deep percolation of applied water, percolation of precipitation, and natural recharge, all of which make it difficult to speculate how much additional pumping, recharge, and fallowing would occur if these requirements were implemented.

Figure 10 – Required Groundwater Pumping Due to 50% Unimpaired Flow Requirement

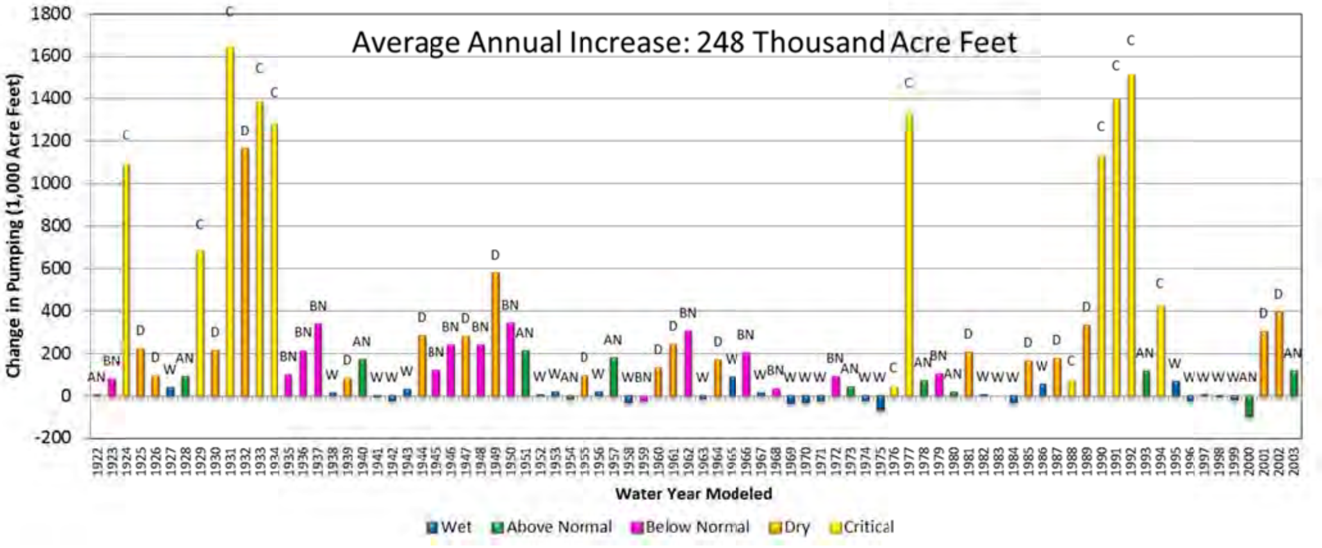
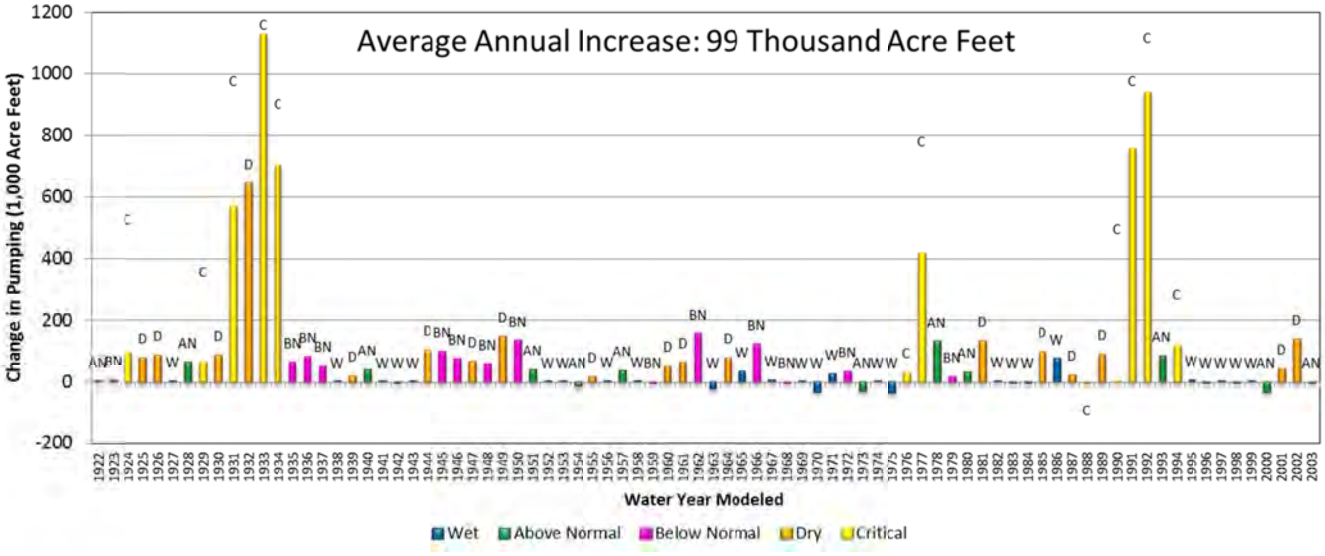


Figure 11 – Required Groundwater Pumping Due to 40% Unimpaired Flow Requirement



Project Reservoir Storage

Figure 12 and Figure 13 show the expected CVP and SWP reservoir levels that would occur at the end of September with implementation of requirements of 50% and 40% of unimpaired flows. The 50% of unimpaired flow requirements would cause Trinity, Shasta and Folsom Reservoirs to be at the dead pools (effectively empty) by the end of September in 20% of all years, and Oroville Reservoir to be at its minimum pool in 40% of all years. In contrast, under current operating rules, such dead pool levels would occur only rarely. With implementation of the 50% of unimpaired flow requirements, average carryover storage reductions for the major project reservoirs would be :

- Trinity Reservoir: - 460,000 AF
- Shasta Reservoir: - 960,000 AF
- Oroville Reservoir: - 620,000 AF
- Folsom Reservoir: - 150,000 AF

The total reduction in upstream carryover project storage that would be caused by implementing a 50% of unimpaired flow requirement would be about 2.2 million AF, and the carryover reduction would be even greater in drier years. These reductions in carryover storage, coupled with substantially increased groundwater pumping, would result in water supply deficits in the Sacramento Valley that would be greater than 2 million AF in below normal, dry, and critical years. Under these conditions, the CVP and SWP reservoir storage levels required by in the National Marine Fisheries Services' 2009 salmon Biological Opinion (BO) could not be maintained. In addition, the cold-water pools in these reservoirs that are necessary to meet temperature conditions downstream for salmon survival and reproduction would be completely depleted in 20% of years, and would be greatly reduced in other years. These depletions and reductions would make it virtually impossible for CVP and SWP operations to achieve acceptable temperature requirements in the rivers downstream of these reservoirs. With implementation of these requirements, maintaining acceptable storage levels in these reservoirs throughout summer months may not be possible, even with severe reductions in agricultural diversions. Reducing reservoir releases by 2 million AF from July through September would result in violations of applicable instream flow requirements and would make it difficult or impossible to meet applicable instream temperature requirements.

Implementation of the 40% of unimpaired flow requirements would result in Trinity, Shasta, Folsom Reservoirs being at their dead pools (effectively empty) by the end of September in roughly 10% of all years, and in Oroville Reservoir being at its minimum pool in 30% of all years. With implementation of the 40% of unimpaired flow requirements, average carryover storage reductions for the major project reservoirs would be:

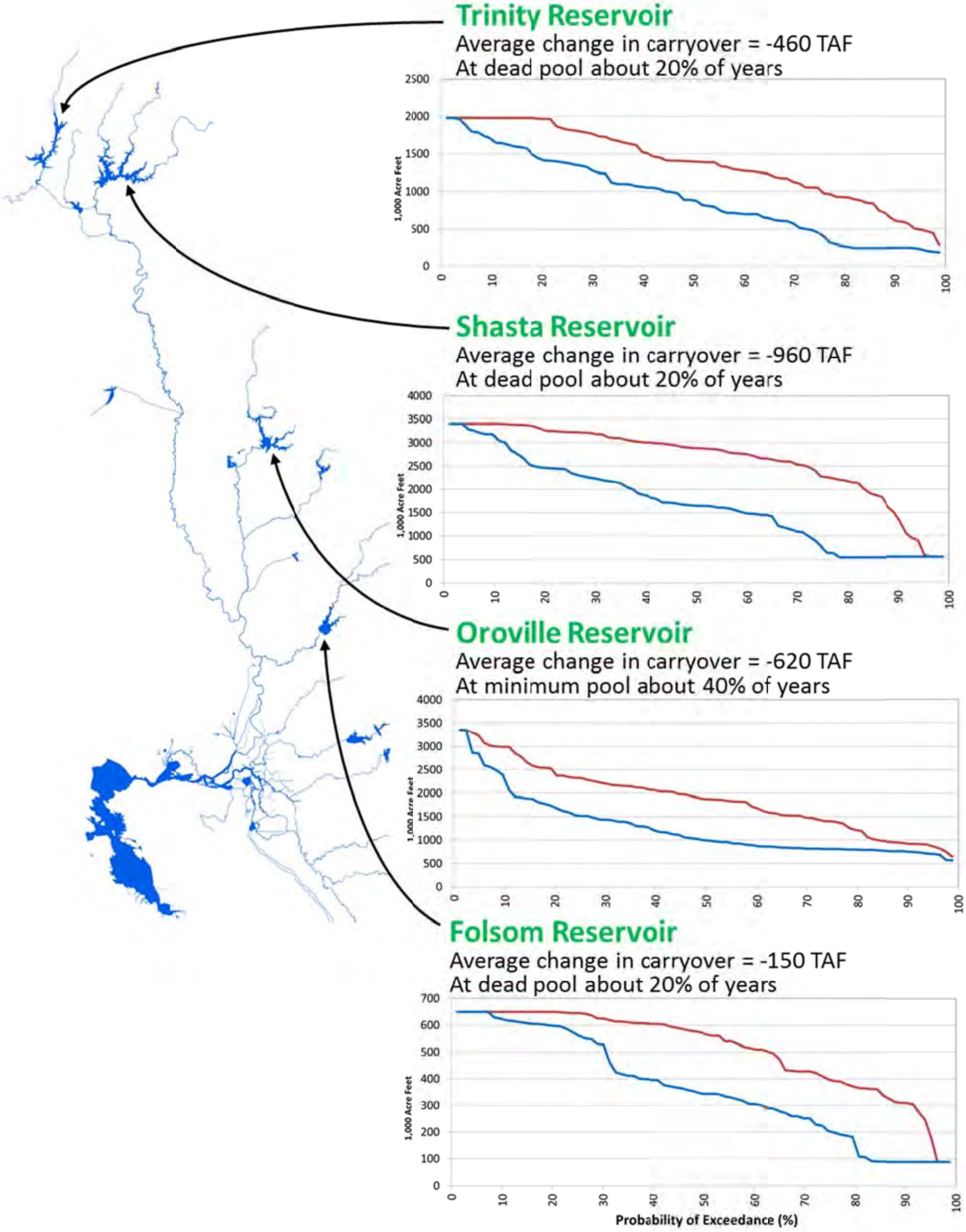
- Trinity Reservoir: - 200,000 AF
- Shasta Reservoir: - 423,000 AF
- Oroville Reservoir: - 390,000 AF
- Folsom Reservoir: - 79,000 AF

The total reduction in upstream carryover project storage that would occur with implementation of the 40% of unimpaired flow requirement would be about 1.1 million AF. Although such reservoir deficits would be about half of the reservoir deficits that would occur with implement of the 50% of unimpaired flow requirement, there still would be similar types of impacts. Reducing upstream reservoir releases by 1 million AF from July through September would result in violations to the applicable instream flow requirements and would make it difficult or impossible to meet the applicable instream temperature requirements.

This extensive loss of carryover reservoir storage would have significant impacts to hydropower, recreation, lake fisheries, and downstream fisheries. During multiyear droughts, project reservoirs would be at minimum or dead pool levels throughout the drought period, which would lead to adverse conditions for fisheries in many consecutive years. Figures 14 through 17 show monthly storage in Trinity, Shasta, Oroville, and Folsom Reservoirs respectively for the 1922-2003 CalSim II simulation period for Existing Conditions and the 50% and 40% of unimpaired flow requirements. By comparing Existing Conditions storage to the 50% and 40% of unimpaired flow storage prolonged reductions in storage due to unimpaired flow requirements are noticeable, particularly in dryer conditions. These prolonged reductions in storage would result in adverse conditions that could persist for several years.

Figure 12 - Project Reservoir Carryover Storage

50% Unimpaired Flow Requirement



Trinity Reservoir

Average change in carryover = -460 TAF

At dead pool about 20% of years

Shasta Reservoir

Average change in carryover = -960 TAF

At dead pool about 20% of years

Oroville Reservoir

Average change in carryover = -620 TAF

At minimum pool about 40% of years

Folsom Reservoir

Average change in carryover = -150 TAF

At dead pool about 20% of years

Figure 13 - Project Reservoir Carryover Storage
40% Unimpaired Flow Requirement

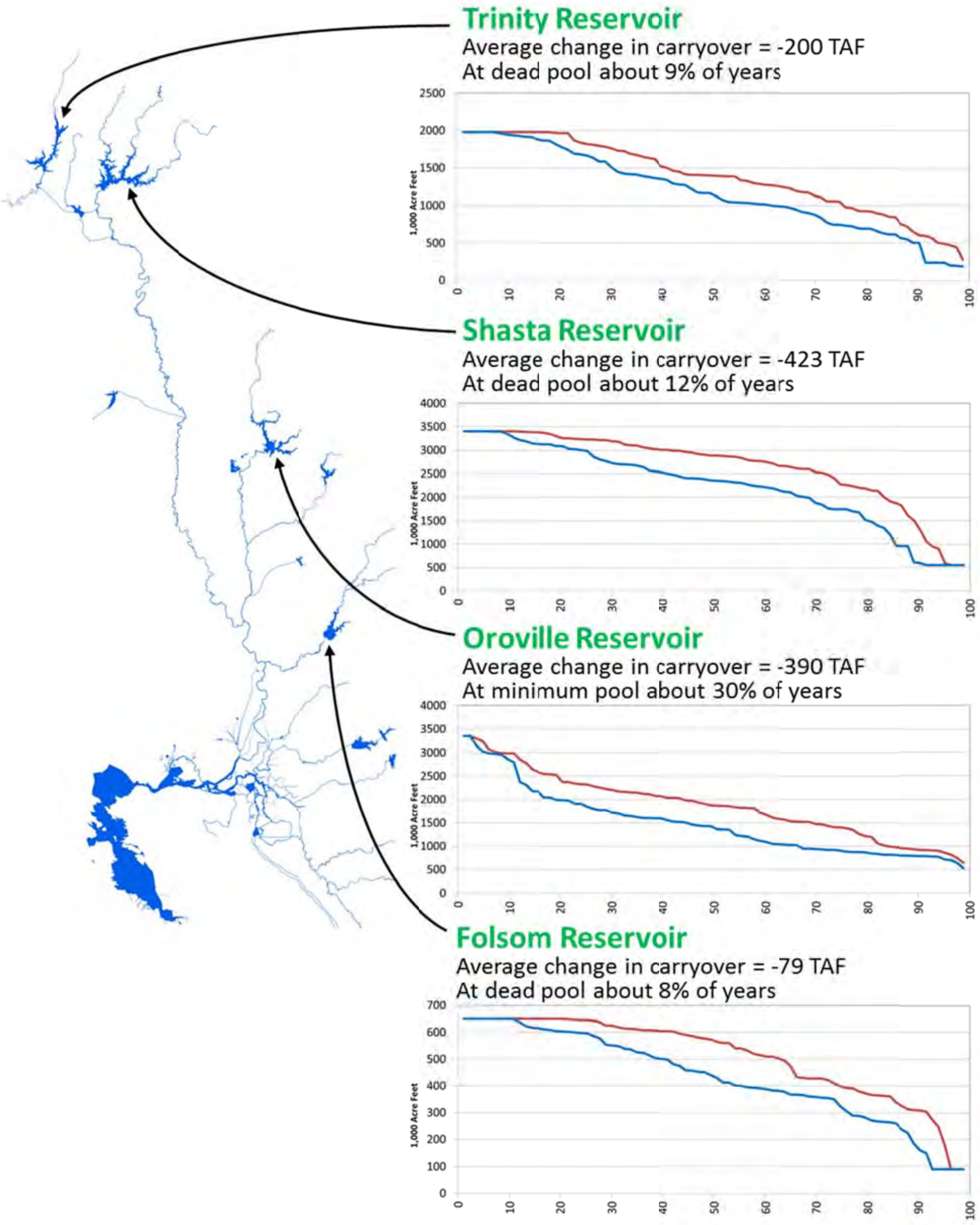


Figure 14 - Monthly Trinity Reservoir Storage
50% and 40% Unimpaired Flow Requirement

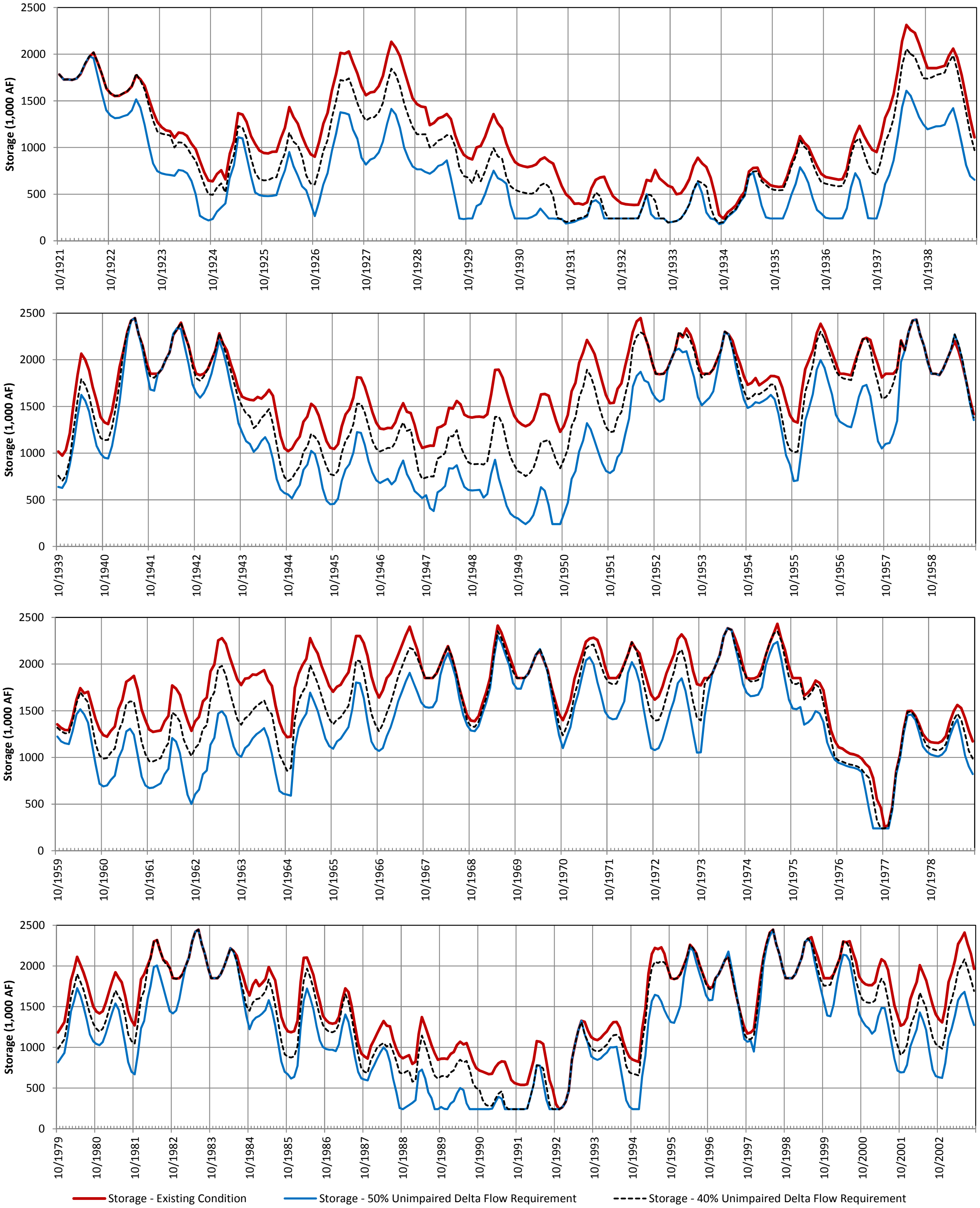


Figure 15 - Monthly Shasta Reservoir Storage
50% and 40% Unimpaired Flow Requirement

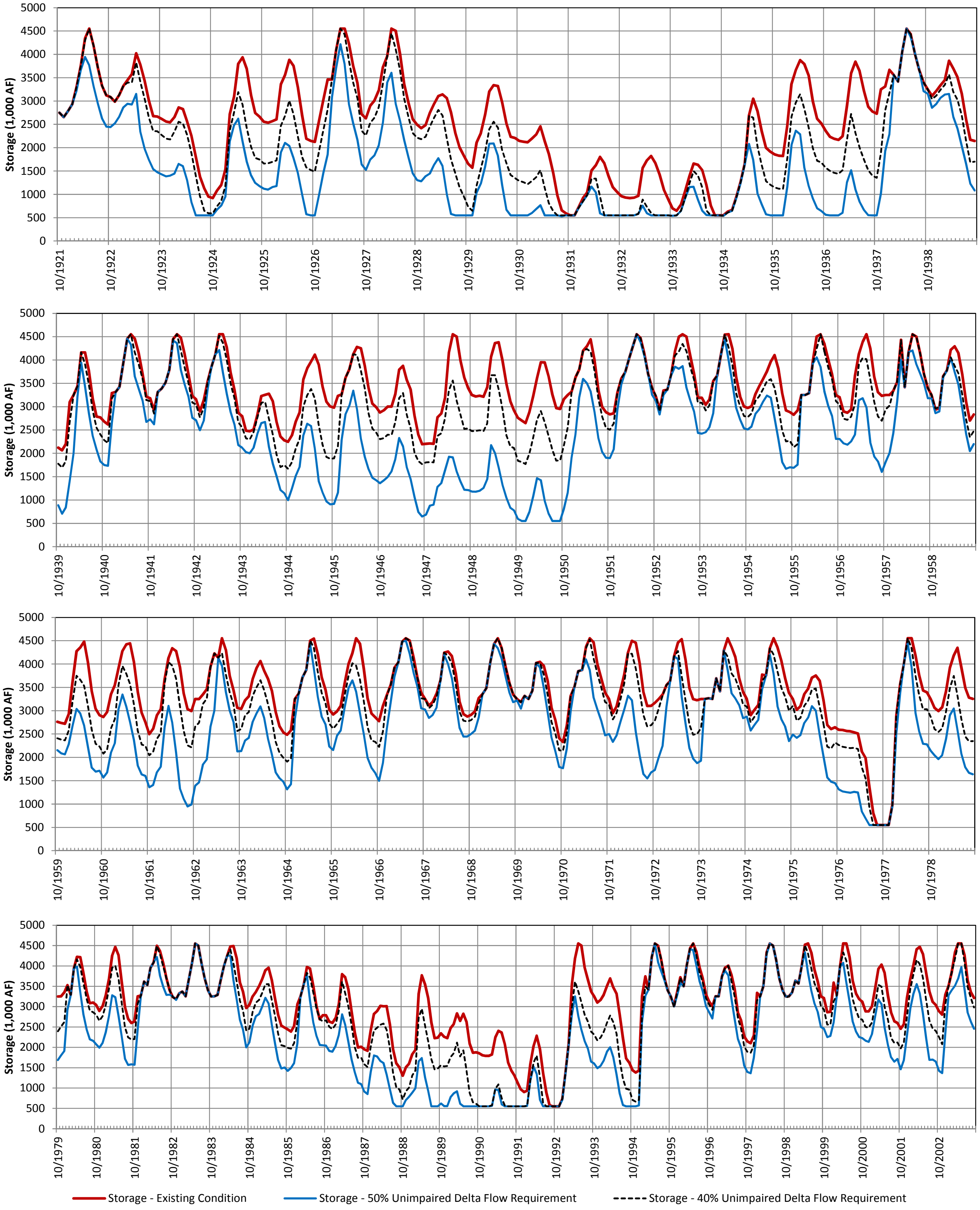


Figure 16 - Monthly Oroville Reservoir Storage
50% and 40% Unimpaired Flow Requirement

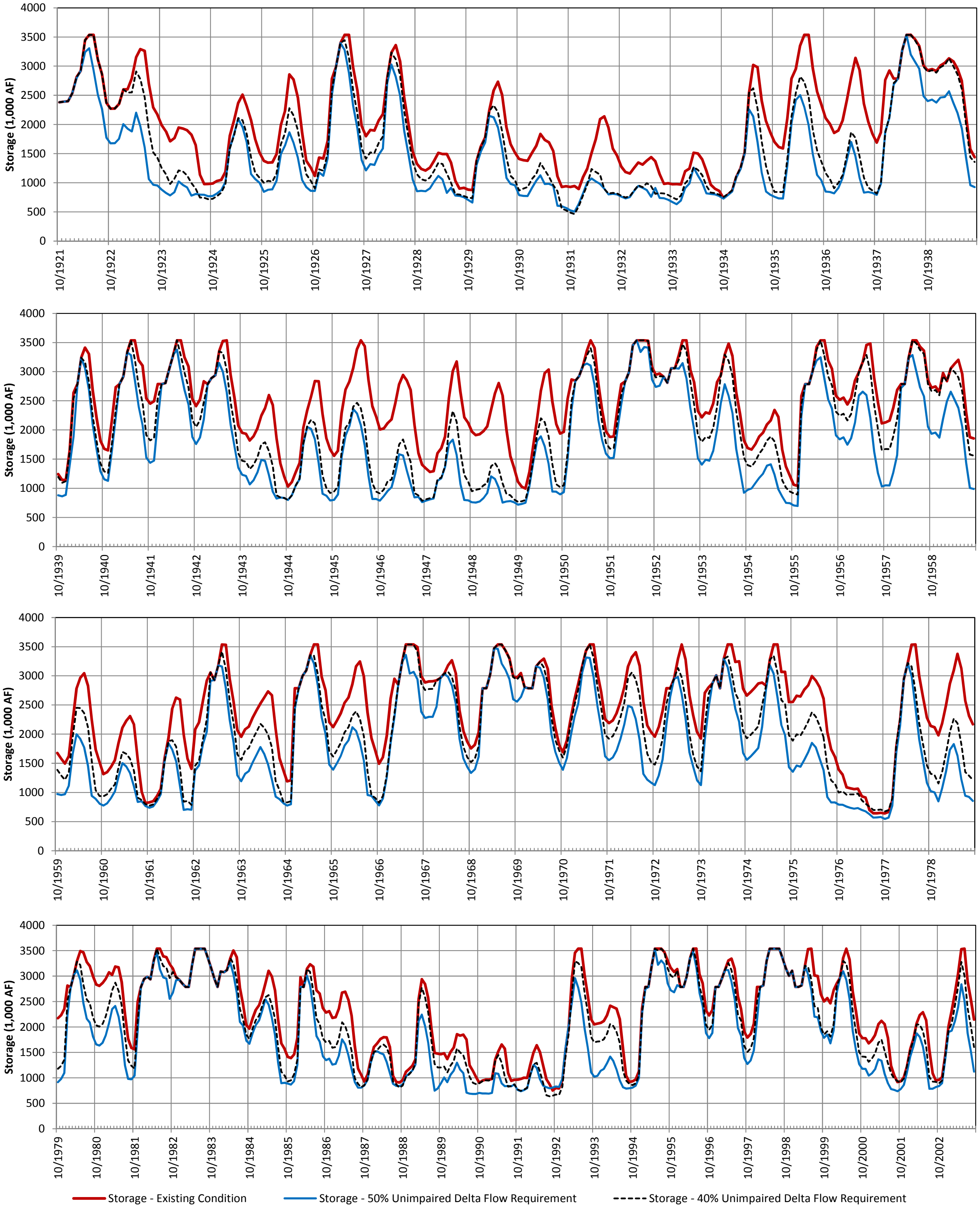
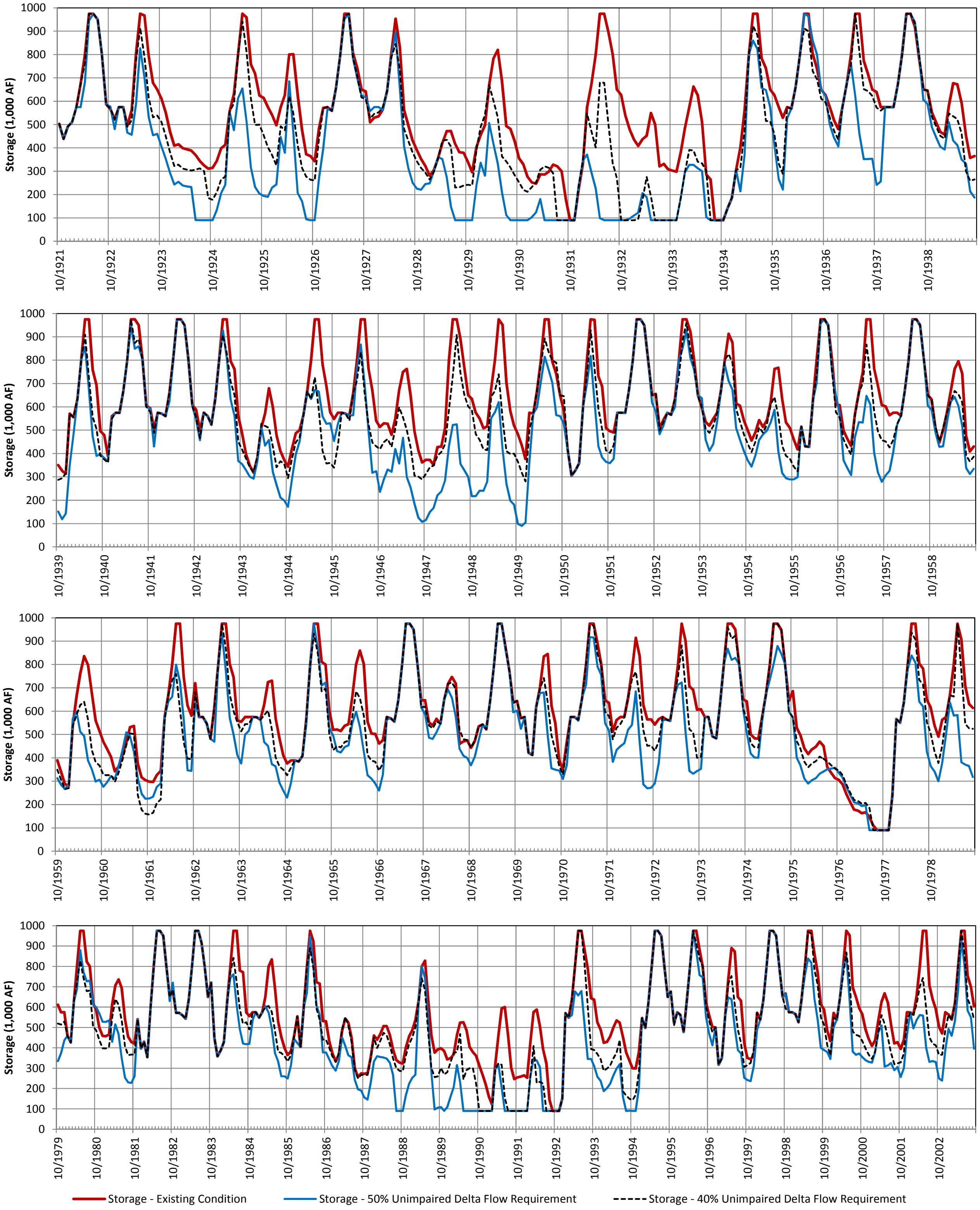


Figure 17 - Monthly Folsom Reservoir Storage 50% and 40% Unimpaired Flow Requirement



Changes in Flow Patterns

Figure 18 and Figure 19 provide summaries of the kinds of changes in the monthly flow patterns that would occur in rivers below the major CVP and SWP reservoirs with implementation of the 50% and 40% of unimpaired flow requirements. These river flows would typically be higher in the months of March, April, and May, and in some Junes, but would be lower in the other months, especially the summer months. Also, as mentioned in the above discussion of impacts to project reservoirs, the changes in river flow patterns that are estimated by CalSim II are underestimates of the impacts that actually would occur. Moreover, reductions in summer river flows would be much greater if reservoir releases were decreased further, to meet reservoir carryover requirements in order to maintain cold-water pools.

These decreased flows, and the resulting increased residence times, would cause the warmer water released into rivers to increase in temperature during the summer, when air temperatures are high. Effects below Oroville and Folsom Reservoirs would be equally dramatic.

These changes in flow patterns would impact hydropower generation as well. There would be increases in generation during spring months when hydropower is already abundant, and there would be decreases in generation during summer months when the State's power demand is greatest.

Figure 18 - Changes in Key River Flow
50% Unimpaired Flow Requirement

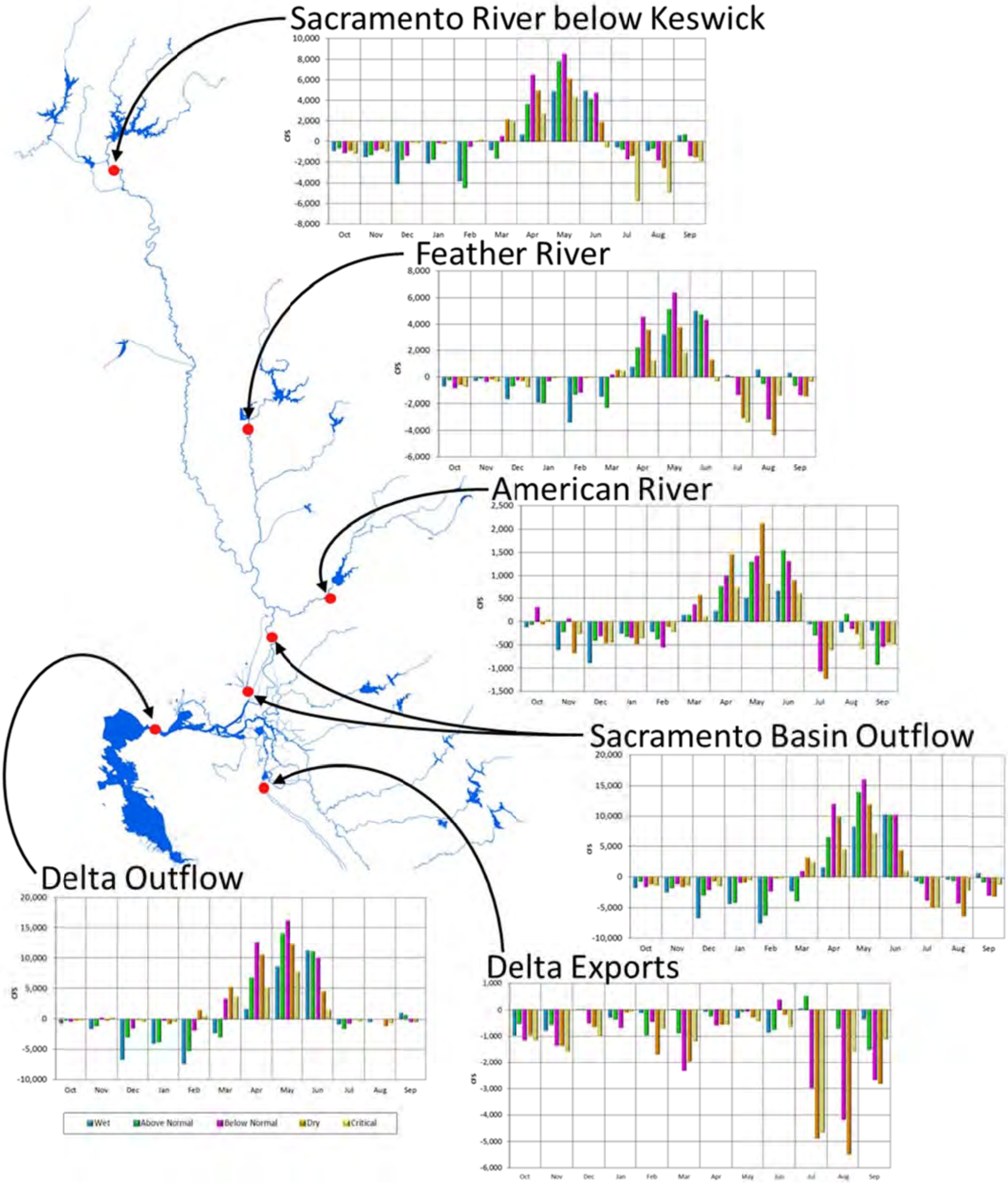
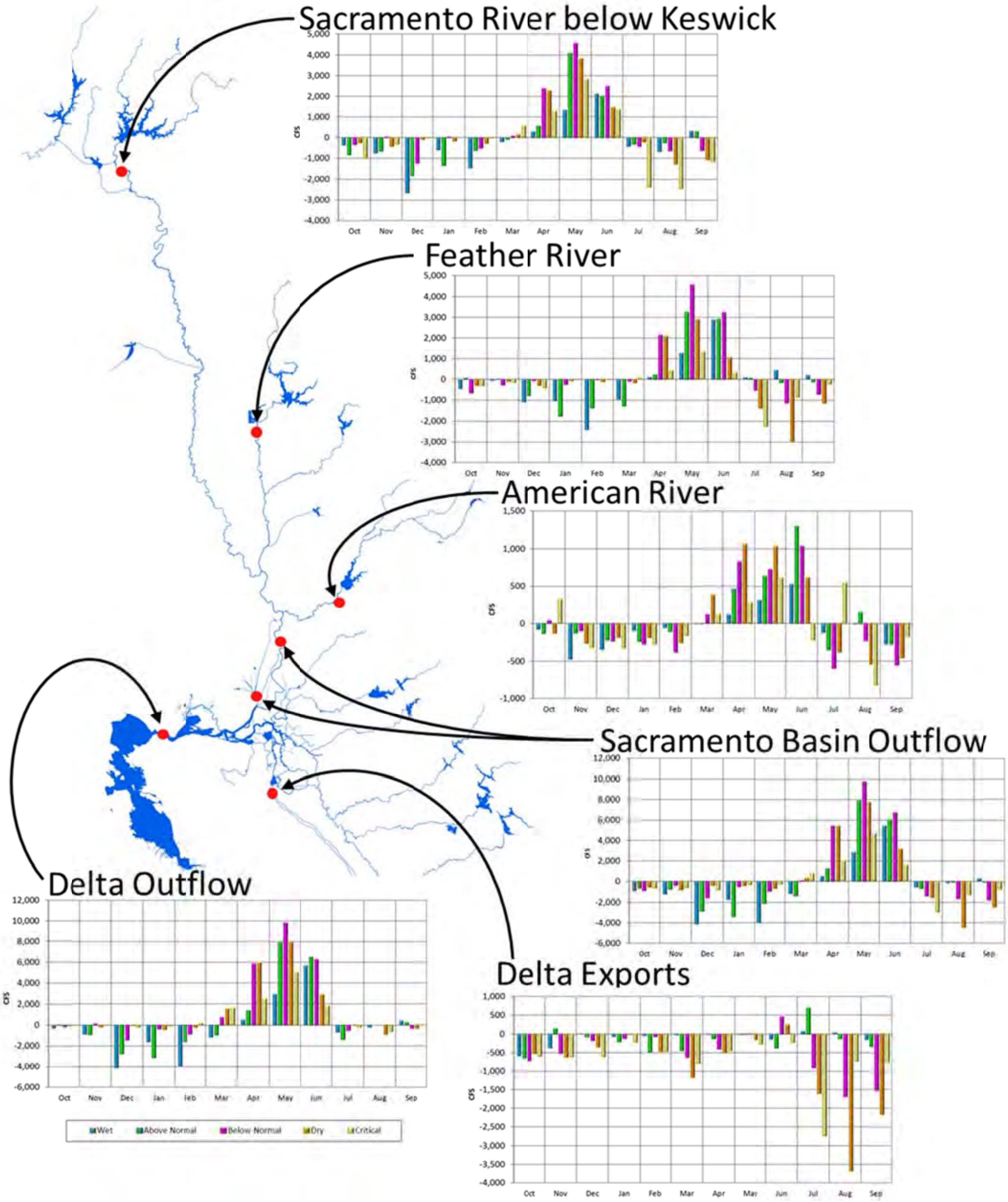


Figure 19 - Changes in Key River Flow
40% Unimpaired Flow Requirement



Violations of Existing Instream flow, Bay-Delta Plan, and ESA Biological Opinion Requirements

The increases in Delta outflows and Sacramento River flows that would occur during the January through June period with implementation of the 50% or 40% of unimpaired flow requirements would result in reduced river flows and Delta outflows in the July through December period. When the CalSim II model is run with these January through June percentage of unimpaired flow requirements, the model assumes that water would be released to satisfy the requirement during a specific month, even if the model then indicates that the reservoir would run out of water in the following month. For the 50% and 40% unimpaired requirement model runs, the model indicates that the CVP and SWP reservoirs would run out of water in about 20% of years. This situation would results in the inability of the CVP and SWP to comply with existing SWRCB requirements. In addition to the inability to comply with SWRCB requirements, there would be an inability to satisfy the requirements specified in the National Marine Fisheries Services' 2009 salmon biological opinion.

Figures 20 and 21 contain charts showing the monthly violations of SWRCB D-1641 requirements for the Sacramento River at Rio Vista that would occur under the 50% and 40% of unimpaired flow CalSim II model runs. In both unimpaired flow scenarios these violations would be larger than 1,000 cfs and typically would occur in drier years. There also would be a potential that D-1641 Delta water quality standards would be violated; however, this issue has not yet been analyzed.

Figure 20 - Violations in D-1641 Flow Requirement at Rio Vista – 50% Unimpaired Flow Requirement

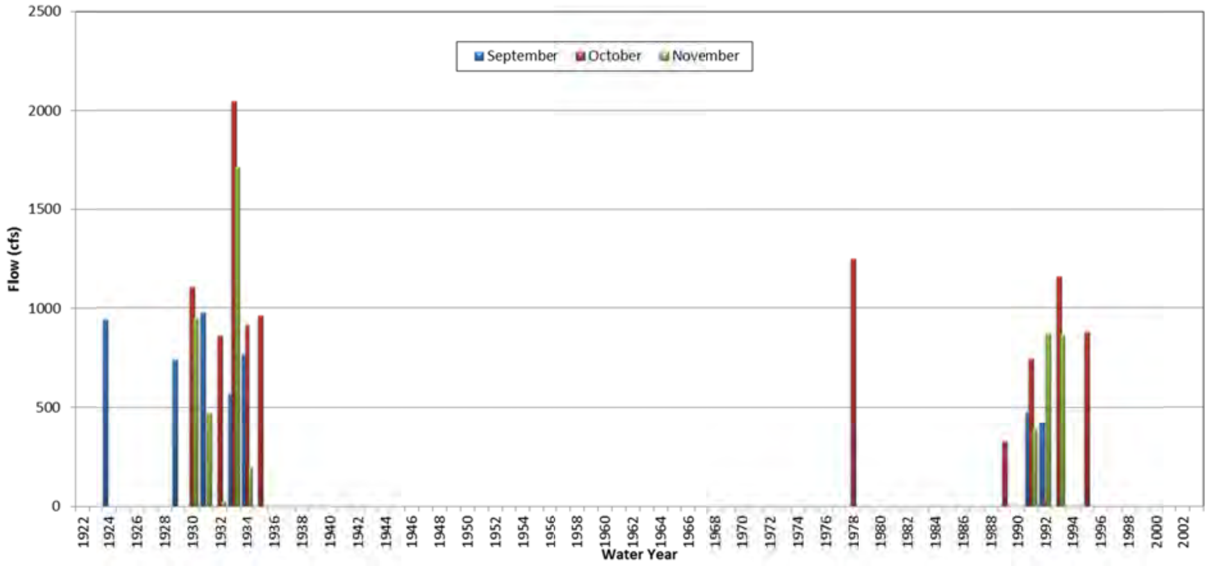
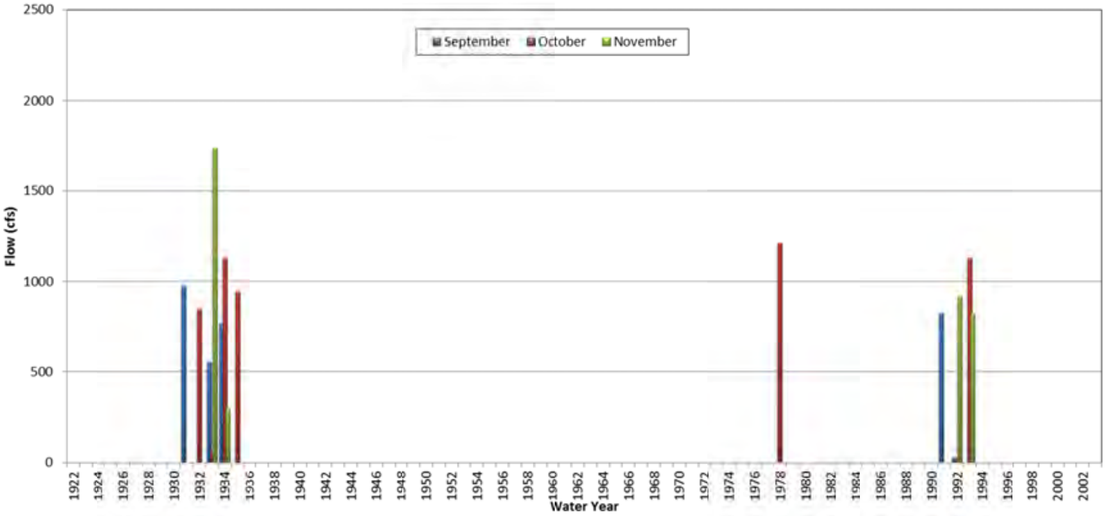


Figure 21 - Violations in D-1641 Flow Requirement at Rio Vista – 40% Unimpaired Flow Requirement



Figures 22 and 23 contain charts showing the monthly violations in Delta outflow requirements that would occur under the 50% and 40% of unimpaired flow CalSim II model runs. Delta outflow requirements include those contained in D-1641, the Delta smelt Biological Opinion, and the unimpaired flow requirement. In many years of the CalSim II model simulations there is not enough water to satisfy both the unimpaired flow requirement and existing Delta outflow requirements.

Figure 22 - Shortage in Minimum Required Delta Outflow– 50% Unimpaired Flow Requirement

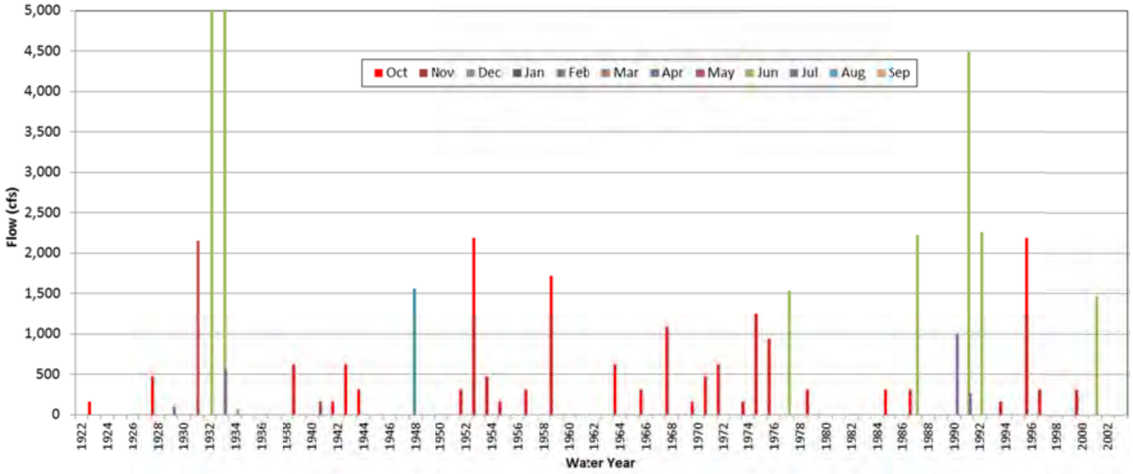
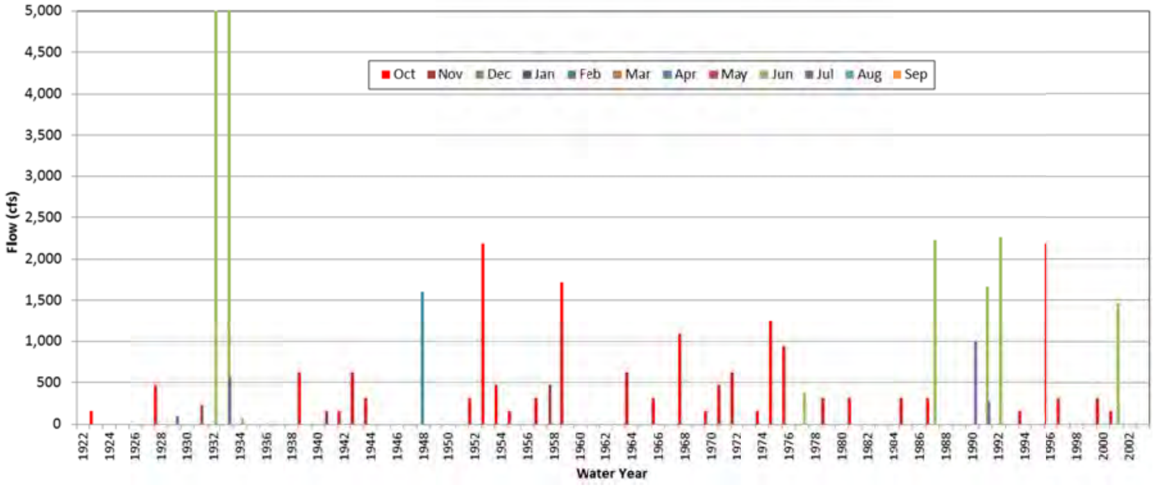


Figure 23 - Shortage in Minimum Required Delta Outflow– 40% Unimpaired Flow Requirement



The CalSim II model assumes that flows in the Sacramento River below Keswick Dam would be reduced when Shasta Reservoir reaches dead pool. The simulation modeling the 50% and 40% of unimpaired flow requirements, indicate that, with implementation of these requirements, Sacramento River flow below Keswick Dam would drop below the minimum flow requirement of 3,250 cfs. Figures 24 and 25 contain monthly exceedance plots of the Sacramento River flows below Keswick Dam that would occur under the 50% and 40% unimpaired flow scenarios. These figures indicate that violations would occur from July through November in the 50% of unimpaired flow scenario and from August through November in the 40% of unimpaired flow scenario. If the 50% or 40% of unimpaired flow requirement model runs were adjusted to maintain required carryover reservoir storage levels, then there would need to be additional dry year reduction of about 2 million AF in the 50% scenario and 1 million AF in the 40% scenario in reservoir releases from July through September; these reductions would require Keswick releases to be reduced from July through September to levels below the applicable flow standards.

Figure 24 – Monthly Exceedance plots of Sacramento River Flow below Keswick
50% Unimpaired Flow Requirement

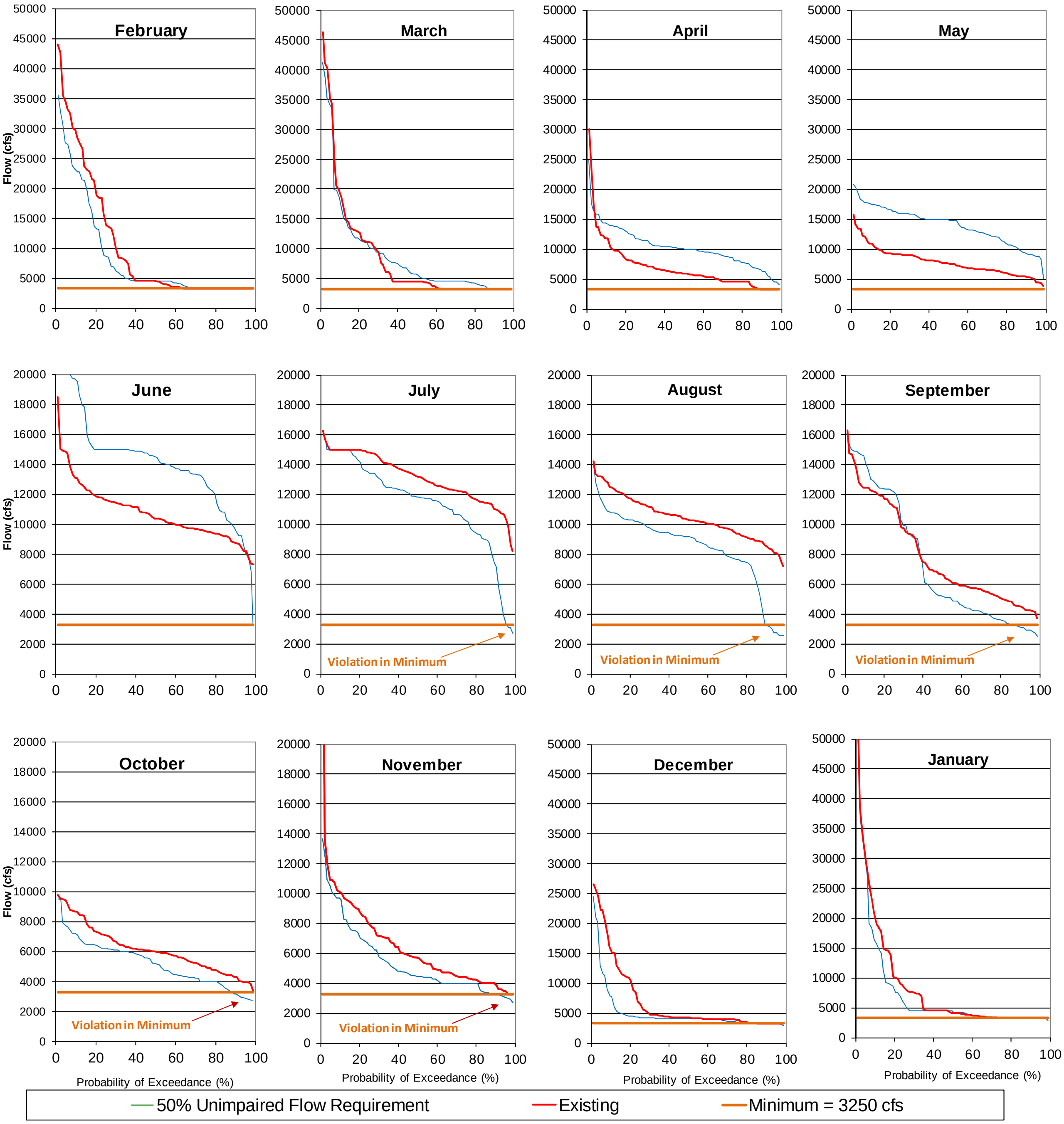
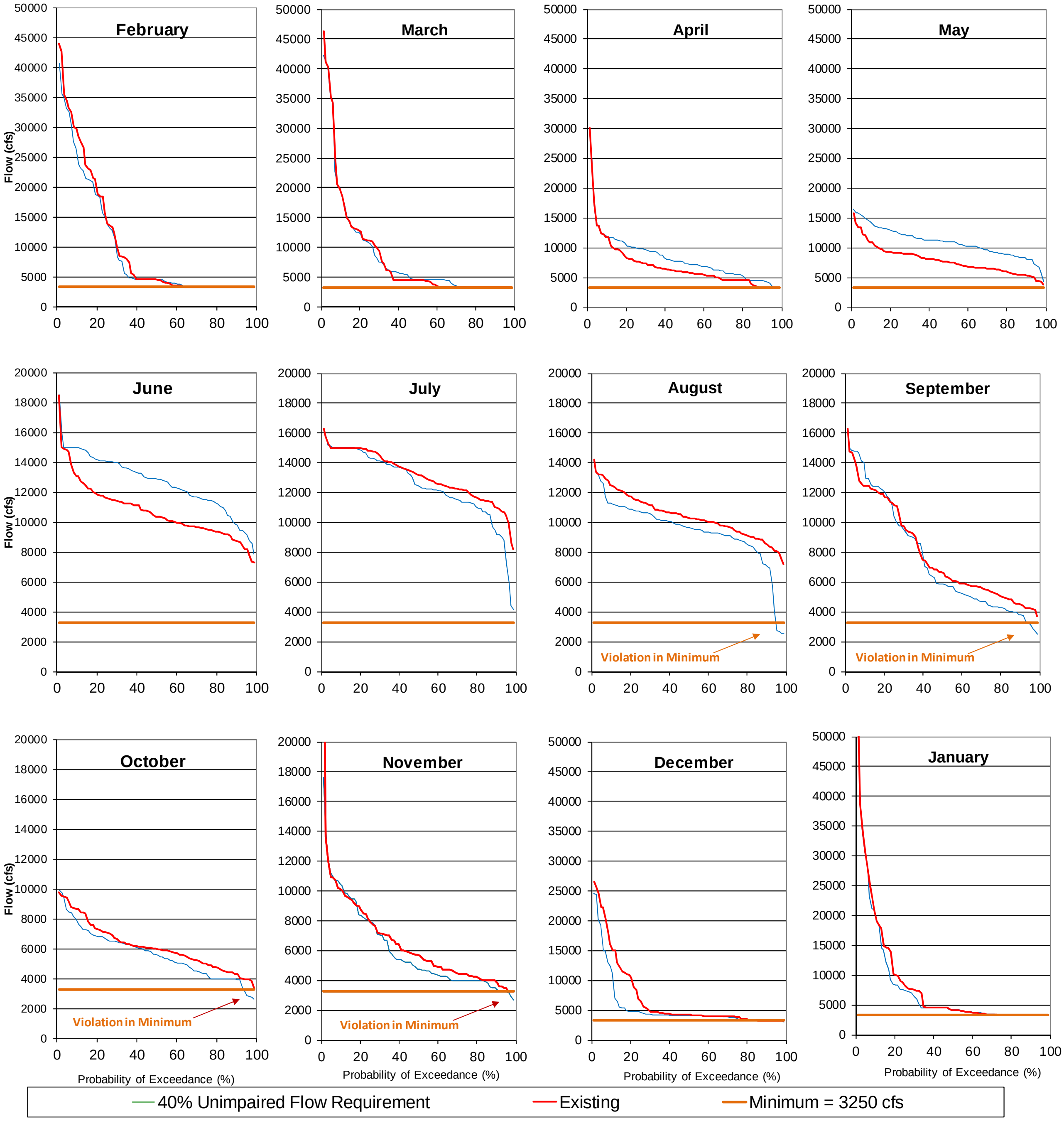


Figure 25 – Monthly Exceedance plots of Sacramento River Flow below Keswick

40% Unimpaired Flow Requirement



Water Supply Impacts

This analysis assumes that the CVP and SWP reservoirs will be operated to meet the 50% and 40% of unimpaired flow requirements; therefore, the analysis assumes that all water supply impacts would be on the CVP and SWP. As discussed above, all of the estimated water supply impacts are underestimates of the actual water supply impacts that would occur from implementation of these requirements. This is because although rules governing CalSim II's simulations of the CVP / SWP system have been developed to produce meaningful operations under a wide range of alterative scenarios, simulation of the 50% and 40% of unimpaired flow requirements requires simulation of operating conditions that would be outside of the range of CalSim II's existing rules. Nevertheless, modeling under CalSim II is the best available method of estimating the impacts of implementing such flow requirements. Additional features would need to be incorporated into the CalSim II model to estimate the full range of impacts to the water system that implementation of the 50% and 40% of unimpaired flow requirements would cause.

Table 5 contains summaries of estimated average annual water deliveries to CVP contractors under Existing Conditions and under the 50% unimpaired flow requirement, and a summary of the differences. Average annual North of Delta (NOD) deliveries would be reduced by 172,000 AF and South of Delta (SOD) would decrease by 346,000 AF. Average critical year reductions NOD would be 542,000 AF and reductions SOD would be approximately 368,000 AF. Table 6 contains summaries of estimated average annual water deliveries to CVP contractors under Existing Conditions and under the 40% unimpaired flow requirement, and a summary of the differences. Average annual North of Delta (NOD) deliveries would be reduced by 74,000 AF and South of Delta (SOD) would decrease by 140,000 AF. Average critical year reductions NOD would be 216,000 AF and reductions SOD would be approximately 172,000 AF. It is important to note that the model assumes that diversions by settlement and exchange contractors would be curtailed, both NOD and SOD, and that the model does not contain any adjustment to maintain these contractors' water diversion priorities. The model results also indicate that municipal and industrial (M&I) deliveries north and south of Delta would be reduced to levels such that public health and safety water supply needs would be difficult or impossible to satisfy.

The model results indicate that water deliveries to wildlife refuges would be reduced to extents that could have effects on the Pacific Flyway. The water supply reductions to agriculture in both the Sacramento and San Joaquin Valleys would also result in water supply reductions to wildlife refuges in these areas. Additionally, the loss of rice production acreage in the Sacramento Valley would affect the Pacific Flyway due to the loss of fall flood-up habitat.

Tables 7 and 8 contain a summary of estimated annual water deliveries to SOD SWP contractors under the Existing Conditions and 50% and 40% of unimpaired flow requirements scenarios, and a summary of the differences. The estimated average annual reductions in SOD SWP contractor deliveries is 352,000 AF in the 50% of unimpaired scenario and 191,000 AF in the 40% of unimpaired scenario. Estimated dry and critical year delivery reductions are 863,000 AF and 460,000 AF, respectively in the 50% of unimpaired flow scenario and 516,000 AF and 299,000 AF, respectively in the 40% of unimpaired flow scenario.

Figure 26 contains exceedance probability plots of CVP water supply allocations for CVP NOD agricultural service contractors, CVP SOD agricultural service contractors, CVP NOD M&I contractors, and CVP SOD M&I contractors for the Existing Conditions and 50% of unimpaired flow scenarios. Figure 27 contains this information for the 40% of unimpaired flow scenario. Under the 50% of unimpaired flow scenario, both NOD and SOD agricultural service contractors would receive no water supplies in 20% of all years, and would experience significant reductions in allocations in most years. Under 50% of unimpaired flow scenario, both NOD and SOD M&I contractors would receive 50% allocations in 20% of all years, which would result in difficulties in meeting public health and safety water needs. There would be difficulty in satisfying public health and safety water needs in the 40% of unimpaired flow study, but not to the degree of the 50% of unimpaired flow scenario. In addition to reduced water supply allocations, when project reservoirs would reach dead pool, most M&I water supply deliveries would be further reduced, and in many months would be zero.

Figures 28 and 29 contain exceedance probability plots of SWP SOD water supply allocations under both of these scenarios. The plots indicate that, in 60% of all years, SWP SOD water supply deliveries would be significantly reduced with implementation of the 50% of unimpaired flow requirements and in 50% of all years with implementation of the 40% of unimpaired flow requirements.

Table 5 - CVP Delivery Summary (1,000 AF)

50% Unimpaired Flow Requirement

	AG NOD	AG SOD	Exchange	M&I NOD	M&I SOD	Refuge NOD	Refuge SOD	Sac. Setlmnt	CVP NOD Total	CVP SOD Total
Existing										
All Years	226	879	852	85	117	68	296	1840	2219	2326
W	318	1380	875	93	136	70	305	1837	2318	2879
AN	286	962	802	85	113	65	279	1696	2131	2325
BN	220	717	875	86	112	70	305	1881	2257	2192
D	159	605	864	81	108	69	300	1876	2184	2061
C	53	233	741	68	87	56	252	1740	1917	1492
50% Unimpaired Flow Requirement										
All Years	150	592	836	75	99	65	287	1758	2048	1980
W	303	1278	875	92	131	71	304	1836	2301	2772
AN	206	686	802	78	105	65	279	1695	2045	2040
BN	78	233	865	70	88	70	301	1859	2077	1660
D	29	125	847	64	79	68	293	1833	1994	1506
C	17	84	664	51	56	35	206	1272	1375	1124
Difference										
All Years	-75	-286	-17	-10	-18	-3	-9	-83	-172	-346
W	-15	-103	0	-1	-4	0	0	0	-16	-107
AN	-80	-277	0	-6	-8	0	0	0	-86	-284
BN	-142	-484	-10	-15	-24	0	-3	-22	-180	-532
D	-130	-479	-17	-17	-30	-1	-8	-43	-190	-554
C	-36	-149	-77	-16	-31	-22	-45	-468	-542	-368

Table 6 - CVP Delivery Summary (1,000 AF)

40% Unimpaired Flow Requirement

	AG NOD	AG SOD	Exchange	M&I NOD	M&I SOD	Refuge NOD	Refuge SOD	Sac. Setlmnt	CVP NOD Total	CVP SOD Total
Existing										
All Years	226	879	852	85	117	68	296	1840	2219	2326
W	318	1380	875	93	136	70	305	1837	2318	2879
AN	286	962	802	85	113	65	279	1696	2131	2325
BN	220	717	875	86	112	70	305	1881	2257	2192
D	159	605	864	81	108	69	300	1876	2184	2061
C	53	233	741	68	87	56	252	1740	1917	1492
40% Unimpaired Flow Requirement										
All Years	190	756	850	80	110	66	292	1809	2145	2186
W	313	1346	875	92	135	70	304	1837	2312	2843
AN	256	896	802	82	113	65	279	1695	2099	2258
BN	158	500	875	80	104	70	305	1881	2188	1968
D	88	375	860	72	99	68	300	1850	2079	1816
C	31	144	730	59	68	47	230	1565	1701	1320
Difference										
All Years	-36	-123	-2	-5	-6	-1	-4	-32	-74	-140
W	-5	-34	0	-1	-1	0	-1	0	-6	-36
AN	-29	-67	0	-2	0	0	0	0	-32	-67
BN	-63	-217	0	-6	-7	0	0	0	-69	-225
D	-71	-229	-4	-9	-9	0	0	-26	-106	-244
C	-22	-88	-11	-9	-19	-9	-21	-176	-216	-172

Table 7 - SWP South of Delta Delivery Summary (1,000 AF)

50% Unimpaired Flow Requirement

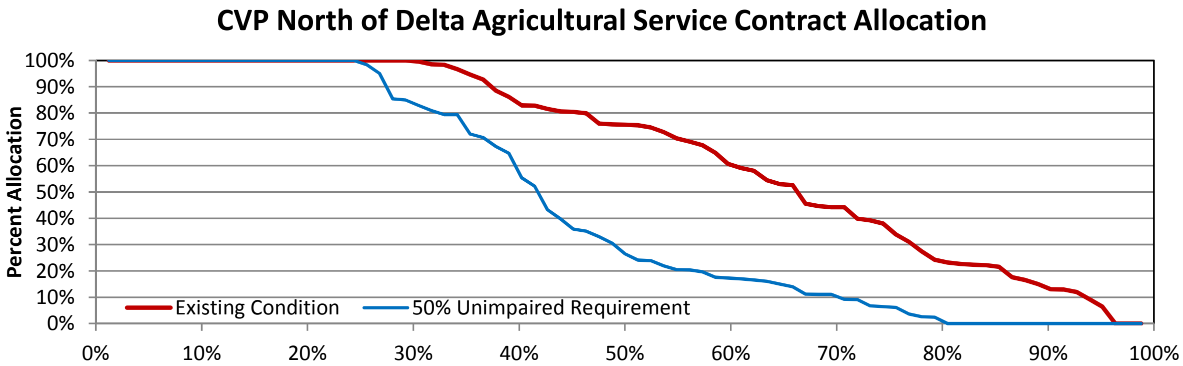
	MWD	"Other" M&I	AG SOD	Art. 56	Art 21	M&I	Table A	Total
Existing								
All Years	1037	610	596	303	71	1647	2242	2616
W	1186	713	738	393	140	1899	2637	3169
AN	1065	606	601	222	60	1671	2271	2554
BN	1121	641	618	376	31	1762	2380	2788
D	1001	582	535	225	39	1583	2118	2382
C	551	348	298	196	21	899	1196	1414
50% Unimpaired Flow Requirement								
All Years	906	540	521	232	66	1446	1967	2264
W	1202	711	738	328	120	1913	2651	3099
AN	1067	605	600	148	113	1672	2272	2533
BN	968	578	521	297	41	1546	2067	2404
D	619	387	334	168	11	1006	1339	1519
C	388	243	210	107	6	631	841	954
Difference								
All Years	-131	-70	-75	-71	-5	-201	-275	-352
W	15	-1	0	-65	-19	14	14	-70
AN	2	-1	-1	-74	53	1	0	-21
BN	-154	-62	-98	-80	10	-216	-314	-384
D	-383	-195	-201	-56	-28	-578	-779	-863
C	-163	-105	-88	-89	-16	-268	-356	-460

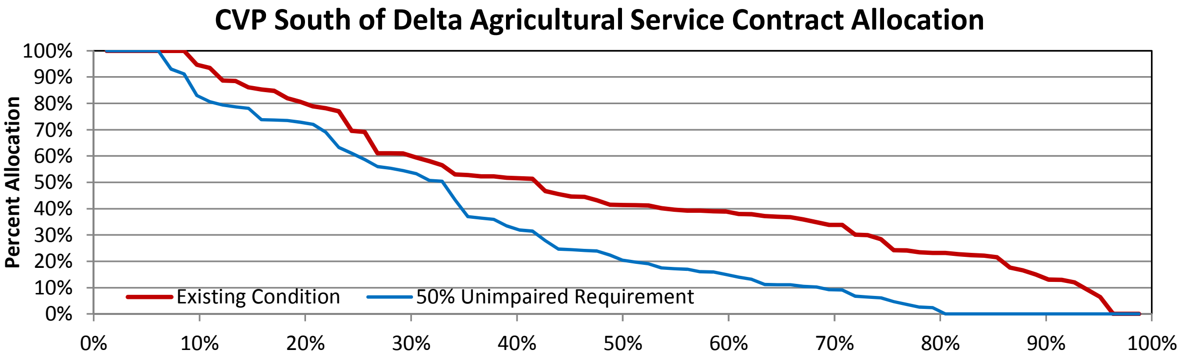
Table 8 - SWP South of Delta Delivery Summary (1,000 AF)

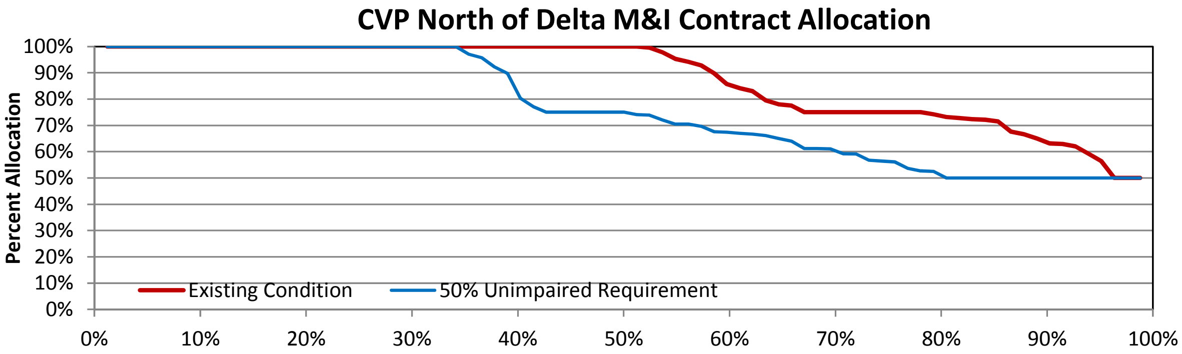
40% Unimpaired Flow Requirement

	MWD	"Other" M&I	AG SOD	Art. 56	Art 21	M&I	Table A	Total
Existing								
All Years	1037	610	596	303	71	1647	2242	2616
W	1186	713	738	393	140	1899	2637	3169
AN	1065	606	601	222	60	1671	2271	2554
BN	1121	641	618	376	31	1762	2380	2788
D	1001	582	535	225	39	1583	2118	2382
C	551	348	298	196	21	899	1196	1414
40% Unimpaired Flow Requirement								
All Years	968	571	555	265	65	1539	2094	2425
W	1194	712	738	356	142	1906	2644	3142
AN	1064	601	598	211	69	1666	2263	2543
BN	1096	619	586	317	41	1715	2301	2659
D	777	475	419	189	7	1251	1671	1866
C	438	278	237	155	6	717	954	1115
Difference								
All Years	-69	-39	-41	-37	-6	-107	-148	-191
W	7	-1	0	-36	2	7	7	-28
AN	0	-5	-3	-11	9	-5	-8	-10
BN	-25	-22	-33	-59	10	-47	-79	-129
D	-225	-107	-116	-35	-33	-332	-448	-516
C	-113	-69	-61	-41	-15	-182	-243	-299

Figure 26 – CVP Water Supply Allocation
50% Unimpaired Flow Requirement







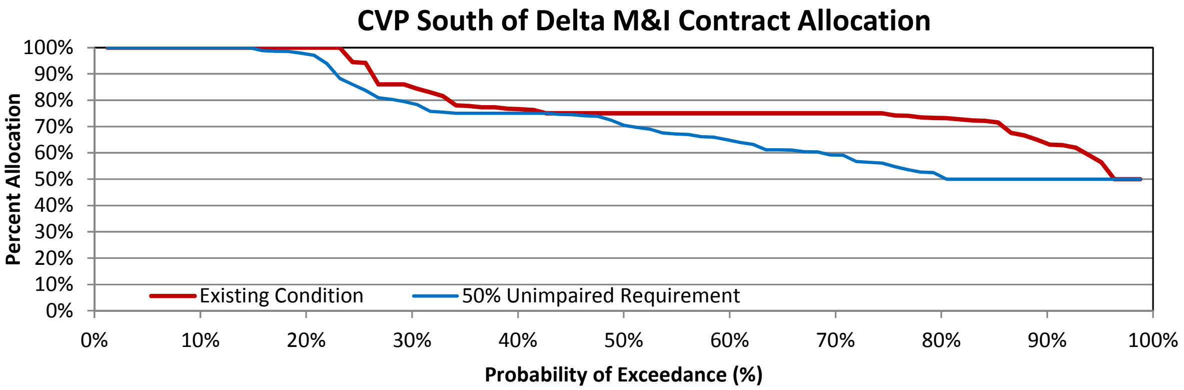
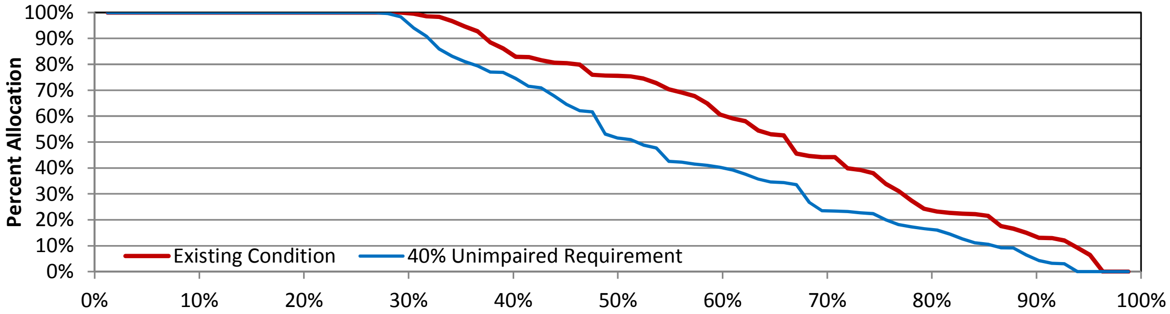


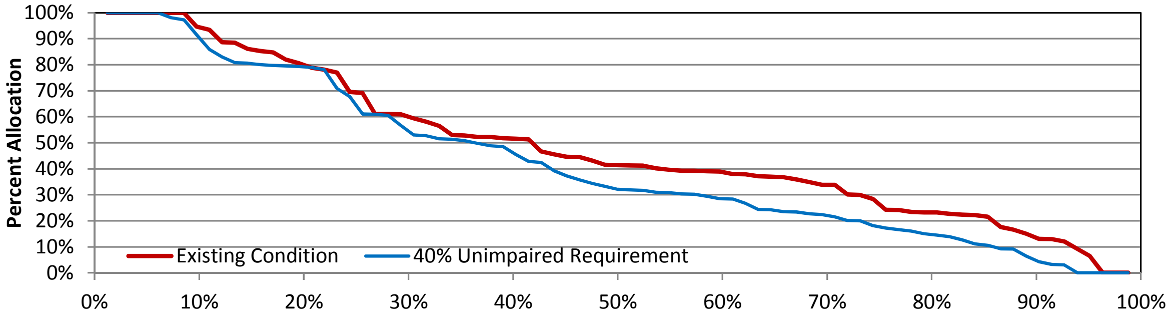
Figure 27 – CVP Water Supply Allocation

40% Unimpaired Flow Requirement

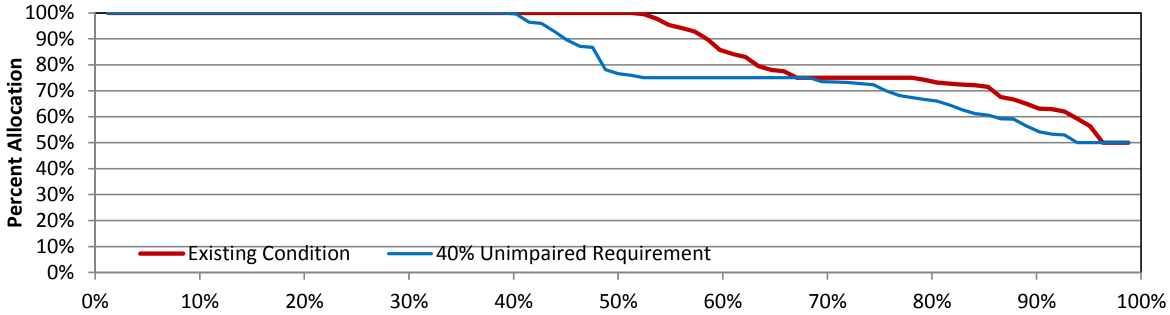
CVP North of Delta Agricultural Service Contract Allocation



CVP South of Delta Agricultural Service Contract Allocation



CVP North of Delta M&I Contract Allocation



CVP South of Delta M&I Contract Allocation

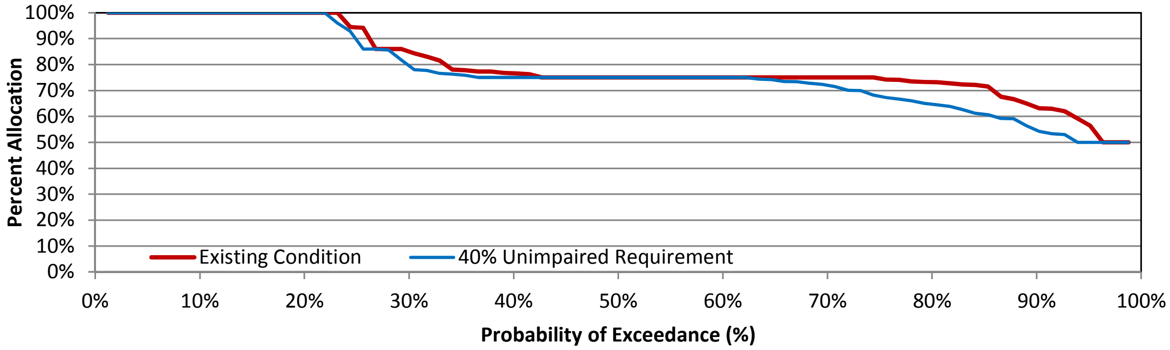


Figure 28 – SWP Water Supply Allocation
50% Unimpaired Flow Requirement

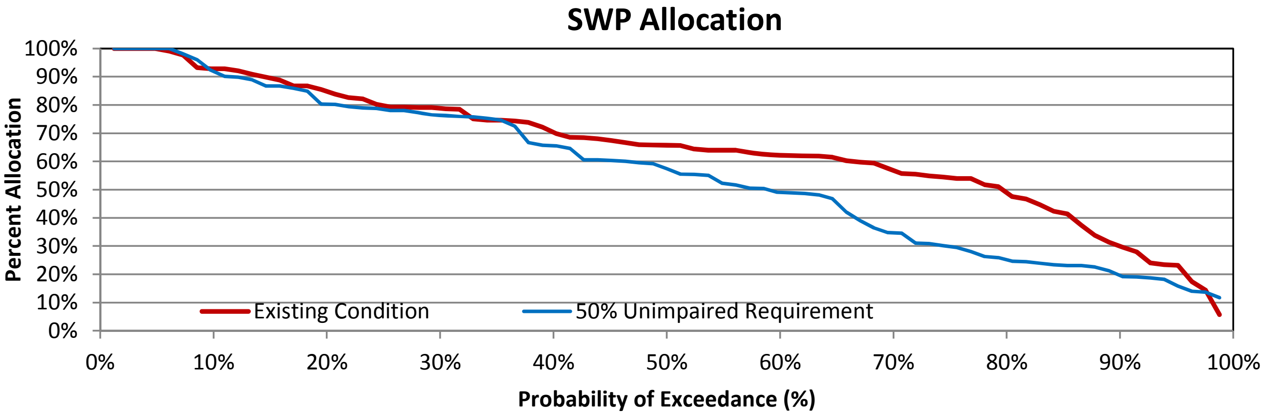


Figure 29 – SWP Water Supply Allocation
40% Unimpaired Flow Requirement

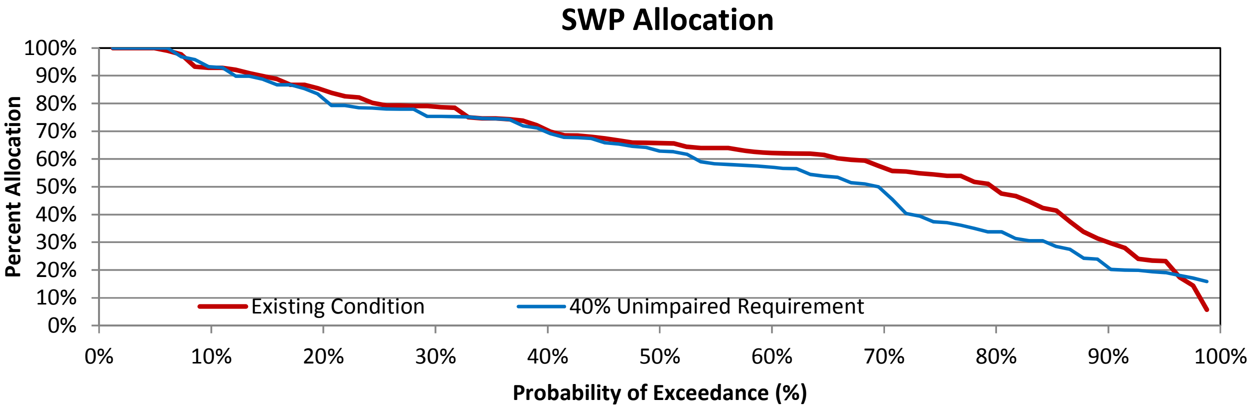
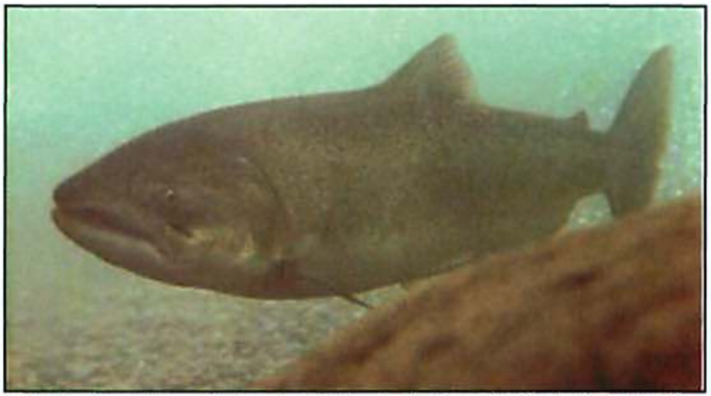


EXHIBIT 3

Insights into the
Problems, Progress, and Potential Solutions
for Sacramento River Basin Native Anadromous Fish Restoration



Spring-Run Chinook Salmon in Mill Creek, California (Photo by Dave Vogel)

April 2011

Prepared for:

Northern California Water Association
and
Sacramento Valley Water Users

Prepared by:

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Executive Summary

Important native anadromous fish populations in the Sacramento River basin have experienced significant declines from historical levels. The reasons have been attributed to habitat degradation which usually encompasses a large variety of factors. **Despite enormous expenditures (*amounting to more than $1 billion*) in recent decades to reverse the decline in fishery resources through habitat restoration, increased flows, harvest restrictions, and other large-scale measures, significant upward trends in the fish population sizes have not been realized.** Even with considerable research on the topic, there remain major uncertainties on why reversals of those declines through many restoration actions are apparently not succeeding. **The key question is: Why are fisheries not recovering?**

Although many restoration plans attribute much of the decline in fish populations to habitat degradation and other "stressors", an adequate description of when the impacts have occurred on the fish populations is generally lacking. Examples include: dam construction, pollution, levee construction, diked wetlands, droughts and floods, unscreened diversions, south Delta diversions, general physical habitat degradation, predation, overharvest, and ocean conditions. This report examines many of these factors in time and space relative to the presence of each of the following life stages of the Sacramento Valley's anadromous fish: adult upstream migration, adult holding, spawning and incubation, fry and juvenile rearing, juvenile outmigration, and ocean conditions.

This report asserts that matching potential stressors on particular fish life phases in time and space should help to tease out the most important factors that have affected and continue to affect the fish populations. If definite stressors co-occur with the anticipated or known impact on specific fish life stages, it may indicate those stressors which are most important. Such an analysis could also suggest that some variables may have minimal importance. Based on analyses of readily-available reports, unpublished reports, gray literature, existing and new data, new study results, and the considerable professional experience of the author derived from working on fishery resource issues in the Central Valley over the past 30 years, numerous conclusions on those factors believed to be most important were developed. This report builds upon and integrates pertinent information to describe some of the more prominent problems for the fish populations and the corresponding progress toward alleviating those problems. Based on the resulting knowledge, this report poses potential solutions to the issues that have not yet been adequately addressed to achieve the ultimate goal of protecting and increasing the fish populations.

To prioritize the stressors currently impacting the Sacramento Valley's salmon, steelhead and green sturgeon populations and the actions that would most benefit those species, this report:

(1) examines the actions, projects, programs and conditions in the Sacramento River and tributaries upstream of the American River confluence and fish migration corridors in the Delta that have affected native anadromous fish resources;

(2) examines how recommended flow regimes in the State Water Resources Control Board's (SWRCB) recent Delta Flow Criteria report (SWRCB 2010) and the Department of Fish and Game's (DFG) Quantifiable Biological Objectives and Flow Criteria report for the Delta (DFG 2010) may be in conflict with and put at risk Sacramento River basin fishery resources; and

(3) provides recommendations for potential habitat restoration actions, water management projects, studies, or other measures that could be implemented in the near-term to provide additional benefits to fishery resources.

In most respects, and relative to other parts of the state, habitat conditions for anadromous fish in the Sacramento River and its tributaries have improved significantly over the past two decades as follows:

- Adult fish passage at many important upstream migration barriers has been significantly improved in recent decades and some major barriers have been completely eliminated, providing fish access to upstream areas essential for increased fish production.

- Thermal conditions in the rivers downstream of large dams have dramatically improved, yielding critically important protection of fish during highly temperature-sensitive periods in the life cycle.

- Remedial actions at an abandoned mine in the upper Sacramento River have largely eliminated a previous major source of fish mortality. Improved flow regimes in the rivers and streams have been implemented in recent decades allowing protection of fish during all the freshwater life phases.

- A massive program over the past two decades to screen unscreened or inadequately screened water diversions amounting to nearly $574,000,000 has resulted, or will soon result, in protection of fish at most diversion sites among which collectively divert a maximum of nearly 13,000 cfs.

- Watershed restoration programs to protect and enhance conditions on numerous tributaries have proliferated in recent times and are believed to have benefited fish habitats and overall watershed health.

Concurrently, freshwater and ocean harvest regulations have become increasingly restrictive over time, which has helped to protect depressed fish stocks. **Yet again, with all these expenditures and improvements, why are fisheries not recovering?**

While some opportunities remain in the Sacramento Valley (as described in this report) -- such as larger additions of gravel in important spawning reaches, juvenile fish rearing habitat improvements, and increased fish protection on smaller tributaries -- the available evidence indicates that conditions have become worse, not better, in the Delta during the most-recent decades. Despite the enormous, unprecedented actions to improve fish production in the upper watersheds, there has been remarkable lack of focus or progress to fix the serious predation and habitat problems in the Delta, through which all Sacramento Valley anadromous fish must migrate. **Overall, predation is likely the highest source of mortality to anadromous fish in the Delta.** Despite well-known in-Delta problems of predation at a variety of locations for many years, very little progress -- in many instances, no progress -- has been made. Ironically, some measures implemented under the auspices of improving fish habitats have likely increased predation of anadromous fish in the Delta. The best available evidence indicates that in-Delta predation and habitat problems have gotten worse during recent decades.

Until significant progress is made on correcting the habitat problems and largely site-specific sources of native juvenile anadromous fish mortality in the Delta, it is likely that many of the benefits of upstream actions are, and will continue to be, negated. Although many studies over decades have demonstrated low survival of anadromous fish in the Delta, more such studies continue and are proposed, but are not oriented to determine site-specific in-Delta mortality sources. Re-focused study efforts in the Delta are sorely needed with the objective of locating and fixing fish mortality sites. Overall, until major predation problems in the Delta are corrected, difficulties for anadromous fish restoration will remain.

Other in-Delta and ocean-related actions also could significantly benefit the Sacramento Valley's salmonid populations. Appropriately-designed restoration of shallow-water rearing habitats in the Delta should be aggressively pursued because they would have a high probability of success. There may also be alternative ocean harvest methods that would increase salmonid populations by increasing the fecundity, or reproduction capacity, of the salmonids that spawn in the Sacramento Valley.

In addition, certain state agencies have recently recommended high reservoir releases (SWRCB 2010, DFG 2010) to attempt to ameliorate problems in the Delta. If implemented as proposed, without considering the risk of drastically reducing reservoir levels in some years, cold-water storage may be depleted, resulting in devastating impacts on anadromous fish egg incubation at critical times. Additionally, improperly timed high flows could provide unfavorable conditions for mainstem rearing fish. **Implementation of the flows described in the SWRCB and DFG reports would have a high potential of largely undoing recent decades' progress in restoring conditions for salmonids in the Sacramento Valley.** Clearly, careful examination of the impacts of large flow increases is warranted by thorough modeling studies to determine the effects on water supplies, thermal impacts to fish, and alteration of instream habitats. Unfortunately, little progress has been made on parsing out the various and most important factors related to flow that may influence fish survival. The causal effects of flow and fish survival relationships in the Sacramento River have been difficult to determine because of complex inter-relationships with numerous variables associated with flow. Focused studies to ascertain those relationships are needed. Furthermore, development of opportunities to reduce site-specific Delta stressors through non-flow measures is warranted and overdue.

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1.0 Introduction

Important native anadromous fish populations in the Sacramento River basin (Figure 1) have experienced significant declines from historical levels. This report examines: 1) the actions, projects, programs and conditions in the Sacramento River and tributaries upstream of the American River confluence and fish migration corridors in the Delta that have affected native anadromous fish resources; 2) how recommended flow regimes in the State Water Resources Control Board's (SWRCB) recent Delta Flow Criteria report (SWRCB 2010) and the Department of Fish and Game's (DFG) Quantifiable Biological Objectives and Flow Criteria report for the Delta (DFG 2010) may be in conflict with and put at risk Sacramento River basin fishery resources; and 3) recommends potential habitat restoration actions, water management projects, studies, or other actions that could be taken in the near term to provide additional benefits to fishery resources.

The most prominent anadromous fish declines have occurred with the winter-run Chinook salmon (*Oncorhynchus tshawytscha*) (a federally-listed endangered species), spring-run Chinook salmon (a federally-listed threatened species), steelhead trout (*O. mykiss*) (a federally-listed threatened species), green sturgeon (*Acipenser medirostris*) (a federally-listed threatened species), as well as late-fall-run and fall-run Chinook salmon (both Candidates for Endangered Species Act listings). Although other native fish species are also essential, this report focuses on the foregoing populations because of their threatened or endangered status, their potential importance to sport and commercial fisheries, and their overall intrinsic value to the ecosystem and society. Also, it can be argued that if many of the freshwater/riverine habitat needs for these species are met, the habitats for other important native fish will be satisfactory.

To counter the downward trend in California's Central Valley fishery resources, restoration has been a major focus for many State and federal agencies and stakeholder groups in recent decades. However, despite major, unprecedented efforts (***amounting to more than $1 billion***)[1] to increase these fish populations through habitat restoration, increased flows, harvest restrictions, and other large-scale measures, significant upward progress in the fish population sizes have not been realized. This begs the question: "***Why not?***"

One might believe that an investigative answer to this question must be embodied within the crowded field of existing reports, study results, data, hypotheses, and opinions on the factors that have contributed to the declines in Sacramento River basin anadromous fish populations (many, but not all, of which are described in this report). Yet, despite considerable research on the topic, there remain major uncertainties on why reversal of those declines through many restoration actions are, based on the author's review of existing literature and personal experience,

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[1] The Central Valley Project Improvement Act program alone has amounted to nearly $1 billion. Source: Cummins, K., C. Furey, A. Giorgi, S. Lindley, J. Nestler, and J. Shurts. 2008. Listen to the river: an independent review of the CVPIA Fisheries Program. Prepared for the U.S. Bureau of Reclamation and the U.S. Fish and Wildlife Service. December 2008. 51 p. plus appendices.

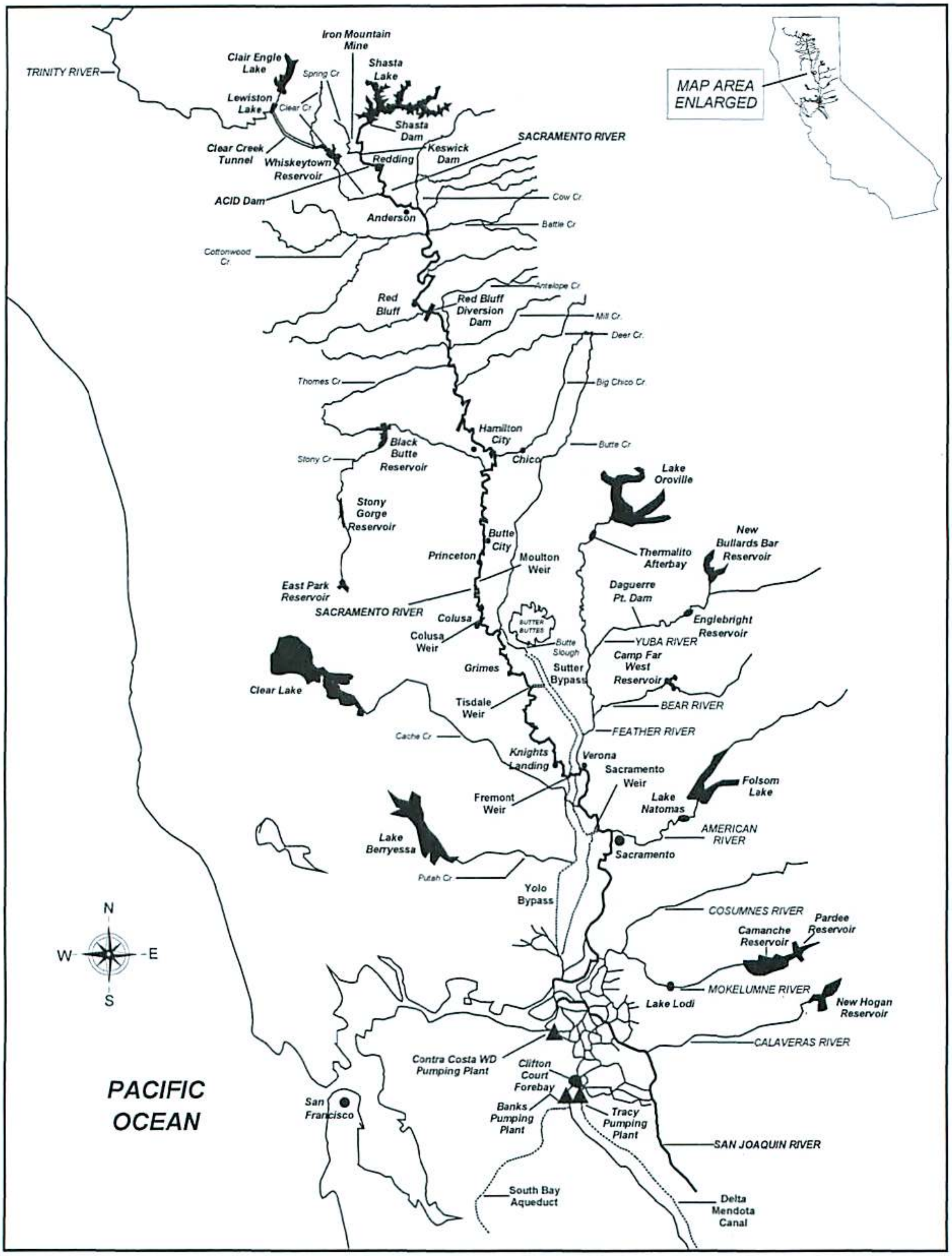

Figure 1. The Sacramento River basin, tributaries, and Delta with important features mentioned in this report.

apparently not succeeding. This report will focus on this issue, and provide recommendations on other actions to benefit anadromous fish populations in the Sacramento Valley watershed and in the Delta. Natural environmental factors (*e.g.*, drought, floods, ocean conditions) can and do play a major role in cyclical fish population declines, and those non-anthropogenic causes are also discussed here. Nevertheless, native fish populations have evolved to adapt to natural perturbations. As pointed out by the U.S. Fish and Wildlife Service (USFWS), "*... populations in healthy habitats typically recover within a few years after natural events. The decline of fish populations has continued through cycles of beneficial and adverse natural conditions, indicating the need to improve habitat*." (USFWS 1997).

The term "habitat degradation" is a universal phrase used in many documents to describe a "stressor" or "limiting factor" contributing to the decline of fish populations. Habitat degradation usually encompasses a large variety of factors[2] and is often presented as all-encompassing lists of known or suspected causes of fishery resource declines. The following are example stressors which are commonly cited as contributing to the declines:

- Dam construction
- Pollution
- Levee construction
- Diked wetlands
- Droughts and floods
- Unscreened diversions
- General physical habitat degradation
- South Delta exports
- Predation
- Overharvest
- Ocean conditions

Notably, such lists are frequently out of context in terms of specifically ***when*** the impacts have occurred on fish populations; the habitat degradation discussion in many existing documents gets blended between eras. For example, in describing the reasons for the declines of Central Valley anadromous fish, the USFWS states:

> "*Habitat degradation is the primary cause of these declines.*" ... "*Habitat quality and quantity have declined due to construction of barriers to migration and levees, modification of natural hydrologic regimes by dams and water diversions, elevated water temperatures, and water pollution.*" (USFWS 1997).

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[2] E.g., Myers *et al.* (1998), citing Clark (1929), Needham *et al.* (1940), Reynolds *et al.* (1993), and Fisher (1994), state: "*Habitat degradation due to dams, water diversions, and placer mining, as well as past and present land-use practices have severely reduced the range and number of spring- and winter-run Chinook salmon and to a lesser extent fall and late-fall runs.*"

Another example, specific to winter-run Chinook salmon, is the 1997 National Marine Fisheries Service (NMFS) recovery plan for the species which states:

> *"The decline of the winter-run Chinook population resulted from the cumulative effects of degradation of spawning, rearing and migration habitats in the Sacramento River and Sacramento-San Joaquin Delta. Specifically, the population's decline was most likely precipitated by a combination of:*
> *1) excessively warm water temperatures from releases at Shasta Dam, 2) hindering and blocking free passage of juveniles and adults at the Red Bluff Diversion Dam, 3) export of vast quantities of water from diversions in the south Delta, 4) heavy metal contamination from Iron Mountain Mine, and*
> *5) entrainment to a large number of unscreened and poorly screened diversions."*
> (NMFS 1997)

Yet another example is provided in the status review on the spring-run Chinook ESU (Evolutionarily Significant Unit), where NMFS concluded:

> *"Habitat problems were considered by the BRT [Biological Review Team] to be the most important source of ongoing risk to this ESU. Spring-run fish cannot access most of their historical spawning and rearing habitat in the Sacramento and San Joaquin River Basins (which is now above impassable dams), and current spawning is restricted to the mainstem and a few river tributaries in the Sacramento River. The remaining spawning habitat accessible to fish is severely degraded. Collectively, these habitat problems greatly reduce the resiliency of this ESU to respond to additional stresses in the future. The general degradation of conditions in the Sacramento River Basin (including elevated water temperatures, agricultural and municipal diversions and returns, restricted and regulated flows, entrainment of migrating fish into unscreened or poorly screened diversions, and the poor quality and quantity of remaining habitat) has severely impacted important juvenile rearing habitat and migration corridors."* (Myers *et al.* 1998)

These foregoing generalizations are typical of most documents[3] describing anadromous fish declines. There is commonly a pattern evident where a particular premise regarding "stressors" on anadromous fish has been posed in early documents, and is subsequently propagated throughout later documents without recognition or acknowledgement that site-specific conditions have changed (for better or worse) during more-recent times. In addition, without a reasonable characterization of specific impacts to fish, fish restoration programs become complicated due to potential misallocation or misdirection of limited resources away from the most important problems.

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[3] An exception is the 2009 NMFS Draft Recovery Plan for winter- and spring-run Chinook and steelhead which will be discussed in this report.

In an attempt to avoid the pitfalls of earlier documents and to more-appropriately characterize when various stressors have exerted their impacts on fish, this report focuses on the recent decades, after large Central Valley dams had been constructed. The theme here is intended to provide insight and attempt to answer the question: *What has happened since large dam construction to increase or decrease the effects of stressors on native anadromous fish?*[4] Earlier periods are not discussed in any detail in this report because meaningful fish population data are lacking or irrelevant. Additionally, prior to major dam construction, there were key factors that adversely impacted fish, but are no longer applicable today. For example, it is known that railroad construction upstream of the present-day Shasta Dam site adversely impacted historical salmon runs and their habitats prior to dam construction (Hanson *et al.* 1940) and historical placer mining for gold in the Feather/Yuba basins caused enormous deleterious effects on fish habitats (HDR/SWRI 2007). Mining debris "totally obliterated" the Yuba River's former channel (Kelley 1989) and covered the Yuba River's salmon spawning beds, with debris covering the river's floodplain up to one and one-half miles from the river with sediments five to ten feet thick. (Yoshiyama *et al.* 1998.) Additionally, in 1919, it was recognized that severe overfishing on salmon stocks was depleting the fish runs and, for the six prior years, the numbers of spring-run Chinook reaching Baird Hatchery on the McCloud River upstream of the present-day Shasta Dam site were so few, egg take from those fish was not feasible (Scofield 1919). Clark (1929) reported that the salmon fisheries were "greatly depleted". Prior to Shasta Dam, Anderson-Cottonwood Irrigation District (ACID) dam in Redding was a partial or nearly complete barrier to upstream migrating spring-run Chinook for 10 years (1917 – 1927) (McGregor 1922, as cited by Moffett 1949) which was likely devastating to the population. Construction of large dams in the Central Valley resulted in loss of anadromous fish habitats in upstream areas that, arguably, cannot be easily remedied. However, as best as researchers could determine in 1949, it was estimated that because Shasta Dam created numerous beneficial effects for salmon in the river downstream of the dam (*e.g.*, temperatures), those improvements had compensated for the loss of spawning habitats above the dam (Moffett 1949). After large dam construction, there were periods when anadromous fish populations were large, indicating conditions for fish in downstream areas after dam construction were suitable to create large fish runs.

In an effort to investigate the reasons for fish population declines, this document analyzes readily-available reports, unpublished reports, "gray literature", existing and new data, new study results, and the considerable professional experience of the author derived from working on fishery resource issues in the Central Valley over the past 30 years (see Exhibit A). Some information presented in this report addresses issues affecting anadromous fish which have received insufficient or no attention (in the author's opinion). To determine the mechanistic causes of the dramatic declines in many fish populations in more-recent times, the major (but not all) anthropogenic changes that occurred during the post-large-dam construction period are evaluated in chronological context.

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[4] The topic of potential re-introduction of native anadromous fish upstream of major Central Valley dams is not discussed in this report. Examination of this issue is being pursued through a recent National Marine Fisheries Service Biological Opinion on the operations of the federal Central Valley Project.

This report examines the location, chronological and seasonal timing, and general magnitude of anthropogenic factors affecting fish species life stages. In particular, it is postulated here that matching potential stressors on particular fish life phases in time and space should help to tease out the most important factors affecting the fish populations. If there are specific stressors that co-occur with the anticipated or known impact on specific fish life stages in a spatiotemporal context (including a recognized time-lagged impact), it may indicate those stressors which are most important. Conversely, it could suggest some variables may have minimal importance. Because much of the relevant data for such analyses are often sparse or lacking, detailed comparisons are challenging. Additionally, environmental "noise" (or variation from random events) and autocorrelation (correlation between variables) adds to the difficulty in evaluation of cause-and-effects on fish (Lehman 1989) as do indirect effects of stressors.

Ultimately, the intent here is to build upon and integrate pertinent information to describe some of the more prominent problems for the fish populations, progress toward alleviating those problems, and, with that knowledge, to pose potential solutions to the issues that have not yet been adequately addressed to achieve the ultimate goal of protecting and increasing the fish populations.

2.0 Existing Fishery Resource Restoration Plans

There is no shortage of fishery resource restoration plans for the Sacramento River basin. The following is a short list of examples:

- **Fish and Wildlife Problems and Opportunities in Relation to Sacramento River Water Developments.** 1972. California Department of Fish and Game. (R. Haley, E.S. Smith, and W.F. Van Woert). 41 p.

- **The Upper Sacramento River – Its Problems and a Plan for its Protection.** 1975. California Department of Fish and Game. (J.W. Burns and others). 17 p.

- **Sacramento River System Salmon and Steelhead Problems and Enhancement Opportunities.** 1987. R.J. Hallock. Report to the California Advisory Committee on Salmon and Steelhead Trout. 92 p.

- **Upper Sacramento River Fisheries and Riparian Habitat Management Plan.** January 1989. California Resources Agency. 158 p.

- **Central Valley Salmon and Steelhead Restoration and Enhancement Plan.** April 1990. California Department of Fish and Game (F.L. Reynolds, R.L. Reavis, and J. Schuler). 115 p.

- **Restoring Central Valley Streams: A Plan for Action.** April 1993. California

Department of Fish Game (F.L. Reynolds, T.J. Mills, R. Benthin, and A. Low). 184 p.

- **Steelhead Restoration and Management Plan for California.** February 1996. California Department of Fish and Game (D. McEwan and T.A. Jackson). 234 p.
- **Sacramento-San Joaquin Delta Native Fishes Recovery Plan.** 1996. U.S. Fish and Wildlife Service.
- **Proposed Recovery Plan for the Sacramento River Winter-Run Chinook Salmon.** August 1997. National Marine Fisheries Service
- **Battle Creek Salmon and Steelhead Restoration Plan.** January 1999. Battle Creek Working Group. 118 p. plus appendices.
- **Final Restoration Plan for the Anadromous Fish Restoration Program: A Plan to Increase Natural Production of Anadromous Fish in the Central Valley of California.** January 9, 2001. U.S. Fish and Wildlife Service. 106 p. plus appendices.
- **Public Draft Recovery Plan for the evolutionarily significant units of Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon and the distinct population segment of Central Valley steelhead.** National Marine Fisheries Service. October 2009. 254 p. plus appendices.
- **Bay Delta Conservation Plan.** Working Draft. November 18, 2010. 1,148 p.

The relatively recent large-scale response and enthusiasm toward fish and fish habitat restoration have been dramatic in the Central Valley. For example, as recently as 1990, the California Department of Fish and Game (DFG) reported that its agency was the only fishery resource agency with a significant fisheries enhancement program (Reynolds *et al.* 1990). At that time, DFG was using special bond funds and annual appropriations to create anadromous salmonid spawning and nursery habitats. Today, the fish population/habitat restoration programs and funding sources among the various state and federal agencies and other groups probably number in the dozens. Universally, these existing plans focus on specific actions recommended under the assumption that implementation will improve habitats and, therefore, result in measureable increases in the fish populations. Although many of the early fish restoration plans are somewhat general in determining potential restoration actions, the recent draft NMFS recovery plan for winter- and spring-run Chinook and steelhead identifies hundreds of possible actions. The recovery plan also differs from many earlier plans by ranking the relative importance of fish population restoration actions. Unfortunately, most fish restoration plans problematically result in a "wish list" for numerous actions without characterization of how they will measurably affect fish. One of the problems of simply listing of all potential factors is that, often, the easiest actions to implement are the ones chosen, instead of the most important factors. Resources will always be limited and many existing plans do not characterize which actions, when implemented, will result in the greatest benefits to fish or ignore the dilemma of limited resources and jurisdictional or legal impediments to their timely implementation.

This report, although not comprehensive, is intended to supplement, not supplant, these existing plans for native anadromous fish restoration.

3.0 Anadromous Salmonid and Green Sturgeon Biology

3.1 Selected Important Habitat Considerations for Anadromous Fish

Because of the importance in understanding how potential factors may have affected Sacramento River basin native anadromous fish populations, the following is a description of the relevant habitat attributes necessary to support their freshwater life phases. The seasonal presence or absence of specific life phases at specific locations is meaningful to determine the relative effects of the anthropogenic factors considered in this report.

The following discussion is organized by salmonid and green sturgeon life phases:

- Adult upstream migration
- Adult holding
- Spawning and incubation
- Fry and juvenile rearing
- Fry and juvenile outmigration
- Ocean rearing

These life phases are used in a conceptual model provided later to characterize how various factors may, or may not, affect the species.

3.1.1 Adult Upstream Migration

Sufficient instream flows and suitable water temperatures are necessary to attract salmonids into the Sacramento River and its tributaries prior to spawning activities. These required flow levels in the lower Sacramento River have never been quantified through scientific investigations but there is no evidence that this parameter has ever limited anadromous fish production in the Sacramento River and its largest tributaries. However, for the smaller tributaries, suitable conditions are usually present only from late fall to early spring when ambient air temperatures cool the tributary water down to acceptable levels for salmon. Tributary flows at the confluence with the Sacramento River or Feather/Yuba rivers and riffles in the stream must be high enough to allow fish physical access into the stream.[5] A general rule is that salmon require

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[5] This circumstance can occur either as a result of storm events, increased reservoir releases, reduction in riverine

approximately one-half foot of flowing water, at a minimum, for passage over riffles. An established run of anadromous fish into a stream explicitly requires that the returning spawning fish were originally hatched in the stream several years prior to their return. This fact is often overlooked when an intermittent, sporadic appearance of some fish in a traditionally non-anadromous stream occurs, which is a phenomenon more likely attributable to "strays" rather than progeny returning to their natal stream.

Green sturgeon have been documented throughout vast regions of the Pacific, from the Bering Sea to Ensenada, Mexico (Moyle, 2002), but can only be found in relatively condensed and specialized regions of the Pacific Northwest when they return to freshwater to spawn. Moyle *et al.* 1994 stated: "*They are known to spawn in three Pacific river drainage systems: The Rogue River in Oregon and the Sacramento and Klamath river systems in California.*" (as cited by Erickson *et al.* 2002). Although the exact details of environmental factors that draw green sturgeon to spawning grounds are not known, variables include, but are not limited to, water temperature, turbidity, availability of food, and topography of the river beds. As with anadromous salmonids, green sturgeon also require sufficient flow for upstream migration, but the appropriate flows have never been identified. However, this factor has not been assumed to limit green sturgeon migration.

3.1.2 Adult Holding Habitat

Adult anadromous fish require habitat where the fish can reside prior to and during spawning activities. These areas provide resting habitat for the fish during the final stages of gamete maturation. Holding generally takes place in the deeper areas of a river such as pools or behind instream structures; this also provides the fish some level of protection from predators (and poachers). The residency time for fish in these holding areas can vary from one or two weeks (exhibited by fall and late-fall Chinook salmon), to as long as several months, as demonstrated by winter-run and spring-run Chinook. Green sturgeon also require particular types of holding habitat prior to spawning. In particular, it appears that sturgeon prefer deep (*e.g.*, 30 feet) pools for holding habitat.

3.1.3 Spawning and Egg Incubation Habitat

The basic components of spawning behavior are similar for most salmonids. Salmonids select sites in the river or stream where suitable water velocities, depth, and substrate are present. Results of extensive research on Chinook salmon and steelhead spawning habitat requirements will not be detailed in this report but are readily available to accurately define substrate particle sizes for optimal redd construction and egg development conditions. Sufficiently high water velocities are necessary to provide inducement to spawning salmon and interstitial flow though salmon redds for egg incubation (Vogel 1983) (*e.g.*, 1.5 to 2.5 feet/second a half a foot above the riverbed).

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diversions, or a combination of these factors.

Incubating salmonid eggs cannot tolerate large quantities of fine particles (*i.e.*, sand and silt) within the redd. Once laid in the river gravels, eggs and larvae must receive oxygenated water of suitable temperature and free from toxic contaminants. The delivery rate of oxygen to the egg is a function of intragravel water velocity and the concentration of oxygen in the water. Heavy siltation on the eggs can reduce intragravel water flow to lethal levels (Wickett 1954). The principal benefits resulting from adequate water velocity to incubating salmonid embryos are the concurrent functions of transferring sufficient dissolved oxygen to the surface of the egg membrane and the removal of the egg's metabolic waste products (Brannon 1965). Lisle and Eads (1991) state that the threshold of concern for fine sediment content in salmonid spawning gravels varies between species and grain size of fine sediment, but most commonly is around 20 percent. The DFG's threshold of concern for fines in spawning gravel is 15 percent (Vogel 1993a).

Water temperature is a significant factor limiting salmon production within their natural range. The most water temperature-sensitive freshwater phase for salmonids occurs during egg incubation (Figure 2). The tolerances of steelhead eggs and larva are similar. The relatively narrow tolerance at increased water temperatures has been a high priority issue on many Central Valley rivers and streams for decades.

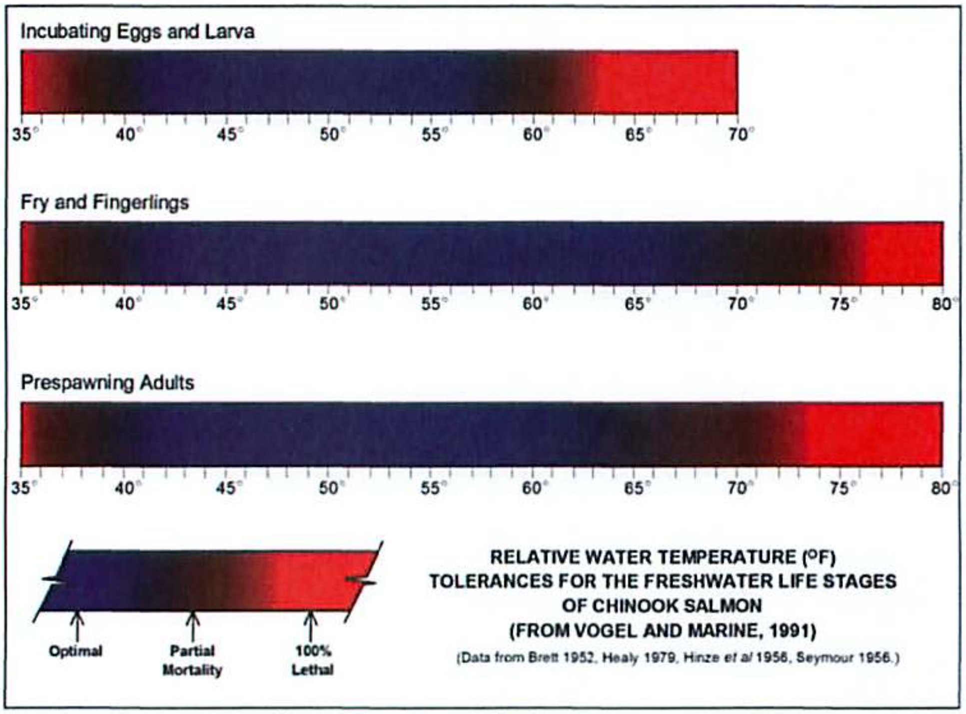


Figure 2. Relative water temperature (°F) tolerances for the freshwater life stages of Chinook salmon (from Vogel and Marine 1991).

Peak green sturgeon spawning generally occurs between mid-April and mid-June (Moyle 2002) when temperatures are ideal. Based on similarities to white sturgeon, and through extensive artificial spawning and egg incubation of green sturgeon, it was determined that temperature of 17-18° C (63-64° F) may be the higher limit of favorable thermal conditions for green sturgeon embryos and that temperatures around 11° C (52° F) can result in a decreased hatch rate as well as smaller length of hatched embryos as compared to a water temperature of 14°C (57° F) (Van Eenennaam *et al.* 2005). However, sturgeon have been found spawning in temperatures as low as 8° C (47° F) (Moyle 2002). Along with temperature, it is generally believed that preferable spawning sites are found in depths of greater than 3 meters (9.75 feet) and in relatively fast water (Moyle 2002). After spawning, adult fish may remain in the river until late fall or early winter before returning to the ocean.

3.1.4 Fry and Juvenile Rearing

Anadromous salmonid fry are particularly vulnerable at emergence and the initiation of feeding because the fish leave the secure, low-energy environment in the interstices of streambed gravels and enter the high-energy environment of the river. Many researchers believe that in an "ideal" natural environment, the general behavioral tendency after emergence is for salmonids to select very quiet shallow water over a variety of substrates. When fish grow, they continually shift their distribution to deeper, faster water. When young salmonids move from spawning areas to rearing areas, complex factors may cause downstream or upstream movements (or both) which may be environmentally and genetically controlled. Many factors may interact to produce these complex instream movements (Vogel 1993b).

Rearing salmonids require a constant food supply from "drift" organisms. The food of young salmon is principally composed of a wide variety of terrestrial and aquatic insects (Moyle 1976). Based on an extensive field research project performed from January through June 1981 in the Sacramento River downstream of Red Bluff, it was concluded that young Chinook salmon: 1) were mainly insectivorous, 2) fed primarily on Chironomidae (a large group of insects), and 3) selected food items that were drifting or floating, not non-drifting benthic forms (Schaffter *et al.* 1982). An earlier study of the food habits of young Chinook salmon throughout the Sacramento River found that larval or adult insects were the principal diet items for salmon during all seasons and at all locations sampled (Rutter 1903). Young spring run in Deer and Mill creeks rear for 9 - 10 months feeding on drift insects (Moyle *et al.* 1989). Sasaki (1966) found that among those salmon he examined in the lower Sacramento River, lower San Joaquin River, and the Delta (which had food in their stomachs), 74 percent had insects in their diet. *Neomysis* (opossum shrimp) was of secondary importance in the lower Sacramento River and both *Neomysis* and *Corophium* (amphipod) were of secondary importance to insects in the lower San Joaquin River. Scofield (1913), as cited by Sasaki (1966) also found insects to be the most important food item for young Chinook salmon. Within the Delta, terrestrial insects are the most important food item for young Chinook salmon (Moyle 1976). Some recent information concerning the impacts of pollutants on salmonid food organisms will be briefly discussed in this report.

Young steelhead consume a diet similar in composition to that of young Chinook salmon. The fish primarily ingest insects during their freshwater life phase. Because steelhead rear for longer periods and grow to larger sizes than Chinook in freshwater, juvenile steelhead are more dependent on larger and more abundant food resources (USFWS 1995). Food organisms of steelhead include aquatic and terrestrial insects, crustaceans, chironomid larvae, *Neomysis mercedis*, amphipods, and larval fishes.

Instream habitat complexity is extremely important for fry and juvenile Chinook salmon and steelhead. Habitat complexity provided by instream structure such as large woody debris (*e.g.*, fallen trees and rootwads) and large rocks or boulders provide young salmonids areas to rear and protection from predatory fish. Proximity of a low-velocity area (for a fish's holding position) to a high velocity area (for feeding), or the proximity of predators and competitors can have overriding influences on how salmonids take up residency at particular locations in a river. The occupation of a sheltered location in the stream near high velocities (and consequently substantial food drift) minimizes the energy expenditure associated with the fish maintaining position in the currents while maximizing food availability. The fish must do so while avoiding predators (*e.g.*, bass, pikeminnow, or birds) and minimizing interactions with competitors. Cover habitat for rearing Chinook has been described as the characteristics associated with water depth, water turbulence, large-particle substrates, overhanging or undercut banks, overhanging riparian vegetation, woody debris, and aquatic vegetation. The needs of Chinook salmon for cover habitats vary diurnally, seasonally, and by size of the fish (Vogel 1993b); steelhead habitats have been similarly described.

Little is known about movements, habitat use, and feeding habits of young green sturgeon. After spawning, green sturgeon larvae average between 8-19 mm in length (Moyle 2002) depending on temperature and amount of nutrients provided to the eggs (Van Eenennaam *et al.* 2005). Juveniles and adults are reported to feed on benthic invertebrates, including shrimp and amphipods, and small fish (70 FR 17386). As with white sturgeon, juvenile green sturgeon in the Delta have been reported to have a diet principally composed of *Corophium* and *Neomysis* (Radtke 1966). *Corophium* was the only item found in the diet for young sturgeon in the size range of 19 - 39 cm in length during the fall. During the spring and summer, both food items were present in the diet. Juvenile and adults are generally considered to be benthic feeders, however it has been documented that juveniles eat small fish as well. In the San Francisco Estuary region they will feed on opossum shrimp and amphipods, (Moyle 2002).

3.1.5 Downstream Migration

Juvenile salmon downstream migrations tend to occur in groups and pulses; these pulses may correspond to increased flow events. For example, USFWS salmon research by Kjelson *et al.* (1982) and Vogel (1982, 1989) reported increased downstream movements of fry Chinook corresponding to increased river flows and turbidity, respectively. Young Chinook salmon may migrate downstream from Sacramento River tributaries and the mainstem river reaches into the Sacramento-San Joaquin Delta as pre-smolts (fry and parr) or as smolts. EPA (1994) describes a smolt as "... *a salmon in the process of acclimating to a change from a fresh water environment to a salt water environment. This occurs when young salmon migrate downstream through the Delta to the ocean.*" Although this definition is accurate, it is simplistic because there are complex morphological, physiological, and behavioral changes associated with the transformation of parr salmon to smolt salmon.

The many variables and consequent interactions associated with the migratory behavior of young salmon are complex and not well understood (Kreeger and McNeil 1992). Abiotic factors which may have primary influence on young salmon migration include photoperiod/date, water temperature, and flow. Other abiotic or biotic factors which may affect migration include barometric pressure, turbidity, flooding, rainfall, wind, species, stock (*e.g.*, fall-run or spring-run), life history stage, degree of smoltification, parental origin (*e.g.*, hatchery or wild), size of juveniles, location (*e.g.*, distance from the ocean), food availability, etc. (Burgner 1991, as cited by Kreeger and McNeil 1992).

Little is known about freshwater movements of green sturgeon but the fish are believed to migrate out to sea before the end of the second year of life, although they may leave as young at one year. However, before reaching this stage, juvenile green sturgeon remain in estuaries and bays, but begin to travel greater distances the larger they become (Moyle 2002).

3.2 Chinook Salmon Life Stage Periodicity

The life span of Chinook salmon may range from two to seven years, but is generally two to four years for Central Valley salmon. Chinook salmon reside most of their life in the ocean (*e.g.*, one and a half to five years) where they rear before maturing and returning to their natal streams to spawn. Their life span and the timing of spawning migrations are primarily genetically controlled. Chinook salmon die upon completion of spawning (Vogel and Marine 1991).

Each of the freshwater life stages (*i.e.*, spawning adult, egg and larva, fry and juvenile) may be found in the upper Sacramento River every month of the year. The actual timing of each of the life stage events varies somewhat from year to year and is primarily a function of weather, river flows, and water temperature (Vogel and Marine 1991). This high degree of variation in life history exhibited by Central Valley Chinook salmon is a function of the differences among the four main seasonal races, fall, late-fall, winter, and spring runs. There is considerable variation within these races for traits such as spawn timing, juvenile riverine residency, and outmigration timing.

3.2.1 Fall-Run Chinook Salmon

Migration of adult fall-run Chinook salmon into the Sacramento River basin begins in July, peaks during October, and ends in December. Spawning occurs in October through December. After egg incubation, fry emergence from the river gravels occurs during January through February. Downstream movement of fry can begin as early as January during winter storm events through the winter months and smolt emigration occurs during April through June.

3.2.2 Late-Fall-Run Chinook Salmon

The principal late-fall-run Chinook migration into the Sacramento River occurs during mid-October through mid-April. Spawning occurs from January through mid-April and egg incubation occurs from January through June. The principal spawning habitat for late-fall-run Chinook is found in the upper Sacramento River in river reaches downstream from Keswick Dam. Rearing and downstream migration or dispersal of juvenile fish from upstream to downstream areas can occur from April through December. The primary movement of smolts through the Delta is believed to occur during the winter months.

3.2.3 Winter-Run Chinook Salmon

Winter-run Chinook salmon spend 1–3 years in the ocean. Adult winter-run Chinook salmon leave the ocean and migrate through the Delta into the Sacramento River from December through July with peak migration in March (Moyle 2002). Many of the early-arriving fish hold for extended periods in the river prior to spawning. Spawning occurs from mid-April to early-August with egg incubation occurring from mid-April to September (Vogel and Marine 1991). The primary spawning habitat in the Sacramento River is above Red Bluff Diversion Dam (RBDD) at river mile (RM) 243, although spawning has been observed downstream as far as RM 218. Spawning success below RBDD may be limited primarily by warm water temperatures (Hallock and Fisher 1985).

Downstream movement of winter-run Chinook salmon fry begins in August, soon after emergence from the gravel. The abundance of juveniles moving downstream peaks at Red Bluff in September and October (Vogel and Marine 1991) but the lower river reaches are generally too warm for fish to enter the Delta at that time. Juvenile Chinook salmon move downstream from spawning areas in response to many factors, which may include inherited behavior, habitat availability, flow, competition for space and food, and water temperature. The numbers of juveniles that move and the subsequent timing are highly variable. Storm events and the resulting high flow and turbidity along with cooler water temperatures appear to trigger downstream movement of substantial numbers of juvenile Chinook salmon. In general, juvenile abundance in the Delta increases in response to increased Sacramento River flow (USFWS 1995). The peak movement of juvenile winter-run salmon into the Delta occurs during the winter months, but winter-run Chinook salmon smolts (*i.e.*, juveniles that are physiologically ready to enter seawater) may migrate through the Delta and bay to the ocean from November through May (Yoshiyama *et al.* 1998). The Sacramento River channel is the main migration route through the Delta. However, the Yolo Bypass also provides significant outmigration passage during higher flow events. During winter in the Sacramento Valley, juveniles rear on seasonally inundated floodplains. Sommer *et al.* (2001) found apparent higher growth and survival rates of juvenile Chinook salmon that reared in the Yolo Bypass floodplain than in the mainstem Sacramento River.

3.2.4 Spring-Run Chinook Salmon

Spring-run Chinook was believed historically to be the most numerous salmon stock in the Central Valley prior to construction of many Central Valley dams, which blocked access of the fish to their historical habitats. Only the main-stem Sacramento and some of its tributaries support remnant spawning runs. Adult spring-run Chinook salmon enter the mainstem Sacramento River from March through September, with the peak upstream migration occurring from May through June (Yoshiyama *et al.* 1998). Spring-run Chinook salmon are sexually immature during upstream migration, and adults hold in deep, cold pools near spawning habitat until spawning commences in late summer and fall. Spring-run Chinook salmon spawn in the upper reaches of the mainstem Sacramento River (downstream of Keswick Dam) and tributary streams (USFWS 1995), with the largest tributary runs occurring in Butte, Deer, and Mill creeks (Yoshiyama *et al.* 1998), the Feather River downstream of Oroville Dam, and the Yuba River downstream of Englebright Dam. Spawning typically begins in late August and may continue through October. Juveniles emerge in November and December in most locations, but may emerge later when water temperature is cooler. Newly emerged fry remain in shallow, low-velocity edgewater (DFG 1998).

Juvenile spring-run Chinook salmon typically spend up to one year rearing in fresh water before migrating to sea as yearlings, but some may migrate downstream as young-of-year juveniles. Rearing takes place in their natal streams, the mainstem of the Sacramento River, inundated floodplains (including the Sutter and Yolo bypasses), and the Delta. Based on observations in Butte Creek and the Sacramento River, young-of-year juveniles typically migrate from November through May. Yearling spring-run Chinook salmon migrate from October to March, with peak migration in November (S.P. Cramer and Associates 1997, Hill and Webber 1999). Downstream migration of yearlings typically coincides with the onset of the winter storm season (Moyle *et al.* 1989), and migration may continue through March (DFG 1998).

3.3 Steelhead Life Stage Periodicity

Steelhead/rainbow trout have one of the most complex life histories of any salmonid species, exhibiting both anadromous and freshwater resident life histories. Freshwater residents typically are referred to as rainbow trout, and those exhibiting an anadromous life history are called steelhead (NMFS 1998). The steelhead trout is an anadromous strain of rainbow trout exhibiting a general life cycle similar to Chinook salmon except that not all adults die after spawning and juveniles rear for longer periods in freshwater before migrating to the ocean. Viable naturally-produced runs of steelhead are found in the Sacramento River and some of its tributaries. Steelhead exhibit highly variable life history patterns throughout their range, but are broadly categorized into winter and summer reproductive ecotypes. Winter steelhead, the most widespread reproductive ecotype and the only type currently present in Central Valley streams (McEwan and Jackson 1996), become sexually mature in the ocean, enter spawning streams in summer, fall or winter, and spawn a few months later in winter or late spring (Meehan and Bjornn 1991, Behnke 1992).

In the Sacramento River, adult winter steelhead migrate upstream during most months of the year, beginning in July, peaking in September, and continuing through February or March (Hallock 1987). Spawning occurs primarily from January through March, but may begin as early as late December and may extend through April (Hallock 1987). Individual steelhead may spawn more than once, returning to the ocean between each spawning migration. Spawning, egg incubation, and fry emergence occurs in a manner similar to that previously described for Chinook salmon. Peak emergence of steelhead fry occurs in the late spring or early summer.

Juvenile steelhead rear a minimum of one and typically two or more years in fresh water before migrating to the ocean during smoltification. Juvenile migration to the ocean generally occurs from December through August. The peak months of juvenile migration are January to May (McEwan 2001), although downstream movements of young-of-the-year steelhead have been reported in the lower Yuba River from late-spring through summer (HDR/SWRI 2007). The importance of main channel and floodplain habitats to steelhead in the lower Sacramento River and upper Delta is not well understood. Steelhead smolts have been found in the Yolo Bypass during the period of winter and spring inundation, but the importance of this and other floodplain areas in the lower Sacramento River and upper Delta is not yet clear. The specific timing of steelhead migration through the Delta is not well defined. Most of the outmigration probably occurs during the wettest months. However, peak numbers of juvenile steelhead at the south Delta water export facilities (perhaps an indication of peak outmigration timing) occur during March and April (USFWS 1995).

3.4 Green Sturgeon Life Stage Periodicity

The green sturgeon is anadromous, but it is the most marine-oriented of the sturgeon species and has been found in near shore marine waters from Mexico to the Bering Sea (70 FR 17386). The northern distinct population segment (DPS) has known spawning populations in the Rogue, Klamath, and Eel rivers and the southern DPS has a single spawning population in the Sacramento River (NMFS 2005). The species is primarily marine and returns to freshwater mainly to spawn during March to July, peaking from mid-April to mid-June (Moyle 2002). Green sturgeon are believed to spawn every 3 to 5 years, although recent evidence indicates that spawning may be as frequent as every 2 years (70 FR 17386). Little is known about the specific spawning habitat preferences of green sturgeon. Spawning is generally associated with water temperatures from 46°F to 57°F. In the Central Valley, spawning occurs in the Sacramento River upstream of Hamilton City, perhaps as far upstream as Keswick Dam (Adams *et al.* 2002), and possibly in the lower Feather River (Moyle 2002). Prior to the listing of the species as threatened, a sport fishery existed on the lower Feather River (HDR/SWRI 2007) and Sacramento River. Capture of larval green sturgeon in salmon outmigrant traps indicates that the lower Feather River may be a principal spawning area (Moyle 2002). It is believed that adult green sturgeon broadcast their eggs in deep, fast water over large cobble substrate where the eggs settle into the interstitial spaces (Moyle 2002). Green sturgeon eggs hatch in approximately 8 days at 55°F (Moyle 2002). Larvae begin feeding 10 days after hatching. Metamorphosis to the juvenile stage is complete within 45 days of hatching. Juveniles spend 1 to 4 years in fresh and estuarine waters and migrate to salt water at lengths of 300–750 mm (70 FR 17386). Green sturgeon have been salvaged at the state and federal fish collection facilities in every month, indicating that they are present in the Delta year-round. Historically, green sturgeon have been much less abundant than white sturgeon and were not as highly prized as a sport fish (Figure 3).

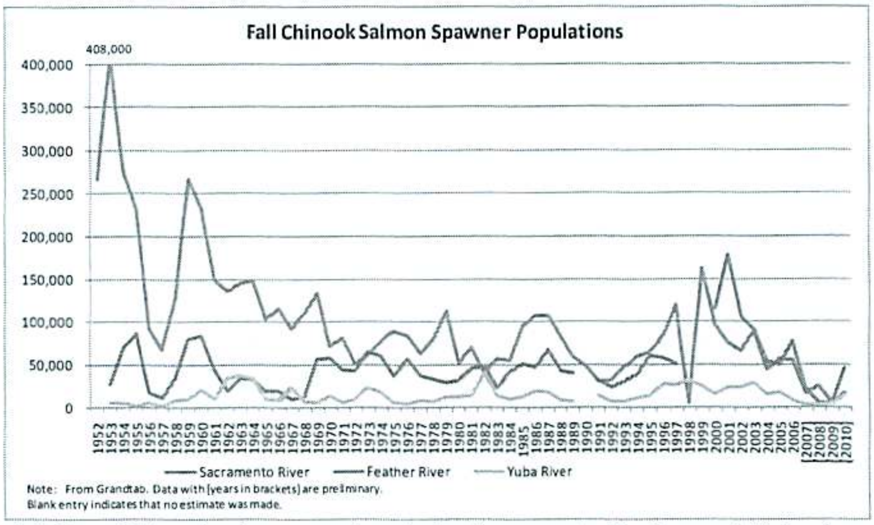
Figure 3. Green sturgeon in left picture (from Vogel 2008a) and a white sturgeon in the right picture held by the author (center) and two of his employees.

4.0 Anadromous Fish Population Status

4.1 Chinook Salmon

4.1.1 Fall-Run Chinook Salmon

Since construction of Shasta Dam, the fall-run Chinook has been the most abundant among the four salmon runs in the upper Sacramento River. Since 1950, when complete data on fall run became available, a peak of 408,000 spawners were observed in 1953 (Figure 4), the presumed largest annual run during the 1939 to 1969 period (Reynolds *et al.* 1990). However, for the period from 1956 to 1985, there was an approximate 50% decline in the mainstem (only) spawning population, mostly upstream of Red Bluff (Reynolds *et al.* 1990).



Fall Chinook Salmon Spawner Populations

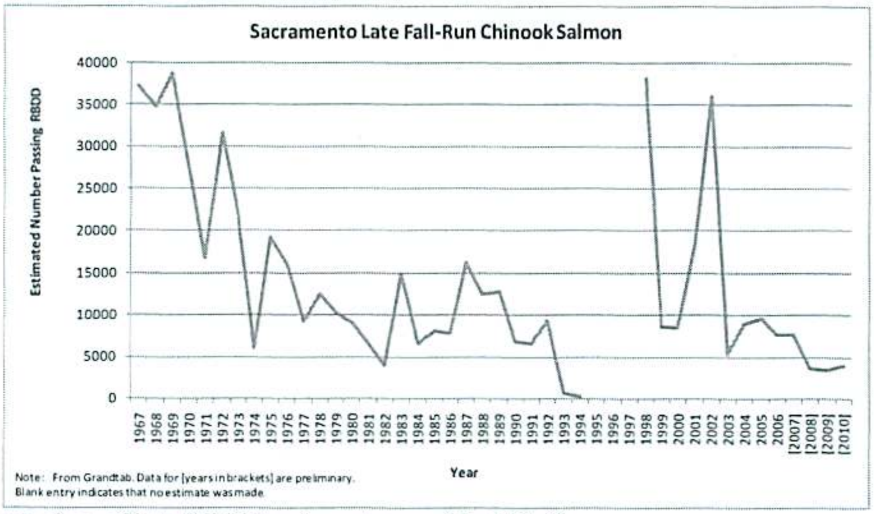
Note: From Grandtab. Data with [years in brackets] are preliminary.
Blank entry indicates that no estimate was made.

Figure 4. Estimated fall-run Chinook salmon run sizes in the Sacramento, Feather, and Yuba rivers. Source: DFG Grandtab.

Extensive mining, agriculture, urbanization, and commercial fishing substantially reduced Yuba River fall Chinook prior to the 1950s. Since then, natural production has been sustained, or in some years increased populations, even with out-of-basin stressors on the salmon runs. Unlike the Feather River, the Yuba River has no hatchery or long-term fish planting program and the run is primarily sustained by natural production (HDR/SWRI 2007).

4.1.2 Late-Fall-Run Chinook Salmon

Because enumeration of late-fall-run Chinook did not begin until Red Bluff Diversion Dam was constructed in the mid-1960s (Figure 5), there are no data available to indicate the population sizes from the construction of Shasta Dam in the 1940s until the mid-1960s.



Sacramento Late Fall-Run Chinook Salmon

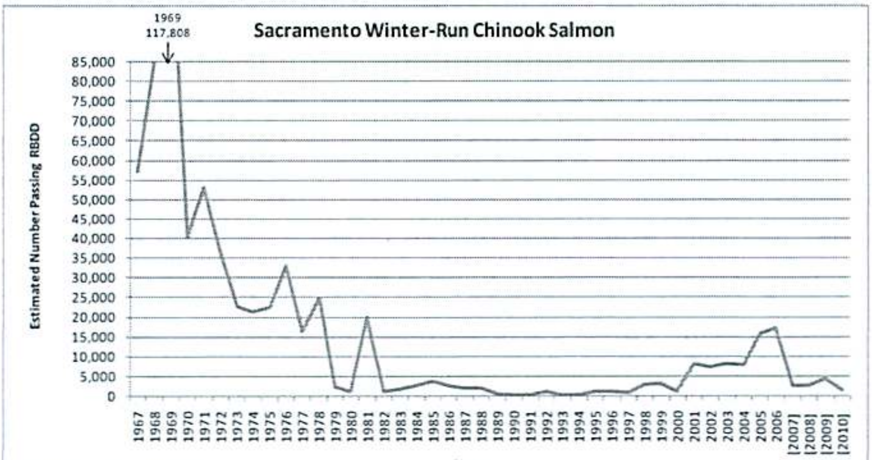
Note: From Grandtab. Data for [years in brackets] are preliminary.
Blank entry indicates that no estimate was made.

Figure 5. Annual run sizes of late-fall Chinook upstream of Red Bluff.

4.1.3 Winter-Run Chinook Salmon

Historically, winter-run Chinook spawned upstream of the present sites of Shasta and Keswick dams. Despite recent popular belief, historically, the winter-run populations were not considered to be large prior to dam construction. As pointed out by Slater (1963), "*In any case, little evidence is extant that this run was distributed widely or that it ever was composed of large populations prior to Shasta Dam.*" However, because of cold-water dam releases during the period when winter-run Chinook spawn, the run size increased "dramatically" during the 1940s and 1950s (after dam construction), eventually surpassing the mainstem spring-run Chinook in significance (Reynolds *et al.* 1993). In 1989, winter-run Chinook salmon escapement was estimated at less than 550 adults. A precipitous decline in winter run since the mid-1960s (Figure 6) prompted the Federal government to list this run as threatened in 1989. Escapement continued to decline, diminishing to an estimated 450 fish in 1990 and 191 fish in 1991, prompting NMFS to reclassify it as endangered in 1994 (Myers *et al.* 1998).

Escapement in 1992 was estimated to be 1,180 fish, indicating good survival of the 1989 class. NMFS data indicate that the population has increased during the late 1990s through 2001. In 1996, returning spawners numbered about 1,000 fish and in 2001, returning adults were estimated to be 5,500 (Pacific Fisheries Management Council 2002). Despite increased efforts to maintain and enhance the population of winter-run Chinook salmon by various entities, in its final listing determination of June 28, 2005, NMFS again found that the Sacramento River winter-run Chinook ESU in-total was in danger of extinction throughout all or a significant portion of its range and concluded that the ESU warranted continued listing as an endangered species under the ESA (70 FR 37191).

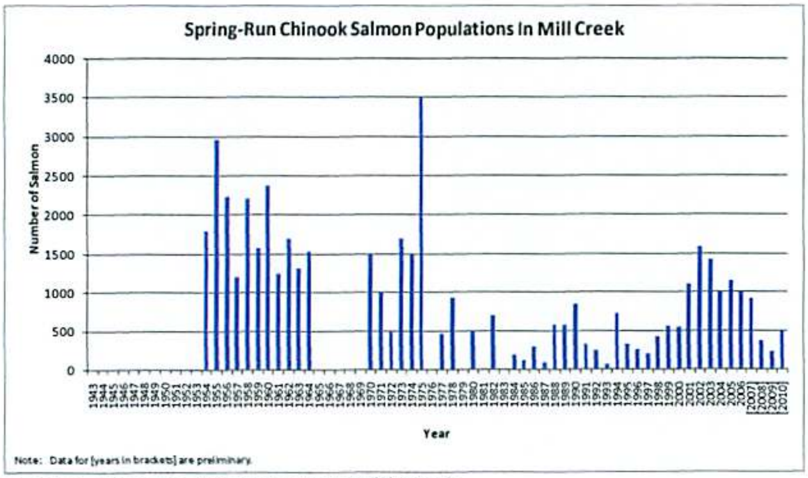


Note: From Grandtab. Estimated from fish counts at RBDD.
Data for [years in brackets] are preliminary.

Figure 6. Annual run sizes of winter-run Chinook upstream of Red Bluff.

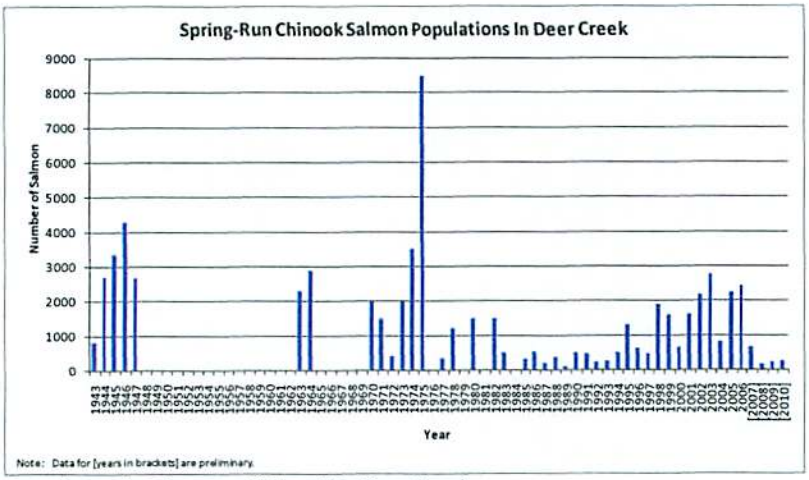
4.1.4 Spring-Run Chinook Salmon

Spring-run Chinook salmon may have once been the most abundant of Central Valley Chinook salmon (Mills and Fisher 1994). They occupied the upstream reaches of all major river systems in the Central Valley where there were no natural barriers. Central Valley spring-run Chinook salmon are now restricted to the upper Sacramento River downstream of Keswick Dam; the Feather River downstream of Oroville Dam; the Yuba River downstream of Englebright Dam; several perennial tributaries of the Sacramento River [*e.g.*, Mill (Figure 7), Deer (Figure 8), and Butte creeks]; and the Delta.



Note: Data for [years in brackets] are preliminary.

Figure 7. Annual run sizes of spring-run Chinook in Mill Creek.



Note: Data for [years in brackets] are preliminary.

Figure 8. Annual runs sizes of spring-run Chinook in Deer Creek.

The abundance of Central Valley spring-run Chinook salmon, as measured by the number of adults returning to spawn, averages about 10,000 adults for natural spawners and another 1,000 to 2,000 adults returning to hatcheries (Mills and Fisher 1994). Spring-run Chinook salmon spawn in the early fall and the spawning periods may overlap with fall-run Chinook salmon if the fish are not geographically isolated. As a result, spring-run Chinook have interbred with fall-run Chinook salmon in the Sacramento and Feather Rivers (DFG 1998). Large dam construction on the Feather River has eliminated the previous spatial separation between the spring and fall runs of Chinook (HDR/SWRI 2007), as has also occurred in the mainstem Sacramento River. Genetically uncontaminated populations may exist in Deer Creek, Mill Creek, Butte Creek, and other eastside tributaries of the Sacramento River. In 1996, DFG believed there were at least eight runs of spring Chinook remaining in the Central Valley (Table 1). Naturally spawning spring run in the Feather and Yuba Rivers, as well as the hatchery stock from Feather River Hatchery, are considered the same Evolutionarily Significant Unit as spring run in the upper Sacramento River (HDR/SWRI 2007). The majority of the spring Chinook in the Sacramento River are the result of hatchery production at Feather River Hatchery. The most important remaining wild runs are in Deer and Mill creeks (Moyle *et al.* 1989); these runs have exhibited substantial declines (Figures 7 and 8). In 1990, Reynolds *et al.* (1990) reported that the spring Chinook runs in Mill and Deer creeks had undergone drastic declines (80-85%) in the prior two decades. The NMFS status review on this run concluded that the only streams considered having wild spring-run Chinook are Mill and Deer creeks, and possibly Butte Creek, and these are relatively small populations with sharply declining trends (Myers *et al.* 1998). DFG (1965), as cited by Myers *et al.* (1998), estimated total spawning escapement of spring-run Chinook in the mid-1960s to be 28,500, with the majority (15,000) spawning in the mainstem Sacramento River and the remainder scattered among tributaries. The mainstem Sacramento River spring runs have widely fluctuated in abundance since 1967 and this run is generally considered to be depressed. Mainstem spawners have declined substantially since the mid-1980s, from 5,000-15,000 to a few hundred fish (Myers *et al.* 1998). A petition to list all spring-run Chinook as endangered was submitted to the State of California in October 1995. On August 28, 1998, the California Fish and Game Commission determined that a state listing of spring-run Chinook as threatened was warranted. The spring-run Chinook was federally listed as a threatened species effective November 15, 1999 (64 FR 50394).

Table 1. Spring-run Chinook salmon stocks, 1996 status of populations and stock purity (DFG 1996).

Spring-Run Chinook Stock	Status of Population		Stock Purity
	Present	Sustaining	
Deer Creek	Yes	Yes/Declining [1/]	Yes
Mill Creek	Yes	Yes/Declining [1/]	Yes
Butte Creek	Yes	Yes/Declining [1/]	Questionable [3/]
Battle Creek [2/]	Sporadic	Sporadic	Questionable [3/]
Big Chico Creek	Sporadic	No	Questionable [3/]
Clear Creek	No	No	Questionable [3/]
Sacramento River	Sporadic	Sporadic	No
Antelope Creek	Sporadic	No	Questionable [3/]
Cottonwood Creek	Sporadic	No	Questionable [3/]
Feather River	Yes	Yes	No
Yuba River	Sporadic	Sporadic	Questionable [3/]
Cow Creek	No	No	No
Thomes Creek	No	No	No

[1/] Population trend data for Deer, Mill, and Butte creeks indicate declining populations since the early 1970s. These three populations are sustaining, and Butte Creek recently had the highest return of spawners ever observed.

[2/] The area of interest on Battle Creek is presently the 20-mile stream reach from the mouth upstream to Eagle Canyon Dam. Future consideration will be given to the 4-mile stream reach above Eagle Canyon.

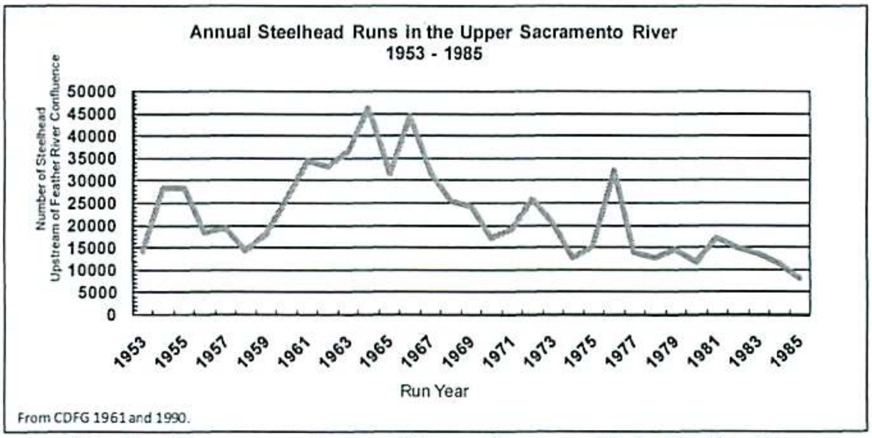
[3/] The purity of these stocks is listed as questionable due to either past introductions of hatchery produced spring-run Chinook salmon or a lack of genetic knowledge of the parentage of spawning fish.

4.2 Steelhead

Central Valley steelhead occur in the Sacramento River and some of its tributaries, including the Feather/Yuba rivers. Most wild, indigenous steelhead populations occur in the Sacramento River basin downstream of Red Bluff including the Yuba, Deer, Mill, and Antelope creeks with additional naturally spawning populations likely influenced by hatchery production in the Feather River and upper Sacramento River (HDR/SWRI 2007). Steelhead populations in the Sacramento River have declined substantially (Hallock 1989). Hallock (1987) estimated that upper Sacramento River steelhead populations decreased from more than 20,000 in the 1950s to less than 5,000 in the 1980s and that most of the decline has occurred since the mid-1960s. Since 1967, the decline of steelhead in the Sacramento Valley has been precipitous (Figures 9 and 10). Hallock *et al.* (1961), as cited by McEwan and Jackson (1996), reported that the composition of naturally produced steelhead in the population estimates during the 1950s averaged 88%. Wild populations in Mill and Deer creeks may be mostly native, but the populations are nearly extirpated. Annual steelhead counts on Mill Creek from 1953 to 1963 ranged from 417 to 2,269 adults; in 1964, 1,006 adult steelhead were counted in Deer Creek. The minimum estimate for steelhead during the 1993-1994 season was 28 in Mill Creek and 0 in Deer Creek (McEwan and Jackson 1996). Natural escapement in 1995 was estimated to be about 1,000 adults each for Mill and Deer creeks and the Yuba River (S. P. Cramer and Associates 1995). Hatchery returns have averaged around 10,000 adults (Mills and Fisher 1994). The most recent annual estimate of adults spawning upstream of RBDD was less than 2,000 fish (NOAA

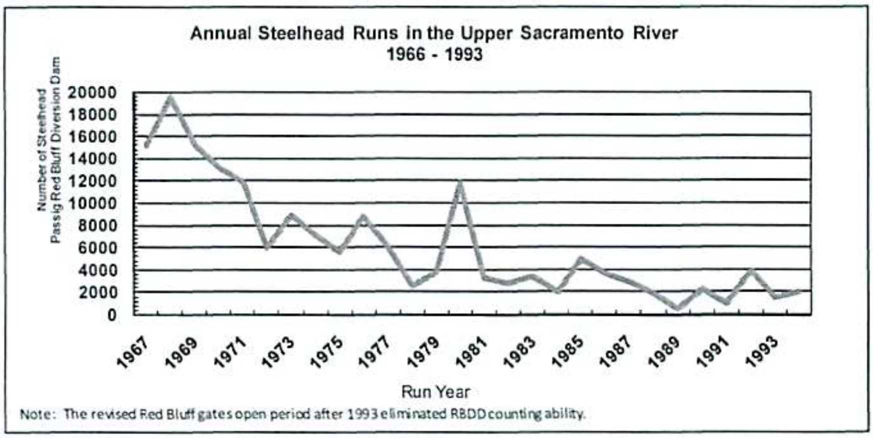
2006).

Central Valley steelhead was federally listed as threatened on March 19, 1998 (63 FR 13347). The threatened status of Central Valley steelhead was reaffirmed in NMFS final listing determination on January 5, 2006 (NOAA 2006), at which time NMFS also adopted the term Distinct Population Segment (DPS), in place of ESU, to describe Central Valley steelhead and other population segments of this species. NMFS originally designated critical habitat for Central Valley steelhead on February 16, 2000 (65 FR 7764). However, following a lawsuit (*National Association of Home Builders et al.* v. *Donald L. Evans, Secretary of Commerce, et al.*), NMFS decided to rescind the listing and re-evaluate how to classify critical habitat for several ESUs (now DPSs) of steelhead. Critical habitat for Central Valley steelhead was redesignated by NMFS on September 2, 2005 (70 FR 52488).



From CDFG 1961 and 1990.

Figure 9. Annual runs of steelhead to areas upstream of the confluence with the Feather River.



Note: The revised Red Bluff gates open period after 1993 eliminated RBDD counting ability.

Figure 10. Annual runs of steelhead upstream of Red Bluff.

One of the primary problems with determining the population status of steelhead is the difficulty in distinguishing between the truly ocean-run fish and the resident rainbow trout. Although NMFS suggested that fish size can be used to differentiate between the two (70 FR 67130), that variable is not applicable to Central Valley steelhead/rainbow trout. This is attributable to the fact that Sacramento River basin *O. mykiss* exhibit a large overlap in sizes of resident and ocean-run fish (*i.e.*, small steelhead and large resident trout are common sizes in Central Valley rivers). Historically, Sacramento River steelhead averaged about three pounds in weight and were generally smaller than steelhead found in other California watersheds (Hallock *et al.* 1961); resident rainbow trout of that size in the Sacramento River are common.

4.3 Green Sturgeon

The population status of green sturgeon has been the subject of considerable debate. Although white sturgeon is the most abundant sturgeon species in the Sacramento – San Joaquin drainage, green sturgeon have always been uncommon (Moyle 2002). In the estuary, white sturgeon is much more common than green sturgeon (Kogut 2002). DFG reported:

> "*Green sturgeon abundance estimates have varied substantially in the Sacramento-San Joaquin Estuary (Table 10). Aside from the high estimated abundance in 2001 of 3,580 fish (based on September and October catches only, to be comparable with estimates in earlier years), the largest estimate was 1,906 in 1979 and the lowest was 198 in 1954. Even without the low estimate in 1954 and the high estimate in 2001, there is no trend in these data ($F_{1,10} = 1.49$, $p > 0.25$), so they provide no evidence for a green sturgeon population decline in the Sacramento-San Joaquin Estuary.*" DFG (2002)

DFG estimated the abundance of green sturgeon indirectly through large-scale tagging studies on white sturgeon which were initiated in 1954. The estimated green sturgeon abundance, which should be viewed with caution due to a variety of assumptions, is obtained by multiplying white sturgeon abundance by the ratio of green sturgeon to white sturgeon caught during the tagging studies (Kohlhorst 2001, Kogut 2002). Green sturgeon abundance has shown no apparent trends over the years, but 8,421 was the highest estimated number of fish (Kogut 2002).

Green sturgeon were classified as a Class 1 Species of Special Concern by DFG in 1995 (Moyle *et al.* 1995). Class 1 Species of Special Concern are those that conform to the state definitions of threatened or endangered and could qualify for addition to the official list. However, DFG specifically responded to the proposed sturgeon petition to list the species as threatened by stating that there are no data to indicate a decline in green sturgeon populations over the past 30 to 50 years (DFG 2002). Moreover, in 2002 DFG believed green sturgeon populations were sufficiently abundant to allow angler harvest. At that time, the agency's regulations allowed sport harvest, permitting year-round take of one fish per day between 117 cm and 183 cm (3.8 feet to 6 feet long) total length and did not contemplate any changes in angling regulations (DFG 2002). However, on March 20, 2006, emergency green sturgeon regulations were put into effect by the DFG which required a year round zero (0) bag limit of green sturgeon in all areas of the state.

North American green sturgeon was determined to be comprised of two populations, a northern and a southern distinct population segment (DPS) by NMFS on January 23, 2003 (NMFS 2003). The northern DPS includes populations extending from the Eel River northward, and the southern DPS includes populations south of the Eel River to the Sacramento River. The Sacramento River supports the southernmost spawning population of green sturgeon (Moyle 2002). The northern DPS was determined as not warranting listing under the ESA by the NMFS on April 6 2005, but remains on the Species of Concern List (70 FR 17386). The southern DPS of green sturgeon was listed as threatened under the federal Endangered Species Act (ESA) on April 7, 2006 (NMFS 2006).

Recently imposed regulations in Oregon and Washington have significantly reduced harvest of green sturgeon (BRT 2005). Although NMFS indicates that this management action primarily benefited the northern DPS of green sturgeon, it also undoubtedly benefited the southern DPS because of the highly migratory nature of the species up the west coast.

5.0 Problems, Progress, and Potential Solutions

This report sequentially focuses on individual anadromous fish life stages from the time of adult upstream migration through holding, spawning, egg incubation, fry and juvenile rearing, outmigration from the rivers and Delta, to ocean rearing. Most reports, and the resultant plans for improvement, instead focus on specific individual stressors to the species (*e.g.*, removing a dam) or specific locations (*e.g.*, a tributary) without necessarily articulating how proposed actions could meaningfully translate into overall effects on the species life cycle compared to other proposed actions. In this regard, it is helpful to have a basic conceptual model of the anadromous fish life cycle to better understand where in specific phases of the life cycles, potential stressors or limiting factors may affect the species (Figure 11). This conceptual model includes many of the primary factors that may limit anadromous fish but does not include every possible factor; life history characteristics are considerably more complex than depicted. For example, among others, it does not include minor factors, the potential deleterious effects of hatchery production on salmonids, and possible effects of disease on wild fish. In most cases, these latter topics and similar factors have only been hypothesized, not empirically demonstrated to have a measurable negative impact on Sacramento River basin anadromous fish. A notable exception is the lack of stock purity of spring-run Chinook caused by interbreeding with fall-run Chinook in the mainstem Sacramento River (Slater 1963) and in the Feather River (DFG 1996, DFG 1998). These latter circumstances place even greater importance on protecting and enhancing true spring-run Chinook in other tributaries discussed in this report.

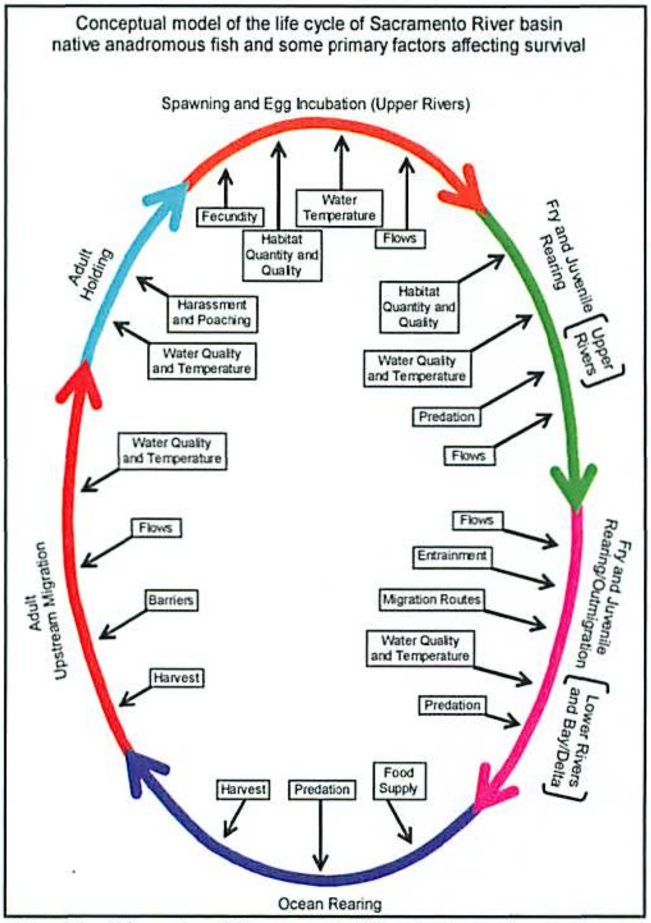


Figure 11. Conceptual model of the life cycle of Sacramento River basin native anadromous fish and some primary factors affecting survival.

The logic presented in this report relies upon a comparison of the seasonal presence of fish life phases with the co-occurrence of the most prominent, relevant anthropogenic factors believed to have adversely impacted anadromous fish. Specifically, the location, chronological and seasonal timing, magnitude, and duration of a particular factor are examined to determine poor or strong correspondence with the declines in anadromous fish populations. Past and present problems for Sacramento River anadromous fish are described relative to the chronological occurrence of those problems. For example, many existing plans discuss problems which no longer exist, or the problems have been diminished to far lesser importance as compared to decades ago.

The preceding is in recognition of the major caveat that, due to the complex nature of the life cycles and the interaction of environmental variables and effects on fish, determining causality of a particular variable translating to measurable effects on adult fish returns is nearly impossible (Cummins *et al.* 2008). Many factors may work in combination on long time scales (*e.g.*, decades) to ultimately create adverse conditions for fish which would not be discernable on short time scales (*e.g.*, annual). For example, it is known that there has been a statistically significant trend toward earlier annual Sierra Nevada runoff and Delta outflow since the late 1940s which has been attributed to an increase in January-March warming in the Sierra Nevada of about 2° F (Dettinger *et al.* 1995). This phenomenon may simply be a function of long-term climate variability, but it could act synergistically with other stressors to create altered freshwater conditions for fish in a more-recent time scale.

The progress of some fish restoration and protection efforts is described herein. Many existing plans often do not describe progress either because the plans are outdated or specific restoration actions were overlooked. New information to benefit anadromous fish either not addressed or only partially addressed in existing plans for fish restoration is also presented here. As mentioned previously, this report is not comprehensive and is intended to supplement, not supplant, these existing plans for native anadromous fish restoration. It draws upon much of the past high quality efforts focused on fish and habitat restoration and is intended to enhance those existing plans.

5.1 Adult Fish Upstream Migration

Adult anadromous fish returning from the ocean and migrating upstream to spawning grounds face a variety of hazards. Protecting adult anadromous fish from time of entry into freshwater until successful reproduction in the upstream spawning habitats is critical. Those adults attaining the reproductive phase are the fewest in number among all the prior life stages. Fish reaching the spawning grounds are the oldest among all prior life stages and have already survived the vast majority of density-independent and density-dependent factors exerting the most influence on the population. Significant changes in the numbers of these adult fish can have resulting profound impacts on subsequent generations. Given the complexity of the anadromous fishes' life cycle, the upstream migrating adult fish should be the easiest to protect. Historically, this has not been the case, but major recent actions have enhanced the probability of successful migration to upstream areas where the fish reproduce.

5.1.1 Delta

5.1.1.1 *Barriers*

There are a number of barriers in or near the Delta believed to block or delay upstream migration of adult fish. The 2009 NMFS draft recovery plan for salmonids identifies the Suisun Bay Salinity Control Gates, the Sacramento Deep Water Shipping Channel, the Delta Cross Channel (DCC), and Fremont Weir as barriers (NMFS 2009). These same structures would also be barriers for sturgeon. Although the total counts of fish blocked in these areas are unknown, the problem remains important. Suisun Marsh, just west of the western Delta, has over 10 percent of California's remaining natural wetlands and is one of the largest contiguous brackish water tidal marshes in the United States (Guivetchi 1990). The Suisun Marsh Salinity Control Gates, located nearly on the western legal boundary of the Delta, were constructed in 1988 and are used to protect the marsh through operations to tidally pump low salinity water into the interior marsh via Montezuma Slough (Brown 1990). However, there is concern that upstream migrating salmon may be blocked or delayed by the control gates which prompted NMFS to investigate potential fish passage problems (Rooks 1998). From Suisun Bay, anadromous fish destined for the Sacramento River have a relatively straight-forward migration route through the Delta. Important exceptions occur if the fish, instead, migrate up the north or south forks of the Mokelumne River or move up into Cache Slough to the Yolo Bypass or Sacramento Deep Water Ship Channel (Figure 1). Once those fish enter the Mokelumne River system upstream of Georgiana Slough and the DCC gates are subsequently closed, those fish become "trapped" in that river system and can only re-enter the Sacramento River by migrating back downstream (uncharacteristic of upstream migrating anadromous fish) or when the DCC gates are reopened. Fish attracted into the Yolo Bypass during flood flows can become stranded or blocked at Fremont Weir when flows recede. This problem is likely to be severe, particularly for green sturgeon. Adult fish migrating into the Sacramento Deep Water Ship Channel can become blocked from upstream areas without flows to attract the fish back into the mainstem river. This is unlikely to be severe due to inadequate flows to divert fish up the channel off Cache Slough. Each of these regions could have structural measures implemented to eliminate the problem. Given the enormous expenditures which have been committed elsewhere in the watershed and Delta to benefit fish and the biological importance of returning adult spawners, it is surprising that more focus has not been given to this issue.

5.1.1.2 *Flows*

No information was found to indicate that the flow regime in the Delta currently adversely impacts Sacramento River basin anadromous fish migrating upstream through the Delta. Although freshwater outflow provides important cues for attracting adult fish to upstream areas (SWRCB 2010), Sacramento River flows have not been shown to be limiting for upstream migrating anadromous fish.

5.1.1.3 *Water Quality and Temperature*

No information was found to indicate that water quality currently significantly impacts Sacramento River basin adult anadromous fish in the Delta. Although pollution in the Delta is known to occur, those effects are largely believed to primarily impact smaller organisms more sensitive to pollution (discussed later). Recently, concern has been expressed over the influence of selenium on green sturgeon (EPA 2011), but no clear negative impacts have been shown. There are a multitude of water quality concerns with a large number of pesticides and other pollutants found in Delta water, but again no distinct effects on anadromous fish have been determined. However, given the numerical magnitude of pollutants in the Delta, this may possibly emerge as an important factor. Low dissolved oxygen in the San Joaquin River near Stockton at certain times of the year has been shown to adversely impact salmon, but Sacramento-origin fish have been unaffected. Water temperatures in the Delta are controlled by ambient conditions, and Central Valley reservoirs are too far upstream to influence Delta water temperatures.

5.1.2 Mainstem Sacramento River

5.1.2.1 *Harvest*

The following discussion is applicable to the Delta, mainstem river, and the tributaries. Sport fishing for anadromous fish in the Sacramento River basin is highly regulated to protect fish returning to the spawning grounds. An extensive discussion on the topic is provided in DFG (1998). The intent of fishery managers is to allow harvest of surplus fish while ensuring sufficient numbers escape in order to reproduce and continue a healthy propagation of the species. Sport fishing regulations impose a variety of restrictions to limit overharvest, including in some instances, total prohibition on harvest. When endangered anadromous salmonids are intermingled with non-listed salmonids, it creates a dilemma for resource managers. For example, because of the overlap in the timing between salmon runs, some inadvertent harvest of listed species can occur even though anglers target non-listed species. NMFS believes the harvest of listed species in this circumstance is minimal, but nevertheless occurs. The fish are also subject to illegal harvest (*i.e.*, "poaching").

During the transition from salt water in San Francisco Bay to the Delta and upstream areas, the adult fish are subject to sport fishery harvest, depending on species, run, and the specific timing. Due to the threatened or endangered species status and recent poor returns of anadromous salmon, severe sport harvest restrictions imposed by the California Fish and Game Commission (CFGC) have been implemented in the Central Valley, including the Delta, to protect the adult life stage. Sport harvest of green sturgeon is now prohibited. To protect threatened steelhead from harvest, a complicated suite of regulations was imposed. Increased law enforcement activity to minimize illegal harvest has increased due to species listings and funding through Delta-related programs (*e.g.*, Delta Bay Enhanced Enforcement Program) (DFG 1998).

Initially, during the 2010 – 2011 sport fishing regulatory period, salmon fishing in the Sacramento River (Keswick Dam to the Carquinez Bridge), the Feather River (below Oroville Dam to mouth), and all other anadromous tributaries was closed, except for the Sacramento mainstem stretch of river from just below Red Bluff to Knights Landing where one salmon was permitted from November 16 to December 31 (CFGCa). Subsequently, after predictions of the salmon runs improved, suggesting greater numbers of returning fish, a daily bag and possession limit of two salmon in the Sacramento River was allowed for three weeks in October from approximately Red Bluff to Anderson with the same limit in the Feather River primarily during August (CFGCb). Other tributaries remained closed to fishing. This management strategy was designed to provide sport fishing opportunities by mainly targeting the more abundant fall-run Chinook and, in particular, hatchery fish.

For the 2010 – 2011 season, regulations protecting steelhead (defined as any rainbow trout greater than 16 inches in total length) were more complicated. From just below Keswick Dam to

Anderson, one trout (up to 16 inches in total length) was allowed as the daily bag and possession limit all year. From Anderson to Red Bluff, two hatchery trout or hatchery steelhead (identified by adipose fin clips) was the daily bag limit and four hatchery trout or hatchery steelhead was the possession limit from January 1 through March 31 and August 31 through December 31. However, from April 1 through August 30, an additional one wild trout (no greater than 16 inches) could be in possession. From just below Red Bluff to the Carquinez Bridge, two hatchery trout or hatchery steelhead was the daily bag limit and four hatchery trout or hatchery steelhead was the possession limit all year long. In the Feather River, from the Fish Barrier Dam downstream of Lake Oroville to the city of Oroville no fish were allowed. From Oroville to the Highway 70 Bridge, one hatchery trout or one hatchery steelhead was the take and possession limit from January 1 through July 15. From the Highway 70 Bridge to the mouth, one hatchery trout or 1 hatchery steelhead was the take and possession limit all year. In the Yuba River from the mouth to the Highway 20 Bridge, two hatchery trout or hatchery steelhead was the bag limit and four hatchery trout or hatchery steelhead was the possession limit all year. From the Highway 20 Bridge to Englebright Dam, two hatchery trout or hatchery steelhead was the bag limit and four hatchery trout or hatchery steelhead was the possession limit from December 1 through August 31 only (CFGC 2010a).

During other times of the year, unlike in past decades, the rivers have been closed to sport harvest to protect steelhead, winter- and spring-run Chinook, and to some extent, late-fall-run Chinook (CFGC 2010a, 2010b). However, historically, sport harvest probably adversely impacted the steelhead populations; both juvenile and adult steelhead were caught. Because of generally favorable riverine conditions during the sport fishing season, the fish are particularly vulnerable to harvest. McEwan and Jackson (1996) suggested that over-harvest of steelhead in Sacramento River tributaries could have been a factor in their population declines. Although some inadvertent freshwater harvest of listed species undoubtedly still occurs, it is assumed to be minimal; no information was located to suggest otherwise. Harvest of non-listed anadromous salmonids (fall-run and late-fall-run) does occur but is maintained to ensure that sufficient numbers of fish return to spawn.

It is not possible to determine the effectiveness of DFG and NMFS law enforcement activities in terms of numbers of fish protected from overharvest. However, because much of the sport fishing activities for anadromous fish on the mainstem Sacramento River occurs by boat, access is largely limited to a relatively small number of boat launching facilities spread over a long distance of river. In some counties, the local county sheriff's boat patrols assist wardens in monitoring fishing activities. Additionally, daytime recreational boating activity is popular throughout the Sacramento River so poaching during daylight would be highly visible to the public. Undoubtedly, some nighttime illegal harvest (*e.g.*, exceeding the daily bag limit) occurs but there is no indication to suggest overharvest from in-river sport fishing has transpired in the recent past. The numbers of fish harvested are much less than the ocean harvest and, unlike the ocean fishery, inland sport harvest does not affect the age structure (discussed in Section 5.6.3) of the populations. Because of the heightened attention on protecting depleted fish stocks, listing of species as threatened or endangered, and increased regulatory oversight caused by these circumstances, it can be assumed that any potential problems caused by sport harvest have been considerably reduced during recent years as compared to decades ago. As demonstrated by recent severe restrictions on sport harvest described above, fishery managers have been able to control and lessen this stressor to anadromous fish. These circumstances have increased, not decreased, protection for anadromous fish as compared to prior decades.

5.1.2.2 *Barriers*

The Red Bluff Diversion Dam (RBDD) on the upper Sacramento River near Red Bluff went into operation in August 1966. The purpose of the dam was to divert water off the Sacramento River into the Tehama-Colusa (T-C) Canal and Corning Canal. The Corning Canal is used only for agriculture whereas the T-C Canal was originally used to convey water for agriculture, wildlife refuges, and the T-C Fish Facilities (Vogel *et al.* 1988). The fact that the T-C Fish Facilities required fall, winter, and spring diversions of water into the T-C Canal is the circumstance that originally necessitated year-round diversions of water at RBDD (in contrast to only seasonal irrigation diversions). During the late 1980s, the T-C Fish Facilities were "mothballed" (*i.e.*, placed into a non-fish-production mode) (Vogel 1989) which eliminated the need for year-round diversions from the Sacramento River.

Fishery resource investigations conducted at RBDD during the 1970s and 1980s identified significant upstream anadromous salmonid passage problems at the dam (Vogel *et al.* 1988). Largely as a result of prior investigations, the USFWS began intensive studies (performed by this author) in the early 1980s to determine specific problems and potential solutions for anadromous salmonid upstream migration at the dam. Primarily, inadequate fish passage (ladders) at the site and fish attraction to heavy water flows under the 11 large dam gates were believed to cause the unusually high delay times and blockage of adult salmonids migration into the upper river. Experiments conducted by gate manipulation to increase fish attraction to the fish ladders met with mixed success. Many other problems with fish passage were uncovered during the studies. At one time, the operation of RBDD was considered one of the largest threat to anadromous fish in the Sacramento River. That has now changed. Numerous actions over the past several decades, most notably raising the dam gates during the fall, winter, and spring months, have significantly improved upstream fish passage (Tables 2 and 3).

Table 2. Improvements in fish passage at Red Bluff Diversion Dam (RBDD).

Fish Protection Measure	Effective Date	Fish Passage Improvement
Eliminating Adult Salmon Delay and Mortality at the Louver Bypass Terminal Box	1985	Elimination of significant adult salmon mortality at the dam bypass
Improved RBDD Fish Ladder Maintenance	1985	Improved fish attraction into the fish ladders
Installation of the Training Wall at the Right-Bank Fish Ladder	1985	Improved fish attraction into the right-bank fish ladder
RBDD gates out 6 months/year	1987	Unimpeded upstream fish passage 6 months/year
Relocation of the Fish Screen Bypass Outfall	1990	Reduced delay of salmon downstream of the dam
RBDD gates out 8 months/year	1993	Unimpeded upstream fish passage 8 months/year

Table 3. Restoration actions[*] developed in June 1986 by Dave Vogel (U.S. Fish and Wildlife Service) and John Hayes (Department of Fish and Game) to benefit winter-run Chinook salmon ("10-Point Action Program").

Restoration Action	Status
1) Raise the Red Bluff Diversion Dam gates from December 1 to April 1	Completed
2) Develop winter-run Chinook salmon propagation program at Coleman National Fish Hatchery	Completed
3) Restore spawning habitat in Redding area	Partially completed
4) Develop measures to control pikeminnow at Red Bluff Diversion Dam	Nearly completed
5) Restrict in-river fishery	Completed
6) Develop water temperature control for drought years	Completed
7) Correct Spring Creek pollution problem	Completed
8) Correct problems at Anderson-Cottonwood Irrigation District diversion dam	Completed
9) Correct stilling basin problem at Keswick Dam	Completed
10) Continue and expand studies on winter-run Chinook	Partially completed

[*] Many of these restoration actions are discussed later in this report.

To assist in protecting the endangered winter-run Chinook salmon, the U.S. Bureau of Reclamation (USBR) raised the RBDD gates from November 1 through April 30 each year beginning in the late 1980s. This action was implemented to provide unimpeded upstream and downstream passage for anadromous fish. A NMFS Biological Opinion concerning USBR's operation of the Central Valley Project (CVP) required that the RBDD gates be raised for a longer period, from September 15 through May 14 of each year (USBR 1993) (Figure 12). That action is believed to have greatly diminished the problems of upstream fish passage previously evident from the late 1960s through the 1980s. However, a consequence of raising the dam gates occurred as adult anadromous fish became stranded in a side channel. For example, in 1993, 384 adult Chinook salmon were rescued and manually removed from isolated pools after the dam gates were raised (USFWS 1993). This problem can also develop when river flows naturally increase and decrease even when the dam gates are raised. Efforts to grade the side channel in an attempt to prevent the formation of isolated pools were temporarily successful, but the channel configuration periodically changes and close monitoring of conditions to prevent fish stranding is required along with fish salvage as necessary.

Figure 12. Red Bluff Diversion Dam with all 11 dam gates raised to provide unimpeded upstream and downstream fish passage. Photo by Dave Vogel.

Several years ago, 10 adult green sturgeon were found dead just downstream of the dam (or impinged under the dam gates). It was determined that dam operations killed the fish. Early that year, prior to irrigation operations, the gates were completely opened to allow unimpeded fish passage to upstream areas. The dam gates were subsequently lowered for seasonal irrigation operations but some gate openings were set with only a six-inch gap to pass water to downstream reaches. The dam operators were not informed that the very large green sturgeon required more than a six-inch opening when the fish migrated back downstream and the fish were subsequently killed. Because the adult fish can pass under the gates with at least a one-foot opening, that measure was later implemented but the circumstance, nevertheless, was one of the rationales used by NMFS as a justification to list the species as threatened with extinction.

Ultimately, for a variety of reasons, and to provide unimpeded passage of adult green sturgeon during the summer months, raising all the dam gates during the remaining four months was deemed the best solution for fish passage at RBDD. With ESA listing of the green sturgeon, the RBDD gates will be permanently raised 12 months/year beginning in 2012 upon completion of a new 2,500 cfs pumping plant located just upstream of the present dam site.

The Anderson-Cottonwood Irrigation District (ACID) diversion in Redding (Figure 1), approximately three miles downstream of Keswick Dam, utilizes a gravity-flow diversion off a 450-foot-wide flashboard dam which was originally constructed in 1917 (USBR 1992). Much of the original concern over fishery resource impacts caused by ACID operations was oriented toward severe upstream migrant fish passage problems. It was believed that in the early years of ACID operations (prior to the installation of a fishway), the dam blocked nearly all upstream migrating salmon en route to their spawning grounds (McGregor 1922). The flashboards on the dam are generally in place from April to October (RAC 1989). DFG previously constructed and maintained a fish ladder at the dam (Reynolds *et al.* 1990). Since installation of this fishway, concern was expressed that the fish passage facilities were inefficient (Reynolds *et al.* 1990) and were subsequently replaced in 2001.

Keswick Dam, located approximately 302 river miles upstream of San Francisco Bay, is the upstream terminus of anadromous fish migration in the mainstem Sacramento River. When flows are high and exceed the hydroelectric power plant capacity, water flows over the spillway where adult fish can be attracted. Historically, these fish became stranded and entrapped in the stilling basin below the spillway (Figure 13). However, recent structural measures were implemented by the USBR to provide for fish reentry back into the river which is believed to have resolved the problem.

Figure 13. Keswick Dam located at river mile 302 on the upper Sacramento River. The stilling basin on the right side of the picture used to trap adult anadromous salmonids. Aerial photo by Dave Vogel.

5.1.2.3 *Flows*

No information was located to indicate that flows in the mainstem Sacramento River impede or limit upstream migration of anadromous fish. Every day of the year, since large dam construction, instream flows have been sufficiently high to provide physical passage of fish to upstream areas.

5.1.2.4 *Water Quality and Temperature*

Although water temperatures at some times of the year are sub-optimal for adult fish, no information was located to indicate that water temperature or quality measurably adversely impact anadromous fish migrating up the Sacramento River. To the contrary, because of the release of cold water and increased flows during summer months to downstream areas (*i.e.*, conveyance to the Delta), upstream migrating conditions for anadromous fish are more favorable now as compared to the era prior to large dam construction. For example, City of Redding residents use to swim in the Sacramento River during the summer prior to dam construction and considered it like "bath water" (Clair Hill, pers. comm.); in the present era it is frigid for swimming and more than suitable for anadromous fish.

5.1.3 Sacramento River Tributaries

The principal tributaries in the Sacramento River supporting anadromous fish include the Feather River, Yuba River, Butte Creek, Big Chico Creek, Deer Creek, Mill Creek, Antelope Creek, Cottonwood Creek, Battle Creek, Cow Creek, and Clear Creek. There are other tributaries where anadromous fish may have historically been present, but never observed in large numbers. Some streams such as Stony Creek and the Bear River[6] are hostile to anadromous fish spawning and incubation because of silted riverbed substrates, high water temperatures, and unsuitable rearing habitats due to river channels formed by very high and frequent winter-time flows (SWRCB 2000, Vogel 1998, Vogel 2003a).

5.1.3.1 *Barriers*

Many of the Sacramento River tributaries possess diversion dams for agriculture, and some possess dams created to control extremely high sediment loads created by hydraulic mining upstream. Such dams can be, and are historically known to be, detrimental for anadromous fish attempting to migrate to spawning and rearing habitats. The construction of Englebright Dam was completed in 1941 by the California Debris Commission to retain hydraulic mining debris in the Yuba River. Currently, the U.S. Army Corps of Engineers (USACE) administers the operation and maintenance of Englebright Dam which, located approximately 24 miles upstream of the confluence with the lower Feather River and 280 feet high, presents an impassible barrier for anadromous fish in the river in the Yuba River system (HDR/SWRI 2007). Daguerre Point Dam is located farther downstream (at approximately river mile 11.5) on the lower Yuba River. Construction of the dam was completed in May of 1906 by the California Debris Commission to retain hydraulic mining debris. Following the floods of 1963 and 1964, the dam was entirely reconstructed except for a short section of the right abutment. Reconstruction of the dam, including the extension and rehabilitation of both fish ladders, was completed in October 1965 (Corps 2001) using the best available science and the engineering technology that was available at that time. However, design of the fish ladders is considered suboptimal in relation to present-day engineering technology (NMFS 2009). Also, it is believed that adult sturgeon are unable to ascend the fish ladders at Daguerre Point Dam (HDR/SWRI 2007).

With early recognition of the problems with fish passage at dams in tributaries, DFG installed fish ladders to accommodate upstream passage. All diversion dams on Mill, Deer, and Antelope creeks had fish ladders installed to benefit the upstream migration of anadromous salmonids (Reynolds *et al.* 1990) (spring-run Chinook, fall-run Chinook, and steelhead) with no evidence that the structures provide undue adult fish mortality (DFG 1998). Additionally, fish ladders had been installed at two natural falls on Deer Creek (Reynolds *et al.* 1990) to expand the habitats available for salmon (primarily for spring-run Chinook) (*e.g.*, Figure 14). Clough Dam on Mill Creek was breached during high flow conditions in 1997 providing unimpeded fish passage.

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[6] Clark (1929) reported that the Bear River "*has never been known to be a salmon stream as only occasional salmon have been observed there.*"

Using approximately $1.25 million in USBR/CalFed funds, the California Department of Water Resources (DWR) permanently removed Clough Dam and improved the fish ladder, fish screen, and canal capacity at the next upstream dam and changed the point of diversion from the original Clough Dam to the upper dam (Curtis Anderson, DWR Northern District Chief, pers. comm.). Stanford-Vina Dam on Deer Creek has fishways believed to be adequate for salmon passage. In 1998, DFG reported that a new high efficiency fish ladder was completed at the Parrott-Phelan Diversion on Butte Creek (DFG 1998). Many other examples exist.

Figure 14. A DFG biologist maintaining a fish ladder in upper Deer Creek for passage of spring-run Chinook salmon. Photo by Dave Vogel.

During the 1990s and 2000s, several dams believed to delay or block anadromous salmonids were removed. Saeltzer Dam on Clear Creek was removed which provided unimpeded access of fall-run Chinook, spring-run Chinook, and steelhead to upstream reaches and is believed to provide improved holding, spawning, and rearing habitat conditions. Altering Western Canal's structure on Butte Creek into a siphon under the creek, as well as constructing new conveyance facilities, eliminated four dams believed to delay or block salmon, particularly spring-run Chinook. This opened 25 miles of unimpeded access for salmon.

New fish ladders were recently constructed on some tributaries to improve anadromous fish passage. The Coleman National Fish Hatchery diversion dam on Battle Creek was redesigned and constructed to facilitate fish passage into upper Battle Creek, allowing access into more than 40 additional river miles (Cummins *et al.* 2008). A large-scale program is currently underway in Battle Creek to restore fish access to upper reaches (discussed later). As part of a Federal Energy Regulatory Commission (FERC) relicense condition, by 1990, PG&E had constructed a new fish ladder at the power company's diversion on South Cow Creek (Reynolds *et al.* 1990). New fish ladders were recently constructed on several dams (*e.g.*, Parrott-Phelan, Gorrill, and Adams) in Butte Creek to improve fish passage, particularly for spring-run Chinook (Figure 15).

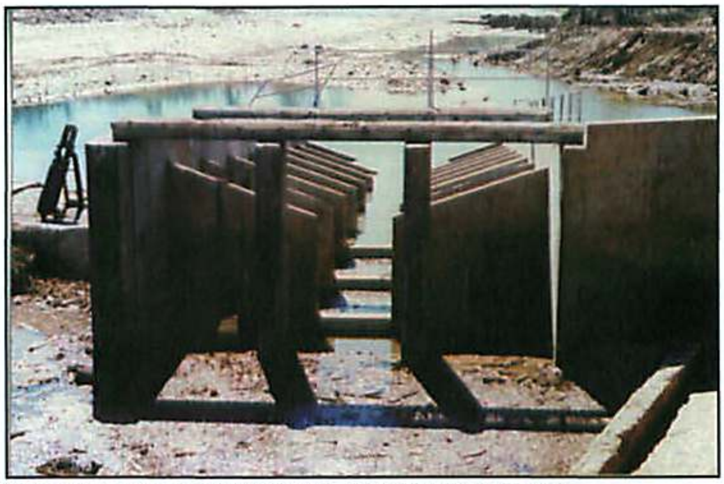

Figure 15. New fish ladder constructed on Butte Creek. Photo by Dave Vogel.

5.1.3.2 *Flows*

Flows in the Feather/Yuba rivers have not been identified as a problem limiting upstream migration of anadromous fish. The Fisheries Agreement of the Lower Yuba River Accord provides for new minimum instream flows in the lower Yuba River that are intended to maintain or increase fishery resource protection (HDR/SWRI 2007). Measures to be implemented through the FERC re-licensing of the Oroville Project can also be expected to benefit anadromous fish. In Butte Creek, removal of passage barriers, construction of screens and ladders on diversions, and increased instream flows through diversion changes have recently benefitted anadromous salmonids (Cummins *et al.* 2008). However, historically, low flows in the spring in some smaller tributaries where spring-run Chinook are present (*e.g.*, Mill, Deer, and Antelope creeks) have made it difficult for late-arriving fish to migrate upstream either due to insufficient flows or warm water temperatures (DFG 1998). For example, in the mid- to late-1940s, hundreds of adult spring-run Chinook perished in Deer Creek because of the low-flow/high-temperature problem (Moffett 1949). This has persisted in some years, prompting actions to provide water exchanges with tributary diverters to improve spring-run upstream migration (RAC 1989). DFG and conservancies on some spring-run tributaries (*e.g.*, Mill and Deer creeks) have recently worked cooperatively to ensure adequate instream flows for upstream migrating salmon (DFG 1998). Flows to benefit spring-run Chinook migration in Butte Creek have also been implemented (DFG 1998).

5.1.4 Conclusions on Adult Fish Upstream Migration

- Previously, sport harvest of anadromous fish was far more liberal than regulations imposed in recent years. Much of the present-day sport harvest is so restrictive that current regulations, depending on the species and run, range from very low daily bag and possession limits and very narrow windows of allowable fishing, to total harvest prohibitions. Law enforcement activities to minimize illegal harvest have increased during recent years. The available evidence indicates that freshwater sport fishing mortality cannot explain the historical decline of anadromous fish. Furthermore, this "stressor" has become less, not worse, over time.

- There are some partial and total barriers to adult anadromous fish in the Delta that have unknown severity of impacts to the species. Under certain flow conditions, adult fish can be totally blocked during their upstream migrations at the DCC (when the gates are closed), the Sacramento Deep Water Ship Channel, and Fremont Weir.

- Previously, the most severe problem for upstream migrating anadromous fish was empirically established at the RBDD but, in the past 15 years, significant structural and operational improvements at the dam incrementally improved passage success, including seasonal removal of the dam gates during the primary migration season. By 2012, the dam gates will be removed year-round and upstream passage problems will be totally resolved. The available evidence demonstrates that this stressor to anadromous fish has become much less, not greater, during the past two decades.

- The precipitous declines and depressed populations of spring-run Chinook in tributaries downstream of RBDD (where fish have been unaffected by the dam) suggest that there are factors other than RBDD causing major impacts on some fish populations.

- Historically, the ACID dam in Redding was known to be problematic for upstream fish passage but, in recent years, modern-day fish ladders were installed which are believed to have improved migration success to important spawning areas been ACID and Keswick dams. The negative impact on adult anadromous salmonids at the site has become less over time.

- Many dams in the tributaries pre-date construction of the large mainstem dams and were historically known to create problems for upstream migrating fish. However, incrementally over the years, new and improved fishways have been installed on many of the dams, lessening the adverse conditions.

- No information was found to indicate the flow and thermal regimes in the Delta, Sacramento, Feather, and Yuba rivers, although not optimal at all times of the year, limits the upstream migration of adult anadromous fish. To the contrary, the available evidence demonstrates that these conditions have improved in areas downstream of the dams and have benefitted the fish populations in recent years.

5.2 Adult Fish Holding Habitat

5.2.1 Mainstem Sacramento River

5.2.1.1 *Water Quality and Temperature*

The mainstem Sacramento River has an abundance of deep, cold-water pools for holding adult anadromous fish all months of the year. There is no information to suggest that the quantity and quality of these habitats in the mainstem Sacramento River have been limiting to anadromous fish. Both winter-run and spring-run Chinook can hold in the upper river for several months prior to spawning. Because of the natural channel morphology and cold hypolimnetic water released from Shasta Reservoir, salmon have many deep pools where the fish can hold between Keswick Dam and Red Bluff and mature prior to spawning. Green sturgeon also appear to prefer deep pools for holding habitat but have a higher tolerance for warmer water temperatures than salmon and can therefore hold in further-downstream habitats. Large numbers of adult green sturgeon have been observed holding over summer in deep pools in the middle Sacramento River near Hamilton City. New sonar and underwater video camera footage, including channel measurements, in the Sacramento River near Hamilton City shows the type of riverbed substrate and habitat characteristics preferred by sturgeon at that location (Figures 16 and 17). The footage also showed more than 100 adult green sturgeon at the location, suggesting that the species may be substantially more abundant than previously believed: Sonar Camera Footage of Green Sturgeon[7]

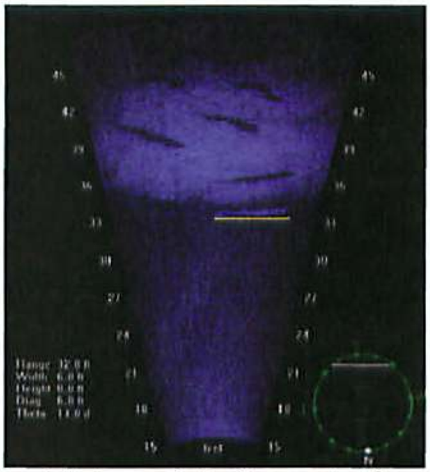

Figure 16. Sonar camera image of five adult sturgeon in the Sacramento River near Hamilton City. A sturgeon located 33 feet from the camera lens is approximately 6-feet long (shown by horizontal yellow bar) and positioned a short distance off the bottom as evidenced by its acoustic shadow 36 feet from the camera lens. The other four sturgeon are positioned on the sand riverbed. Water depth is 27 feet. (from Vogel 2008a).

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[7] A variety of videos are provided in this report which can be viewed by clicking on the underlined hyperlink and accessing to the Internet.

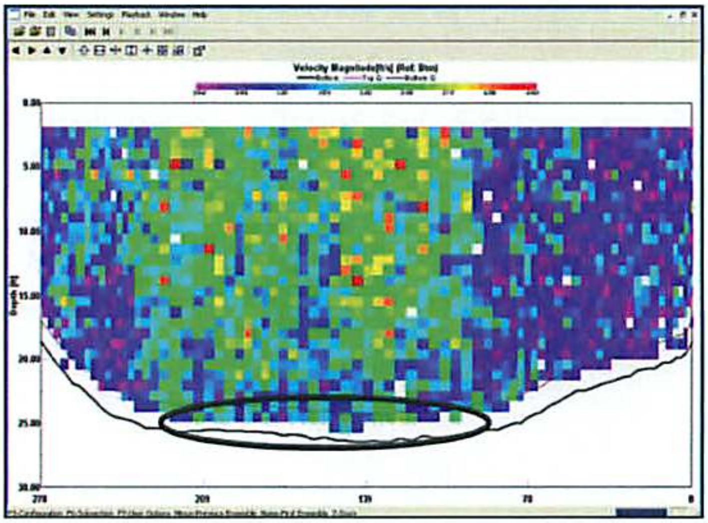

Figure 17. Acoustic Doppler Current Profiler cross section of water velocity distribution in the Sacramento River channel near Hamilton City where abundant green sturgeon were found. Black oval shows location where most sturgeon were observed. Transect was measured on August 28, 2007 during a river flow of approximately 9,450 cfs. (from Vogel 2008a)

These types of habitats are prevalent throughout the mainstem Sacramento River. Additionally, recent acoustic tagging of adult green sturgeon revealed that some fish utilize deep, bedrock pools a short distance upstream of Red Bluff (UC Davis, unpublished data). With the RBDD gates raised, green sturgeon have unimpeded access to upstream reaches as far as ACID dam in Redding, although it appears the fish favor areas much further downstream. At the time green sturgeon spawn, Sacramento River flows are generally high due to conveyance of water from upstream reservoirs to downstream areas. Additionally, the water is favorably cold because of a combination of release of hypolimnetic water from Shasta Reservoir, use of the new water temperature control device on Shasta Dam, the trans-basin diversion of cold water from the Trinity River to the Sacramento River, and the Whiskeytown temperature control curtain. It can be concluded that these conditions have improved in recent years compared to earlier times.

Historically, there were instances where adult salmon were exposed to lethal levels of metals originating from Iron Mountain Mine (IMM) and other abandoned mines near Keswick Dam. For example, in 1944 heavy mortalities of adult fish occurred when toxic runoff was not diluted in the reach several miles downstream of Shasta Dam (Moffett 1949). However, since the EPA cleanup of this IMM Superfund site, the problem has been resolved.

5.2.2. Sacramento River Tributaries

5.2.2.1. *Water Temperature*

Water temperature conditions generally are favorable for anadromous fish in the Feather and Yuba rivers due to the influence of upstream reservoirs. New Bullards Bar Dam and Reservoir, constructed by the Yuba County Water Agency (YCWA) on the North Yuba River in the late 1960s, has provided favorable conditions for over-summering spring-run Chinook in the lower Yuba River (in areas that were previously upstream migration corridors) due to higher, colder flows (HDR/SWRI 2007). Releases of cold water from Oroville Dam, which has structural facilities for selective withdrawal from vertical water layers in the reservoir to benefit fish (Reynolds *et al.* 1990), have improved holding habitat conditions for anadromous species in downstream reaches.

Holding areas on some smaller tributaries may be more problematic, primarily for spring-run Chinook. Although water temperatures are suitable for oversummering periods in upper Mill and Deer creeks, very high mortalities of spring run have been observed in Butte Creek, supposedly attributed to warm water. Butte Creek is likely on the marginal edge of suitable conditions for spring run because of the naturally restricted access for fish to low-elevation reaches. Removal of Saeltzer Dam on Clear Creek has provided spring-run Chinook access to cold-water upstream reaches but, for unknown reasons, the fish do not necessarily migrate far enough upstream early in the season to avoid undesirable later-season temperature problems. The latter issue may be caused by interbreeding between spring-run and fall-run due to a lack of sufficient spatiotemporal separation in the runs. Ironically, prior to the removal of Saelzer Dam, DFG recommended that a fish ladder be installed and operated there to provide separation between the two runs: "*To optimize benefits for all anadromous species, only spring-run Chinook salmon and steelhead should be allowed access to the upper reach above Saeltzer Dam.*" "*This segregation is essential to successful restoration of spring-run Chinook salmon to Clear Creek.*" (Reynolds *et al.* 1990). A recent peer review of Central Valley Project Improvement Act (CVPIA) restoration actions was highly critical of the Clear Creek plan which was termed ".. *a largely unprecedented experiment with little or no scientific merit.*" (Cummins *et al.* 2008). In Big Chico Creek, access of spring run to cold holding habitats in upstream reaches is dependent on fish passage at barriers at Iron Canyon Dam. Planning efforts to improve fish passage in Big Chico Creek have been completed but, apparently, funds are lacking for implementation (D. Coulon, DFG, pers. comm.). Both Butte and Big Chico creek spring run are highly prone to human disturbance during the summer months (discussed below) which undoubtedly results in stress in marginal water temperatures and could lead to significant pre-spawning mortality. Large-scale habitat and fish passage improvements underway in the Battle Creek watershed (discussed later) are expected to result in major improvements for anadromous fish which may establish winter-run and spring-run Chinook through fish access to upstream cold-water areas during the spring and summer.

5.2.2.2. *Harassment and Poaching*

As compared to the mainstem, anadromous fish in the tributaries are much more prone to human disturbance from harassment and poaching. In particular, because adult spring-run Chinook hold over summer in clear-water pools in some tributaries (Figure 18) (Spring Chinook), the fish are highly vulnerable to disturbance by human activities. This circumstance is particularly true in Mill, Deer, Big Chico, and Butte creeks where the public has ready access to important spring-run Chinook holding areas and swimming in the cold pools is popular during the hot northern California summers (Figure 19). Another form of human disturbance of oversummering spring run occurs during research and monitoring activities. Due to heightened concern over the population status of spring run, annual surveys of the streams are conducted. Adult fish are easily counted via snorkeling in the clear-water pools (Figure 20). Ironically, these efforts likely stress, or at the least harass, adult spring run and could inadvertently cause pre-spawning mortalities. There have also been anecdotal reports of poaching in lower tributary reaches. During the 1980s, DFG trained their wardens to increase focus on fish; prior to that time, most attention was on deer poaching. In an effort to increase public awareness and response to illegal activities, DFG launched a confidential secret witness program (CalTip) in 1981 to encourage the public to report poachers and polluters. The benefits of these law enforcement efforts are difficult to discern.

Figure 18. Adult spring-run Chinook salmon in Butte Creek. Photo by John Icanberry, USFWS.

Figure 19. Swimmers in Big Chico Creek in holding habitat for adult spring-run Chinook. Photo by Dave Vogel.

Figure 20. Adult spring-run Chinook in Deer Creek. Underwater photo by Dave Vogel.

5.2.3 Conclusions on Adult Fish Holding Habitat

- With a few exceptions, adult fish holding habitats for anadromous fish in the Sacramento River and its tributaries are good to excellent.

- There is an abundance of deep, cold pools for anadromous fish in the mainstem Sacramento River. Access of adult fish to areas upstream of Red Bluff where water temperatures are cooler has been incrementally improved since the 1980s with fish passage improvements at RBDD.

- Over the past one to two decades, remedial actions to eliminate the discharge of acid mine drainage historically known to have killed adult salmon in the upper river have essentially solved that problem.

- Recently, structural measures implemented at the Keswick Dam spilling basin have also eliminated that source of mortality to adult fish holding in the upper river.

- The thermal regime for mainstem holding habitats has improved since installation of the water temperature control device on Shasta Dam and structures on the Trinity River trans-basin diversion into the Sacramento River.

- The available evidence shows that mainstem holding habitats for anadromous fish have consistently and significantly improved in recent decades.

- Spring-run surveys have become common in all tributaries possessing sustained or remnant populations, but these surveys likely adversely impact adult fish during periods when they are most susceptible to stress and marginal water temperatures.

5.3 Spawning and Incubation

5.3.1. Mainstem Sacramento River

5.3.1.1. *Fecundity*

Changes in the fecundity of anadromous fish can have profound effects on the reproductive capabilities and resilience of the populations. As discussed later in a subsequent section of this report pertaining to "Ocean Rearing" (Section 5.6.3), the available evidence indicates that the greatest change in salmon fecundity is attributable to the effects of how the fish are harvested in the ocean through the sport and commercial fisheries.

5.3.1.2. *Habitat Quantity and Quality*

Based on early surveys prior to the construction of Shasta and Keswick dams, it was estimated that 187 miles of habitat for Chinook salmon were available upstream of the present dam sites (Hanson *et al.* 1940). Because these dams blocked salmon passage, a large amount of habitat in the Sacramento River basin was eliminated, resulting in large-scale reductions in physical habitats for all runs and for all freshwater life stages. However, significant declines in both spring-run and fall-run Chinook were noted by 1929, prior to the construction of Shasta Dam, which were attributed to overharvest, blockage by irrigation dams (*e.g.*, ACID dam during 1917 – 1927), and habitat degradation caused by railroad construction and hydraulic mining (Reynolds *et al.* 1990). Although Shasta Dam eliminated the majority of spring-run and winter-run Chinook spawning and rearing habitats in the Sacramento River basin, the runs' present-day migration and spawning timing still reflects the historical migration and spawning timing (Myers *et al.* 1998).

Additionally, construction of Shasta and Keswick dams eliminated the recruitment of spawning gravel to the main-stem river immediately below the dams and resulted in "armoring" of the riverbed making much of the substrate unsuitable for spawning (Buer *et al.* 1984, Buer 1985). Prior to construction, about 100,000 tons of spawning gravels per year were recruited to downstream areas (Buer *et al.* 1984). Based on underwater surveys, the Sacramento River downstream of Keswick Dam has become scoured to bedrock in many areas and armored with large cobbles (Vogel and Taylor 1987). Most spawning gravel recruitment in the upper Sacramento River is presently derived from bank erosion and tributaries, but controlled dam releases are limiting the amount of gravel recruitment from riverbanks (Buer 1985). Gravel mining on some tributaries has also reduced the recruitment of spawning gravels into the mainstem channel (Reynolds *et al.* 1990). Overall, the elimination of gravel recruitment from sources upstream of the dams and gradual armoring of riverbed substrates downstream of the dams has resulted in a chronic, but nevertheless important, adverse impact to salmonids by reducing the quantity and quality of spawning areas. Synoptic spawning substrate surveys elsewhere in the mainstem Sacramento River indicate that the substrates are sub-optimal for spawning. Potential spawning gravels possess considerable fines (sand and silt) near the threshold of concern for egg and alevin incubation and many of the spawning riffles are composed of sub-optimally-sized large cobbles instead of smaller gravels (D. Vogel, pers. observations). The Resources Agency of California believed that the loss of spawning gravel downstream of Keswick Dam and gravel mining in some tributaries partially caused the decline in upper Sacramento River Chinook salmon (RAC 1989).

In 1987, the USFWS mapped the entire riverbed (bank-to-bank) from ACID dam to Keswick Dam (Figure 21). Findings from those surveys demonstrated that some spawning habitat for salmon was still present in this three-mile reach and salmon (particularly winter-run Chinook) were utilizing those areas, but the riverbed had been scoured in many areas to bedrock or coarse, armored substrate (*e.g.*, large cobbles) too large for salmon spawning (Vogel and Taylor 1987). In that year, approximately 10 percent of the entire winter run utilized this reach for spawning (Vogel and Taylor 1987), empirically emphasizing the importance of the reach. As a result of those surveys, this author and DFG initiated a plan during the 1980s to infuse large quantities of spawning gravels downstream of Keswick Dam to increase salmon spawning habitats (Table 3). With partial funding by USBR, approximately 30,000 cubic yards of gravel were dumped in this area of the river by DFG during 1988 and 1989 (Reynolds *et al.* 1990). Additionally, to partially compensate for the historical loss of spawning gravel in the upper river, DFG and DWR have been involved in Chinook salmon spawning gravel replenishment projects in the upper reaches of the Sacramento River since 1978. Since then, spawning gravel replenishment has periodically occurred in this reach and other areas further downstream once prior gravel additions are mobilized during high flows. In 1990, eight sites were chosen for gravel replenishment (USFWS 1993). Flows as high as 50,000 cfs mobilized and dispersed the spawning gravels and have increased spawning substrates for fish, particularly for winter-run Chinook (USFWS 1993). Anadromous fish spawning is not uniform, and in most instances is more concentrated in upstream areas closer to dams. It has therefore been recognized that replenishment of good spawning gravel in the uppermost reaches immediately downstream of the dam sites will likely enhance population recovery efforts.

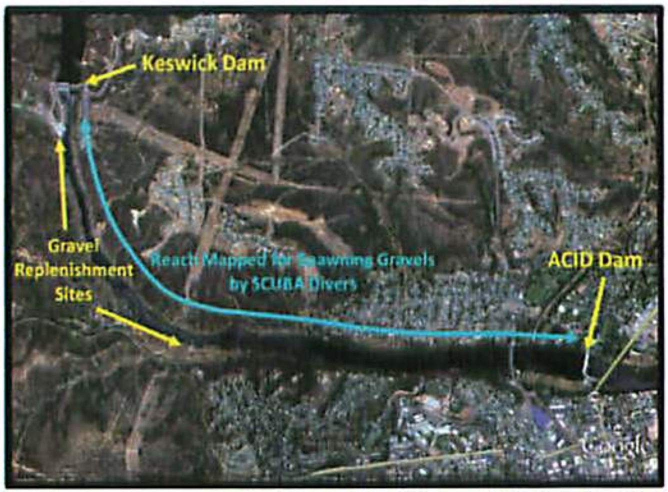

Figure 21. Location of spawning habitat surveys by the USFWS in 1987 (Vogel and Taylor 1987).

Because of the concern over impacts to winter-run Chinook salmon spawning and egg incubation, recent bridge retrofit construction projects in the upper Sacramento River where salmon may spawn prompted new restrictions on in-river construction activities. Generally, any bridge project in the upper Sacramento River has required pre-construction spawning gravel surveys in the vicinity of the bridge and, based on those findings, required restrictions on any in-river work which may adversely impact spawning or egg incubation. Recent examples include Diestelhorst Bridge (Vogel 1994), South Bonnyview Bridge (Vogel 1995a), Deschutes Road Bridge (Vogel 2000), North Street Bridge (Vogel 2003b), Jellys Ferry Bridge (Vogel 2007a), I-5 Bridge in Anderson, and Cypress Street Bridge. None of these projects are believed to have harmed anadromous fish.

5.3.1.3. *Water Temperatures*

Good Chinook salmon spawning success in the Sacramento River is determined by the length of the river reach that possesses cold water. In most years, the area of suitable spawning habitat with respect to water temperature is located in the 60 river miles between Keswick Dam and Red Bluff. Water temperatures between Keswick Dam and Red Bluff are affected by the following factors (RAC 1989):

- Ambient air temperature
- Tributary inflows
- Volume of water released from Keswick Dam
- Ratio of Spring Creek Power Plant to Lake Shasta releases
- Total storage at Shasta and Clair Engle (Trinity) Lakes

- Depth of water released from Shasta Lake

Historically, in some instances, warm water temperatures in the Sacramento River downstream from Shasta Dam have caused egg mortalities. The problem has impacted mainstem-spawning spring-run Chinook and the earliest-spawning fall-run Chinook in the early-fall during dry years when low flows of relatively warm water were further influenced by high ambient air temperatures (SWRCB 1995). The adverse impacts of warmer water were most evident for winter run and mainstem spring run because their egg incubation timing encompasses seasonally warm months. For example, during the droughts of 1976 and 1977, warm water temperatures undoubtedly adversely impacted winter-run Chinook egg incubation. Hallock and Fisher (1985) found that water temperatures suitable for winter-run Chinook salmon egg incubation were present downstream of Red Bluff in only 4 of the 18 years for the period of 1967 through 1984. This indicates that optimal spawning and incubating temperatures for winter run below Red Bluff were historically highly unlikely during any given year. This circumstance was exacerbated after the construction and operation of Red Bluff Diversion Dam which impeded and blocked some upstream migrating salmon.

The change in the thermal regime also affected the rate of incubation and subsequent emergence timing of salmonids. Earlier emerging fish may have an advantage over later emerging fish because they may occupy "optimum" habitats and cause displacement (dispersal) of later fish to downstream areas. Additionally, water temperature has a strong influence on salmonid growth rates during fry and juvenile rearing. Temperature could influence seasonal shifts in micro-habitat use or become an overriding factor in establishing the longitudinal distribution of fishes in a river. A thermal advantage to salmon was provided by relatively warmer water (but still suitable) releases during the winter months which accelerated incubation of salmon eggs and subsequent growth and emigration from the river (Moffett 1949). *O. mykiss* also have benefited from the warmer winter water temperatures that resulted from the construction and operation of Shasta Dam and Reservoir. As early as the late-1940s, greatly accelerated rainbow trout production below the dam and excellent trout fishing was enhanced in downstream reaches (Moffett 1949). In the present day, trout fishing in the upper Sacramento River downstream of Keswick Dam is considered excellent.

The periodic summer water temperature problems associated with Shasta Reservoir during lower water elevations were largely eliminated following the installation of the $84 million water temperature control device on the face of the dam and the installation of a water temperature curtain in Whiskeytown Reservoir which maintained cooler water introduced into the upper Sacramento River via the Trinity River trans-basin water diversion. Releases of hypolimnetic water deep in the reservoir provides for suitable water temperatures during critical salmon egg incubation periods while concurrently providing for power generation (Vogel 1990).

The thermal regime resulting from construction of Shasta Dam also has benefited green sturgeon. The range of green sturgeon in the mainstem Sacramento River is now likely greater than it was historically because of an improved and expanded thermal regime in the river at times important for sturgeon. There are no records of green sturgeon from Lake Shasta or Lake Oroville

(USFWS 1995) and no evidence that green sturgeon were ever present upstream of Shasta Dam. Prior to construction of Shasta Dam, the Sacramento River downstream of the site was characterized by low, warm flows during the late-spring and summer months when green sturgeon spawn. Water temperatures could exceed the thermal tolerances of sturgeon eggs and become sub-optimal or lethal[8]. After dam construction, the seasonal thermal regime changed dramatically such that the river became much colder providing consistently optimal temperatures during the entire sturgeon spawning and egg incubation season (Figure 22). This greatly improved thermal regime extended far downstream of the dam site (Figure 23)[9] and is now recognized to continue past the Red Bluff Diversion Dam. This circumstance is attributable to three principal factors: 1) release of cold, hypolimnetic water from the deep reservoir, 2) the trans-basin diversion of Trinity River water to the Sacramento River, and 3) increased releases of reservoir water and conveyance of water in the river for downstream beneficial uses during the spring and summer months. The mid-Sacramento River mainstem flow regime during the late spring and summer months (when green sturgeon spawn and larvae and fry rear) is higher and cooler than it was historically. The biological significance of this phenomenon is that post-Shasta Dam operations undoubtedly improved and expanded the range of suitable green sturgeon habitats in the mainstem Sacramento River as compared to pre-Shasta Dam conditions. The installation of the water temperature control device on Shasta Dam has further enhanced the thermal regime for anadromous fish in the mainstem.

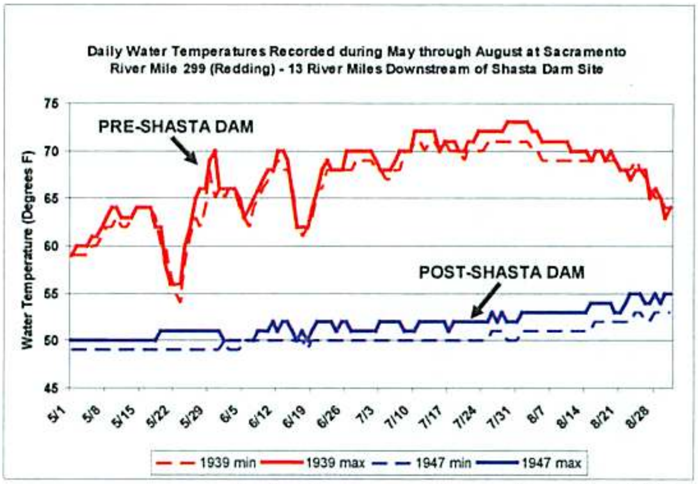

Figure 22. Daily water temperatures measured in the Sacramento River at river mile 299 during May through August, 1939 (pre-Shasta Dam) and 1947 (post-Shasta Dam) (constructed using data from Turek 1990).

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[8] Lethal to eggs above 68°F.

[9] Comparable data were only available for August. However, these data provide an indication of how the thermal regime improved because of characteristic temperatures during the spring and summer months (reference back to Figure 22).

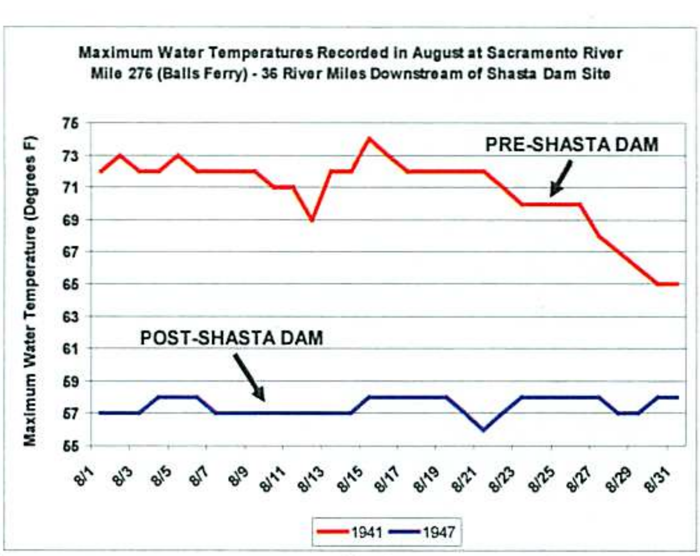

Figure 23. Daily maximum water temperatures measured in the Sacramento River at river mile 276 during August, 1941 (pre-Shasta Dam) and 1947 (post-Shasta Dam) (constructed using data from Turek 1990).

However, the large-scale changes in the reservoir operations that would result from proposed new Delta flow criteria (*e.g.*, SWRCB 2010, DFG 2010) could seriously jeopardize spawning and egg incubation conditions for some species at critical times of the year. These draft reports by the SWRCB and DFG have suggested that high flows should be released from upstream reservoirs in an attempt to alleviate mortality problems in the Delta. If implemented, those flow measures would result in frequent, major drawdowns on Shasta Reservoir, even to dead pool MBK (2010). Large drawdowns on the reservoir would severely deplete the cold-water pool available for fish in downstream reaches and would have devastating impacts on anadromous fish and largely undo the major progress made on upstream fishery restoration in recent years. As appropriately described by SWRCB (2010) and DFG (2010), "*temperature and water supply modeling analyses should be conducted...*" prior to implementation of such dramatically increased flows.

5.3.1.4. *Flows*

Changes in the flow regime after Shasta Dam and Keswick Dam construction also altered spawning and incubation habitat for salmonids on the mainstem Sacramento River. The minimum flow for spawning salmon downstream of Keswick Dam immediately after construction was specified at 2,500 cfs for protection of eggs and fry (Moffett 1949). There were sporadic instances of redd dewatering that occurred in the years shortly following dam construction. As recently as 1990, DFG believed that the existing flow requirements downstream of Keswick Dam (Table 4) were inadequate for salmon with a primary concern focused on stranding of salmon redds along with a lack of a specified down-ramping rate to protect for the stranding of juvenile fish (Reynolds *et al.* 1990). The latter problem has been largely eliminated by appropriate ramping of reservoir releases. The CVPIA has resulted in improved flow management by avoiding inadequate or fluctuating flows that could cause fish losses (DFG 1998). During the 1980s, DFG and USBR negotiated a new instream flow schedule to eliminate the deleterious effects of redd dewatering from a flow of 3,900 cfs during the fall to 2,600 cfs in the winter (Table 4). There is no evidence that this modern-day flow regime has been detrimental to anadromous fish spawning and incubation. During many years, the actual flows are much higher than the minimum specified flow levels because of reservoir operations, downstream flow needs, and tributary accretions.

Table 4. Required minimum instream flows (cfs) downstream of Keswick Dam.

	Pre-1981 flow regime	Post-1981 flow regime
January 1 – February 28	2,600 cfs	3,250
March 1 – August 31	2,300 cfs	3,250
September 1 – November 30	3,900 cfs	3,250
December 1 – December 31	2,600 cfs	3,250

5.3.2 Sacramento River Tributaries

5.3.2.1. *Habitat Quantity and Quality*

There are two reaches in the Feather River where both fall-run and spring-run Chinook spawn: the low-flow channel from Oroville to Thermalito Afterbay outlet, and the lower reach from Thermalito Afterbay outlet to Honcut Creek, near the town of Live Oak (Sommer and McEwan 1995). Approximately 75% of Feather River natural fall-run Chinook spawning occurs in the eight-mile reach between the Fish Barrier Dam (RM 67) and the Thermalito Afterbay outlet (RM 59) which is regulated at 600 cfs, (except during flood flows) with the remainder of the spawning activity occurring in the 15-mile reach between the Afterbay outlet and Honcut Creek (RM 44) (Sommer *et al.* 2001, as cited by HDR/SWRI 2007). The Feather River downstream of Oroville Dam in the low-flow channel has an armored cobble bed due to lack of gravel recruitment and periodic high flows in the reach where most salmon spawn and has become progressively more armored over the past 16 years (Sommer *et al.* 2001). There has been a significant increase in the proportion of spawning salmon using the low-flow channel in recent years which may be partially attributable to increased flows, but hatchery operations and introgression between fall and spring runs may also play a role (Sommer *et al.* 2001). The lower reaches contain more gravel and less armoring partly due to actively eroding riverbanks (HDR/SWRI 2007). Some limited steelhead spawning occurs in small secondary reaches in the low-flow channel which possesses smaller-sized substrate and more cover habitat, but is less than 1% of the available habitat in the low-flow channel (DWR 2000, as cited by HDR/SWRI 2007). Water temperatures in the low-flow channel typically average about 47°F in the winter to about 65°F in the summer (HDR/SWRI 2007), the latter of which can limit any salmon production during the warmest months of the year. However, cold water releases from Oroville Reservoir generally provide suitable temperatures for spawning later in the season (DWR 2001, as cited by HDR/SWRI 2007).

Construction of New Bullards Bar Dam and Reservoir on the North Yuba River has improved conditions for anadromous fish in the lower Yuba River due to a better thermal regime and higher flows in downstream reaches (HDR/SWRI 2007). A 1965 DFG and YCWA agreement and the 1966 Federal Power Act license placed limits on flow reductions and fluctuations, which have generally been effective in protecting fall- and spring-run Chinook redds (SWRCB 1994, as cited by HDR/SWRI 2007). Additionally, a 2005 FERC order provided even further protection of salmonid redds and juvenile stranding from flow reductions and fluctuations (FERC No. 2246, as cited by HDR/SWRI 2007). More recently, the Lower Yuba River Accord was negotiated and now provides instream flows at an equivalent or higher level of protection for spring-run, fall-run, steelhead, and green sturgeon compared to previous conditions (HDR/SWRI 2007). Although the present-day instream flows on Sacramento River basin rivers downstream of the major dams may or may not be optimal, the flow regime and physical effects on spawning and incubation habitats are probably not a major limiting factor to the salmonid runs. As previously mentioned, the Fisheries Agreement of the Yuba River Accord provides for new minimum instream flows in the lower Yuba River that are intended to maintain or increase fishery resource protection. This Agreement was developed by State, federal, and consulting fisheries biologists, fisheries advocates and policy representatives, and establishes higher minimum instream flows during most months of most water years (HDR/SWRI 2007).

Historically, flows and habitat conditions on some of the smaller tributaries important for anadromous fish production were believed to be insufficient. For example, Fry (1960) reported that Battle Creek, beginning a short distance upstream of Coleman National Fish Hatchery, was badly degraded by low flows caused by upstream power diversions and Mill and Deer creeks suffered from low flows due to irrigation diversions. Although some other important tributaries for anadromous salmonids do not have large dams blocking gravel recruitment, gravel mining has impacted the supply for spawning fish (Buer *et al*. 1984). Gravel replenishment projects in important spawning areas lacking natural gravel recruitment would undoubtedly benefit anadromous fish. Many of the important anadromous fish tributaries currently have restoration programs underway (discussed later) which are assumed to also benefit spawning habitats during recent years.

Physical habitat conditions for spawning and incubation in Mill and Deer Creek are believed to be highly favorable for spring-run Chinook and these two tributaries are considered as the best habitats currently available (NMFS 2009). However, the runs are currently depressed indicating the primary problems affecting the species are elsewhere. The USFWS has recently proposed extracting fertilized spring-run Chinook eggs from these tributaries as a potential source for a proposed program to re-introduce salmon into the upper San Joaquin River downstream from Friant Dam. However, doing so is premature and has a high probability of adverse impacts to Mill or Deer creek populations because of the currently depressed populations. Furthermore, the likelihood of success for San Joaquin spring-run restoration is very low due to a multitude of factors (*e.g.*, probable inter-breeding with fall-run Chinook[10] and extremely poor juvenile fish outmigration survival in the San Joaquin River and Delta).

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[10] Such as has already occurred on the mainstem Sacramento River downstream of Keswick Dam and the Feather River downstream of Oroville Dam.

5.3.3 Conclusions on Spawning and Incubation

- Construction of dams has resulted in the lack of gravel recruitment to some downstream anadromous fish spawning areas, a problem that is particularly acute downstream of Keswick Dam.

- Although Englebright Dam has halted recruitment of gravels from upstream areas, spawning gravel for salmonids is abundant and is not limiting in the lower Yuba River (with the exception of the Englebright Dam reach, for which the Corps has embarked on a gravel reintroduction project).

- The flows and thermal regimes resulting from the reservoirs associated with these dams have significantly improved spawning and incubation habitats, particularly during recent years.

- Recent recommended high reservoir releases (SWRCB 2010) to ameliorate problems in the Delta (*e.g.*, predation) could drastically reduce reservoir levels in some years and deplete cold-water storage; if implemented as proposed, such measures could have devastating impacts on anadromous fish egg incubation at critical times in some years.

- Watershed restoration programs on numerous tributaries are believed to have benefited habitat conditions and those collective efforts are expected to continually improve habitats for fish.

5.4 Fry and Juvenile Rearing

5.4.1 Mainstem Sacramento River

5.4.1.1 *Habitat Quantity and Quality*

In addition to the major reduction in reproductive habitat, a large amount of rearing habitat for young salmonids was lost in upstream areas when the large Sacramento River basin dams were built. Following construction, fish produced within the main-stem reaches downstream of the present dams were forced to rear in large river channels formed by historical high flows because of the change in the species geographic distribution. The instream habitat attributes of complexity and diversity previously available upstream of large dams cannot be re-created in the large river channels downstream of dams through flow alone and cannot serve as a surrogate for the lost habitats upstream of the dams. The biological significance of this circumstance is that the dam construction did more than simply reduce the amount of habitat. Juvenile salmonids originating from present-day main-stem spawning (unlike previously available habitats in smaller stream channels upstream of the dams) have to contend with the rigors of a larger riverine channel. It is generally acknowledged that the biological quality for fry and juvenile rearing of past available reaches upstream of the dams was superior to the habitats downstream of the dams and the reduction in physical habitat (*i.e.*, quantity) was absolute. Thus, the resultant effects on the fish populations would be expected to appear shortly following dam construction, but was not realized.

The Sacramento River below Keswick provides a diversity of aquatic habitats, ranging from fast water riffles (relatively shallow, turbulent water flowing over cobbles) and glides (deeper, slower-moving water) in the upper reaches, to slow-water pool and glide habitats under tidal influence in the lower reaches. It is presently not known if the main-stem Sacramento River instream habitats provide sufficient amounts of the micro-habitat diversity and complexity required for juvenile salmonid rearing. Each life stage of riverine fishes demonstrates a marked "preference" for different velocities in a river or stream. In all cases, their documented utilization with higher velocities declines precipitously. Higher releases from dams result in increased velocities within the spawning and rearing habitats downstream of the dams and, if too high, are detrimental to fish habitats. Certain increases in reservoir releases can substantially reduce the number and areas of low water velocity which could displace fry from optimal to suboptimal habitats and induce premature downstream movement. Such circumstances could result in non-uniform dispersal to inferior rearing habitats or may cause density-dependent problems (*e.g.*, 90 percent of the fish using 10 percent of the rearing habitat). High flow regimes recommended by SWRCB (2010) could result in premature displacement of fry to unfavorable rearing habitats.

There are indications that the mainstem river channel may not provide adequate rearing areas for anadromous fish, as evidenced by rapid displacement of fry from upstream to downstream areas and into non-natal tributaries (Vogel 1993b) during increased flow events. Underwater observations of salmon fry in the mainstem Sacramento River suggest that optimal habitats may be limited. As discussed previously, recently emerged fry prefer different habitats for rearing than larger-sized juvenile fish which can reside in the higher velocity regions of the mainstem channel. Much of the main river channel is devoid of structural complexity necessary for fry rearing and, due to the channel morphology and relatively high flows released from Shasta Dam during the primary rearing period, the best habitats are on the channel fringes (*e.g.*, Winter-Run Chinook Fry Rearing on the Sacramento River near the Riverbank). Underwater observations near artificial structures in the main channel have shown fry rearing activity, but may suggest the fish are utilizing those areas because insufficient other natural structures are limited or lacking. The following are examples:

Winter-Run Chinook Salmon Rearing Behind a Trashrack in the Sacramento River at Redding, California

Winter-Run Chinook Fry Rearing in Front of a Fish Screen at Redding, California

Winter-Run Chinook Fry Rearing near a Bridge Pier in the Sacramento River at Redding, California

Salmonid Fry Rearing Behind a Cylindrical Fish Screen in the Sacramento River

Winter-Run Chinook Fry Rearing near a Bridge Pier in the Sacramento River at Red Bluff, California

As the fish grow larger, they are better able to rear in the mainstem away from structures, often shoaling (schooling) and using much deeper water areas as demonstrated below:

Juvenile Salmon Rearing in a 35-ft Deep Pool in the Sacramento River

Juvenile Salmon Rearing in a 60-ft Deep Pool in the Smith River

The benefits of riparian habitat for native anadromous fish within the primary rearing areas are undisputed. Riparian habitat provides for recruitment of large and small woody debris into the rivers which can be used by fish for protective rearing habitat. Terrestrial insect input from overhanging or streambank vegetation has been shown to be an important source of food for juvenile fish. Cover, in the form of shade, is often sought by young fish for preferred rearing areas. Additionally, the shade provides some cooling effects from reduced insolation. The mainstem Sacramento River has been characterized as a relatively natural, well-defined channel between Keswick Dam and Red Bluff, meandering "somewhat freely" from Red Bluff to Colusa, but virtually canalized by flood control and reclamation levees downstream of Colusa (Boles and Turek 1986). DWR (1979), as cited by Boles and Turek (1986), estimated that native vegetation in the Sacramento River riparian zone from Redding to Colusa between 1952 and 1977 had decreased 14 percent, while agricultural use and urban use in the same reach increased 12 percent and 3 percent, respectively.

DWR indicated that bank stabilization on the mainstem Sacramento River downstream of Red Bluff has reduced bank erosion, which was believed to have impeded salmonid rearing habitats as affected by riparian vegetation (Buer *et al.* 1989). The great majority of these bank stabilization projects were constructed decades ago. Very little spawning habitats for most anadromous fish are present in this river reach (primarily because of seasonally warm water temperatures) and the principal rearing habitats for these species are in upstream reaches and some tributaries. Although this mainstem reach is a migratory corridor for anadromous fish and obviously serves as rearing area for at least some portion of their freshwater life phase, its relative importance is not known. An exception to the foregoing is the transitional reach between Red Bluff and those downstream areas that have been leveed and stabilized, generally within the reach from Red Bluff to Chico Landing. This area possesses the most significant area of remaining riparian habitat; it is "generally un-leveed and contains significant and substantial remnants of the Sacramento Valley's riparian forest" (RAC 1989), and it should be a primary focus of efforts to improve rearing habitat on the mainstem.

There have been recent attempts to improve potential rearing habitats in downstream reaches by adding in-channel woody debris near the stream banks. However, downstream warmer reaches possess a higher abundance of native and non-native predatory fish, many of which prefer and use submerged woody debris as velocity refugia and favorable habitat for ambushing prey. The interaction of rearing salmonids with woody debris in their primary upstream, cold-water rearing areas where the predatory fish are less abundant is well accepted as beneficial. However, those same benefits in downstream areas, depending on specific locations, are debatable and could, in some instances, be detrimental by favoring plentiful predatory fish over juvenile native anadromous fish. Any in-channel structures, natural or artificial, in the lower-most river and Delta could be detrimental (discussed in Section 5.5.3.6).

In recent decades, there have been major programs to increase the riparian forests along the upper and transitional reaches of the Sacramento River where colder temperatures will be less favorable to predatory fish. In 1989, the Resources Agency of California completed a comprehensive riparian management plan. Within that plan, it was postulated that reestablishment of a viable riparian ecosystem along the upper Sacramento River would help reverse the decline in Sacramento River fishery resources (RAC 1989). By 1990, the DFG and DWR had become extensively involved in a stream and riparian habitat restoration program (Reynolds *et al.* 1990). Additionally, the Sacramento River National Wildlife Refuge within the Sacramento National Wildlife Refuge complex was recently established among 27 property units along a 77-mile reach of the Sacramento River between Red Bluff and Princeton (Figure 24) (source: USFWS). Presumably, efforts such as these to reverse the historical loss of riparian habitats have improved the instream environment for anadromous fish in recent years. Although quantification of those fishery resource benefits is difficult, it is reasonable to conclude that this factor has improved, rather than worsened, conditions for anadromous fish during the past decade or so.

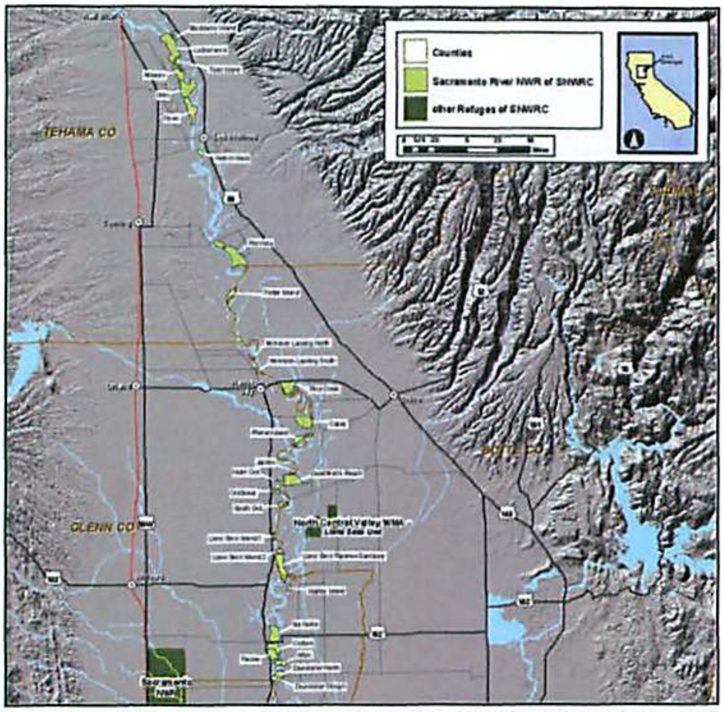

Figure 24. Locations of parcels of the Sacramento River National Wildlife Refuge along the Sacramento River (source: USFWS).

In recent years, large numbers of juvenile fish stranded upstream of RBDD have been documented shortly after the gates were raised at the end of the irrigation season. The stranding occurs in a large side channel just upstream of the dam. Some attempts to reduce this problem were implemented by partial configuration of the channel to improve drainage of isolated pools. This dilemma for rearing fish needs to be continually monitored and avoided. The situation will persist even after the RBDD gates are raised year-round because the river bed elevation is on the cusp of providing unfavorable conditions during the winter months when the high presence of juvenile fish and the frequent, naturally occurring fluctuating river flows can strand fish in pools as flows recede.

The CVPIA fish restoration program has not addressed the topic of invertebrate prey base for rearing juvenile salmonids (Cummins *et al.* 2008). Invertebrate food supply in the Sacramento River is apparently highly abundant for resident *O. mykiss* indicating that this factor would not be limiting for juvenile salmonids, which consume the same or similar organisms. Following construction of Shasta Dam, the salmonid food base in the river below the dam was believed to improve and the population of *O. mykiss* expanded significantly (Moffett 1949). The same can be assumed in the Feather and Yuba rivers where healthy populations of *O. mykiss* are present. Mitchell (2010) found consistently high average freshwater growth rates of yearly and older *O. mykiss* in the lower Yuba River.

Adverse impacts of poor water quality on rearing salmonids resulting from historical pollution in the upper Sacramento River have been well documented. It appears that the most significant past pollution impacts occurred from Iron Mountain Mine (IMM) acid mine drainage (AMD). AMD from the mine entered Spring Creek which flows into the Sacramento River between Shasta and Keswick dams (Figure 1). Iron Mountain Mine was periodically mined for copper, gold, iron, pyrite, silver and zinc from the 1860's until 1963. The site has been associated with water quality degradation and impacts on aquatic resources in nearby drainages during much of its history. Impacts include numerous fish kills in the upper Sacramento River that have been attributed primarily to the contamination of surface waters with IMM AMD that has a low pH and high concentrations of cadmium, copper and zinc. A recent EPA Environmental Endangerment Assessment of Iron Mountain Mine made the following conclusions: The primary species and populations of concern because of IMM AMD contamination are the Sacramento River's four runs of Chinook salmon, a run of steelhead trout, and resident rainbow trout. Of particular concern are the potential effects of the IMM AMD on the endangered winter-run Chinook salmon and steelhead. The early life stages of these fish (particularly swim-up fry) are highly susceptible to the toxicity of and suffocation from aqueous and sediment-borne metals and their resulting effects. (CH2M Hill 1992)

Previously, contamination from AMD released from IMM has been a major risk to Sacramento River fishery resources because of the presence of various freshwater life phases within the zone of impact of IMM AMD and the high dependence of these fish on this area for reproduction and rearing. It is evident that juvenile anadromous salmonids have been at particular risk from IMM AMD because these fish have been present in the upper Sacramento River when uncontrolled spills from Spring Creek Reservoir[11] have occurred (Table 5). The presence of some of the fish species' most susceptible life stages within the zone of potential impact has been documented to occur at the time of year when the risks to their populations are the greatest (*i.e.*, the rainy season). Adverse impacts to one salmon year class can be accentuated over time because there is little age-group overlap between year classes (discussed later). The specific magnitude and long-term effect on Sacramento River fishery resources were largely unknown because the duration and magnitude of exposure of the various fish life stages to the contaminants have not been thoroughly documented. (CH2M Hill 1992)

Table 5. Uncontrolled Spills from Spring Creek Reservoir

Start of Spill (date)	Length of Spill (days)	Volume of Spill (acre-feet)
12/22/64	7	5,159
1/13/69	10	5,195
1/9/78	14	15,248
2/6/78	2	355
3/28/79	2	22
2/19/80	2	496

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[11] Spring Creek Reservoir was constructed in 1963.

1/30/81	4	194
3/22/82	3	1,065
11/24/81	3	30
1/26/83	4	1,662
3/1/83	4	5,177
2/15/86	4	3,457
3/25/89	43	2,535

Note: Information obtained from U.S. Bureau of Reclamation, Central Valley Operations- Report of Operations, 1967-1990.

As mentioned earlier, a large-scale cleanup of IMM through the EPA Superfund has essentially resolved this previously major problem for rearing salmonids. There are no documented occurrences of other pollutants having a significant adverse impact on juvenile anadromous fish rearing in the upper river. It was therefore assumed that the degree of pollution and its potential attendant immediate effects on anadromous fish were probably greater during the 1945 to mid-1960s era than the mid-1960s to present era, primarily because of more recent environmental reforms and regulatory actions, and would not have adversely impacted recent fish populations.

5.4.2 Sacramento River Tributaries

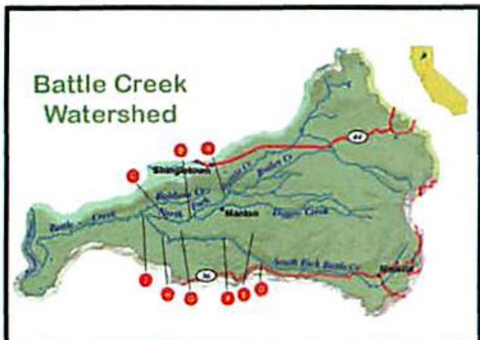
5.4.2.1. *Habitat Quantity and Quality*

It has been commonly stated that Sacramento River tributary habitats for salmonids are degraded (*e.g.*, Reynolds *et al.* 1993). The negative salmonid habitat alterations are often attributed to water diversions causing reduced stream flows and land use practices, including hydraulic mining and gold dredging, which radically changed the sediment structure and bed profile of rivers and sometimes altered stream channel courses. Because most of the diversions have been in place for a long period (with some exceptions), it is presumed that the total volume of water diverted has not changed appreciably over time. The continuing effects of gold mining operations have also been present since the late nineteenth century, and thus the timing of their effects are not well correlated with the more recent rapid decline of anadromous fish runs.

A comprehensive, stream-by-stream assessment to ascertain historic habitat alterations in the tributaries supporting anadromous salmonids is outside the scope of this report. However, based on the author's familiarity with many of these streams over approximately the past 30 years, on discussions with landowners in some of the watersheds, and based on review of dozens of related documents since the early 1980s, it can be reasonably concluded that the most significant adverse salmonid habitat alterations in these tributaries occurred decades ago, but that significant habitat improvements have been realized in recent years. For example, all the diversion dams constructed in Mill and Deer creeks on the valley floor took place prior to 1945. Another example is Battle Creek, where the primary impacts to fish occurred prior to the mid-1940s because of hydroelectric development and the construction of Coleman Hatchery (RAC 1989).

Hanson *et al.* (1940) provide accounts of the relative condition of habitats in the primary and secondary salmon-producing tributaries between Redding and the mouth of the Feather River shortly prior to the completion of Shasta Dam. In comparison to the present day, those prior surveys on these streams indicate that these habitats for salmon, in many instances, are in better condition now than they were just prior to construction of Shasta Dam. It can be reasonable concluded that major habitat alterations in the tributaries supporting anadromous fish have not occurred during the most recent decades and, therefore, measureable changes in tributary habitat conditions during recent years cannot account for the recent precipitous declines in some salmonid populations. An exception to the general lack of major habitat alterations in recent decades is the construction of Whiskeytown Dam on Clear Creek, an important fall-run Chinook (and possibly late-fall-run Chinook) stream, in the mid-1960s. Notwithstanding its construction, that does not appear to have had a significant effect because Saeltzer Dam was constructed in 1903 downstream of the Whiskeytown Dam site and its ineffective fish ladder blocked upstream movement of salmon (Hallock 1987), indicating that the most significant habitat loss in Clear Creek occurred prior to Whiskeytown Dam construction. Black Butte Dam was constructed on Stony Creek in the mid-1960s, but this tributary has never been considered a major salmon-producing stream and historically probably supported only small runs of salmonids upstream of the present dam.

The available evidence therefore indicates that habitat conditions in the tributaries have improved over time in recent decades. The following are a few examples. Significant habitat improvements on Mill, Deer, and Butte creeks have been implemented which are believed to have benefitted spring-run Chinook (DFG 1998). Major actions implemented or soon to be implemented on Battle Creek (Figure 25) are also believed to improve conditions for rearing anadromous salmonids. The Battle Creek Salmon and Steelhead Restoration Project, scheduled for completion in 2014, will restore 48 miles of salmonid habitat. During implementation of the federal Anadromous Fish Restoration Program and the CALFED Ecosystem Restoration Program, there were significant efforts to establish local watershed groups to promote public education on the values of fish restoration through improved land and water management practices. Watershed groups have proliferated (Figure 26) and have been and are used as a channel to obtain grants to study and improve watershed conditions in important native anadromous fish tributaries in the Sacramento River basin.



A. North Battle Creek Feeder Diversion Dam
New fish ladder to improve adult fish passage; new fish screen to prevent loss of juveniles; increased stream flow to improve habitat

B. Eagle Canyon Diversion Dam
New fish ladder; new fish screen; removal of a segment of the Eagle Canyon Spring Collection Facility; increased instream flow

C. Wildcat Diversion Dam, Pipeline, and Canal
Dam and related facilities removed

D. South Diversion Dam and Canal
Dam and related facilities removed

E. Soap Creek Feeder Diversion Dam
Dam and related facilities removed

F. Inskip Diversion Dam and So. Powerhouse
New fish ladder; new fish screen; construction of South Powerhouse and Inskip Canal connector tunnel; increased instream flow

G. Lower Ripley Creek Feeder Diversion Dam
Dam and related facilities removed

H. Coleman Diversion and Inskip Powerhouse
Dam removed; construction of Inskip Powerhouse and Coleman Canal connector; Inskip Powerhouse bypass replaced

I. Asbury Pump Station and Diversion Dam
Provide minimum flows to benefit fish; install flow and stage recorder.

Figure 25. The Battle Creek Restoration Project (from the Greater Battle Creek Watershed Working Group).

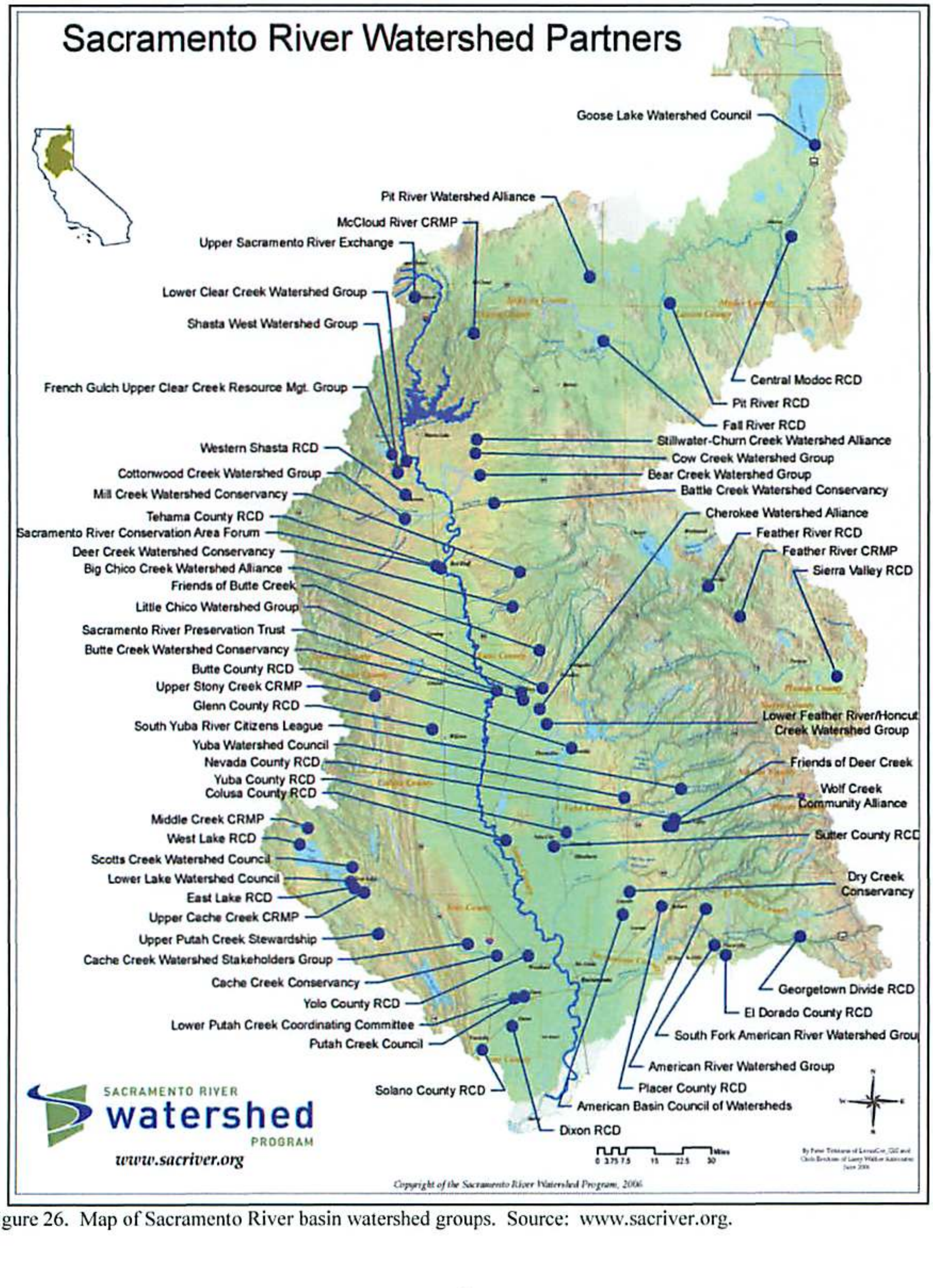


Figure 26. Map of Sacramento River basin watershed groups. Source: www.sacriver.org.

Operations of New Bullards Dam and Reservoir on the North Yuba River have led to significantly improved flow and thermal regimes in the lower Yuba River. Spring-run Chinook juvenile rearing extends year-round in the lower Yuba River (HDR/SWRI 2007) indicating habitats are suitable for anadromous fish. Higher densities of juvenile spring run are evident in areas upstream of Daguerre Point Dam, which may be attributable to a higher number of spawning salmon in this reach, more complex high-quality cover, or lower numbers of predatory fish (HDR/SWRI 2007). Higher densities of juvenile steelhead are also found upstream of Daguerre Point Dam and larger juveniles and resident trout have been commonly observed both upstream and downstream of the dam (SWRI *et al.* 2000, as cited by HDR/SWRI 2007). Implementation of the Lower Yuba River Accord has improved conditions for rearing anadromous fish. Instream flows through the Accord provide an equivalent or higher level of protection for spring-run, fall-run, steelhead, and green sturgeon compared to previous conditions (HDR/SWRI 2007). Release of cold, hypolimnetic water from Oroville Reservoir has improved the thermal regime for rearing salmonids in downstream reaches. Additionally, the FERC re-licensing process associated with Oroville Dam is assumed to result in improved rearing habitats for anadromous fish in the Feather River.

It is, therefore, reasonable to conclude that the foregoing collective efforts have improved habitat conditions for anadromous fish on many tributaries.

5.4.3. Conclusions on Fry and Juvenile Rearing

- Unprecedented, large-scale fish habitat restoration actions have been implemented in most Sacramento River basin tributaries important for native anadromous fish production; many of these measures have been recently completed, are underway, or will soon be accomplished.

- Dam construction in the Feather and Yuba rivers led to cooler water and more-reliable instream flows in downstream reaches, benefiting fish rearing in the lower rivers through dam operations over recent years.

- Incremental improvements on many tributaries have been achieved through a variety of regulatory and voluntary actions.

- Smaller, but extremely important tributaries such as Battle, Clear, and Butte creeks are expected to have greatly expanded and improved anadromous fish rearing habitats through dam removals, improved flow regimes and other actions.

- Due to heightened awareness of the importance of anadromous fish, there has been a proliferation of watershed groups in most tributaries which have focused on improving overall watershed health.

- There are no indications that the quality and quantity of fry and juvenile rearing in the tributaries have declined in recent decades. To the contrary, based on restoration activities in the tributaries, it is reasonable to conclude that fish habitats in the tributaries are considerably better than what existed decades ago.

- Relative changes in the quantity and quality of mainstem Sacramento River rearing habitats since the construction of Shasta and Keswick dams are difficult to discern, largely due to lack of site-specific data.

- In the many decades since large dam construction, there has undoubtedly been a chronic, slow decline in the physical/structural attributes for optimal rearing habitats. Substrates and in-channel structures important for complex, high-quality rearing habitats have declined because of lack of replacement due to a downturn in riparian habitats which provide woody debris input into the river and lack of any significant ongoing gravel recruitment from areas upstream of the dams.

- The location and timing of the source of Iron Mountain Mine pollution corresponded with the presence of the important anadromous fish in the potential zone of impact. The magnitude of impacts is sufficient to have caused substantial fish kills in some years. The water quality in juvenile rearing habitats have vastly improved due to enormous Super Fund expenditures to remediate acid mine drainage (metal pollution) from Iron Mountain Mine in the upper portion of the river.

- In many cases, dams now prevent access to former rearing areas but over the decades following dam construction, the instream flow regimes in areas below the dams have improved for rearing fish.

- Carefully controlled timing and magnitude of flows from Shasta and Keswick dams and dams in the Feather and Yuba river watersheds have reduced fish losses caused by stranding; this fish mortality factor has been reduced over the years.

- The benefits of large storage reservoirs which convey large quantities of high quality water to downstream areas have improved water temperatures for rearing.

- The mainstem Sacramento River is not flow-limited for fish rearing habitats.

- The existing flows in the mainstem Sacramento River at important times of the year may actually be too high to maximize the quantity and quality of rearing habitats for fry and juvenile life stages of salmonids.

- The significant changes to the flow regime that would result from the proposed new Delta flow criteria in SWRCB (2010) and DFG (2010) could jeopardize conditions for anadromous fish in the upper reaches. Among these potential detrimental changes is an alteration in the thermal regime which could be unfavorable for rearing fish during portions of the year.

5.5 Fry and Juvenile Outmigration

5.5.1. Sacramento River Tributaries

5.5.1.1. *Entrainment*

The importance of screening water diversions on Sacramento River basin tributaries has been widely recognized for many years. In recent decades, there have been an increase in the number and quality of fish screens; the following are a small sample of numerous examples. As of 1987, there were 13 satisfactorily working fish screens on tributary streams supporting anadromous salmonids. Most of these were installed from the 1950s through the 1970s (Hallock 1987). Since then, DFG has continually upgraded and improved the agency's screens in anadromous fish tributaries. In 1990, DFG reported that all water diversions on Mill, Deer, and Antelope creeks had been adequately screened for fish protection (Reynolds *et al.* 1990). By 1990, as part of a FERC relicense condition, PG&E had constructed a new fish screen at the power company's diversion on South Cow Creek (Reynolds *et al.* 1990). USFWS recently upgraded the fish screens on Coleman National Fish Hatchery water supply intakes in Battle Creek. Several new fish screens were installed on Butte Creek, an important spring-run tributary, at Adams Ranch, Gorrill Land Company, and Parrott-Phelan Dam (Figure 27). A water diversion facility on lower Big Chico Creek was relocated to the mainstem Sacramento River with new fish screens in 1997 (DFG 1998). Browns Valley Irrigation District completed a fish screen on the Yuba River approximately one mile upstream of Daguerre Point Dam in 1999 and completed a major rebuild of the 65 cfs capacity facility in 2005. There are numerous additional examples, but it can be reasonably assumed that irrigation operations on the tributaries have resulted in far less fish entrainment during recent years as compared to decades ago. A significantly expanded discussion on this topic is provided later in Section 5.5.2.1.

Figure 27. New fish screens constructed on Butte Creek. Photo by Dave Vogel.

5.5.1.2 *Flows*

No information was found to indicate that flows during the outmigration of salmonids on tributaries have decreased in recent years. To the contrary, it appears that outmigration conditions have become more favorable. The following describe several examples of these flow improvements. Instream flows under the recently executed Lower Yuba River Accord provide an equivalent or higher level of protection for spring-run, fall-run, steelhead, and green sturgeon compared to previous requirements (HDR/SWRI 2007). Measures to be implemented through the FERC relicensing process for Oroville Dam are anticipated to benefit anadromous fish. However, DFG has expressed concerns that flows over Daguerre Point Dam on the Yuba River can disorient outmigrating juvenile salmonids and increase their vulnerability to predation (DFG 1996). Numerous, unprecedented fish habitat restoration actions have been executed or are underway on many anadromous fish tributaries (*e.g.*, Battle Creek). Implementation of measures resulting from federal Biological Opinions has resulted in improved instream flows in Clear Creek. In 1989, the Resources Agency of California formally recognized the importance of outmigration flows for juvenile salmonids on some tributaries which resulted, in part, in planning and application of improvements in Mill and Deer creeks. Heightened public awareness and the potential for law enforcement actions to ensure significant adverse impacts to threatened or endangered fish do not occur are assumed to have benefitted fish during recent years, but this is difficult to determine. It is reasonable to conclude that this factor affecting anadromous fish has not been shown to have appreciably changed in recent years to the detriment of anadromous fish as compared to decades ago. Nevertheless, due to the overlap of early irrigation and late outmigration of salmonids on some tributaries (*e.g.*, Mill and Deer creeks), this problem remains for part of the outmigration period in the spring, particularly during drought years, and solutions should be developed to minimize or eliminate deleterious effects on fish (*e.g.*, structural facilities or other measures to provide water exchanges to improve the timing and magnitude of outmigration flows for fish).

5.5.2 Mainstem Sacramento River

5.5.2.1. *Entrainment*

Loss of young anadromous fish in unscreened riverine diversions is almost universally cited as a significant contributing cause for declines in fish populations. Even prior to large dam construction, unscreened water diversions were considered a serious hazard for salmon (Moffett 1949). Nearly all anadromous fish restoration plans call for screening these diversions. For this reason, a substantial amount of discussion on the topic is provided in this report.

In 1989, the Resources Agency of California (RAC) reported that there were more than 300 unscreened diversions on the Sacramento River between Redding and the Feather River confluence (RAC 1989). It was estimated that approximately 1.2 million acre feet of water is diverted annually through these diversions. It was previously hypothesized that most fish losses may occur between Ord Ferry and Knights Landing (Figure 1) based on the following estimated annual diversions by river reach during April through October (Hallock 1987):

Redding to Red Bluff	0.3 %
Red Bluff to Ord Ferry	1.6 %
Ord Ferry to Knight's Landing	56.0 %
Knight's Landing to Sacramento	42.0 %

The first largest empirical evaluation of anadromous salmonid losses entrained into unscreened irrigation diversions from the Sacramento River was conducted by DFG during 1953 and 1954. At that time, DFG estimated there were more than 900 irrigation, industrial, and municipal water supply diversions upstream of the Sacramento-San Joaquin River Delta from stream sections used by anadromous salmonids within the entire Central Valley (Hallock and Van Woert 1959). DFG reported that most of these diversions were for irrigation purposes and very few were screened to prevent fish losses. During their investigation, the ACID diversion at Redding was the only gravity-flow diversion found; all others were pumped diversions. [Since their study, the RBDD became a large-scale gravity diversion on the main-stem Sacramento River beginning in August 1966 (Vogel *et al.* 1988)]. The 1953-1954 DFG investigations did not include sampling at the large diversions at Glenn-Colusa Irrigation District (GCID) or ACID. In 1953 there were 335 separate diversions (utilizing 448 pumps) along the 246-mile reach of the Sacramento River between Redding and Sacramento. Hallock and Van Woert (1959) concluded from intermittent sampling at 23 diversions in the Sacramento River during the 1953 irrigation season that no diversion was found to be taking young Chinook salmon or steelhead in significant quantities. Results of their sampling during the entire 1954 irrigation season at nine selected diversions in the vicinity of Colusa showed that losses at individual pumps were small. The greatest seasonal loss found in 1954 was 2,116 fingerling salmon and 110 yearling steelhead in a 24-inch centrifugal pump (Hallock and Van Woert 1959). DFG concluded:

> "*Individually, most of the small irrigation diversions do not destroy many young salmon and steelhead. Collectively, however, they take considerable numbers.*"
>
> "*In view of the migration time of fingerling salmon, which results in the bulk of the fish moving out of the upper river and reaching the delta by late March, and an irrigation season which does not get into full swing until late April and early May, the small losses encountered in the diversions are not surprising.*" (Hallock and Van Woert 1959) (Figure 28).

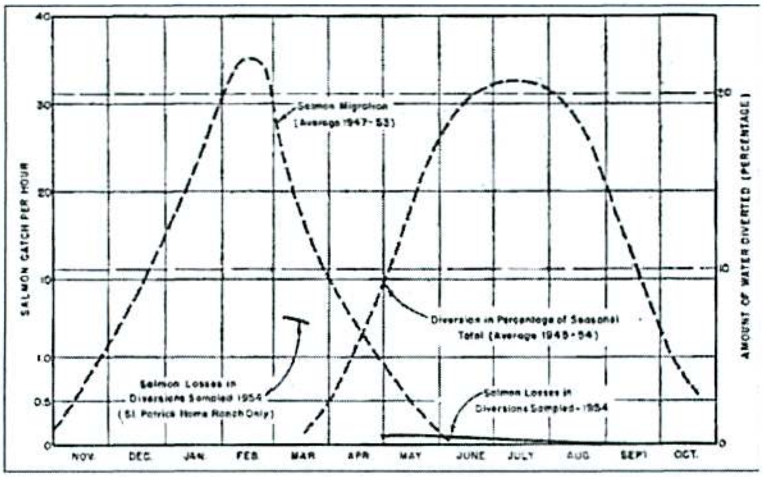


Figure 28. Comparison between times of the seaward migration of Sacramento River juvenile Chinook salmon, their losses in irrigation diversions, and the diversion of water for irrigation. (from Hallock and Van Woert 1959)

In examining the topic of potential effects of diversions on young anadromous salmonids, there are numerous aspects which should be considered. A particular element that may have an overriding influence at one diversion site could have a negligible influence at another diversion site. The following factors (from Vogel 1995b) are not listed by priority because each diversion has site-specific characteristics which influence the diversion's effects on fish.

- Seasonal timing and magnitude of the water diversion
- Proximity of the diversion to salmonid rearing habitat
- Longitudinal location of the water diversion in the river relative to the proportion of juvenile salmon which would ultimately migrate past the diversion
- Hydrologic conditions preceding the principal downstream migration (*e.g.*, wet or dry water year type)
- Specific life phase of the downstream migrants passing the diversion (*e.g.*, fry versus smolt)
- Physical configuration of the diversion intake and associated facilities
- Location of the diversion intake in the water column
- Concentration of the downstream migrants at various location in the water column and across the river channel
- Day-to-night changes in fish distribution and behavior
- Day-to-night changes in water diversion rate
- Hydraulic conditions near the diversion intake
- Water temperature in the vicinity of the diversion intake
- Location of the diversion intake in the river channel (*e.g.*, oxbow, inside or outside bend, set back or on the river, etc.)
- Absence or presence and concentration of predatory fish at the diversion site

Among these factors, the specific location, timing, and magnitude of the diversion relative to the seasonal presence of fish at the site are likely the primary considerations in determining potential effects on fish.

Although there are obviously differences among Sacramento River diversion operations depending on the number and types of crops irrigated, climate, and numerous other factors, most diversions generally begin operations in April. The greatest magnitude of irrigation diversions occur during the late spring and summer months. Sharp reductions in these diversions occur in the fall, and little or no diversions occur during the late fall and winter months. As previously noted, the greatest proportion of water diverted from the Sacramento River occurs downstream of the principal rearing areas for anadromous salmonids. If the diversions occurred within the principal salmonid rearing habitats, the magnitude of impacts would be expected to be significant; however, that is not the case with the Sacramento River in the areas where many irrigation diversions occur. There are no empirical data to demonstrate that this region is an important rearing area for anadromous salmonids during the time the majority of irrigation diversions occur (Figures 29-32). However, these fish migrate and undoubtedly rear in the mid- and lower Sacramento River but during a time when minimal or no irrigation diversions occur. A significant exception to this occurs during the fall and winter period when water is diverted through a small number of these facilities for wetlands/waterfowl and rice stalk decomposition purposes. An ongoing study of fish entrainment (discussed below) will help determine the relative differences in the timing of diversions and potential effects on juvenile anadromous fish (Vogel 2011).

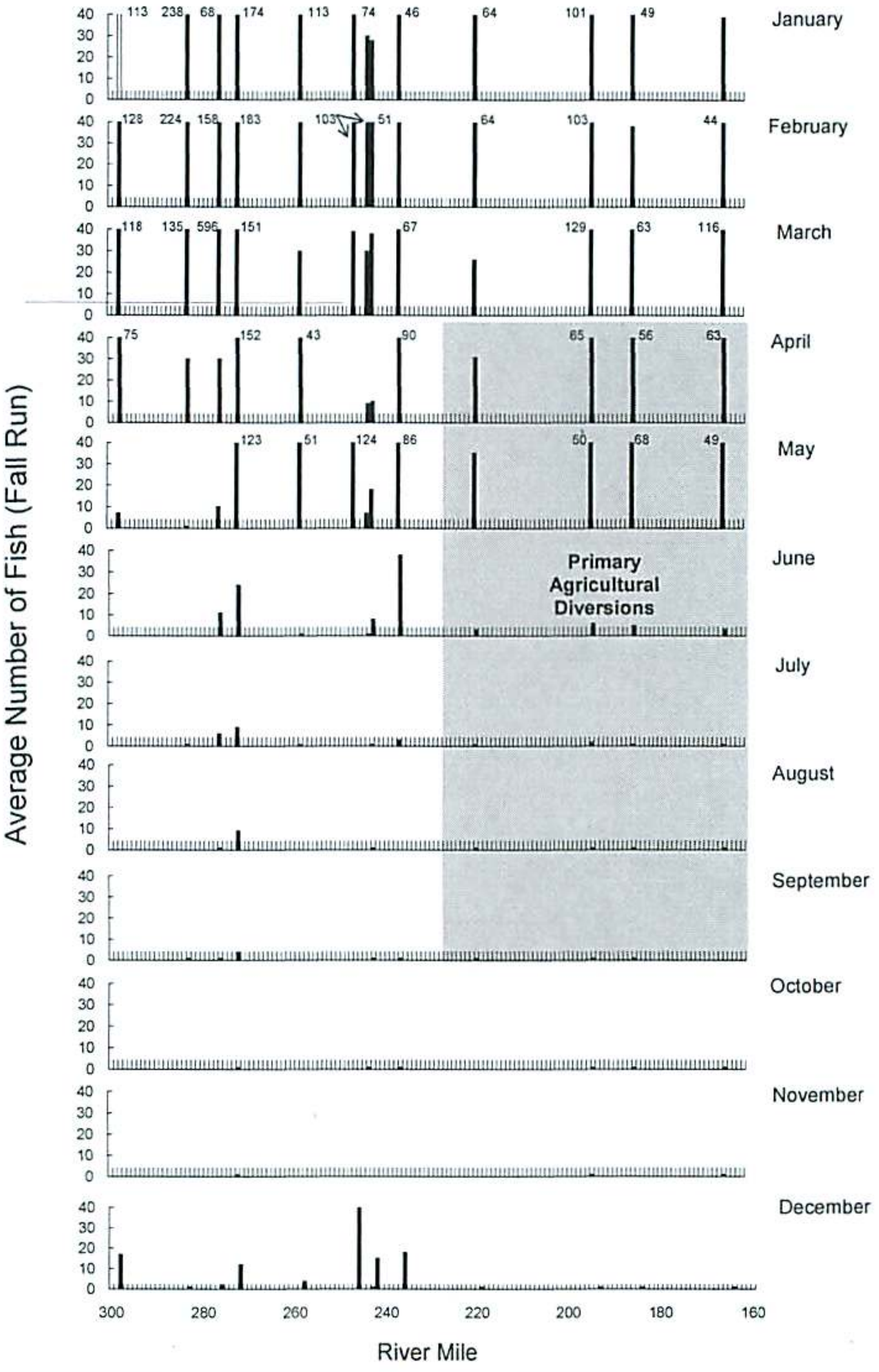


Figure 29. Spatial and temporal distribution of fall-run Chinook captured by the USFWS during year-round monthly beach seining at 13 sites in the Sacramento River, 1981 – 1991 [(N = 60,728) from Johnson *et al.* 1992].

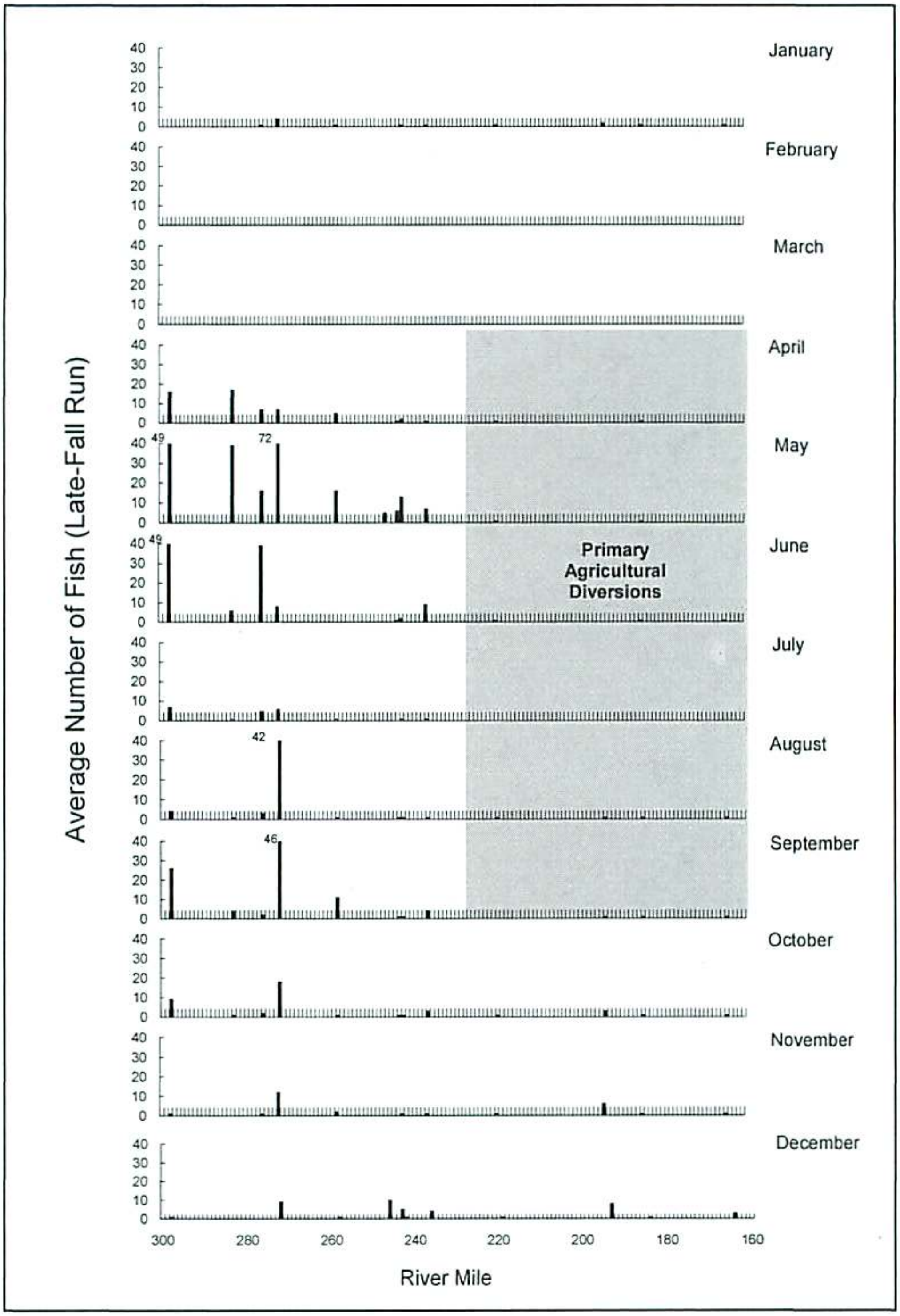


Figure 30. Spatial and temporal distribution of late-fall-run Chinook captured by the USFWS during year-round monthly beach seining at 13 sites in the Sacramento River, 1981 – 1991 [(N = 6,284) from Johnson *et al.* 1992].

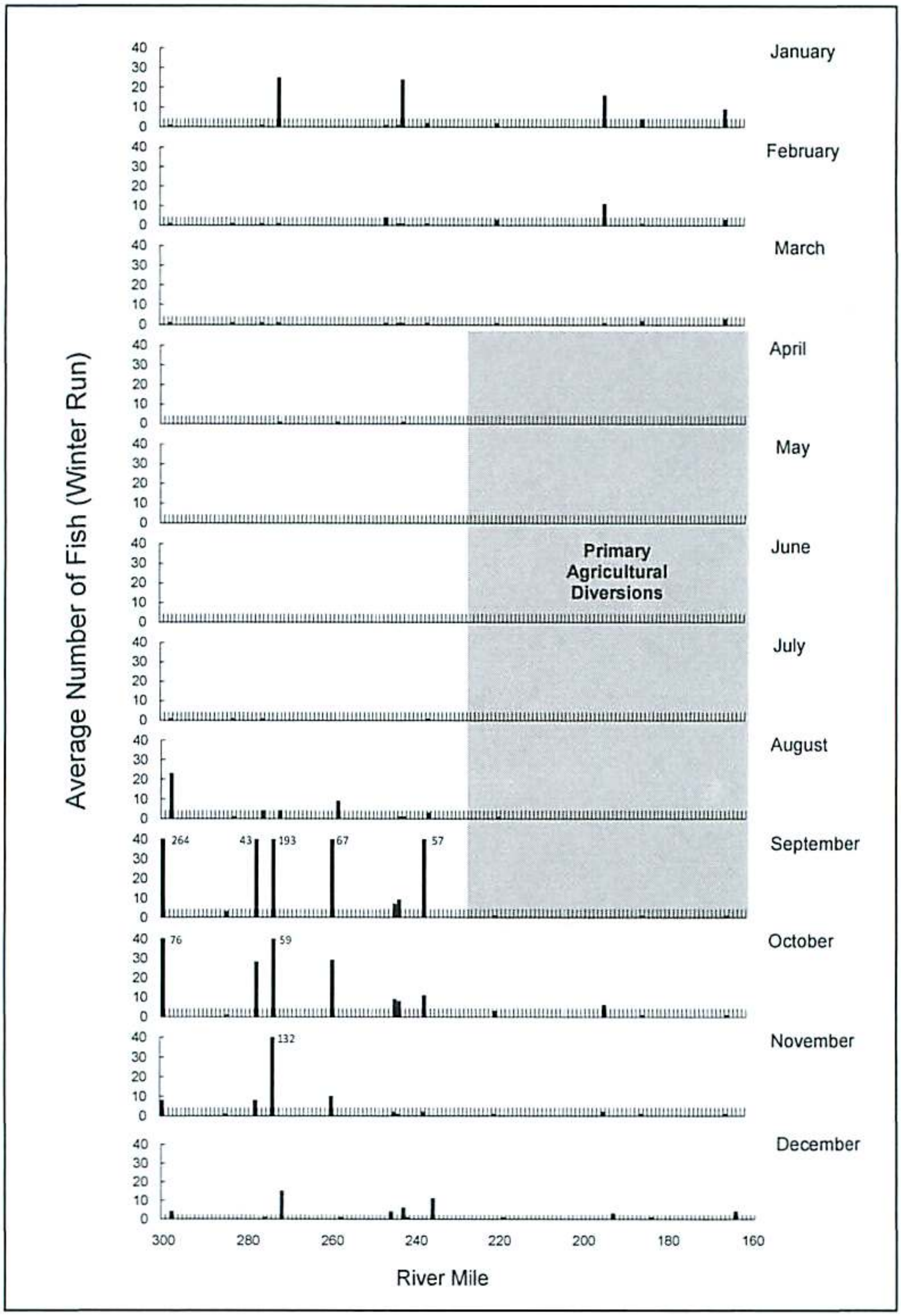


Figure 31. Spatial and temporal distribution of winter-run Chinook captured by the USFWS during year-round monthly beach seining at 13 sites in the Sacramento River, 1981 – 1991 [(N = 10,778) from Johnson *et al.* 1992].

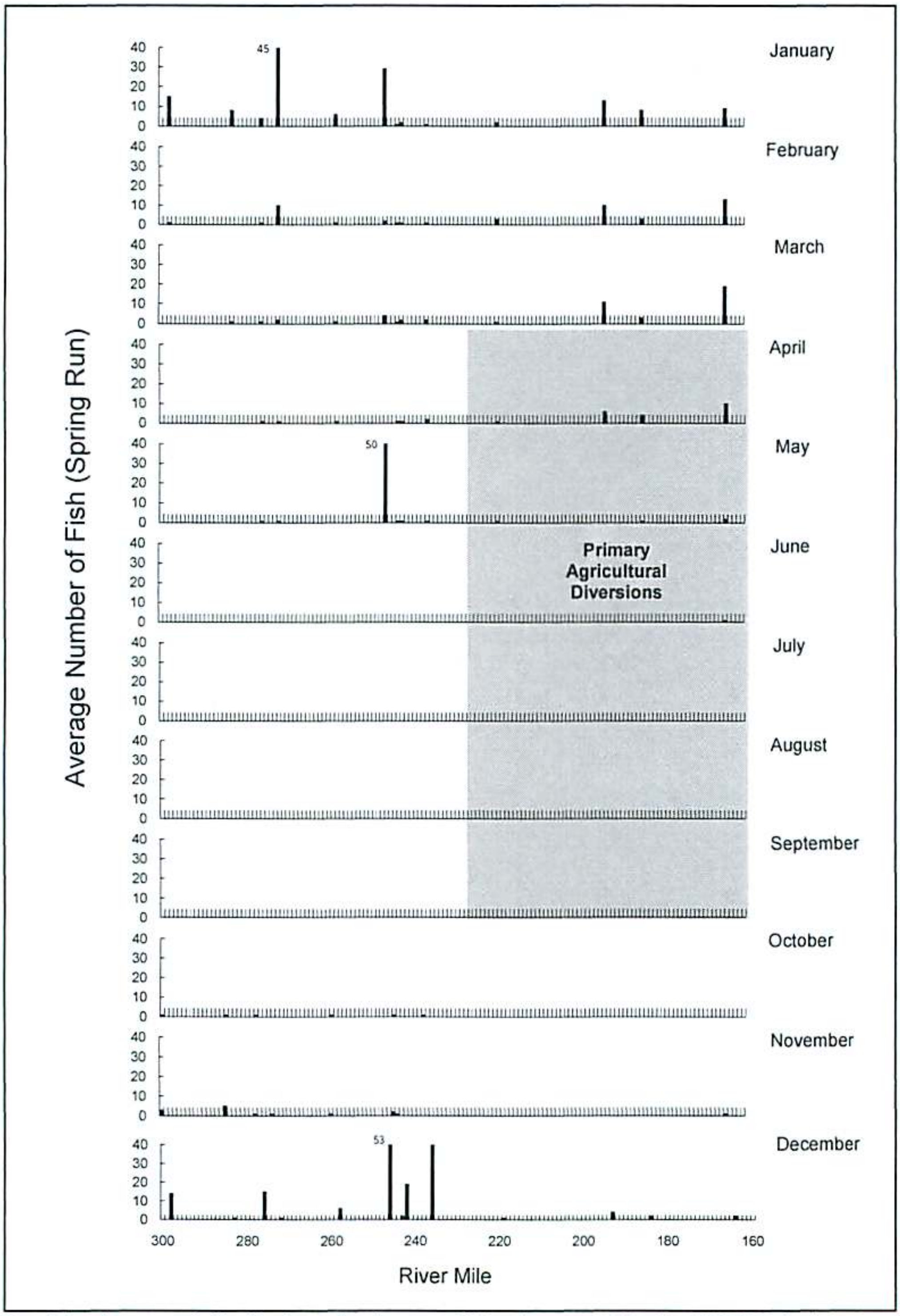


Figure 32. Spatial and temporal distribution of spring-run Chinook captured by the USFWS during year-round monthly beach seining at 13 sites in the Sacramento River, 1981 – 1991 [(N = 4,768) from Johnson *et al.* 1992].

The majority of the salmon emigration during wet winter conditions occurs during January through March (Vogel and Marine 1991) and is demonstrated by the DFG fish sampling program which, among other purposes, is conducted to determine the timing and relative abundance of juvenile anadromous salmonids emigrating from the upper Sacramento River system (Vincik and Bajjaliya 2008) (Figures 33 and 34). The DFG monitoring program ceases during the summer months, due to minimal or no juvenile salmon presence. Storm events increase river flow and turbidity which causes many salmon to either volitionally or non-volitionally move from the upper river to the Delta. If the fish have not already emigrated from the primary rearing grounds in the upper river, a later emigration of juvenile salmon occurs during April and May as smolts (Vogel 2011); this is particularly true during dry hydrologic conditions (Vogel and Marine 1991). In this latter instance, there is greater overlap between the onset of irrigation and the presence of outmigrating salmon.

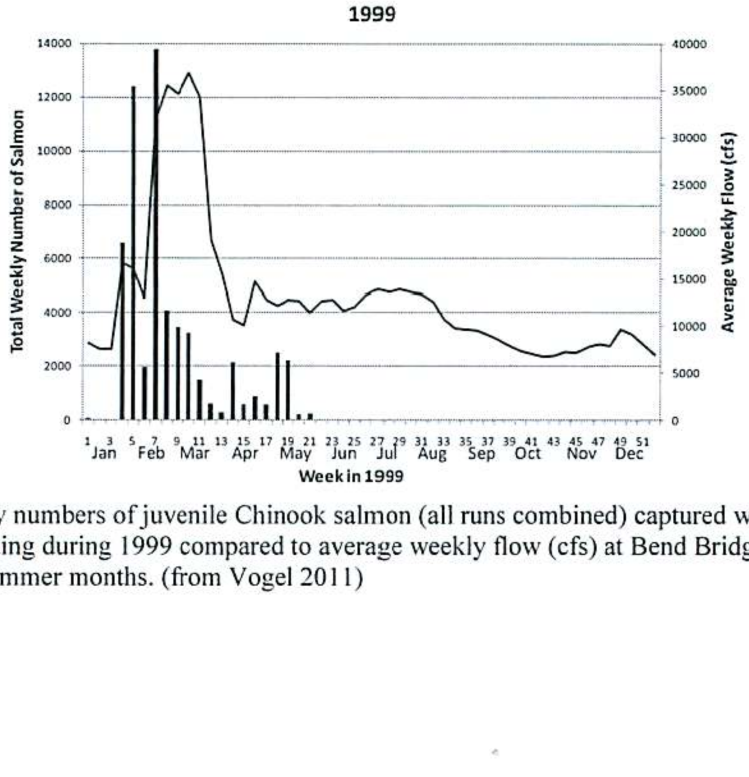


Figure 33. Total weekly numbers of juvenile Chinook salmon (all runs combined) captured with two rotary screw traps near Knights Landing during 1999 compared to average weekly flow (cfs) at Bend Bridge. Monitoring is not conducted during the summer months. (from Vogel 2011)

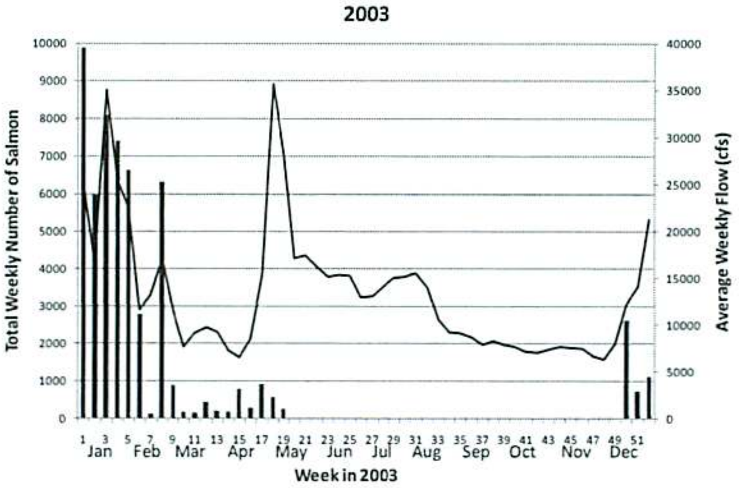


Figure 34. Total weekly numbers of juvenile Chinook salmon (all runs combined) captured with two rotary screw traps near Knights Landing during 2003 compared to average weekly flow (cfs) at Bend Bridge. Monitoring is not conducted during the summer months. (from Vogel 2011)

In 1981, Quelvog (1981) reported only three fish screens in operation on the mainstem Sacramento River. These were located at the ACID diversion (max. 400 cfs) (installed 1969), the Tehama-Colusa Canal diversion (max. 2,700 cfs) (installed 1966), and the GCID diversion (max. 3,000 cfs) (originally installed in 1935, and initially replaced in 1972). As of the early 1990s, there were very few fish screens in operation on the mainstem Sacramento River (Phil Warner, DFG, pers. comm.; Nick Villa, DFG, pers. comm.). In 1990, the DFG stated that only four diversions on the Sacramento River had fish screens of which only two were considered adequate (Reynolds *et al.* 1990).

The largest Sacramento River mainstem diversion occurs at GCID's Hamilton City 3,000 cfs capacity pumping station (Figure 35) which is within the rearing area for anadromous fish. Phillips (1931), as reviewed by Ward (1989), reported the results of the first fisheries monitoring investigation at GCID which consisted of fish sampling in the diversion canal below the old pumping plant. Based on these findings and a court ruling in 1931, a fish screening device was installed in 1935 to reduce fish entrainment at the old pump station. This original apparatus remained in place until 1972 after which DFG installed a large rotary-drum fish screen facility. However, the newer fish screen provided inadequate protection of young salmon primarily due to entrapment zones under the screens (Fish Entrapment Zone), insufficient fish bypasses, leaks in screen seals, and screen mesh large enough to pass salmon fry. A major flow event in the 1980s degraded the riverbed elevation in the river outside of the diversion's oxbow location, reduced water surface elevations on the screens and created reverse flow conditions in the lower oxbow which was previously used to bypass fish past the screens and out to the main river. Ward (1989) concluded that, historically, large numbers of juvenile salmon annually may have been lost at the diversion. The losses were not specifically attributed to any one particular mortality factor, but were due to a combination of suspected predator congregations near the fish screens and in the oxbow, impingement on the fish screens, and entrainment through the screen facility.

Based on results from other studies and on a reputation of pikeminnow for adapting to and exploiting man-made habitat alterations to their advantage, predation by pikeminnow on juvenile salmon was believed to be potentially problematic at the site (Garcia 1989). More recent research indicated that both pikeminnow and striped bass were principal predators at the GCID screen (Vogel 2008a). Interim measures taken by GCID (*e.g.*, flat-plate screens installed in 1993, increased sweeping and bypass flows, and use of alternative water supplies, including groundwater pumping) increased fish protection at the pump station. However, these measures did not accommodate key fish screen criteria [*i.e.*, approach velocity of 0.33 feet per second (ft/s) as specified by DFG and bypass flows of 500 cubic feet per second (cfs) as specified by a USACE permit (1996)]. Therefore, a new fish screen facility was deemed necessary for meeting fish protection requirements. Ultimately, a new 3,000 cfs capacity 1,000-ft-long, flat-plate fish screen was completed in 2001 and a gradient facility to re-aggrade the riverbed and alter channel hydraulics at a cost of $76 million (combined) was completed in 2000 (Figure 35). Extensive hydraulic and biological evaluations of the facility were conducted following completion and the screen was recently determined to meet state and federal standards for fish protection.

Figure 35. Aerial view of the new GCID fish screens and gradient facility on the Sacramento River near Hamilton City (from Vogel 2008a).

Screening of agricultural diversions has been a common practice in recent years in order to conserve and restore populations of anadromous fishes in the Central Valley. During the 1990s, fish screening projects increased significantly, largely as a result of new state and federal funding with principal focus on protecting winter, spring, fall and late-fall runs of Chinook salmon and steelhead, as they migrate down the Sacramento River. For example, prior to installation of both the interim and long-term screens at GCID, new angled rotary drum screens (Figure 36) were installed at the Tehama-Colusa Canal (TCC) headworks at RBDD to replace the inefficient fish louvers which were found to entrain fish into the TCC and Corning irrigation canals (2,700 cfs capacity diversion) (Vogel 1989). Subsequent USFWS research at the site demonstrated that the new screens eliminated the fish entrainment problem (Johnson 1991, Johnson and Croci 1994). Additionally, a new fish screen bypass routed juvenile fish further downstream from RBDD to alleviate the previous problem of predation (Vogel *et al.* 1988, Vogel *et al.* 1990).

Figure 36. State-of-the-art angled rotary drum screens installed at the headworks to the Tehama-Colusa Canal and Corning Canal at RBDD in 1990. Photo by Dave Vogel.

Since installation of the new screens at RBDD, there have been significant efforts under both the CVPIA and the CALFED Bay-Delta Program to screen agricultural diversions in the Central Valley, particularly the larger unscreened diversions (over 150 cfs) on the Sacramento River. For example, further downstream from GCID, two large-scale fish screening facilities meeting state and federal criteria for fish protection have been completed at Reclamation District (RD) 108. The $11 million Wilkins Slough diversion screen (830 cfs capacity) went into operation in 1999, and the $30 million 300 cfs capacity Poundstone pumping plant diversion and fish screen (which consolidated and removed three previously unscreened diversions and resulted in lower total water diversion requirement) was completed in 2008. Additional state/federal funded fish screens have recently been installed on the mainstem river at Wilson Ranch, M&T Ranch, Princeton-Codora-Glen & Provident Irrigation District, RD 1004, Maxwell ID, Sutter Mutual Water Company, Pelger Mutual Water Company, City of Sacramento, RD 999, Meridian Farms, and other sites, including Suisun Marsh. In 1992, new fish screens were also installed at the ACID dam (Figure 37) at a cost of $11,600,000 (including two new fish ladders) and ACID's diversion near South Bonnyview Bridge (USBR 1992). Additionally, in an area critically important for winter-run Chinook salmon rearing, the City of Redding installed new fish screens at its municipal water intake upstream of ACID dam. The most-expensive project currently underway is construction of new 2,500 cfs capacity flat-plate screens for the Tehama-Colusa Canal anticipated to be completed in 2010 at a cost of $220,000,000 (including a pumping plant and associated facilities) (Table 6). Dozens of other small diversions in the Sacramento River have recently been or will soon be similarly screened for fish protection (Tables 7 and 8) (Figure 38).

Figure 37. The ACID dam on the Sacramento River in Redding, California.

Table 6. Recently completed or soon-to-be constructed fish screen/fish passage projects (costs are estimated for projects not completed).

Project Name	Location	Total Costs	Federal Share	Capacity (cfs)	Year Completed
GCID	Sacramento River	$76,000,000	$57,000,000	3,000	2000
ACID	Sacramento River	$11,600,000	Unknown	450 (includes ladders)	2001
Meridian Farms	Sacramento River	$26,272,000	$12,850,000	165	2013
Natomas Mutual	Sacramento River	$52,000,000	$26,000,000	434	2013
RD 2035	Sacramento River	$26,240,000	$12,873,000	400	2016
Tehama-Colusa	Sacramento River	$220,000,000	$209,000,000	2,500	2012
Anadromous Fish Screening Program projects summary (provided by Dan Meier, USFWS).					
Maxwell ID	Sacramento River	$1,545,000	$709,000	100	1997
Pelger Mutual Water Co.	Sacramento River	$278,000	$139,000	40	1996
Wilson Ranch	Sacramento River	$231,000	$90,000	40	1996
M&T Ranch	Sacramento River	$4,584,000	$2,200,000	150	1997
RD 1004	Sacramento River	$7,250,000	$1,535,000	290	1999
RD 108 – Wilkins Slough	Sacramento River	$12,051,000	$6,101,000	832	2000
RD 108 – Poundstone	Sacramento River	$30,170,000	$14,938,000	300	2008
Adams Ranch	Butte Creek	$1,090,000	$545,000	135	1999
Gorrill Land Co.	Butte Creek	$1,516,000	$756,000	122	1999
Western Canal Water District	Butte Creek	$9,068,000	$3,023,000	Siphon	1998
Lower Butte Creek/Ducks Unlimited	Butte Creek	$480,000	$240,000	Fish Ladders and Barriers	2003
Princeton-Codora Glenn/Provident ID	Sacramento River	$10,958,000	$5,350,000	605	1999
Meridian Farms	Sacramento River	$5,000,000	$2,500,000	30	2009
RD 999	Sacramento River	$636,000	$318,000	100	2006
Sutter Mutual	Sacramento River	$21,500,000	$10,046,000	960	2007
Browns Valley ID	Yuba River	$298,000	$107,000	65	1999
City of Sacramento/Fairbairn	Sacramento/American Rivers	$44,000,000	$3,685,000	245/210	2005/2004
Dayly Lee	Steamboat Slough	$38,000	$0	20	2000
Suisun Resource Conservation District (5 screens)	Suisun Marsh	$900,000	$621,000	93	1997
	TOTALS:	**$563,705,000**	**$370,626,000**	**11,286**	

Table 7. Family Water Alliance Fish Screening Program projects summary.

Project Name	Project Location	Project Cost	Capacity (cfs)	Year Completed
Oji Bros. Farms	Sacramento River	$ 181,513	20	Prior to 2002
Cliff Liddy	Sacramento River	$ 4,640	1	Prior to 2002
Steidlmayer	Sacramento River	$ 101,489	15	Prior to 2002
Tiff Farms	Feather River	$ 97,201	9.3	Prior to 2002
Andreotti #1 & #2	Sacramento River	$ 263,347	30	2002
Davis Ranches #6	Sacramento River	$ 186,900	15	2002
Butte Creek Farms #3	Butte Creek	$ 80,000	15.5	2002
Rancho Caleta #3	Butte Creek	$ 86,000	15.5	2002
Tom Ellis	Sacramento River	$ 79,500	6	2002
Tom Gross	Sacramento River	$ 160,000	23	2002
Joyce Wells Trust	Sacramento River	$ 125,000	18	2002
Butte Creek Farms Replacement	Sacramento River	$ 132,946	38	2002
Roberts Ditch Irrigation Company	Sacramento River	$ 176,940	36	2003/2004
Jerry Forster	Sacramento River	$ 147,800	41	2003/2004
Williams Ranch	Sacramento River/Delta	$ 84,800	18.6	2003/2004
Tisdale Irrigation and Drainage	Sacramento River	$ 110,500	21	2003/2004
A & L Ag Rental and Leasing	Sacramento River	$ 95,000	15	2003/2004
Davis Ranches Site 1	Sacramento River	$ 615,800	30	2003/2004
Davis Ranches Site 1	Sacramento River		20	
Davis Ranches Site 1	Sacramento River		30	
Ferraro-Locvich	Sacramento River	$ 76,000	7	2003/2004
Reclamation District No. 999/307	Sacramento River/Delta	$ 645,947	100	2006
H & L Partnership & Wallace	Sacramento River	$ 220,000	25	2007
Larry Pires Farms	Sacramento River	$ 145,000	13	2007
SMWC State Ranch Bend Pumping Plant	Sacramento River	$ 1,252,000	128	2010
Sycamore Mutual Water Company	Sacramento River	$ 503,000	65	2010
River Garden Farms #2 Missouri Bend	Sacramento River	$ 303,000	32	2010
SMWC Portuguese Bend Pumping Plant	Sacramento River		106	2011
Reclamation District No. 108 So. Stiener	Sacramento River		30	2011
Windswept Land & Livestock #3	Sacramento River		9	2011
Oji Bros. Farms Kirkville Diversion	Sacramento River		25	2011
River Garden Farms #3 Town Site	Sacramento River		62	2012
Tisdale Irrigation District #2	Sacramento River		27	2012
Alamo Farms #1	Sacramento River		35	2012
Cranmore Farms #1	Sacramento River		36	2012
Joe Sanchez Farms	Steamboat Slough/Delta		25	2012
	TOTALS:	**$ 5,874,323**	**1,143 cfs**	

Table 8. Additional Intake Screens Inc. fish screening projects not included in Table 7 (provided by Russ Berry, ISI).

Project Name	Project Location		Project Cost	Capacity (cfs)	Year Completed
	Latitude	Longitude			
Club 506	38°10'16.07"N	122° 1'3.40"W	$ 240,000	11	1996
Club 502	38° 9'27.96"N	122° 2'48.21"W	$ 245,000	17	1996
Club 425	38° 09' 11.77"N	122° 02' 59.40"W	$ 240,000	11	1996
Club 426	38° 08' 26.23"N	122° 03' 26.39"W	$ 250,000	26	1996
RD 2112	38° 08' 05.03"N	121° 54' 55.67"W	$ 250,000	26	1997
Club 625	38° 8'17.57"N	121°54'45.30"W	$ 240,000	11	1997
Club 527	38°10'12.48"N	121°57'32.84"W	$ 245,000	17	1997
Club 501	38° 9'27.44"N	122° 2'48.64"W	$ 250,000	26	1997
Club 503	38° 9'54.68"N	122° 2'27.30"W	$ 250,000	26	1997
Club 525 East	38°10'14.19"N	121°57'40.72"W	$ 250,000	26	1997
Club 525 West	38°10'14.29"N	121°57'40.95"W	$ 250,000	26	1997
Lower Joyce	38° 9'18.03"N	122° 3'12.66"W	$ 300,000	26	1997
Boeger / Anderson	39°15'53.33"N	121°59'55.89"W	$ 126,000	24	2002
Butte Sink - Ducks Unlimited - F&WS	39°14'21.86"N	121°56'48.33"W	$ 75,000	11	2003
City of Redding	40°35'32.72"N	122°24'26.34"W	$ 900,000	74	2006
Berryhill 16" Siphon	38° 4'33.21"N	121°28'13.90"W	$ 43,000	11	2007
Mark Lasher	38°15'58.73"N	121°38'31.46"W	$ 16,000	4	2007
Joe Suprenant 16" Siphon	38° 3'57.61"N	121°29'58.25"W	$ 43,000	11	2008
Al Medvits	38° 6'41.33"N	121°42'50.74"W	$ 15,000	9	2008
		TOTALS:	**$4,228,000**	**393 cfs**	

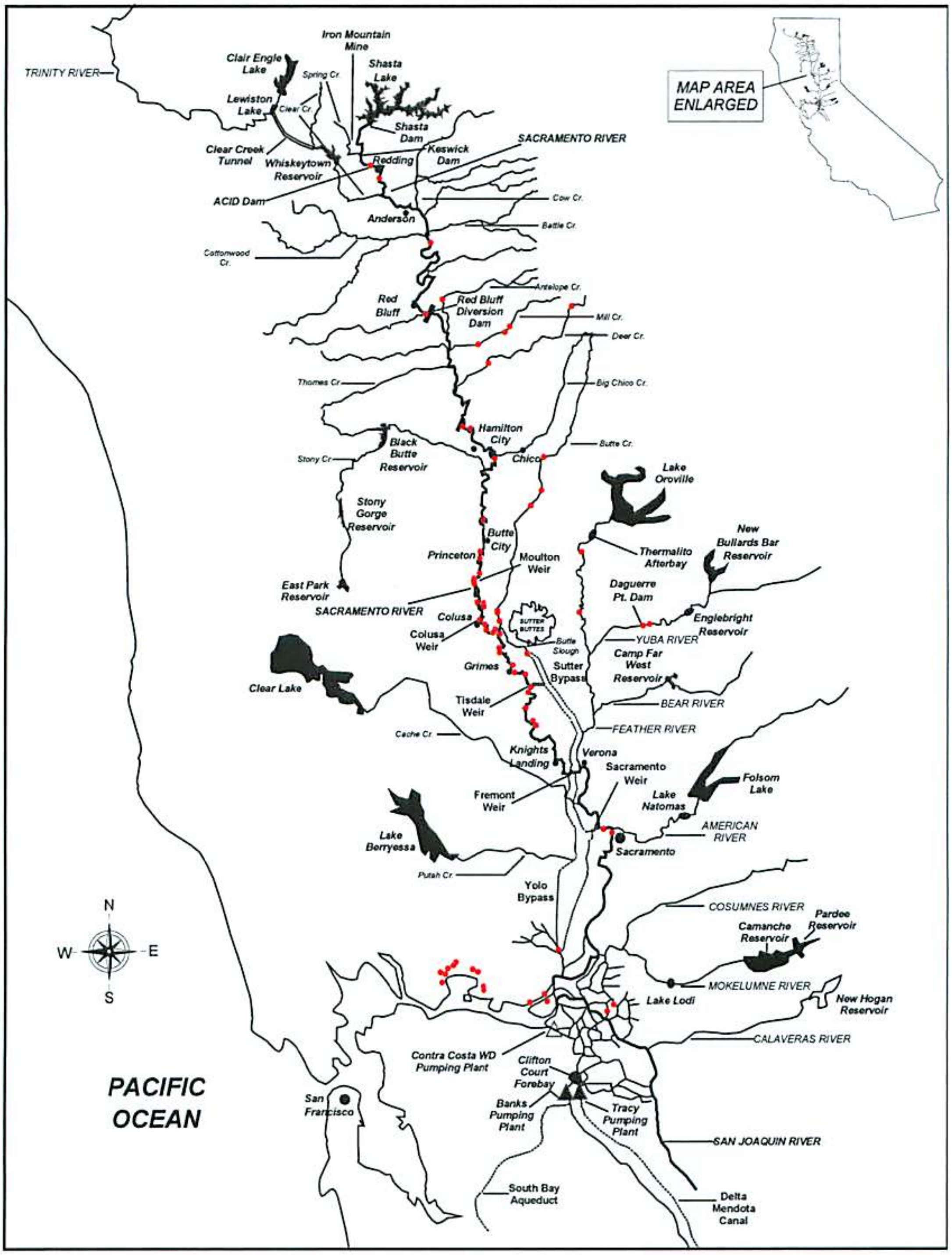


Figure 38. Recent fish screening projects (depicted by red dots).

There are many small and moderate sized agricultural diversions (under 150 cfs) on the Sacramento River that remain unscreened. However, there is a general lack of data available about the potential effects of these agricultural diversions on existing fish populations (Vogel 2011). In an effort to prioritize unscreened water diversions in the Sacramento River for possible future installation of fish screens, the Anadromous Fish Screen Program (AFSP), administered by the USBR, the USFWS and the CALFED Ecosystem Restoration Program, recently initiated a process to acquire detailed information at smaller diversion sites. The objective of this project is intended to lead to a better understanding of which diversions are most important to screen by quantifying site-specific characteristics. The ultimate project goals are to correlate fish entrainment data (from past and future monitoring efforts) at unscreened diversions with the physical, hydraulic, and habitat variables at diversion sites. The in-river survey was conducted in the Sacramento River between Red Bluff and Verona (Figure 1) by collecting extensive data using new technology to measure bathymetry, hydraulic, physical, and biological characteristics at each site (Vogel 2008b). A dozen diversion sites were selected by state and federal agencies for monitoring of fish entrainment during the irrigation season. Fyke nets are placed in the irrigation canals and fished continuously during the irrigation season to determine daily and total fish entrainment (Figure 39). To date, no significant losses of anadromous fish have been detected at sites monitored, although some of the early season sampling was limited due to Section 10 permit delays and an unusually late onset of irrigation (Vogel 2009, 2011).

Figure 39. Examples of unscreened diversions sampled for fish entrainment by Natural Resource Scientists, Inc. Photos by Dave Vogel.

A potentially serious problem for outmigrating anadromous fish in the lower Sacramento River near Verona exists. When water diversions in the Natomas Cross Canal exceed positive flows down the Canal, reverse flows may occur at the Canal's confluence with the Sacramento Rier.

Water can be diverted into the Natomas Cross Canal through pumping activities off the mainstem river. Under certain conditions, a temporary dam is installed to partially control the water elevation in the canal and water is pumped through the dam into the canal (Figure 40). These conditions create reverse flows in the canal and could divert outmigrating anadromous fish off the mainstem Sacramento River into the canal with no means of return back to the river. The presently unknown severity of the problem depends on the timing of diversions and the seasonal presence of fish. Because flows from the Feather River enter the Sacramento River immediately upstream of the Natomas Cross Canal on the same side of the river, it may pose greater hazards for Feather River outmigrating fish. Attempts to determine fish entrainment at Verona Dam were largely unsuccessful because of physical limitations at the site (Vogel 2009).

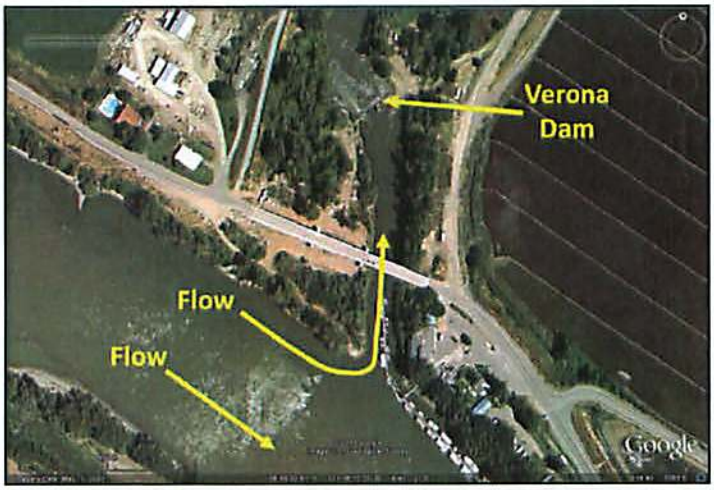


Figure 40. Location of Verona Dam in the Natomas Cross Canal on the lower Sacramento River.

5.5.2.2. *Predation*

Predation can be a serious problem contributing to losses of young anadromous salmonids. The principal predator on juvenile salmon at riverine sites is commonly the Sacramento pikeminnow (a native species), although other highly predacious species (*i.e.*, striped bass and largemouth bass -- both popular sport fish, but non-native species; Figure 41) contribute to these losses. The feeding behavior of pikeminnow is dependent on the abundance and size of their prey, water temperature, physiological and health conditions, and nutritional status and time since last feeding (Vigg 1988, Vigg *et al.* 1991). Pikeminnow generally ambush their prey either solitarily from concealed locations (*e.g.*, underwater structures such as boulders and submerged vegetation) or in large roving schools, particularly in areas where the salmon are disorientated such as at dam spills (Moyle 1976, Vogel *et al.* 1988, Garcia 1989). The number of juvenile salmon consumed by individual pikeminnow is related to the environmental factors previously mentioned and is highly correlated with the size of the pikeminnow (Vigg *et al.* 1991, Vondracek and Moyle 1983). In the Sacramento River, predation may be highest at localized sites (*e.g.*, diversions) where habitat conditions favor predatory fish (*e.g.*, Pikeminnow at Intake)

Figure 41. Sacramento pikeminnow (4 pounds) on left (photo by Dave Vogel), striped bass (38 pounds) in middle (photo by Matt Manuel), and largemouth bass (8.9 pounds) on right (photo by Dave Vogel).

There is currently no information to indicate if predation immediately downstream of ACID, a gravity water diversion dam, is a problem for anadromous fish. Striped bass and largemouth bass are not known to inhabit this area although Sacramento pikeminnow are present. Historically, striped bass and largemouth bass were present in this area prior to Shasta Dam but were largely absent after construction due to a cooler thermal regime (Moffett 1949) which was a significant benefit to salmonids. Reduced populations of these highly predacious fish in the area are particularly important because of the high concentration of many juvenile anadromous salmonids rearing between Keswick Dam and Red Bluff. However, trout fishing in the area just downstream of ACID Dam is known to be excellent and those fish could potentially prey on juvenile fish, particularly winter-run Chinook fry, as the young fish are exposed to turbulence and disorientation passing over the dam (Figure 37).

Fishery resource investigations conducted at RBDD, another gravity water diversion dam, during the 1970s and 1980s identified severe downstream anadromous salmonid passage problems (Vogel *et al.* 1988). DFG study results indicated that substantial losses of juvenile salmonids were attributable to the dam's operations for water diversions into the adjoining canals (Hall 1977, Hallock 1980, Hallock 1983). For example, a DFG study conducted during the 1970s suggested that losses of young salmon could be in the range of 29% to 77% (Hallock 1983). Largely as a result of these and other prior investigations, the USFWS began intensive studies (performed by this author) in the early 1980s to determine specific sources of fish mortality at the water diversion facilities (Vogel *et al.* 1988). The majority of the mortality was attributed to Sacramento pikeminnow predation (Figure 42). Based on that research, numerous corrective actions were incrementally implemented to reduce predation impacts (Table 9). It is reasonable to conclude that predation on anadromous fish at RBDD has been significantly reduced since the mid-1980s to the present.

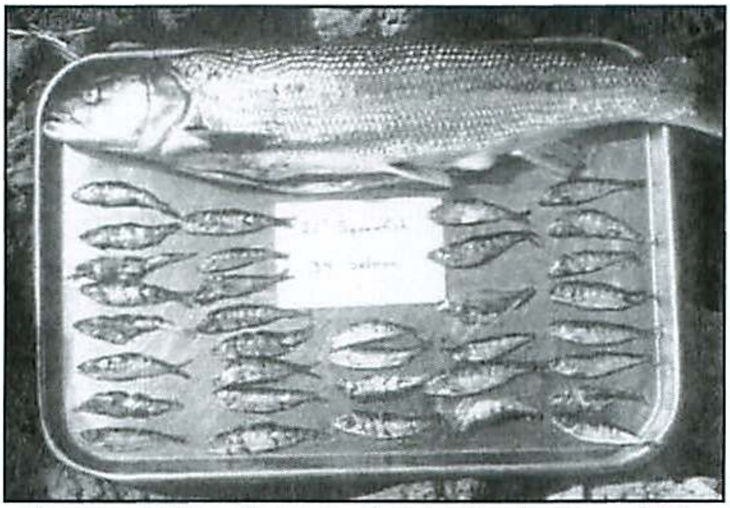


Figure 42. A 21-inch long Sacramento River pikeminnow (previously called squawfish) captured just downstream of Red Bluff Diversion Dam and 34 juvenile salmon removed from its stomach. Photo by Dave Vogel.

Table 9. Downstream fish passage improvements at Red Bluff Diversion Dam (RBDD).

Fish Protection Measure	Effective Date	Fish Passage Improvement
RBDD lights off at night	1983	Significant reduction in predation when RBDD gates in
Improved louver maintenance	mid-1980s	Major reduction of entrainment when RBDD gates in
Unclogging fish bypass pipe	1985	Major elimination of physical injury when RBDD gates in
Elimination of flow-straightening vanes inside fish bypasses	1985	Elimination of physical injury and mortality of large numbers of juvenile fish
Implementation of spring pulse flow	1985	Significant reduction in salmon mortality at RBDD
Fixing leaks on the Dual-Purpose Canal fish screens	1985, 1986	Elimination of fish entrainment into the Tehama-Colusa irrigation canal
Change in Acrolein treatment in the Dual-Purpose Canal	mid-1980s	Elimination or significant reduction in juvenile salmon mortality
TCC headworks deflector wall	late 1980s	Significant reduction in entrainment when RBDD gates in
RBDD gates out 6 months/year	1987	Major seasonal elimination of predation and significant reduction of predation when RBDD gates in
Abandonment of salmon spawning channels	1987	Elimination of seasonal entrainment and significant reduction when RBDD gates in
Installation of new fish screens	1990	Elimination of entrainment when RBDD gates in
Installation of new fish bypass	1990	Major reduction of predation when RBDD gates in
RBDD gates out 8 months/year	1993	Major seasonal elimination of entrainment and significant reduction of predation when RBDD gates in

5.5.2.3. *Water Quality and Temperature*

Water quality in the mainstem Sacramento River may affect outmigrating juvenile anadromous fish. A DWR literature review in the 1980s found that the major sources of water quality degradation for the Sacramento River include municipal wastes, industrial wastes (primarily food processing and lumber industries), agricultural drainage, and acid mine wastes (Boles and Turek 1986). Among these, the most significant sources potentially affecting salmonids appear to be acid mine drainage in the upper Sacramento River (previously discussed) and agricultural drainage in the lower Sacramento River. Water quality problems in the Sacramento River basin associated with irrigated agriculture and municipal and industrial discharges, however, are relatively minor compared with these types of problems in other parts of the Central Valley. This lower effect is partially because of the use of the Sacramento River to convey increasing quantities of water developed within the Sacramento River basin and imported from the North Coastal basin (SWRCB 1995).

The major source of waste water is agricultural drainage which historically contributed to lower water quality during low flow periods in the Sacramento River and lower reaches of the major tributaries. As described by SWRCB (1995), "*Water quality concerns in tributaries include: low dissolved oxygen levels in Butte Slough, Sutter Bypass, and Colusa Basin Drain; high water temperatures below diversion structures on Butte Creek; concentrations of minor elements (chromium, copper, iron, lead, manganese, selenium, and zinc) that exceed beneficial use criteria in the Sutter Bypass; and pesticide residues in the Sutter and Yolo bypasses and Colusa Basin Drain. Additional concern exists for effects of tributary discharges to the Sacramento River, including elevated temperature, dissolved solids, minor elements, pesticides, and turbidity, especially from the Sutter and Yolo bypasses and Colusa Basin Drain.*" Rice field herbicides caused the most significant water quality degradation in the past, but recent efforts by the State Department of Food and Agriculture (DFA) and the Central Valley RWQCB have largely controlled this problem (SWRCB 1995).

Recently there has been increased attention focused on the potential role of agricultural chemicals in the decline of Central Valley fish species. Information presented in Bailey *et al.* (1994) and earlier SWRCB proceedings describe some of the possible causal impacts of those chemicals on fish such as striped bass. Much of that information focused on non-winter seasons and is not particularly relevant to winter-run, late-fall run, spring-run, and fall-run Chinook and steelhead because of minimal presence of their early life phases within the potential geographic zone of impact. Insufficient information is available for green sturgeon to derive any conclusions.

Relatively recently, additional information has been developed on the potential harm to the aquatic ecosystems resulting from agricultural chemicals introduced into the riverine environment during the winter months (*e.g.*, diazinon, a dormant spray on tree crops) when it is relevant to anadromous salmonids. With the possible exception of dormant spray applications (discussed below), it appears that agricultural drainage probably has not played a significant role affecting anadromous fish because the location, timing and nature of the drainage does not correspond well to the time periods when the anadromous fish are present in relevant areas of the Sacramento River system.

It has been hypothesized that some chemicals used in Sacramento Valley agricultural operations, although not acutely toxic to salmonids in the river, may indirectly impact salmonids by affecting their food organisms. The off-site movement of pesticides used in Sacramento Valley agriculture is a potential concern to downstream fisheries because as much as one-third of the flow in the Sacramento River at certain times of the year can originate from rice fields. In 1988, insecticides (*e.g.*, carbofuran and methyl parathion) were shown to cause mortality in aquatic invertebrates in agricultural drains and possibly the Sacramento River (Saiki and Finlayson 1993). An ecological risk assessment of diazinon in the Sacramento and San Joaquin River basins found that the principal risk to anadromous salmonids was from the potential effects on their food organisms, and not direct acute toxicity (Giddings *et al.* 1997). The timing of potential impacts on food organisms from dormant sprays was during January and February, important rearing months for some anadromous fish. Giddings *et al.* (1997) concluded: "*Indirect effects on some fish populations cannot be dismissed if sensitive native arthropods are reduced at critical periods when they are needed as food by early life stages of fish.*" However, the most significant impacts (but brief) were believed to occur on cladocerans, which are not a primary food organism for anadromous fish. As a result, the relative effects of this source of pollution on salmonids relative to other factors must be considered as low.

Because the large dams in the Sacramento River basin, including the Feather and Yuba rivers, release large quantities of cold water for conveyance to downstream areas during the period when air temperatures are seasonally warm, anadromous fish have benefited from an improved thermal regime. In the Sacramento River, this benefit was recognized as early as 1949 (Moffett 1949). However, high summer water temperatures in the lower Sacramento River and Delta present a thermal barrier to juvenile salmon downstream migration (Kjelson *et al.* 1982). In the Sacramento River, subyearling salmon emigration is related to the avoidance of high summer water temperatures (Gard 1995). During the late spring through summer periods when air temperatures are the warmest, releases of cold water from the large dams are often high but the dams are far upstream from the lower Sacramento River and Delta. Therefore, ambient conditions control temperatures in these downstream areas. Additionally, the emigration of most juvenile anadromous fish to downstream areas has ceased by the time water temperatures are the warmest. For example, DFG does not conduct downstream migrant salmonid monitoring at Knights Landing because of the low presence of those species. There are no indications that water temperatures in the lower river and Delta have been a factor in fish population declines or that water temperatures in these areas in recent decades have changed appreciably.

5.5.2.4. *Flows*

The primary focus on flows for outmigrating juvenile anadromous fish has been in the Delta. Because of the interrelationships between mainstem flows and outmigrating anadromous fish, this topic will be discussed in Section 5.5.3.1.

5.5.3 Delta

The CVPIA fish restoration program has focused on actions in the Delta region as the highest priority within the Central Valley because it is exceedingly degraded (due in part to CVP and SWP operations), because all anadromous fish must pass through the Delta as juveniles and adults, and because some of these fish rear there (Cummins *et al.* 2008). Impacts on young salmonids entering the Delta are significant because the fish have already survived density-dependent (*e.g.*, redd superimposition, disease) and density-independent (*e.g.*, temperature, dessication, siltation) factors in upstream areas. In other words, those fish reaching the Delta would be expected to have the highest survival *rates* as compared to all earlier life phases (*e.g.*, a salmon smolt reaching the Delta has a higher probability of surviving to an adult fish than a salmon fry in one of the upstream-most river reaches). The earliest life phases suffer the greatest losses, whereas the later life phases can be expected to have higher survival rates and more likely reach the adult life phase, perpetuating the population. Ultimately, minimizing exposure to potentially lethal factors in the Delta will provide a major complement to ongoing efforts to save emigrating salmonids in upstream areas of the Sacramento River basin.

Because of its relevance and timeliness, most of the following information (unless otherwise noted) is extracted from the NMFS Winter-Run Chinook Salmon Recovery Plan (NMFS 1997). The probable impacts of various anthropogenic factors affecting salmon are described in the NMFS Recovery Plan. Much of the information presented here is similarly described in public documents such as the SWRCB 1995 Environmental Report, and Biological Assessments and Biological Opinions on the CVP and SWP.

> "*As flow has become highly manipulated in the Delta, a broad scope of direct and indirect impacts has likely diminished winter-run Chinook survival. These problems are primarily related to changes in hydrology, whereby the timing, quantity, export and distribution of water flow into and through the Delta have been altered. The primary factors causing salmon mortality in the Delta are considered to be: 1) the diversion of winter-run Chinook from the main stem Sacramento River into the central and south Delta where environmental conditions are poor; 2) reverse flow conditions created by pumping; and 3) entrainment at CVP and SWP pumping plants and associated problems in Clifton Court Forebay. In addition, poor food supply may limit the rearing success of winter-run Chinook. There are other related water management projects which may adversely affect winter-run Chinook, including barriers at Grant Line Canal, the head of the Old River, Old River at Tracy, and the Middle River.*" (NMFS 1997)

> "*The sources of mortality for fish entering into the central Delta are likely a combination of adverse conditions resulting from: CVP and SWP operations; poor riparian, tidal marsh and shallow water habitat conditions; predation; and a longer migration route to the ocean (USFWS 1992a; IEP Estuarine Ecology*

> *Project Work Team 1996). The central Delta also has a greater number of agricultural diversions and more complex channel configurations than the main stem Sacramento River. The channel complexity, in conjunction with the tidal and reverse flow patterns, likely delays migration to the ocean, which increases the length of time that smolts are exposed to adverse conditions. Also, susceptibility to diversion into Clifton Court Forebay or entrainment at the CVP and SWP pumping plants is more likely for fish migration through the central Delta than for those migrating down the main stem Sacramento River (USFWS 1992a). Historically, the central Delta was probably beneficial for rearing juvenile Chinook salmon, including winter-run Chinook, due to the extensive acreage of tidal marsh habitat and its associated nutritional and cover benefits. However, degradation of central Delta waterways have [sic] led to adverse conditions for the rearing and migration of winter-run Chinook."* (NMFS 1997)

NMFS summarized the impacts to winter-run Chinook attributable to CVP/SWP pumping operations in the following manner.

> "*The indirect effects from operating the DCC and pumping plants likely have far greater impacts on the winter-run Chinook population than is indicated by the number of fish surviving to the salvage facilities. More likely, the vast majority of juvenile Chinook mortality results from the indirect effects of pumping operations, rather than actual entrainment at the pumps. Specifically, juvenile Chinook diverted into the central and south Delta experience higher mortality through reversed flows, predation, reduced shallow water habitat for fry, higher water temperatures, possibly small agricultural water diversions, and reduced river inflows during the spring which decreases available nutrients, turbidity, and transport flows for migration. If the DCC gates were not open, fewer juveniles would move into the central and south Delta and in the absence of CVP/SWP, aquatic habitats throughout the central and south Delta would be markedly better for migrating smolts and rearing fry. Finally, the specific mechanisms by which pumping operations influence fish behavior and movement are not well understood. However, salmon arrive in pulses at the pumping facilities indicating that entrainment is not a random process but likely to be directly related to pumping operations.*" (NMFS 1997)

5.5.3.1. *Flows*

Based largely on tagging studies of hatchery fish, a significant increase of freshwater flow in the Delta has been suggested as a principal factor benefiting survival of anadromous fish (Brandes and McLain 2001). Juvenile anadromous salmonid emigration through the Delta usually occurs during the fall, winter, and spring months, depending on the particular species and run. High flow years during wet hydrologic conditions are generally believed to provide favorable conditions for juvenile fish in the Delta. The factors affecting green sturgeon survivability in the Delta remain largely unknown. White sturgeon exhibited large year-classes during years with exceptionally high spring outflows and juvenile recruitment also appears related to the magnitude of spring flows (Fish 2010). If green sturgeon life history attributes in the Delta are similar to white sturgeon, that species may be similarly affected by high outflow, but it has yet to be ascertained.

The specific threshold of flow necessary to provide good survival for anadromous fish has yet to be determined. The causal effects of flow/survival relationships have been difficult to determine because of complex inter-relationships with numerous variables associated with flow. The following are just some examples, and many others exist. Flow can affect turbidity, which is known to stimulate juvenile salmon outmigration. Higher turbidity, increased channel velocities, and faster outmigration timing may positively affect juvenile fish survival by reducing predation and exposure to hazards. Increased flows of high magnitude can result in large numbers of young fish using flood bypasses where survival and growth may be better than mainstem reaches (discussed in Section 5.5.3.5). Increased flows can affect the proportional distribution in various migration routes in the north Delta (*e.g.*, mainstem, Sutter, Steamboat, and Georgiana Sloughs) where survival rates can be different (discussed in Section 5.5.3.5). The magnitude of flow alters the extent of tidal excursion in some lower reaches (discussed in Section 5.5.3.5), which can alter migration timing and routes. Increased flows may affect the relative abundance and distribution of predatory fish in key salmon migration corridors. Higher flows may provide a dilution effect and alter lateral fish distribution in river channels, thereby reducing the numbers of fish entrained into unscreened diversions.

However, little progress has been made on parsing out the various factors related to flow that may influence fish survival. Most fish tagging studies over the past several decades have appeared to simply conclude "more flow is better" without determining numerical thresholds or examination of site-specific causal mechanistic effects of flow on survival. This circumstance is partially attributable to study designs reliant on relatively few releases of coded-wire tagged salmon annually at only several locations under limited environmental conditions. Additionally, those studies required years to complete due to waiting for tag recoveries from adult fish that are captured in the fisheries or return to the rivers, resulting in only a few data points for each year. Perhaps most importantly, there has been a lack of data collected on other factors (*e.g.*, site-specific environmental conditions in the Delta, relative distribution and abundance of predatory fish) that could have affected survival after juvenile fish were released. Plainly stated, the traditional coded-wire tagged hatchery salmon studies have run their course. Future research should place more focus on this topic using different (and more modern) techniques and analytical tools. There is promise in this area of research with using miniaturized acoustic transmitters to evaluate fish movements, but some of these studies are prone to errors if not properly implemented and analyzed (Vogel 2010a) and, very importantly, have not been designed to determine specific sources of fish mortality. Much like the coded-wire tag studies, some recent telemetry studies are only oriented toward attempts to estimate overall survival in very long reaches of the Delta. This is unlikely to yield site-specific data, which can lead to remedial actions to increase fish survival. Enough studies have been conducted over the decades to demonstrate overall fish survival through the Delta is poor. A new approach should be designed and implemented to determine exactly where mortality is occurring and how to fix the specific problems where they are occurring.

The large-scale increases in reservoir releases that would be necessary to implement proposed new Delta flow criteria (SWRCB 2010, DFG 2010) are examples of a proposed approach to use flow, and flow alone, as a possible means to try to alleviate non-flow related stressors in the Delta. As described above, there are many variables intertwined with flow that may be the most important variables affecting fish survival. Depending on the timing, magnitude, and duration of flow increases, reservoir releases to downstream areas according to schedules different than existing regimes could have beneficial effects on anadromous fish (if those releases do not impact cold-water storage and water supplies needed at other important periods for fish). For example, increased reservoir releases at appropriate times could have beneficial effects on outmigrant fish through enhanced floodplain rearing; alternatively, if not appropriately implemented, such releases could be devastating to large numbers of fish through fish stranding and high predation mortality in flood bypasses. Increased transport timing through appropriately timed pulse flows could increase turbidity, stimulate outmigration, and reduce transport timing from upstream to downstream areas. In the Sacramento River basin, such flows already frequently occur through accretions and flood control operations. However, flows must be carefully timed and tailored to specific needs instead of one rule-of-thumb percentage of unimpaired flow throughout much of the year and in every watershed as contemplated by SWRCB (2010). The problem is that the underlying reasons for how flow specifically affects survival of fish in the Delta are lacking and the site-specific problems are not being addressed (discussed later).

5.5.3.2 *Water Quality*

Presently, although contaminants in the Delta are considered one of the contributing factors in the decline of pelagic organisms in the Delta (EPA 2011), adverse water quality conditions in the region have not been implicated as a significant problem for Sacramento River basin juvenile native anadromous fish. Most of the attention on pollution impacts in the Delta has been on potential effects on the food chain and other fish species (*e.g.*, Delta smelt) or within the San Joaquin River drainage. However, DFG has reported that there is no direct evidence of food limitation for young salmon in the Delta or lower estuary (DFG 1998). From 1990 to 1996, routine water quality monitoring in the Sacramento River below the city of Sacramento found conditions that were toxic to larval fathead minnow about 50 percent of the time and prompted a hypothesis that an unknown toxin has contributed to the decline in a number of species such as striped bass (Fox and Miller 1996). There have been periodic episodes of unexplained fish mortality (primarily to sub-adult striped bass) at the Tracy Fish Facilities in the south Delta (Thompson 1996), the cause of which has not been determined. Numerous pollutants are present in the Delta [*e.g.*, 160 pesticides (EPA 2011)], so it would not be surprising if future research were to reveal adverse impacts on native anadromous fish as well.

5.5.3.3 *Habitat Quantity and Quality*

All juvenile anadromous fish utilize the Delta for rearing in some degree. However, the length of rearing is dependent on the species, race of salmon, and complex environmental variables. Juvenile salmon may enter the Delta as fry-sized fish during the winter months (Brandes and McLain 2001) and rear to smolt-sized fish prior to entry into salt water. Previously, the large emigration of salmon fry from the upper river system to the Delta precipitated by high flows and turbidity were deemed "washouts" and were not believed to significantly contribute to subsequent salmon runs. However, the advent of technological advances in the late 1970s, allowing coded-wire tagging of fry-sized salmon with "1/2-sized tags", demonstrated that "washout" fry can contribute substantially to salmon runs. Nevertheless, fry survival in the Delta is less than survival from fry rearing in the upper Sacramento River, especially in wet years (Brandes and McLain 2001). Also, the survival rate of hatchery-tagged fry-sized salmon is less than that for the larger, later life phases of juvenile salmon. Based on a comparison of coded-wire tagging of fry-sized, smolt-sized, and yearling-sized fall-run Sacramento River Chinook salmon, Reisenbichler *et al.* (1981) found that survival increased (but at a decreasing rate) with larger fish sizes.

For those juvenile salmon sufficiently large enough to smolt and emigrate to salt water, the time of passage through San Francisco Bay is rapid; however, the rate of growth is slow compared to the growth rate upon first entry into the ocean (when growth increases) (MacFarland and Norton 2002). This slow pace of growth suggests that the priority of rearing of larger-sized salmon in the estuary may not be as important as previously believed. However, the rearing of fry-sized fish in the Delta remains vital but is most likely limited by loss of shallow-water rearing habitats.

Characteristics of juvenile steelhead rearing are considerably more complex than salmon. During the 1980s, the author conducted an extensive analysis of fish scales collected from *O. mykiss* throughout different regions of the Central Valley over a long time scale. The study was initiated after it was determined that a portion of juvenile steelhead released from Coleman National Fish Hatchery took up residency in the river instead of migrating to the ocean. Hundreds of scales were collected from a variety of locations in the Sacramento River basin, including DFG archives scales, and analyzed to determine life history characteristics. Growth features of rainbow trout and steelhead scales collected from Sacramento River tributaries, the upper and lower mainstem, and the Delta encompassing several decades were compared. It was found that a wide diversity in patterns existed. In particular, it was evident that fish migrating and rearing in different parts of the river system, including fish remaining in the upper river, fish that migrated to the lower river and Delta, and fish migrating to the ocean, had different growth rates. In summary, it was established that Sacramento River *O. mykiss* exhibited short, medium, and long migrations as a continuum, not simply two discreet migration phases as suggested by NMFS to justify the ESA listing of the species. That analysis of hundreds of scales indicated that there were at least three types of freshwater rearing characteristics for *O. mykiss*: fish that remained in the upper river system for their entire lives, fish that migrated to and reared in the ocean, and fish that migrated to and reared in the Delta prior to returning to the upper river system (D. Vogel, unpublished data). More recent analyses have also indicated that at least some steelhead rear in the Delta for extended periods (*e.g.*, months) (Foss 2005). Presently, USFWS personnel at Coleman National Fish Hatchery cannot accurately discriminate between resident and ocean-run *O. mykiss* in their broodstock selection program[12] (USFWS, unpublished information).

The loss of shallow-water rearing locales for salmon in the Delta has been severe (Cummins *et al.* 2008). The available habitats where USFWS personnel can seine in the Delta to monitor the relative abundance and distribution of rearing fish are limited due to the low presence of naturally occurring shallow water areas. In some instances, recreational swimming beaches and boat ramps have been used to sample fish because most areas are deep and rip-rapped. In studies where fish sampling to compare shallow beaches with rip-rapped zones was achieved, salmon fry densities were higher in shallow beach areas (McLain and Castillo 2009). An obvious restoration measure which should be pursued to a larger degree because of its high probability of success is the re-creation of shallow, near-shore water habitats that juvenile salmon prefer in the Delta (as contrasted to flooded islands described later in this report). Importantly, these sites must be designed to avoid creation of predatory fish habitats and be established in locations likely to be utilized within the principal fish migration corridors.

5.5.3.4 *Entrainment*

It has been commonly cited that there are approximately 1,800 unscreened diversions in the Delta that may cause significant fish losses (*e.g.*, Reynolds *et al.* 1990). More recently, Herren and Kawasaki (2001) counted the number of smaller diversions in the Delta at 2,200. Most of these are 12 to 24 inches in diameter, draw water two to three feet off the bottom, and are unscreened (Matica and Nobriga 2002, Nobriga *et al.* 2002). However, the fish losses at these diversions are primarily to non-salmonid species. Because of the nature and timing of diversion activities, there is no strong evidence that they measurably impact threatened or endangered anadromous salmonids. An exception is located near the western edge of the Delta in Suisun Marsh. This highly managed wetland relies on the operation of water diversion facilities which do operate when juvenile salmon are present. Furthermore, entrainment studies conducted in 1981 and 1982 confirmed that juvenile Chinook salmon were vulnerable to entrainment in Montezuma Slough through unscreened diversions (Wernette 1995). A fish screen was installed on DFG's diversion intake in Grizzly Slough just prior to 1995 (Wernette 1995) and several other diversions in the area have been similarly screened (Figure 38).

Although Delta irrigation diversions (principally non-export use of water in the Delta) are relatively large[13] (Figure 43), they are primarily operated during the summer months when environmental conditions are generally unfavorable for salmonids in the Delta. The timing of these diversions does not correspond well with the primary migration period of juvenile spring-

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[12] In 1988, the author initiated a USFWS steelhead broodstock selection program of using only sea-run fish based on scale analyses which DFG referred to as a "Blue Ribbon" steelhead strain but was since abandoned for unknown reasons [similar to a program conducted in the 1950s and also abandoned (Hallock 1989)].

[13] The peak summer diversions collectively exceed 4,000 cfs (DWR 1995).

run, late-fall-run, winter-run Chinook, and likely steelhead, in the Delta. However, during the spring months, a large portion of the non-ESA-listed fall-run juvenile population is in the region and some overlap in seasonal presence and agricultural operations can occur, particularly during drought years. However, overall, fish entrainment in the Delta is not considered to have been a major contributing cause to recent declines in the threatened or endangered anadromous salmonid populations because of poor correspondence between water diversions and the primary presence of the species. The effects of these diversions on juvenile green sturgeon are unknown.

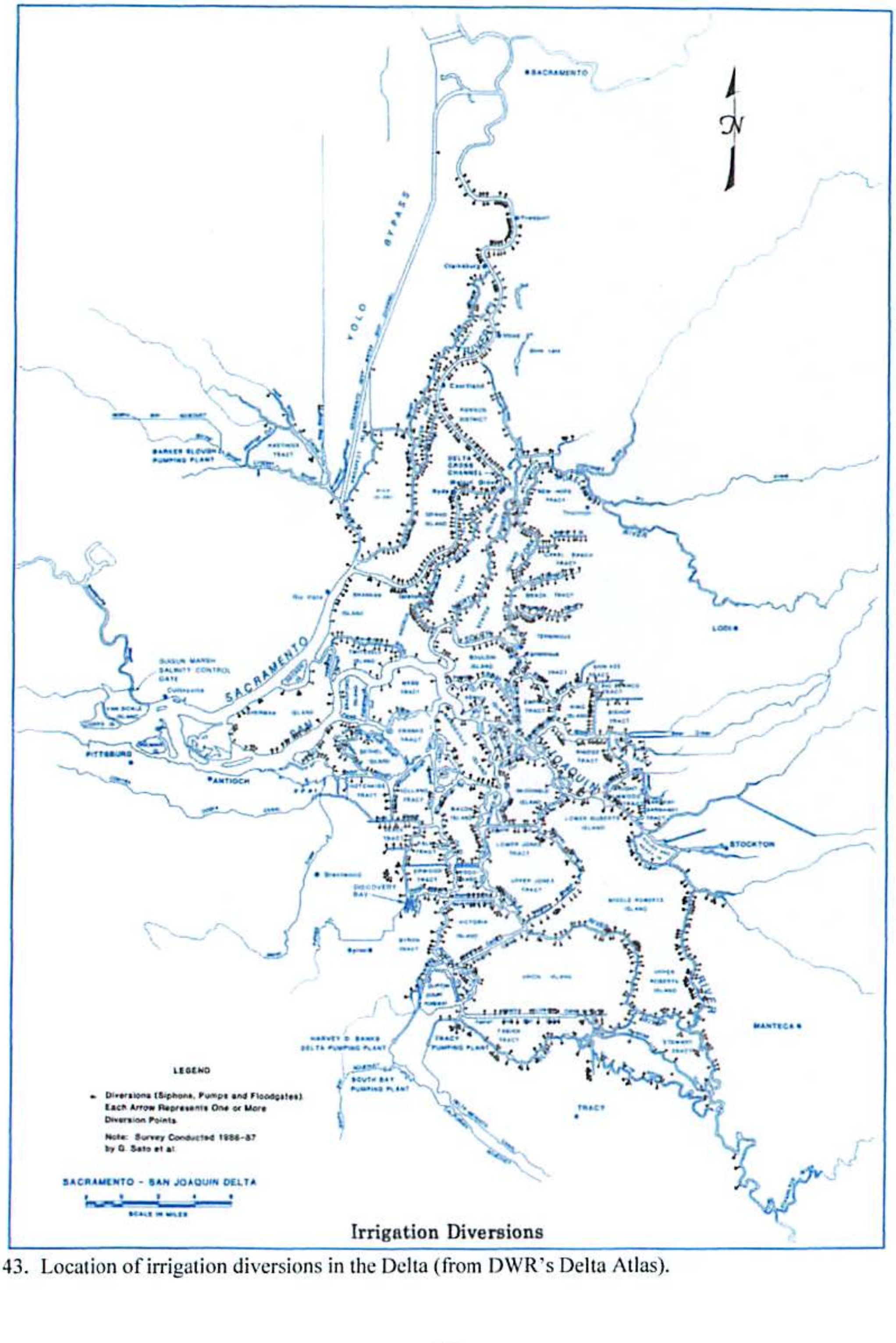

Figure 43. Location of irrigation diversions in the Delta (from DWR's Delta Atlas).

5.5.3.5 *Migration Routes*

The pathways used by outmigrating juvenile anadromous fish from the river and through the Delta are known to affect fish survival. Each of these migration routes possesses unique characteristics that could be beneficial or detrimental to the survival and growth of juvenile fish.

For example, fish originating in the upper Sacramento River may be entrained into one of five flood-control weirs upstream of the Delta: Moulton, Colusa, Tisdale, Fremont, and Sacramento (Figure 1). Depending on the timing and magnitude of the salmonid emigration, if high flows cause flood control weirs to crest, fish may be swept out of the main river channel and over or through Moulton, Colusa, or Tisdale weirs into the lower Butte sink. The lower Butte sink is a highly complex wetlands basin; flood flows ultimately re-enter the Sacramento River just upstream of the Feather River confluence. Additionally, under high-flow conditions fish can pass the Fremont or Sacramento weirs and enter the Yolo Bypass which empties into Cache Slough in the northern Delta. The overall biological significance of fish utilizing these routes is unknown and has been debated for many years. These routes may be highly beneficial to fish through enhanced growth rates in flood plains and higher survival through a variety of mechanisms or, alternatively, may subject the fish to significant losses through high levels of stranding and predation.

Utilization of juvenile salmon emigrating through Sacramento River bypasses such as the Yolo Bypass many enhance nursery habitat for juvenile salmon (Sommer *et al.* 2003). Data suggest that growth rates of juvenile salmon in the bypass are higher than those salmon remaining in the Sacramento River (Sommer *et al.* 2000), perhaps at least partially because of warmer water in the bypass than in the river (Sommer *et al.* 1998). A potential advantage of salmon utilizing the bypass for a migration corridor is reduced exposure time to mortality in the Delta from predation and water diversions (Sommer *et al.* 2000). Additionally, fish entering the Delta via the Yolo Bypass into Cache Slough are not exposed to undesirable migration routes further downstream at the DCC and Georgiana Slough (discussed below).

There is a risk that salmon can be trapped and perish in the flood bypasses when waters recede (Sommer *et al.* 1998, Sommer *et al.* 2000), and that these fish, possibly number in the hundreds of thousands, depending on various assumptions (Sommer *et al.* 1998). The stranding and loss of juvenile salmon in flood bypasses has been known for years. Quantification of fish fatalities in these areas has been difficult to determine. In 1996, five concrete ponds with a total surface area of one acre behind the Sacramento weir in the Sacramento bypass were seined to capture and remove fish. A limited effort over two days using a 50-ft long net captured about 11,000 juvenile Chinook salmon. These fish would have otherwise died. Although it would be difficult to extrapolate these results to the entire bypass, the sampling indicated that during periods when bypasses flood, large numbers of salmon may perish (IEP 1996). Fish losses in the flood bypasses are difficult to detect due to bird predation and other predatory fish which may reside in isolated stranding pools. Losses of fish entering into the Butte Sink have not been evaluated and would be considerably more difficult to assess, given the complexity of wetlands and waterways. Recent advances in technological tools (*e.g.*, acoustic telemetry) could potentially be used to estimate fish survival among the different migration routes through the various bypasses.

The flood bypasses have been in place for many decades, even pre-dating large dam construction. During this period, there have been both large and small runs of anadromous fish. There is nothing apparent in changes to flood bypass operations which would suggest these bypasses are a significant contributing factor to fish population declines. Studies are underway to determine if an increase of fish utilization of the bypasses would potentially benefit the populations. However, this must be tempered with the realization that fish stranding could pose major hazards if flows and flood channel topography for appropriate drainage are not carefully managed. For example, early season, short-term pulses of water into the bypasses may inadvertently trap large numbers of fish emigrating from the upper rivers during the first high flow, high turbidity events. A delay in the use of the bypasses, or sufficient duration of flows after such early events might help to ensure the vast majority of fish exit the bypass prior to flow recedence. However, without proper implementation, providing such flows would likely result in significant upstream reservoir drawdown, and a loss of carryover storage for temperature control (MBK 2010).

Downstream of the flood bypasses, there are five primary routes where juvenile anadromous fish enter the Delta: the mainstem Sacramento River, Sutter Slough, Steamboat Slough, Delta Cross Channel, and Georgiana Slough (Figure 44). The most-studied fish migration routes affecting survival have pertained to the DCC and Georgiana Slough in the north Delta (Figure 44). Studies using coded-wire tagged fry- and smolt-sized Chinook salmon have demonstrated that fish survival is lower in the central Delta relative to the north Delta. Generally, these studies and the conclusions were based on releasing paired groups of thousands of differently marked/tagged young salmon upstream and downstream of the flow splits and within the channels downstream of each flow split. Tagged salmon released in the Sacramento River upstream of the DCC and Georgiana Slough generally exhibit lower survival than tagged salmon released further downstream in the mainstem (Kjelson 1989).

Figure 44. Migration routes for juvenile anadromous fish entering the Delta.

Young salmon diverted into the central Delta via the DCC or Georgiana Slough have reduced survival compared to fish remaining in the Sacramento River downstream of those diversion points, not only in the spring, but also during the winter (Brandes and McLain 2001). The earliest salmon tagging studies conducted in the north Delta focused on fall-run Chinook which usually emigrate as smolts during April and May. The low survival of fall-run Chinook entrained into the central Delta has been well established and the causal mechanisms for mortality have been attributed to warm water temperatures and predation (Wullschleger 1994). Similar experiments using late-fall run Chinook, as surrogates for winter-run Chinook, both of which migrate through the Delta during winter months have also demonstrated lower survival when these fish are diverted into the central Delta (Wullschleger 1994).

Experiments conducted at the DCC during 2000, 2001, and 2002 using radio-tagged juvenile salmon indicated that fish entrainment into the DCC depends on site-specific flow conditions at the time juvenile salmon encounter the flow split (Vogel 2004). For example, during ebb tide conditions, fish released upstream of the DCC migrated past the DCC when flow in the DCC was minimal. Conversely, during flood tide conditions, fish released upstream of the DCC were swept into the DCC when flow was high entering into the Mokelumne River portion of the Delta. It was also determined that even when fish successfully passed the DCC during ebb tides and remained in the Sacramento River, the fish could be subsequently advected back upstream and into the DCC with subsequent flood tidal conditions (Figure 45).

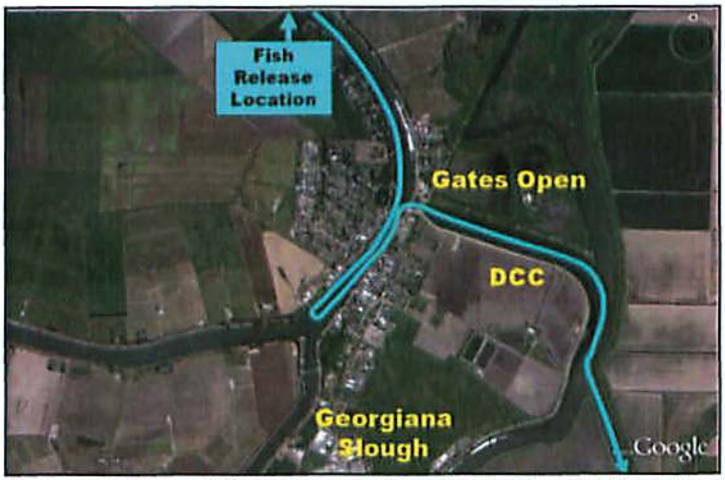

Figure 45. The lower Sacramento River at Walnut Grove with depicted pathway of juvenile salmon movements passing the DCC on an ebb tide then advected back upstream and into the DCC on a flood tide [based on juvenile salmon radio-tagging studies by Vogel (2000, 2001)].

As previously discussed, it has been commonly assumed that one of the primary reasons for the dramatic decline in winter-run Chinook was caused by the drought-induced reservoir drawdowns in 1976 and 1977 depleting much of the hypolimnion in Shasta Reservoir, which caused releases of warmer-than-suitable water into downstream areas, causing salmon egg mortality. However, the drought also resulted in no DCC gate closures during the period when the 1976 and 1977 progeny would have emigrated (Figure 46). This circumstance would have been expected to cause greater entrainment into the central Delta where mortality can be high and could have been a significant additional contributing cause for the poor fish returns from those brood years.

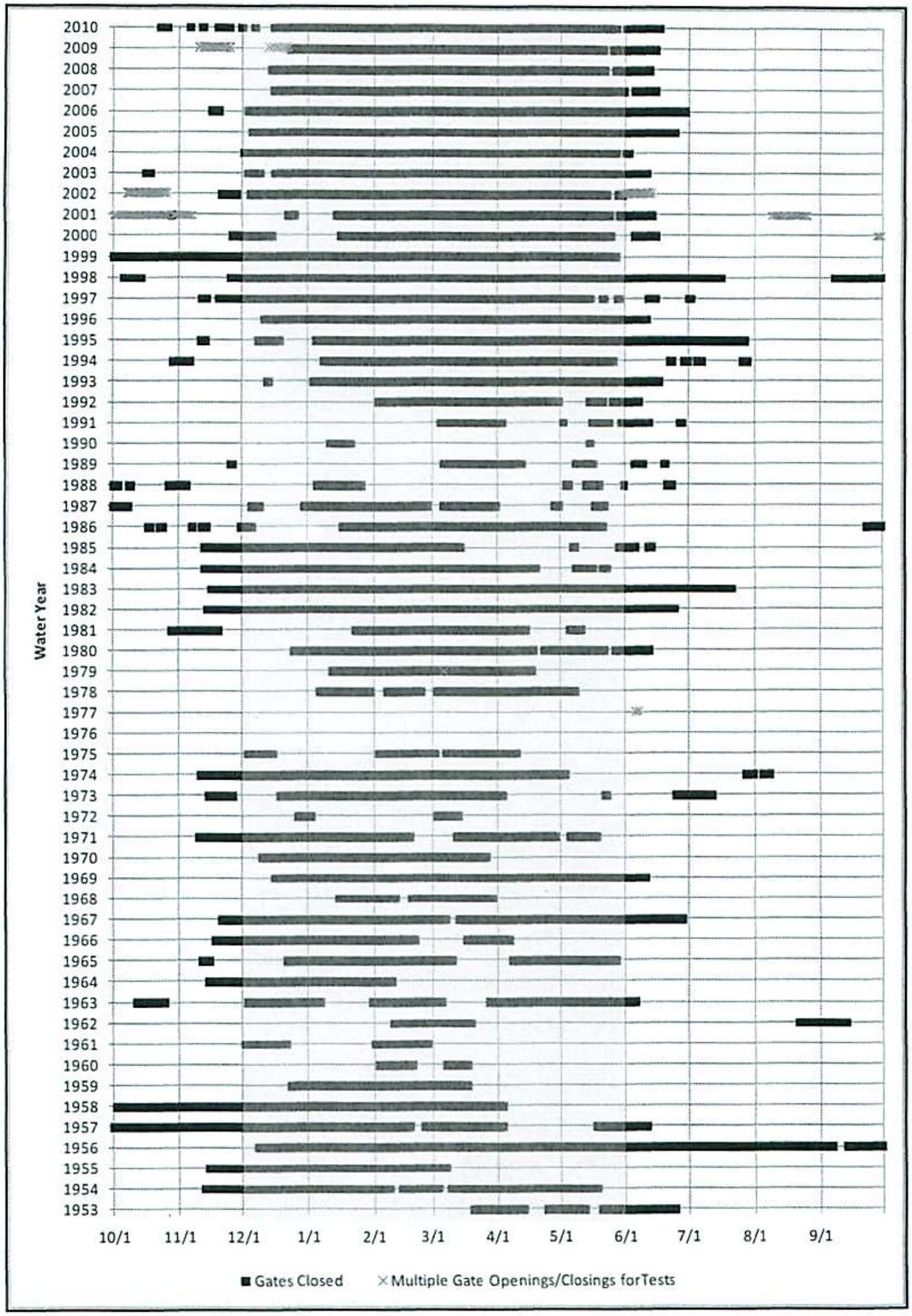

Figure 46. Historical operations of the DCC gates showing periods when the gates have been closed and the generalized primary presence of juvenile salmon (shaded).

Based on the historical record of DCC gate operations (Figure 46), it is evident that protection for native anadromous fish has increased in recent years due to much more frequent closures of the gates to minimize entrainment of fish into the central Delta where fish mortality is higher.

To date, no simple solution for operating the DCC for concurrent fish protection and water conveyance through the north Delta has emerged. As a result, complete closure of the DCC gates during portions of the fish migration period has been implemented. Since just prior to and after the listing of the winter-run Chinook as a threatened or endangered species, mandatory measures have been implemented to reduce fish entrainment at the DCC. The 1995 SWRCB Water Quality Control Plan provided for 45 days of DCC gate closure from November 1 through January 31; after January 31, the gates were closed until mid-May under the Winter Run Protection Plan (Chappell 2003). The more-recent NMFS Biological Opinion stipulates even greater closures of the DCC.

During SWRCB workshops in July 1994, the author testified as to the potential benefits of implementing a near- or real-time monitoring program to detect the emigration of juvenile salmon approaching the DCC. As far as the author's knowledge, this was the first formal recommendation on the topic. The rationale of such a program would be to implement protective fish measures such as closing the DCC gates prior to the arrival of large numbers of fish. Pilot testing of a real-time monitoring effort demonstrated its feasibility and is now a standardized program conducted every year. Sufficient data have been collected over the years which have resulted in criteria (*e.g.*, changes in flow, temperature, and turbidity) to predict the emigration of salmon from the upper river system to the Delta, and facilitate timing of the DCC gate closure periods (Chappell 2003). For example, the average catch of juvenile salmon in beach seines during the USFWS fish monitoring program in January through March is significantly positively related to flow measured at Freeport (Burmester 2001) providing empirical support to justify specific times of DCC gate closures.

Even when the DCC gates were closed, studies have demonstrated that the diversion of young salmon into Georgiana Slough negatively affects their survival (Brandes and McLain 2001). Once entering the Slough, fish are unlikely to re-emerge back into the Sacramento River because the Slough's flows generally do not reverse with tidal phase. A recent study conducted by releasing radio-tagged juvenile Chinook salmon in upper Georgiana Slough and in the lower Sacramento River downstream of Georgiana Slough found a higher rate of fish mortality in the former release location. The difference was attributed to nearly three times greater predation losses on radio-tagged salmon in Georgiana Slough compared to those fish migrating down the lower Sacramento River (Vogel 2004). Flow in Georgiana Slough is largely unidirectional and, unlike the DCC, fish may enter Georgiana Slough under both ebb and flood tide conditions (Figure 47).

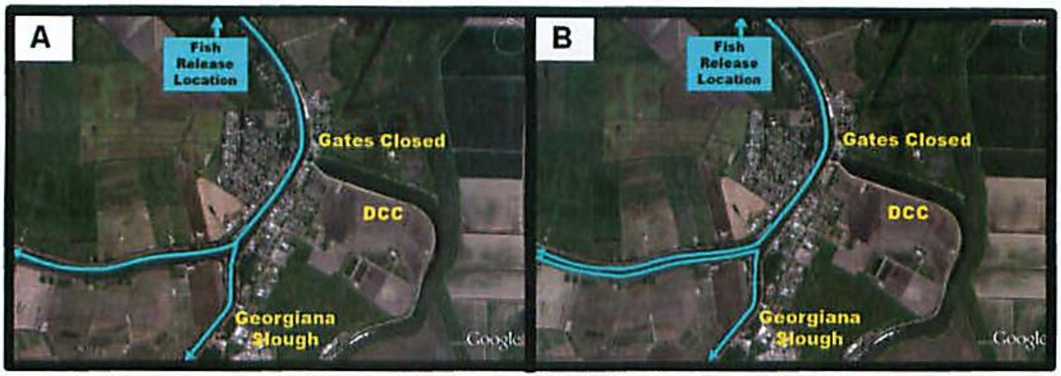

Figure 47. The lower Sacramento River at Walnut Grove with depicted pathway of juvenile salmon movements passing Georgiana Slough on: (A) an ebb tide and (B) an ebb tide then advected back upstream and into the Slough on a flood tide [based on radio-tagging studies by Vogel (2001)].

There are obviously numerous variations of fish movements at the DCC and Georgiana Slough flow splits depending on the magnitude of river flow and tidal phase. These studies showed the highly complex and continually changing hydrodynamic conditions and fish behavior at these flow splits.

Preventing or minimizing fish entrainment into Georgiana Slough is problematic because, unlike the DCC, there are no physical structures at the location to alter flow conditions. However, there have been attempts to reduce fish entrainment into Georgiana Slough using behavioral barriers when the DCC gates are closed. In 1993 and 1994, an acoustic fish behavioral barrier was tested to determine if juvenile salmon could be deterred from entry into the slough (IEP 1995). The results of this measure were mixed. For example, during high flow conditions in 1996, the study at the barrier indicated that juvenile salmon were not deterred away from Georgiana Slough and extensive damage to the mooring system and cables was caused by the high flows (Coulston 1997). DWR is testing a new fish behavioral barrier at the flow split in early spring of 2011 using a combination of lights, bubbles, and sound. Even if the device shows some measure of success, the typical conditions present during high fish migration under elevated, turbid flows will likely diminish its effectiveness as compared to low, clear-water conditions. This fish migration route remains a problem with no clear solution in sight.

Research using both coded-wire tagged salmon and acoustic-tagged salmon has also focused on potential effects of fish utilizing Sutter and Steamboat Sloughs just upstream of the DCC and Georgiana Slough. It has been hypothesized that fish migrating through these sloughs may exhibit higher survival that those fish exposed to the DCC and Georgiana Slough by avoiding entrainment into the Central Delta where survival is lower. Studies using coded-wire tagged fish have shown that juvenile salmon utilizing Steamboat or Sutter Sloughs generally exhibit higher survival than fish exposed to the DCC and Georgiana Slough (Kjelson 1989). More-recent research in the north Delta (Figure 48) found that acoustic-tagged juvenile salmon were diverted into Sutter and Steamboat sloughs in relatively high proportions both when the DCC gates were opened and closed (26% and 37%, respectively) (Figure 49) (Vogel 2008c). When the DCC gates are closed, there is a decrease in net flows in the Sacramento River just upstream of the DCC which results in increased flow into Sutter and Steamboat Sloughs (Oltmann 1995). This may be favorable for fish survival, but it has not yet been empirically confirmed. However, further downstream, fish exposed to the Georgiana Slough flow split entered the Slough in a higher proportion than when the DCC gates were opened (Figure 49).

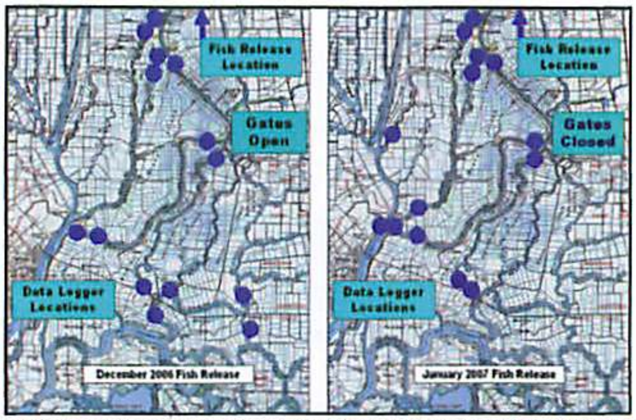

Figure 48. Approximate locations of acoustic receivers positioned in the Delta reaches downstream of acoustic-tagged juvenile salmon released during December 2006 and January 2007 in the Sacramento River at West Sacramento with the DCC gates open and closed, respectively (from Vogel 2008c).

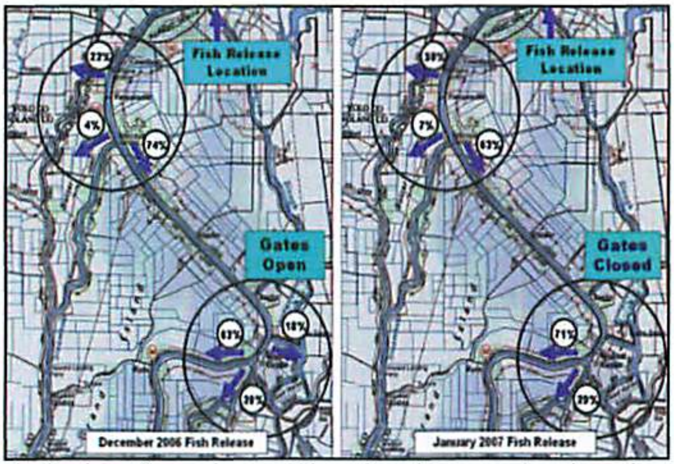

Figure 49. Proportional distribution of acoustic-tagged juvenile salmon entering channels at flow splits near the Sutter/Steamboat Slough region and the DCC/Georgiana Slough region in December 2006 when the DCC gates were open and January 2007 when the DCC gates were closed (from Vogel 2008c).

Compounding the problem of evaluating anadromous fish movements in the Delta is the inability to accurately quantify fish survival within the complex, multi-channel tidal environment. A recent attempt by USGS to quantify fish survival in the Delta by releasing acoustic tagged fish in the north Delta and recording their movements at strategically-placed dataloggers in downstream channels has not yet been completed. However, numerous concerns with the experimental design of the USGS study were expressed by a CALFED Science Review Panel (Monismith *et al.* 2008, as cited by Larry Walker Associates 2010). Additionally and unfortunately, more-recent research has clearly demonstrated that the accuracy and precision of survival estimates of acoustic-tagged salmon are highly prone to error and misinterpretation because tagged salmon consumed by predatory fish and subsequently detected on the dataloggers can, in many instances, be misconstrued as a live salmon (Vogel 2010a). Worse, if invalid salmon survival estimates were used for management decisions in the Delta, inappropriate measures could be implemented and considerable time, resources, and fish could be lost. Until methods or technologies are developed to differentiate between live tagged salmon and tagged salmon eaten by predators, such survival studies will be prone to misinterpretation and error.

After Sacramento River juvenile salmon enter the central Delta either through the DCC or Georgiana Slough, the mechanisms by which salmon subsequently enter the south Delta remain perplexing. For example, experiments conducted by releasing radio-tagged salmon in the South Fork of the Mokelumne River showed that fish can enter the mainstem San Joaquin River, but be subsequently advected back upstream in the mainstem and enter channels such as Middle River south of the mainstem (Figure 50) (Vogel 2010a).

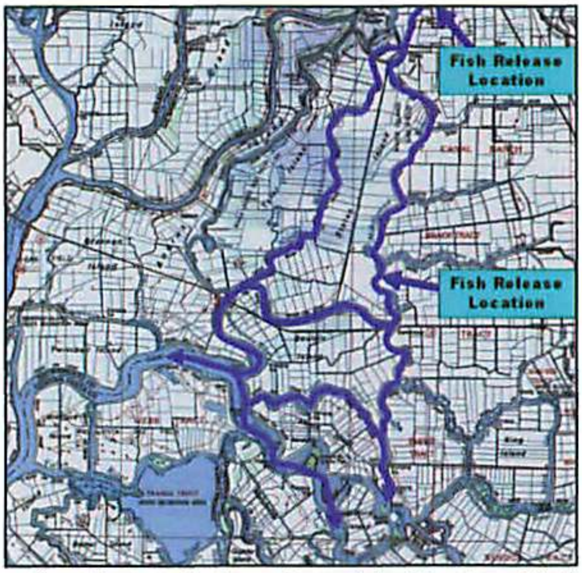

Figure 50. Migration pathways for radio-tagged salmon observed for fish released in the lower Mokelumne River in the north Delta (Vogel 2010a).

Fish emerging from the north Delta, but subsequently moving to the south Delta must traverse across the mainstem San Joaquin. The maximum tidal flow exhibited in the San Joaquin at Jersey Point during ebb and flood is about 150,000 cfs (Oltmann 1995), so it is surprising fish can enter south Delta channels. Even during wet year conditions, tagging studies demonstrated that a significant fraction of juvenile salmon entrained into the central Delta via Georgiana Slough subsequently enter the south Delta (Winternitz *et al.* 1995). Juvenile steelhead have also been documented to move from the north to south Delta (Foss 2005). This southerly movement of fish off the San Joaquin River into the south Delta has also been empirically confirmed for fish released in the San Joaquin upstream of flow splits into the south Delta (Figure 51). In one instance, a radio-tagged salmon released in the mainstem San Joaquin River downstream of Stockton was later recaptured live at the south Delta Tracy Fish Facilities (Vogel 2002).

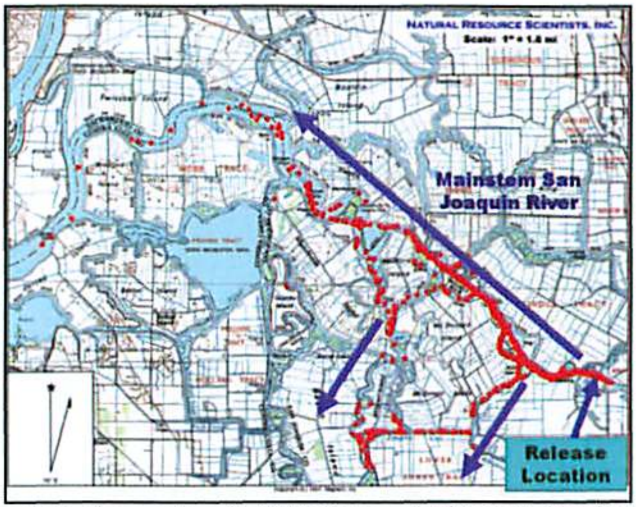

Figure 51. Telemetered locations of approximately 100 radio-tagged salmon smolts released in the lower San Joaquin River near 14-Mile Slough (data from Vogel 2002).

For those fish present in south Delta channels in close proximity to the south Delta export facilities, southerly fish movement (as compared to northerly movement leading to salt water) has been empirically confirmed. For example, radio-tagged juvenile salmon released in northern Old River north of Clifton Court Forebay showed strong southerly movements directly into the Forebay. These occurrences were evident under both medium and low water export conditions (Figure 52) (Vogel 2002).

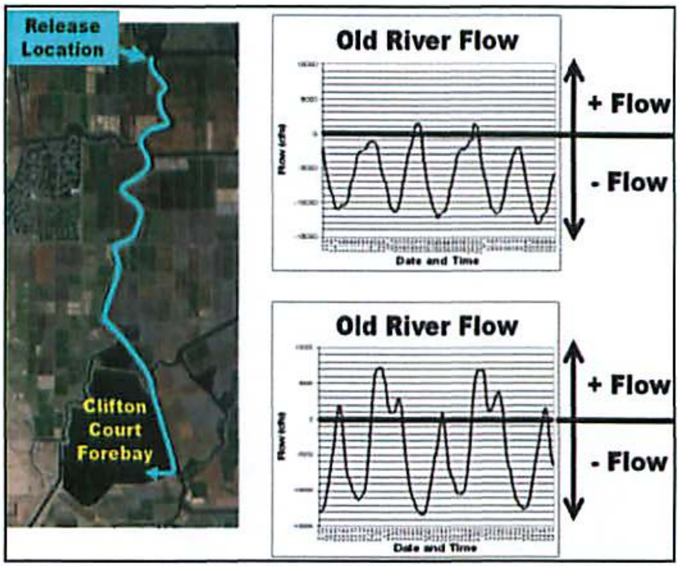

Figure 52. Typical migration pathway for radio-tagged Chinook salmon smolts released in northern Old River during medium- and low-level south Delta water exports (data from Vogel 2002).

The increase in south Delta water exports corresponds with the period when significant declines of anadromous fish occurred. Reverse flows, entrainment of fish into the pumping facilities, and increased predation at water facilities have been believed to be problems for salmon for a long time (Reynolds *et al.* 1993). Additionally, operations of the CVP and SWP have been believed to have had a detrimental effect on steelhead smolts emigrating through the Delta (Reynolds *et al.* 1993). The consensus of California steelhead experts in the late 1970s attributed the overall decline in steelhead to the significant increases in south Delta exports (Vogel 1984). Recently, Lindley *et al.* (2009) suggest that "*... the biggest problem with the state and federal water projects is not that they kill fish at the pumping facilities, but that by engineering the whole system to deliver water from the north of the state to the south while preventing flooding, salmon habitat has been greatly simplified.*" Effects of south Delta exports on green sturgeon are largely unknown.

Prior to 1966 and during the earlier era of the CVP (pre-San Luis Reservoir), CVP south Delta exports were concentrated in the spring, summer, and early fall, with only minor exports in the late fall and winter. More specifically, the seasonal Delta export pattern was a peak in summer and a low in winter (Figure 53). The timeframe of this pattern was when the populations of the anadromous salmonids were large. After the mid-1960s when the SWP and San Luis Reservoir facilities began operation, the south Delta exports continued year-round with more reliance on winter-spring diversion after San Luis Reservoir operation; this era corresponds to the period when the populations of anadromous salmonids experienced a precipitous decline. More recently, total annual exports from the Delta increased from a maximum of about 5 million acre-feet (MAF) in the late 1990s to about 6 MAF after 2000 (EPA 2011).

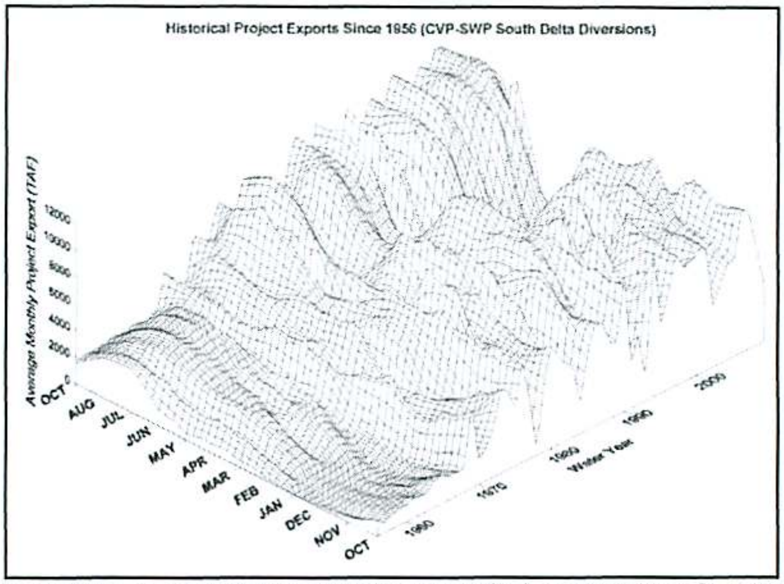

Figure 53. Historical south Delta exports (SWP and CVP combined) since 1956 (data from DWR DAYFLOW).

5.5.3.6 *Predation*

Predation of anadromous fish has emerged as one of the hypothesized primary sources of mortality in the Delta. Although over 200 exotic species have been introduced into the estuary and the rate of invasion is apparently increasing (Cohen 1997), the greatest probable impact to native anadromous fish would be expected from only several introduced predatory species (*e.g.*, striped bass and largemouth bass). Beginning in 1992, DFG ceased stocking juvenile striped bass in the Delta due to concerns of impacts on winter-run Chinook salmon (IEP 1992). Nevertheless, the population of sub-adult and adult striped bass capable of preying on native juvenile anadromous fish remains large. DFG introduced the Florida strain of largemouth bass into the Delta in the early 1980s and the sport fishery for largemouth bass has become increasingly popular during recent decades (Lee 2000). Amazingly, given all the focus on anadromous fish protection and enormous expenditures in upstream areas, predation mortality in the Delta has received little attention in the form of remedial actions. For many years most of the attention has focused on predation in the south Delta, keying in on the two large water export facilities, but little or no corrective actions have been implemented.

Clifton Court Forebay (CCF), in the south Delta (Figure 1), is a 2,200 acre reservoir, located just upstream of the SWP Banks Pumping Plant. Large radial gates are usually opened during high tide to flood the Forebay, then closed, to facilitate pumping at the SWP. Fish entrained into CCF but not reaching the fish salvage facilities upstream of the pumping plant are called "pre-screen losses" which have been measured through juvenile salmon studies at about 75% mortality (IEP 1993) and have ranged from 63% to 97% (Schaffter 1978, Hall 1980, Kano 1985, Kano 1986, as cited by Kano 1990). Gingras (1997) summarized the results of 10 DFG studies on pre-screen fish losses conducted from 1976 through 1993 which ranged from 63% to 99%. Since the late 1970s, DFG has been studying this pre-screen loss and attributes the fish mortality to predation, primarily by striped bass (Coulston 1993), which are the primary predator in the Forebay (IEP 1993). Recent studies using acoustic-tagged juvenile salmon have also confirmed extremely high predation rates in the Forebay, also believed to be attributable to striped bass (Vogel 2010b).

Apparently, numerous studies of predators in CCF have been conducted, but little action has transpired to control the predators or alleviate the site-specific problem (other than federal Biological Opinion measures controlling water exports). In 1984 and 1985, striped bass movements inside CCF were monitored and it was demonstrated that the fish can exit the Forebay into the Delta (IEP 1992). It was subsequently confirmed through additional large-scale tagging studies that striped bass move in and out of the Forebay (IEP 1993). In 1991, DWR contracted with a commercial fisherman to seine CCF as a potential measure to control predatory fish populations; that effort netted numerous striped bass (IEP 1991). In 1992, 2,000 predators were removed from CCF and relocated elsewhere in the Delta; population estimates associated with that effort indicated the population of striped bass was about 150,000 fish inhabiting the Forebay (Coulston 1993). A subsequent, similar predator removal project ending in 1993 removed more than 32,000 predators (including nearly 29,000 striped bass) and the striped bass population estimate grew to about 200,000 fish (Coulston 1993). Additional research at CCF in 1994 and 1996 provided strong evidence that emigration and immigration of sub-adult and adult striped bass frequently occurs when the gates are open which would significantly hamper predator control efforts in the Forebay (Gingras and McGee 1996, McGee and Gingras 1996).

Because of the concern about predation in CCF, a workshop was held in 1993 to discuss options to reduce predatory fish in the Forebay. The principal options examined included an increase in recreational fishing opportunities and an aggressive, non-lethal removal and relocation program. Interestingly, two of the primary reasons posed for not pursuing these actions were largely policy related. Water exporters were concerned that predator removal would result in increased numbers of salmon reaching the fish salvage facilities and would penalize exports due to a perceived increase in "take" of winter-run Chinook (unless a relaxation in the NMFS pre-screen loss estimates for winter-run Chinook was initiated). Conversely, recreational fishing interests were opposed to predator removal because of their concern that increased water exports would take place, resulting in greater indirect losses of salmon (Coulston 1993).

Recent studies using acoustic-tagged juvenile salmon and acoustic-tagged striped bass also empirically demonstrated the severe predation problem in Clifton Court Forebay. Specifically, the small area immediately behind the CCF gates was shown to harbor striped bass for extended periods (Vogel 2010b, 2010c) and mortality was severe when salmon passed under the gates (Figure 54) and were eaten by predators (Vogel 2010b). This very small isolated area undoubtedly causes the highest mortality for anadromous fish reaching the south Delta. This predator haven has been, and will continue to be, severe without corrective measures.

Figure 54. Clifton Court Forebay showing turbulence behind the radial gates. Photo by Dave Vogel.

Predation mortality at the Tracy Fish Facilities (TFF) (Figure 55) is also an extremely serious problem for anadromous fish and has been known for a long time. These issues are well-described in a recent peer review of CVPIA restoration program activities, which was highly critical of the lack of significant efforts to correct the problem:

> *"... the operation of the Tracy Pumping Plant and Fish Collection Facility is a serious mortality source for salmon and steelhead (and for Delta smelt). All aspects of the pump operations have significant adverse impacts on salmon and steelhead, from the way juveniles are drawn to the pumps and away from the natural migration routes out through the Delta, to predation and other mortality factors in the channels leading to the pumps, to high mortalities at the out-dated louvers screening the pumps, to even higher mortalities likely during the archaic "salvage" collection and transport operation at the pumps, to predation mortality at the point of re-release, and finally to the overall adverse effects on salmon survival and productivity from regulating and diverting that much of the natural Delta outflow. Data on direct and indirect juvenile mortality is uncertain but likely to be high, and may run as high as 50% for spring-run Chinook and steelhead, and possibly 75% for winter-run Chinook."* Cummins *et al.* 2008.

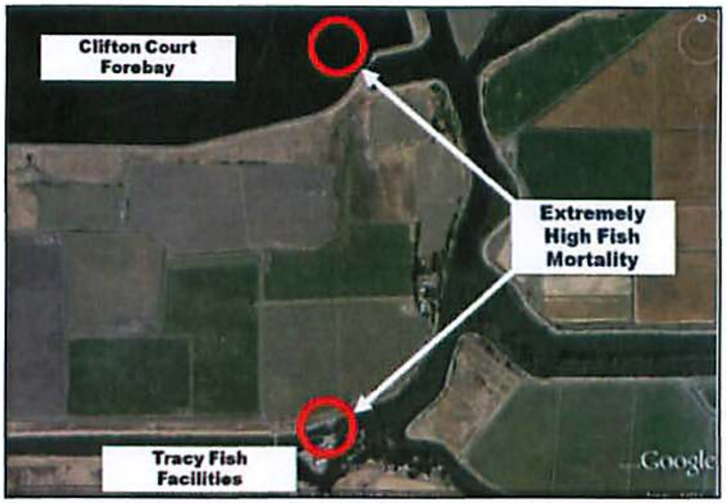

Figure 55. Location of extremely high mortality of acoustic-tagged juvenile salmon at the Clifton Court Forebay gates and in front of the Tracy Fish Facilities (from Vogel 2010b).

Recent studies using acoustic-tagged juvenile salmon found that fish mortality near the TFF may be much higher. For example, in 2007, mortality of tagged salmon in front of the facilities was estimated at 100% and no tagged salmon successfully reached the downstream fish salvage facilities (D. Vogel, unpub. data). Detailed analyses of recorded acoustic "signatures" from data loggers at the site determined that predators just upstream and downstream of the trashracks in front of the TFF (Figure 56) had consumed the tagged salmon. The magnitude of striped bass accumulation in the area was demonstrated in 1991 when the USBR removed 1,925 striped bass from the TFF (IEP 1992). USBR periodically removes striped bass from the area between the trashrack and fish louvers (Figure 57).

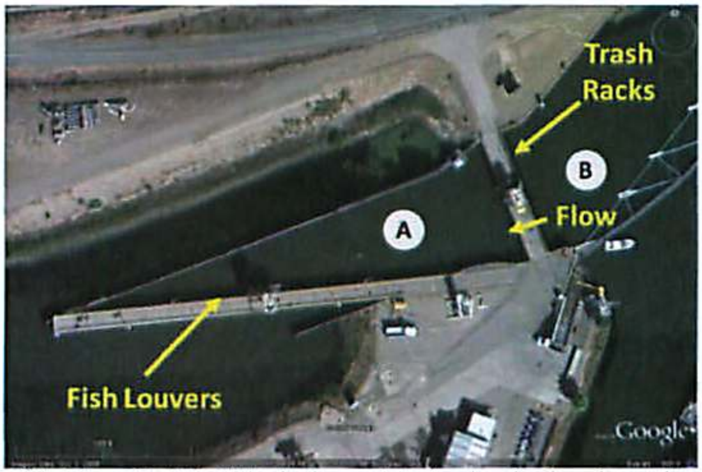

Figure 56. Aerial view of the Tracy Fish Facilities in the south Delta showing locations where high predation mortality occurs (A) between the trashracks and the trashrack and (B) in front of the trashracks.

Figure 57. Removing striped bass (seven in picture) by gill netting behind the trashracks and in front of the fish louvers at the Tracy Fish Facilities. Photo by Dave Vogel.

Until the site-specific predation issues are resolved at CCF and TFF, mortality of juvenile salmonids reaching the south Delta will continue to be significant.

Predation in the Delta (outside of CCF and TFF). Over the past 15 years, this author has become extensively familiar with the primary waterways in the Delta where juvenile anadromous fish may be present and the associated habitats. Most of this familiarity was derived from conducting more than 20 telemetry studies on both juvenile salmon (Figure 58) and predatory fish in the Delta [including wide-ranging mobile telemetry surveys tracking fish throughout the region (Figure 59)]. Additionally, numerous surveys at a variety of sites in the Delta were conducted using a Dual-Frequency Identification Sonar (DIDSON^{TM}) camera which is capable of underwater viewing and recordation of fish and structures over long distances in turbid water (Figure 60). During the course of these studies, numerous observations and findings relevant to this report were made and are discussed here.

Figure 58. Radio-tagged and acoustic-tagged salmon smolts used in Delta telemetry studies (photos by Dave Vogel).

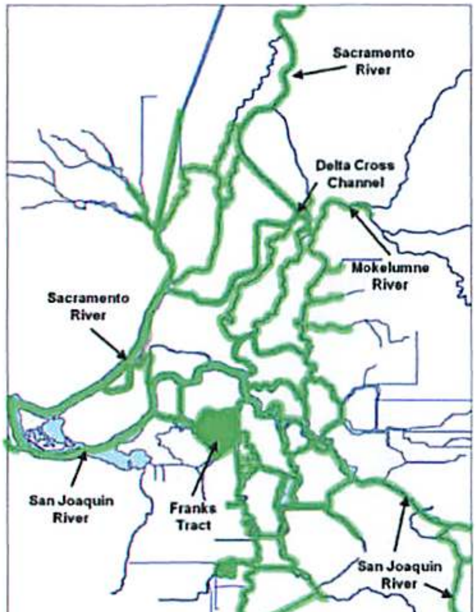

Figure 59. Map of the Sacramento – San Joaquin Delta showing areas (shaded in green) the author has frequently traversed by boat during radio and acoustic fish telemetry studies within the past 15 years.

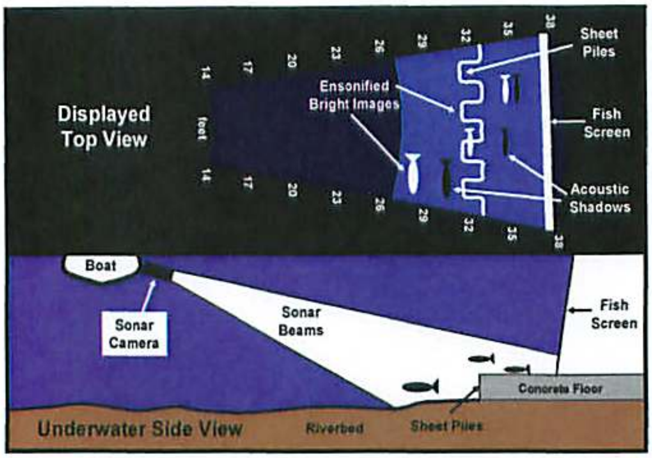

Figure 60. Schematics of DIDSON^{TM} imaging at the base of a flat-plate fish screen. Bottom diagram shows orientation of sonar beams from the acoustic camera off the side of a boat and submerged objects at the fish screens. Top diagram shows the resultant corresponding sonar imaging of objects ensonified with acoustic shadows from the objects. (from Vogel 2008b)

From 1996 through 2010, Natural Resource Scientists, Inc. conducted 22 separate research projects on juvenile salmon (including four studies of predatory fish) in the Delta using acoustic or radio telemetry as a means to gain an improved understanding of fish movements and mortality (Vogel 2010a). The reason juvenile salmon telemetry studies were initiated in the Delta was to acquire detailed data on fish behavior, fish route selection through complex channels, and estimate fish survival in discrete reaches. Past efforts using traditional coded-wire tagging could not answer those critically important questions. Research findings from the telemetry investigations indicate that smolt survival assumptions and models must incorporate these new conclusions to avoid misinterpretation of data and improve quantitative estimates of fish survival and movements (Vogel 2010a).

The first successful use of telemetry on juvenile salmon in the Central Valley was conducted by Natural Resource Scientists, Inc. on behalf of EBMUD in 1996 and 1997. At that time, the specific behavior of juvenile salmon in the Delta was largely unknown. The initial studies quickly determined that the fish did not move as a school, but instead, dispersed, exhibiting a wide range in migratory behaviors in the complex Delta environment. Salmon moved many miles back and forth each day with the ebb and flood tides and the side channels (where flow was minimal) were largely unused. Site-specific hydrodynamic conditions present at flow splits when the fish arrived had a major affect in initial route selection. Importantly, some of the salmon were believed to have been preyed upon based on very unusual behavior patterns (Vogel 2010a).

Subsequent, additional juvenile salmon telemetry studies were conducted by Natural Resource Scientists Inc. on behalf of the USFWS and CALFED in the north Delta (Vogel 2001, Vogel 2004). Triangulating radio-tagged fish locations in real time (Figure 61) clearly demonstrated how juvenile salmon move long distances with the tides and were advected into regions with very large tidal prisms, such as upstream into Cache Slough and into the flooded Prospect and Liberty Islands (Figure 62). During the studies, it was determined that some radio-tagged salmon were eaten by predatory fish in northern Cache Slough, near the levee breaches into flooded islands (discussed below). Also, monitoring telemetered fish revealed that higher predation occurred in Georgiana Slough as compared to the lower Sacramento River (Figure 63). As discussed previously, past coded-wire tagging studies found that salmon released into northern Georgiana Slough were found to have a higher mortality rate than fish released downstream of the slough in the Sacramento River (Brandes and McLain 2001).

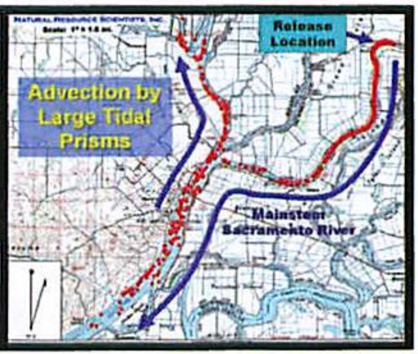

Figure 61. Left picture, mobile telemetry conducted in the north Delta. Photo by Dave Vogel.
Figure 62. Right picture, telemetered locations of approximately 100 radio-tagged salmon smolts released in the lower Sacramento River near Ryde (data from Vogel 2001 and Vogel 2004).

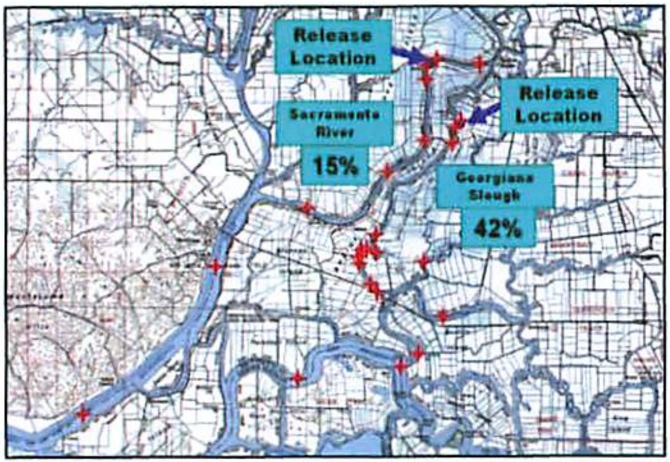

Figure 63. Estimated mortality rate for groups of radio-tagged salmon released at two locations in the north Delta and locations where radio-tagged salmon smolts were detected to have been preyed upon (Vogel 2001, Vogel 2004).

More recently, a 2007 study conducted by releasing acoustic-tagged juvenile salmon in the San Joaquin River found 116 motionless juvenile salmon transmitters in the lower San Joaquin River near the Stockton Waste Water Treatment Plant and a nearby bridge (Figure 64) (Vogel 2007b). This was an all-time record for the largest number of dead radio- or acoustic-telemetered juvenile salmon verified at one location. The cause of death of these fish, which were released far upstream and at different times and locations, was never established. Representatives of the Central Valley Regional Water Quality Control Board attributed the mortality to "a predation event" near the bridge. Although numerous bridges are positioned within many Delta channels where anadromous fish migrate, the magnitude of mortality at the Stockton site has never been observed elsewhere among more than a dozen fish telemetry studies. The finding amply demonstrated that fish mortality in the Delta can be high at very localized areas ("hot spots"[14]).

Figure 64. Location of 116 motionless juvenile salmon acoustic transmitters found in the lower San Joaquin River in 2007 (Vogel 2007).

A similar study conducted in 2009 found 173 acoustic transmitters from dead juvenile salmon believed to have been preyed upon (Figure 65). Often, the transmitters were located in sharp channel bends, deep scour holes, and near pump station structures (Figure 66) (Vogel 2010b).

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[14] One of the most significant early findings from the telemetry studies was the determination of locations of where high salmon mortality had occurred, a location the author had termed "hot spots" many years ago during science symposia on Delta research programs. The term has become popular in recent documents (e.g., BDCP). Prior studies over the past several decades, because of design and technology limitations, were unable to determine these problem areas in the Delta.

Figure 65. Left picture, locations of 173 acoustic tags detected in 2009 believed to be dead acoustic-tagged salmon or tags defecated by predatory fish (Vogel 2010b).

Figure 66. Right picture, locations of acoustic tags (showing designated transmitter codes) detected in the lower Joaquin River in 2009 believed to be dead acoustic-tagged salmon or tags defecated by predatory fish (Vogel 2010b).

As demonstrated by mobile telemetry studies (some discussed above), predation on juvenile anadromous fish is unlikely to be uniform throughout the Delta, and instead, is likely to be concentrated in limited areas where unique site-specific conditions favor predation. The following are just several examples where predation on salmon may be an ongoing concern and warrant close examination.

A large pipe partially buried in the riverbed perpendicularly across the river channel adjacent to the Freeport Waste Water Treatment Plant outfall in the Sacramento River (Figure 67) (Freeport Pipeline) appears to provide favorable conditions for predatory fish. This particular area is highly popular with sport fishermen who are frequently seen anchoring and fishing at the site. DIDSON™ sonar camera footage and angling at the pipeline revealed that the fish species at the time of the survey were striped bass and white catfish: Predatory Fish Near Freeport Pipeline Depending on seasonal timing, downstream migrating juvenile anadromous fish near the riverbed at this location would be expected to be highly prone to predation.

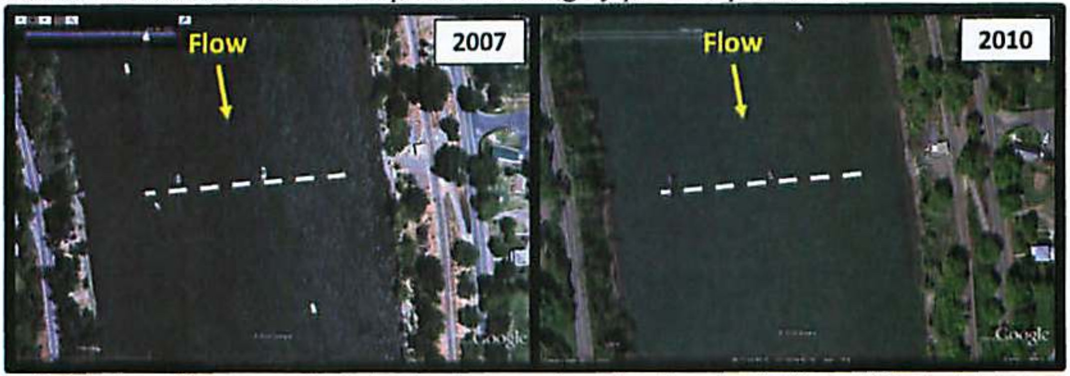

Figure 67. The lower Sacramento River showing the approximate location of a pipeline partially buried on top of the riverbed (dotted line). Sport anglers commonly anchor and fish at the site.

Although fish entrainment at in-Delta diversions may not be a significant problem for anadromous fish (previously discussed), the structures positioned year-round in flowing water in reaches where juvenile fish migrate could pose significant hazards during non-irrigation seasons. Predatory fish such as striped bass, largemouth bass, and white catfish are known to often be present near these water diversion facilities (*e.g.*, Striped Bass near Delta Ag. Diversion). Also, numerous agricultural drains (Figure 68) may similarly attract high concentrations of predatory fish particularly when water is discharged off of agricultural lands into the Delta (*e.g.*, Striped Bass near Delta Ag. Drain). Individually, the predation impacts in the vicinity of these in-channel structures could be low, but remain unquantified. Cumulatively, given the large number of artificial structures attracting predators within fish migration pathways, the adverse effects could be large.

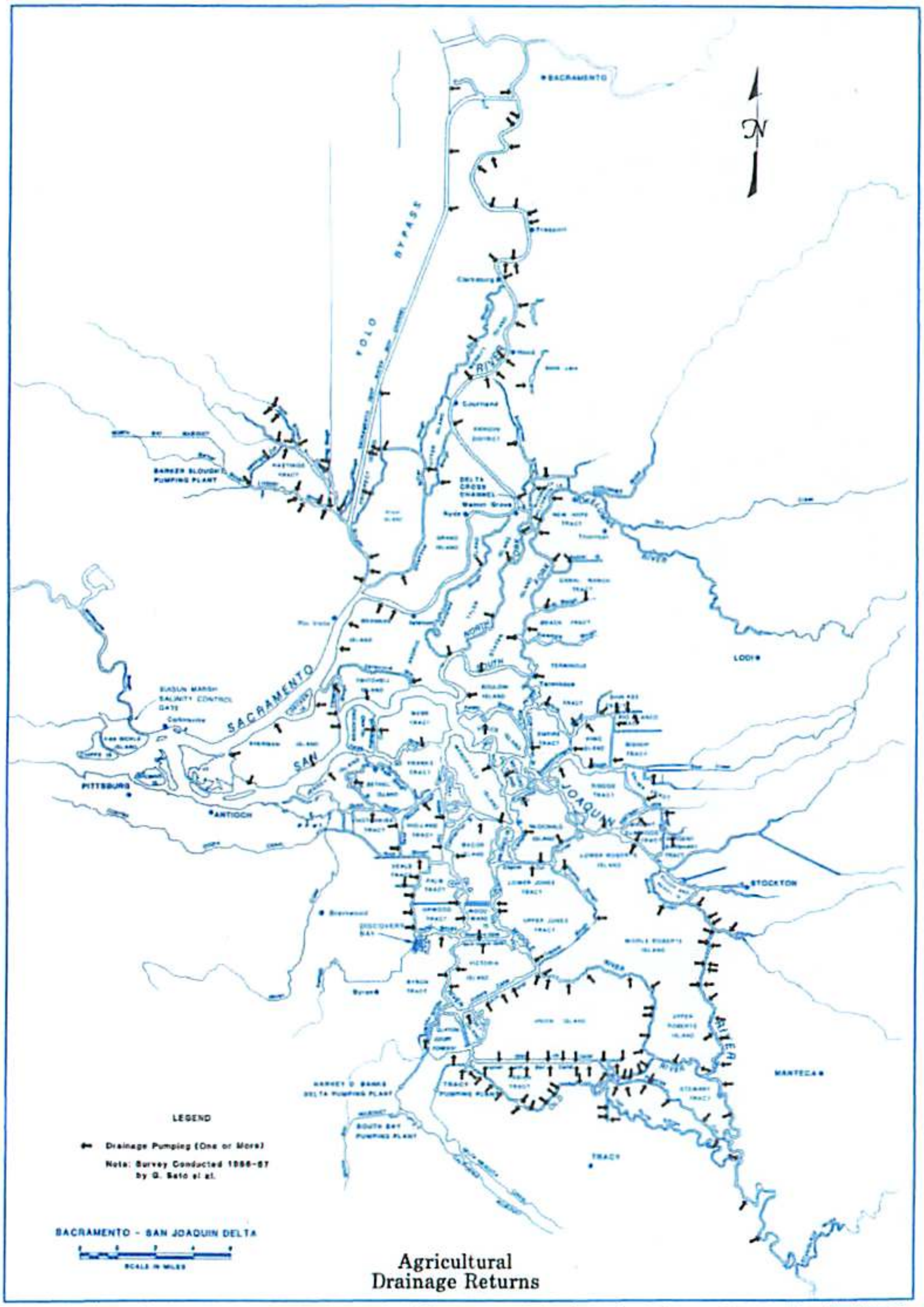

Figure 68. Location of irrigation drains in the Delta (from DWR's Delta Atlas) (not to be confused with Figure 43).

Installation of new boat docks and marinas in the Delta has not been adequately studied to quantify potential increased predator concentrations (*e.g.*, largemouth bass). The overall impact of these facilities on juvenile anadromous fish migrating through the area is unknown. Surprisingly, the relevance of the issue has not been evaluated even though it is generally assumed that predatory fish can be concentrated in those areas. Construction of boat docks and marinas within flowing water where salmon must migrate creates ideal conditions for predation. Invariably, marina structures require vertical posts driven in the channel bed with supporting overhead structure (*e.g.*, docks, shade canopies, etc.). The potential problem may be particularly acute when the marina and dock structures are positioned over a considerable portion of the cross-sectional profile of the river channel where many salmon must transit. Large quantities of water move under these structures and juvenile anadromous fish moving with the flow under the structures are exposed to conditions considered as favorable predatory fish habitat. An added problem for the salmon in the Delta at these structures is created when tidal seiching may cause exposure to the predatory fish habitats not just once, but perhaps several times, as the fish move back and forth with the tides (*e.g.*, Figures 69 and 70). Similarly, numerous bridges across Delta waterways are known to attract predatory fish.

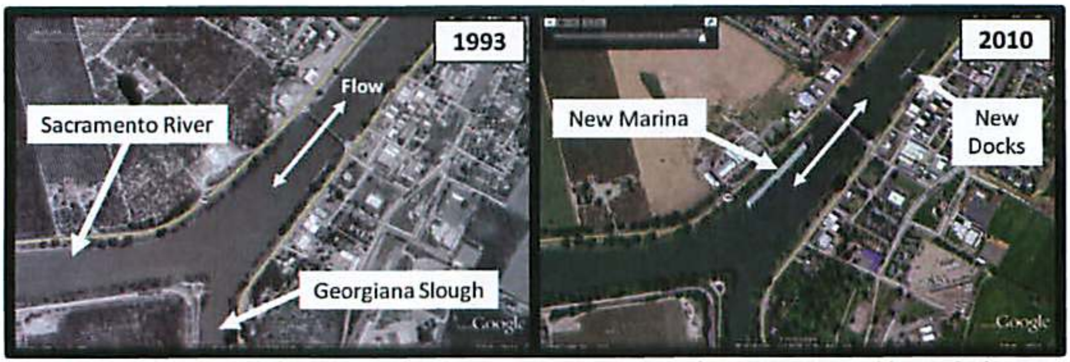

Figure 69. Lower Sacramento River at Walnut Grove showing locations of a new marina and boats docks.

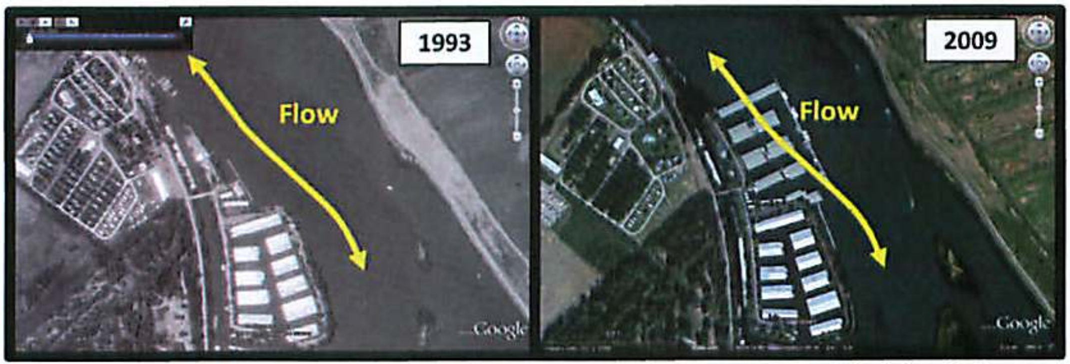

Figure 70. Aerial photos of the lower Mokelumne River before and after new marina and dock installations.

In the north Delta, the lower Sacramento River near Sacramento also possesses numerous boating and waterway structures positioned within the cross-sectional area of the channel where juvenile fish may migrate. Figure 71 shows some examples.

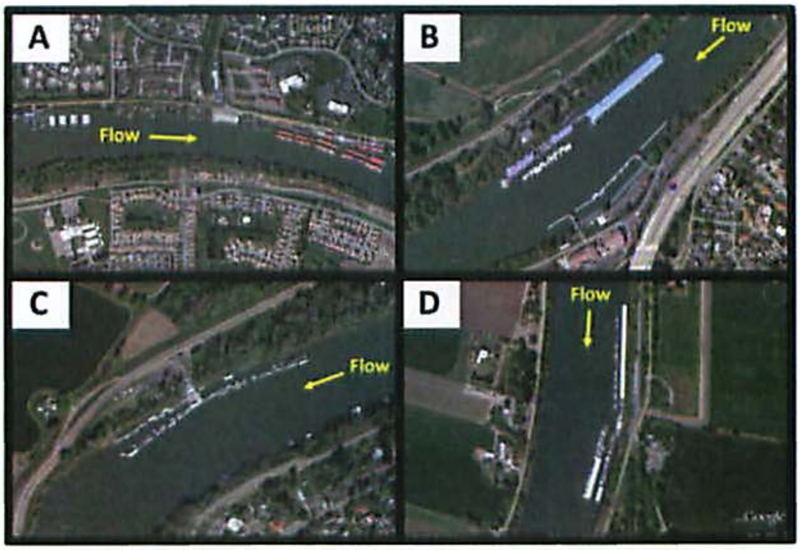

Figure 71. Boating and waterway facilities on the lower Sacramento River: (A) Just upstream of Sacramento; (B) just downstream of Sacramento; (C) downstream of Sacramento; and (D) near Freeport.

A variable which may affect predation on juvenile salmon in the lower river and Delta is water clarity. The feeding success of sight predators such as striped bass and largemouth bass (the latter being a Centrarchid fish species) is expected to be higher in clearer water conditions compared to turbid water. In recent decades, there has been an increase in water clarity in the Delta (DWR 1996, as cited by Grimaldo and Hymanson 1999). Turner (1996), as cited by Shaffter (1998), reported the relatively small size of centrarchids in the Delta was likely due to the high turbidity in the region. During the 1980s, largemouth bass growth rates in the Delta were the slowest among low-elevation bass populations in California (Shaffter (1998). These conditions have now changed. Due to changes in land-use practices and water development, there was a rapid decline in sediment loads to the Delta during the first half of the 20th century followed by a gradual steady decline in the last half of the century (Shvidchenko *et al.* 2004). Data collected on suspended sediment in the lower Sacramento River near Sacramento and Freeport since 1960 has shown a downward trend (Oltmann 1996), with the exception of high flow years in 1996 – 1997 (Oltmann, *et al.* 1999). Suspended sediment and water clarity are strongly inversely correlated and the decline in suspended sediment entering the north Delta suggests that water clarity, over time, has increased.

Additionally, increased water clarity is also believed to be attributable to the introduction of the non-native Brazilian water weed (*Egeria densa*) in the Delta. Water clarity is higher in stands of *Egeria*, which is the dominant submerged vegetation in central Delta shallow waters, as compared to nearby shallow areas without vegetation (Grimaldo and Hymanson 1999). Nobriga *et al.* (2003) noted a positive correlation between higher densities of submerged aquatic vegetation at some sites in the Delta and water clarity. Increased water clarity for sight predators such as black bass and striped bass would presumably favor predatory fish over prey (*e.g.*, juvenile salmon). Fewer native fish species are found in *Egeria* stands compared to introduced fish species (Grimaldo and Hymanson 1999). Additionally, it has been hypothesized that high densities of *Egeria* in portions of the Delta may restrict juvenile salmon access to preferred habitats, forcing salmon to inhabit deep water or channel areas where predation risks may be higher (Grimaldo *et al.* 2000).

During recent years, there has been an emphasis to reclaim or create shallow, tidal wetlands to assist in re-recreating the form and function of ecosystem processes in the Delta with the intent of benefitting native fish species (Simenstad *et al.* 1999). Among a variety of measures to create such wetlands, Delta island levees either have been breached purposefully or have remained unrepaired so the islands became flooded. A recent example is the flooding of Prospect Island which was implemented under the auspices of creating shallow water habitat to benefit native fish species such as anadromous fish (Christophel *et al.* 1999). Initial fish sampling of the habitat created in Prospect Island suggested the expected benefits may not have been realized due to an apparent dominance of non-native fish (Christophel *et al.* 1999). Importantly, a marked reduction of sediment load to the Delta in the past century (Shvidchenko *et al.* 2004) has implications in the long-term viability of natural conversion of deep water habitats on flooded Delta islands into shallow, tidal wetlands. The very low rates of sediment accretion on flooded Delta islands indicate it would take many years to convert the present-day habitats to intertidal elevations which has potentially serious implications for fish restoration (Nobriga and Chotkowski (2000) due to likely favorable conditions for non-salmonid fish species that can prey on juvenile salmon. Studies of the shallow water habitats at flooded Delta islands showed that striped bass and largemouth bass represented 88 percent of the individuals among 20 fish species sampled (Nobriga *et al.* 2003).

There have likely been significant adverse, unintended consequences of breaching levees in the Delta. There is a high probability that site-specific conditions at the breaches have resulted in hazards for juvenile anadromous fish through the creation of favorable predator habitats. The breaches have changed the tidal prisms in the Delta and can change the degree in which juvenile fish are advected back and forth with the tides (Figure 61; previously discussed). Additionally, many of the breaches were narrow which have created deep scour holes favoring predatory fish. Sport anglers are often seen fishing at these sites during flood or ebb tides. Breaching the levees at Liberty Island is an example (Figure 72 and 73). Recent acoustic-tagging of striped bass in this vicinity confirmed a high presence of striped bass (Figure 74, D. Vogel, unpub. data).

Figure 72. Liberty Island in the north Delta before and after flooding.

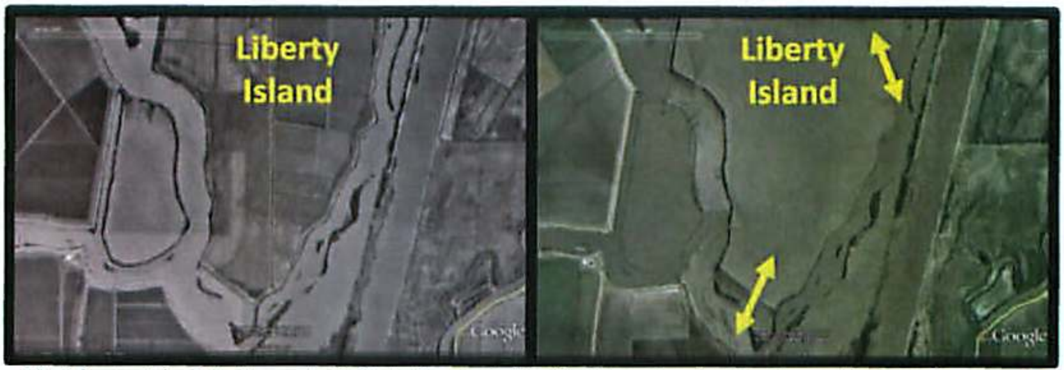

Figure 73. Liberty Island in the north Delta before and after flooding showing locations of narrow breaches in the levee.

Figure 74. Locations (squares) where predatory striped bass were acoustic-tagged with transmitters during the winter of 2008 – 2009 in the north Delta near Liberty Island (D. Vogel, unpublished data).

Another example is Mildred Island, flooded many years ago (Figure 75). The levee breach at the north-east portion of the island has created a very deep scour hole known to harbor large numbers of fish. Another example is in False River where the author has frequently caught striped bass (Figure 76). Additionally, artificially created scour holes within Delta channels can create ideal habitats for predatory fish (*e.g.*, Scour Hole) Many other examples are present in the Delta.

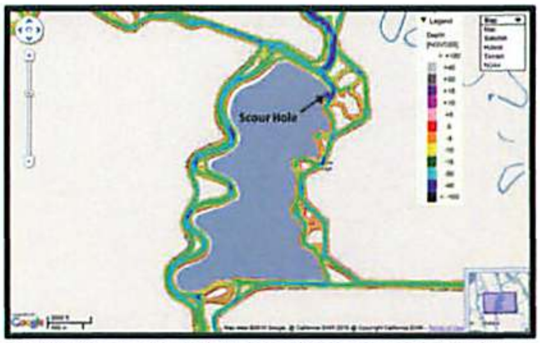

Figure 75. Mildred Island (flooded) in the central Delta showing location of a deep scour hole. Adapted and modified from dsm2bathymetry.

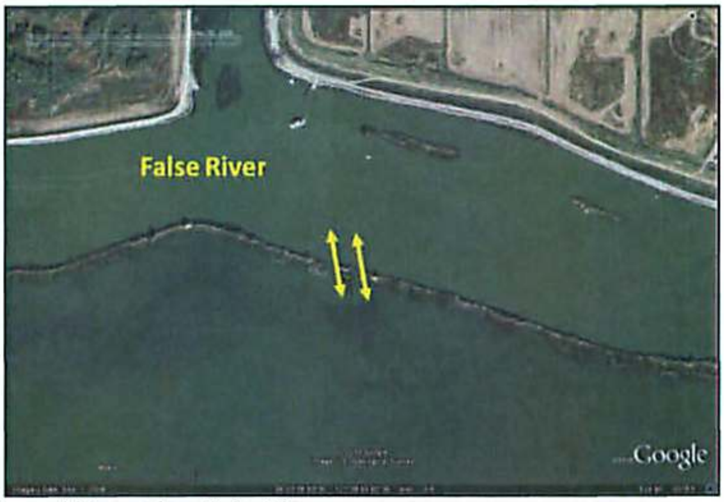

Figure 76. Breaches in an old levee along False River.

Many of these levee breaches have been present for numerous years, but nevertheless still pose significant hazards for juvenile anadromous fish.

Fish produced in the upper watersheds have survived all the density-dependent and density-independent mortality factors at earlier stages in the life cycle (*i.e.*, egg incubation, fry and juvenile rearing, outmigration from the upper rivers and streams) and must ultimately migrate through the channels in the Delta. As compared to the earlier life phases, the fish reaching the Delta are the least numerous. The impacts of these sites in the Delta have never been evaluated but, cumulatively, the predation mortality could, and likely does, have a major adverse impact on juvenile anadromous fish.

5.5.4 Conclusions on Fry and Juvenile Outmigration

- Factors such as unscreened diversions, predation, Delta water exports and others have been cited over decades as having been major problems for fish but each of those factors have evolved in various degrees, in some cases dramatically, up to the present day in terms of positive or negative importance to fish survival.

- Although riverine diversions were identified as a major problem for salmonids before and after large dam construction, the site-specific effects were more significant for fall-run Chinook than other anadromous salmonids. This is attributable to the fact that the timing and location of diversions in relation to the seasonal presence of juveniles on their rearing grounds and outmigration timing do not coincide well for most anadromous salmonids.

- The majority of water diverted from the Sacramento River and its tributaries have now been screened to prevent fish entrainment. The cost of recently completed screens and screens soon-to-be completed is nearly $574,000,000. The maximum flow screened by these diversions is nearly 13,000 cfs. A program is currently underway to determine the highest priority remaining sites where entrainment could be a problem.

- The construction and historical operations of RBDD strongly correlates to the timing of fish population declines. Historically, prior to the present practice of raising the RBDD gates during the non-irrigation season, the location, timing, and magnitude of impacts of RBDD on anadromous fish coincided with the presence of the majority of anadromous fish.

- The high entrainment of juvenile fish into the Tehama-Colusa Canal and Corning Canals was resolved with the installation of the angled, rotary drum screens in 1990.

- Year-round removal of the RBDD gates in 2012 is anticipated to solve the remaining fish passage problems.

- The declines in spring-run Chinook in tributaries downstream of RBDD suggest that there are factors other than RBDD also causing major impacts on some fish populations.

- Increased flows could benefit outmigrant anadromous fish, depending on timing, magnitude, and duration, but those specific thresholds necessary to provide increased survival for anadromous fish have yet to be determined.

- There is the high risk that improper increased flows such as recommended by SWRCB (2010) and DFG (2010) under the auspices of improving fish outmigration in the Delta could severely adversely impact cold-water storage in upstream reservoirs critically necessary for reproduction of some anadromous fish.

- The causal effects of flow/survival relationships have been difficult to determine because of complex inter-relationships with numerous variables associated with flow. Little progress has been made on parsing out the various and most important factors related to flow that may influence fish survival.

- Past and present studies solely oriented toward estimating "global" fish mortality in the Delta under limited environmental test conditions are not leading to solutions. Furthermore, conditions in the Delta are changing so rapidly, that the traditional native anadromous fish studies that have been, and continue to be conducted are unlikely to yield information relevant years later.

- The timing and magnitude of CVP/SWP exports during recent years corresponds to the seasonal presence of the majority of juvenile anadromous fish in the Delta. Additionally, the annual increase in south Delta exports since the mid-1960s corresponds with the significant decline of some anadromous fish populations.

- The CVP/SWP impacts on fish may be very high, particularly when compared to other factors described in this report. However, the mechanisms of how south Delta exports affect fish migrating through the north Delta remain perplexing. The adverse impacts may be attributable to inferior rearing habitats in the Delta and the potentially severe indirect effects resulting from predation.

- With some exceptions in upstream areas, the greatest opportunities for increasing populations of anadromous fish remain in the Delta.

- Overall, predation is likely the highest source of mortality to anadromous fish in the Delta. Despite well-known problems of predation in the Delta at a variety of locations for many years, very little progress (in many instances, no progress) has been made on ameliorating those problems. Ironically, some measures implemented in the Delta under the auspices of improving fish habitats have likely increased predation of anadromous fish. The best available evidence indicates that the predation problems have gotten worse, not better, during recent decades.

- Despite the enormous, unprecedented actions to improve fish production in the upper watersheds, there has been remarkable lack of focus or progress to increase shallow-water rearing habitats and fix the serious predation mortality in the Delta, through which all fish must migrate. Until significant progress is made on correcting these in-Delta problems, it is likely that many of the benefits of upstream actions will continue to be negated in the Delta.

5.6 Ocean Rearing

5.6.1 Food Supply

Conditions in the ocean can affect the abundance of salmon due to effects on the food base during the ocean-rearing life phase. Between years, ocean conditions related to El Niños affect salmon in the California ocean current and changing ocean conditions appear to exert a strong effect on salmon populations. This circumstance is usually the primary source of unexplained variability in research on salmon in freshwater (Botsford 2002). Longer-term cyclical inter-annual warming and cooling trends in ocean conditions (Pacific Decadal Oscillation[15]) has occurred during the past century (Figure 77). Warmer or cooler ocean conditions off the northern California coast can be detrimental or beneficial, respectively, to the abundance of salmon food organisms.

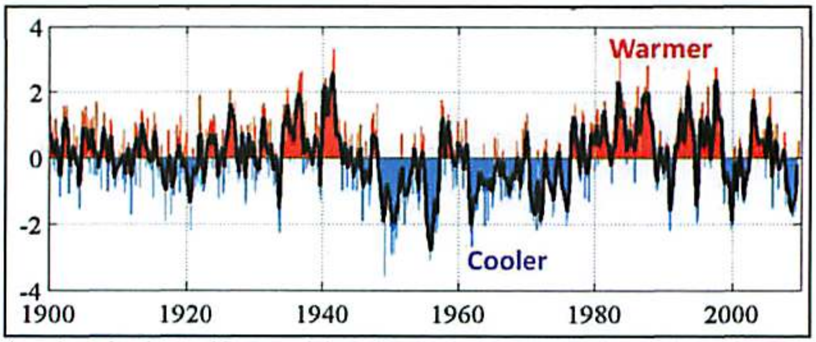

Figure 77. Monthly values for the Pacific Decadal Oscillation index: 1900 – September 2009 (from jisao.washington.edu)

One of the most robust and recent analyses of the potential profound effects of ocean food supply for salmon were conducted by Lindley *et al.* (2009). These authors provide a detailed account of the causal reasons for the poor production resulting from the 2004 and 2005 brood years of Sacramento River fall-run Chinook. They believed that anomalous ocean conditions in 2005 and 2006 were the primary factors contributing to the poor survival. Specifically, as young fish from those brood years entered the ocean, conditions exhibited weak upwelling, warm sea temperatures, and low densities of prey (Lindley *et al.* 2009).

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[15] *"The 'Pacific Decadal Oscillation' (PDO) is a long-lived El Niño-like pattern of Pacific climate variability. "The PDO Index is defined as the leading principal component of North Pacific monthly sea surface temperature variability." "Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States"* (source: jisao.washington.edu)

5.6.2 Predation

Predation on adult anadromous fish during the ocean rearing phase is a stressor that was previously not believed to be a significant factor affecting the species. However, more recent research on the topic indicates that predation on salmon can be significant, particularly by sea lions. Empirical evidence of the impacts has been difficult to obtain due to the difficulty in obtaining direct observations (Scordino 2010), although ocean sport anglers commonly complain about reeling in heads of salmon which had been eaten by sea lions after the fish are hooked. However, those instances may be attributable to hooked fish being more vulnerable to predation by sea lions. In 1999, Congress appropriated approximately $750,000 annually from 1998 to 2005 to study the impacts of California sea lions and Pacific harbor seals on salmonids and West Coast ecosystems. During that time, over 150 studies were performed to determine the impact of pinniped predation on salmonids in west coast rivers, estuaries and open water regions. After compiling the results, Scordino (2010) determined that pinnipeds (*e.g.*, Pacific harbor seals and California sea lions) can adversely affect the recovery of ESA-listed salmonid populations. Furthermore, "*In most areas, it appears that as adult salmon migrate into an area, some of the pinnipeds in that area will alter their foraging behavior to target salmonids.*" Some areas near northern California salmon ocean rearing grounds are known to harbor large concentrations of sea lions (*e.g.*, Figure 78). The population of California sea lions has increased dramatically since the 1970s (Scordino 2010). As recently as the fall of 2009, more than 1,500 sea lions were observed concentrated in San Francisco Bay[16] near where anadromous fish migrate and high numbers are commonly seen at Pier 39 in San Francisco Bay which is a popular tourist attraction (Figure 78). The problem of high predation on salmon by sea lions is obvious.

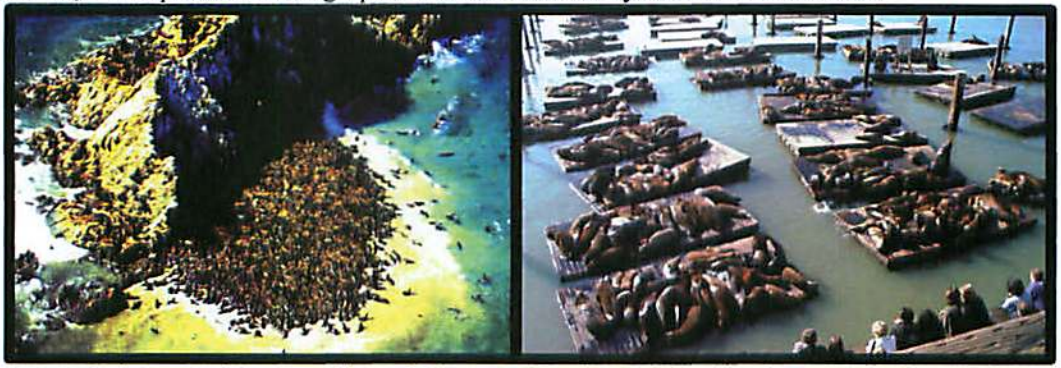

Figure 78. Left picture: California sea lions off the coast of northern California. Photo provided by Charles Ciancio. Right picture: sea lions on docks at Pier 39 in San Francisco Bay. Photo by David Ball.

5.6.3 Harvest

As discussed earlier, the impacts of overharvest on northern California salmon stocks have been recognized for many decades, even pre-dating large dam construction. As described by DFG (1998), freshwater sport, ocean sport and commercial fishing for salmon are highly regulated to

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[16] Source: wordpress.com

protect fish for eventual return to the spawning grounds. The intent of fishery managers is to allow harvest of surplus fish while ensuring sufficient numbers escape in order to reproduce and continue a healthy propagation of the species. Ocean sport fishing and commercial regulations impose a variety of restrictions to limit overharvest, including in some instances, total prohibition on harvest. Fishing is closed in all marine protected areas. With limited entry restrictions, the number of commercial vessels declined from nearly 6,000 in 1982 to approximately 1,800 in 1999 (Boydstun (2001). Because of extremely depressed salmon runs, all ocean fishing was closed during several recent years. Prior to that time, the commercial fishery harvested about two-thirds of Chinook salmon off the coast of California. Commercial catches averaged 407,700 salmon during 1995 – 1999 compared to a sport harvest of 200,000 fish (Boydstun 2001). In 2010, with projections of improved salmon runs, ocean salmon sport fishing was open April 3rd to April 30th seven days per week. From May 1st through September 6th fishing was open Thursday through Monday only. The limit was two salmon per day (CFGC 2010c). The laws for commercial salmon fishing are not described here but, similar to freshwater regulations, they are also intended to allow harvest of surplus fish while ensuring sufficient numbers of returning spawners. However, because of the difficulty in calculating the numbers of fish in the ocean, over estimates can lead to overharvest, which has happened in the recent past (Lindley *et al.* 2009). Also, ocean harvest cannot discriminate between depressed and surplus stocks nor between endangered and non-endangered salmon runs. For example, DFG believes that the ocean fisheries may have had a significant impact on spring-run Chinook (DFG 1998). Research is underway to benefit future fish populations by developing new techniques to discern the differences between stocks.

Barbed hooks were used in the commercial troll fishery up until the 1980s. During that time, high numbers of "hook-scarred" salmon (*e.g.*, Figure 79) were noted passing through the fish ladders at RBDD. Hooked-scarred salmon are those which have received visible physical damage from being hooked by anglers and volitionally or non-volitionally released. Notably, USFWS SCUBA divers working inside the concrete pools of the RBDD ladders during the 1980s found large numbers of stainless-steel barbed hooks in the base of the ladders (D. Vogel, pers. observation). These hooks undoubtedly originated from salmon hooked in the ocean that escaped to return to the upper Sacramento River. The flow inside the fish ladders was the first high velocity water encountered by the returning salmon which broke the hooks loose from their mouths. By law, commercial fishermen must release sub-legal sized salmon even if the fish are wounded. It was believed that significant numbers of salmon were historically mortally wounded due to the difficulty in disengaging barbed hooks from the fish's mouth. These fish were termed "shakers" and the consequence of fish dying from physical damage from release was termed "shaker mortality". The level of shaker mortality prior to the ban in the 1980s on barbed hooks is unknown, but the ban undoubtedly reduced that mortality. However, in the present day, there remains a concern that the stress imposed by releasing sub-legal fish in the ocean fishery, even with barbless hooks, can cause a significant degree of mortality. Recently DFG estimated that hooking mortality of released salmon is about 30 percent in the commercial fishery and less than 24 percent in the sport fishery (Boydstun 2001).

Figure 79. Adult spring-run Chinook at the bottom of a deep pool in upper Mill Creek. Note the large hook scar under the eye. Picture taken prior to the ban on the use of barbed hooks in the ocean fishery. Underwater photo by Dave Vogel.

Besides the obvious direct effects of harvesting salmon and the resultant reduction of adult fish "escaping" back to freshwater spawning grounds, ocean harvest can also affect the age structure and fecundity of salmon stocks. This important adverse impact is commonly overlooked in fishery management and restoration plans. It has been documented that the age structure and population fecundity of west coast salmon stocks have declined from historical levels. This is believed to be primarily attributable to ocean fishing cropping off the older age groups because of their extended exposure to the fishery as compared to younger age groups. Scientific literature dealing with Chinook salmon produced in the Sacramento River basin shows that the average age of all mature stocks has decreased by 0.2 to 1 year from approximately the mid-1940s to the early 1970s. Fish maturing at age 5+ years historically were not uncommon (Ricker 1972). A 1948 U.S. Department of the Interior (USDOI) document states:

> "*Approximately 50 percent of the Sacramento-San Joaquin salmon return from the sea as adult salmon to spawn during their fourth year. The remainder return, in decreasing order of abundance, as five-year fish, three-year fish, and two-year fish.*" (USDOI 1948)

Even earlier, Clark (1929) reported that six-year-old fish were more abundant than two-year old salmon. This historical age structure represents a markedly different pattern from present-day Central Valley salmon stocks. DFG reported that, based on recoveries of coded-wire tagged salmon in the ocean fisheries during the late 1970s to early 1990s, the majority of fish caught were three-year-old fish, followed by two-year-old fish. The composition of four- and five-year-old fish in the sport and commercial catch was less than 10% (DFG 1998).

Ricker (1972) proposes two possible causes for explaining the decline in age of mature Chinook salmon:

1) *Trollers catch some Chinook salmon that would not have matured in the year that they were caught, as opposed to gill nets and seines that are used to capture salmon almost*

exclusively during periods of spawning and capture almost exclusively mature fish. Fish maturing at age 3+ years are exposed to an additional year of harvest as opposed to those that mature at age 2+ years; subsequently, older fish become more scarce.

2) *The selection for larger (older) fish by fishing trollers may be changing the genetic structure of the salmon stocks to favor those that mature at a younger age.*

The net result of the ocean fisheries' impact on the age structure of Chinook salmon populations is a decrease in the number of larger, older fish. The ocean fishery crops off the older age groups because Chinook salmon that would mature at a later age (*i.e.*, stay out in the ocean for a longer period) experience extended (greater) exposure to the fishery as compared to younger age groups which mature earlier (*i.e.*, the younger fish spend less time in the ocean). The older fish are typically females, while the younger, smaller fish are disproportionately males. As a result of smaller, less-fecund fish returning to the rivers at a younger age, less freshwater salmonid production would be expected. Under such circumstances, the egg producers of the population become fewer and smaller, essentially causing a decrease in the fecundity of the stock (Ricker 1972). In his scientific report entitled "Fecundity and Mortality in Pacific Salmon", Neave (1948) points out the importance of this component to the overall health of salmon populations:

> "*Although the level of abundance of the whole population may change from time to time, any continued underproduction or overproduction of eggs by the average individual would quickly change the status of the species.*"

In addition, loss of the older age groups dramatically reduces the resilience of salmon populations to "bounce back" after natural disasters (*e.g.*, floods and droughts). The loss of historical, multiple-age-group composition causes salmon runs to be particularly vulnerable to consecutive years of adverse conditions. For this reason, a uniform age structure of Central Valley salmon stocks (*e.g.*, mostly 3-year-old fish) is not desirable. If dominated by one age group, a natural or man-made disaster impacting one year's spawning escapement can be evident for many future years. Using a simple example for illustration, if a salmon population is composed of mainly three-year-old fish and the reproductive success is extremely poor in one particular year, a low spawning escapement three years later could be expected. This phenomenon is a potential factor which could have significantly contributed to the decline in the winter-run Chinook salmon. These predominately three-year-old fish were severely impacted by lethally warm water temperatures in the 1976 and 1977 droughts. Consequently, the returns were very low every three years following both 1976 and 1977. Had there been a more substantial age-group overlap for this species (*e.g.*, more four-and five-year olds), the runs would have had more resilience to recover in years following the drought.

A reduction in the size and age of salmon spawners also can significantly alter their reproductive success. Healey and Heard (1984), as cited by Myers *et al.* (1998), reported that large body size in female Chinook salmon may be advantageous because of the success of larger fish in establishing, digging, and protecting their redds. In their studies on coho salmon, *Oncorhynchus kisutch*, van den Berghe and Gross (1984) stated:

> *"Nest depth was strongly correlated with female size in coho salmon (Oncorhynchus kisutch). Since nests of different-sized females are at different depths, they are differentially vulnerable to destruction by floods and to other females competing for the same nest sites." "Managers of salmon populations should recognize that there is a selective advantage to larger bodied females resulting from their ability to dig nests deeper."*

Central Valley rivers and streams are highly prone to substantial bed load movement during high flow events which scour the upper portion of salmon spawning grounds. Salmon eggs deposited deeper in the river gravels (by older, larger female salmon, such as a five-year old fish) would be expected to experience lower losses during flood events as compared to eggs deposited in shallower depths (by younger, smaller female salmon, such as a three-year old fish). Eggs deposited deeper in the river gravels during spawning activities would also be less susceptible to losses from subsequent salmon spawning activity in the same area (*i.e.*, spawning superimposition) as compared to eggs deposited in shallow gravel depths. However, large-sized salmon in the Sacramento River are now rare (Figure 80).

Figure 80. Chinook salmon carcass found in Battle Creek estimated to have weighed 88 pounds. Photo by DFG. Larger, older salmon within spawning runs can be expected to have higher reproductive success through the ability to move coarser riverbed substrate (cobbles) during redd construction; highly-fecund females laying eggs deeper in the gravels would also reduce impacts of riverbed scour during high flow events.

The problems with ocean harvest influencing fish reproduction at an earlier age and smaller size, spawning activity earlier in the season (Hard *et al.* 2008, as cited by Lindley *et al.* 2009), and a truncated age structure affecting variation in population abundance (Huusko and Hyv¨arinen 2005, Anderson *et al.* 2008, as cited by Lindley *et al.* 2009) have been recognized by others [reviewed by Hard *et al.* (2008)]. Without restoration of multiple age-group structures, and other remedial actions (*e.g.*, a more-terminal ocean harvest nearer to San Francisco Bay to selectively harvest the fish returning to spawn), boom-and-bust cycles will likely persist (even with significant habitat restoration efforts) and continue to plague salmon recoveries. Surprisingly, given the known adverse impacts of this major problem, corrective actions have not been pursued.

5.6.4 Conclusions on Ocean Rearing

- Recent management of the ocean fishery has demonstrated that regulatory measures, sometimes severe, can benefit resultant fish runs, but this has not always been the case in the past when overharvest occurred. Although measurable anthropogenic changes to ocean habitats to benefit the species are not feasible, fishery management measures such as harvest regulations or prohibitions can benefit the populations when fish runs are known to be depressed and surplus fish are unavailable.

- Ocean harvest and its effects on the reproductive success of the populations are indicators of a significant effect on recent salmon population declines. Smaller, less fecund fish returning to the rivers would be expected to result in less freshwater salmonid production. Also, the loss of historical, multiple-age-group composition in salmon populations allows the runs to be particularly vulnerable to consecutive years of adverse conditions. The reduction in average age of Sacramento River populations caused by ocean fishing has "carried through" to the present and has to be considered a significant factor contributing to recent population declines. This stressor to salmon stocks has gotten worse, not better, over time.

- Unless the historical age structure of Sacramento River basin salmon stocks is restored, the runs will always be subject to wide fluctuations caused by natural or anthropogenic conditions and continue to plague salmon restoration efforts.

- Predation by marine mammals such as sea lions is likely problematic for some salmon populations, but unless significant changes to the Marine Mammal Protection Act are made to control mammal populations in key areas where salmon may be concentrated (which is not likely), depressed anadromous salmonid populations will be continually subject to this stressor and reduce the resilience of fish populations.

- Unless major improvements in earlier freshwater fish survival are achieved (primarily in the Delta) to ensure fish populations remain sufficiently abundant in the ocean while concurrently providing for human harvest and forage by marine mammals, future low runs of fish can be expected.

6.0 Recommendations

6.1 Adult Fish Upstream Migration

- Research on the potentially serious problem with fish passage barriers in the Delta should be conducted or continued and, where warranted, remedial actions should be implemented as soon as possible to assist in restoring depressed fish populations. In each instance, engineering solutions or operational measures to correct the problem are likely to be feasible. For example, short-duration pulses of relatively low-volume, but high-velocity flows can attract fish into bypasses. Elimination of these migration barriers through the installation of fish passage facilities or operational measures presents a significant restoration opportunity. (Fremont Weir: High Priority Action; Other Barriers: Medium Priority Study)

- There still remain additional opportunities to improve conditions for upstream migrating fish in some tributaries, particularly for spring-run Chinook. For example, sufficient spring flows in Mill and Deer creeks could be improved (particularly during drought years) to ensure unimpeded access and the migration of late-arriving fish to upstream holding and spawning areas. (High Priority Action)

- Some new fishways to provide access for spring-run Chinook to upper reaches of Big Chico Creek have yet to be constructed and should be implemented as soon as feasible. (High Priority Action)

- All existing fishways on important anadromous fish tributaries should be continually maintained and periodically examined to ensure conditions are optimal for fish passage. (High Priority Action)

- Government agencies should continue to work cooperatively with watershed groups in Butte, Mill, Deer, and Big Chico creeks (and other watershed organizations) to protect adult spring-run migrating up through lower reaches of those streams where the fish are highly vulnerable to illegal harvest. (Medium Priority Action)

- Because Butte, Mill, and Deer creeks likely possess the only true remaining wild spring-run in the entire Central Valley, both State and federal law enforcement presence in the watersheds should be maintained or increased as a deterrent for illegal harvest. Low-cost, digital infrared motion-detecting cameras could be installed at locations where adult fish are highly vulnerable to illegal harvest or human disturbance. (High Priority Action)

- There remain some flow and temperature problems in some small tributaries, particularly for spring-run Chinook, that should be closely examined to determine appropriate remedial measures to ensure the runs are protected. (High Priority Study)

6.2 Adult Fish Holding Habitat

- The relatively few and small holding areas where over-summering adult spring-run Chinook are exposed and highly vulnerable to human recreational activities in the summer months should be better protected. (High Priority Action)

- Greater scrutiny of snorkeling surveys in spring-run Chinook holding areas or development of alternative survey techniques should occur through the ESA 4(d) or

Section 10 research provisions to minimize and perhaps eliminate that risk to the populations. (Medium Priority Action)

- Because spring-run Chinook prefer shade and cover during over-summering in small tributary pools, greater protection of riparian corridors in holding areas should be provided. In some areas, such as in Butte Creek, adult spring run are highly exposed and could benefit from structural measures to provide shade and cover. (High Priority Action)

- Formal seasonal refuges at critical areas, akin to that historically provided for bald eagle nesting areas, should be provided to protect adult spring run and minimize human disturbance. (High Priority Action)

- Government agencies should continue to work cooperatively with watershed groups in Butte, Mill, Deer, and Big Chico creeks and other streams (*e.g.*, Battle Creek, Clear Creek) to protect adult spring-run and other species holding in the upper reaches of those streams where the fish are highly vulnerable to illegal harvest and human disturbance. (Medium Priority Action)

- Because Butte, Mill, and Deer creeks likely possess the only true remaining wild spring-run in the entire Central Valley, both State and federal law enforcement presence in the watersheds should be maintained or increased as a deterrent for illegal harvest. Low-cost, digital infrared motion-detecting cameras could be installed at holding locations where adult fish are highly vulnerable to illegal harvest or human disturbance. (High Priority Action)

6.3 Spawning and Incubation

- Because of the biological importance and high probability of success, spawning gravel introductions should continue and be significantly expanded downstream of all major dams. (High Priority Action)

- Gravel extraction on some tributaries should be closely examined to ensure adverse impacts to anadromous fish are not occurring. (Medium Priority Study)

- Detailed data on spawning habitat quantity and quality in many tributaries are limited, but because of their importance, those habitats should be examined to determine potential restoration measures; such studies are easy to conduct and relatively low in cost. Gravel replenishment projects in important spawning areas lacking sufficient natural gravel recruitment would undoubtedly benefit anadromous fish. (Medium Priority Study)

- Proposed plans to extract spring-run Chinook fertilized eggs from Mill or Deer Creek should be held in abeyance until the populations recover from currently depressed levels.

Butte Creek would be a more-appropriate egg source for a donor stock to be used elsewhere. (High Priority Action)

- Detailed modeling studies should be conducted of the effects of the high flow regimes contemplated by SWRCB (2010) to determine impacts to water supplies and the thermal regime as those factors affect anadromous fish spawning and incubation. (High Priority Study)

6.4 Fry and Juvenile Rearing

- Instream studies should be conducted to determine the quantity and quality of favorable rearing habitats. (High Priority Study)

- Projects to replenish coarse substrates (*i.e.*, gravels, boulders) and woody debris in the upper portion of the mainstem river in key locations should be implemented because of the high probability of improving and expanding mainstem rearing habitats. (High Priority Action)

- Pilot projects to create new rearing habitats should be conducted, and if found feasible, be expanded in reaches immediately downstream of dams. (High Priority Study)

- Modeling studies should be conducted of the impact of the high flow regimes contemplated by SWRCB (2010) to determine impacts to water supplies, the thermal regime, and the physical attributes of rearing habitats as those factors affect anadromous fish fry and juvenile rearing. (High Priority Study)

- Attempts to create anadromous fish rearing habitats in the lower Sacramento River through placement of woody debris structures and other measures should be closely scrutinized to determine if those efforts are inadvertently creating favorable predatory fish habitats at the expense of anadromous fish. (Medium Priority Study)

6.5 Fry and Juvenile Outmigration

- Instream studies of potential predation problems immediately downstream of Daguerre Point Dam on the Yuba River and ACID dam on the Sacramento River should be conducted; if necessary, remedial actions should be developed and implemented. The issue may be particularly important at the ACID dam because of the high concentration of winter-run fry in the vicinity during the period the diversion is in operation. (High Priority Study)

- A variety of solutions to the periodic reverse flow condition at Verona Dam have been contemplated and measures to correct this potentially serious problem should be implemented. (High Priority Action)

- New study approaches in the Delta should be designed and implemented to determine exactly where mortality is occurring in the Delta and how to ultimately fix the problems. (High Priority Study)

- Potential solutions to avoid predation at breached levees should be developed and implemented. For example, "feathering" back these levees over a much wider area instead of keeping the narrow channels would reduce high water velocities, reduce scour hole formation, and reduce predation opportunities as tides flood and ebb. (High Priority Study)

- Significant efforts should be implemented to re-create shallow-water rearing habitats for anadromous fish in the Delta. However, those restoration sites should designed to minimize predation. (High Priority Action)

- Studies should be conducted of the channel geometry at key locations in the Delta where predatory fish are concentrated and remedial actions, where warranted, should be developed and implemented to reduce predation losses of anadromous fish. (High Priority Study)

- An aggressive predator removal program at Clifton Court Forebay and Tracy Fish Facilities should be designed and implemented. The removal should be either lethal or relocation to waters not connected to the Delta. (High Priority Action)

- The technology is available to determine the presence of predatory fish and survival of juvenile anadromous fish moving with the flow under in-Delta structures (*e.g.*, telemetry, sonar camera). Depending on site-specific findings, measures to reduce predatory fish habitats or localized predatory fish control measures could be implemented. (High Priority Study)

- Plans for future structures, including habitat restoration projects, contemplated in the Delta should recognize and avoid the potential hazards for anadromous fish. (High Priority Action)

- Detailed modeling studies should be conducted of the impact of the high flow regimes contemplated by SWRCB (2010) for fish outmigration to determine impacts to water supplies and the thermal regime. (High Priority Study)

6.6 Harvest

- Early evaluation of oceanographic conditions that may be favorable or unfavorable for anadromous fish should be conducted so resource managers would have greater ability to adjust harvest regulations accordingly and prevent overharvest of depressed salmon populations. (High Priority Action)

- An evaluation of alternative ways to harvest salmon to reduce adverse impacts on the species' fecundity should be conducted. Biologically important fishery management measures to increase the diversity of salmon age structure should be developed (absent total fishery closures). Doing would increase fish fecundity, increase natural production, improve freshwater survival, provide greater buffers against natural or anthropogenic disasters, and protect depressed fish stocks. (High Priority Study)

7.0 References

Adams, P. B., C. B. Grimes, S. T. Lindley, and M. L. Moser. 2002. Status review for North American green sturgeon, *Acipenser medirostris*. NOAA, National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, CA.

Anderson, C. N. K., C. H. Hsieh, S. A. Sandin, R. Hewitt, A. Hollowed, J. Beddington, R. M. May, and G. Sugihara. 2008. Why fishing magnifies fluctuations in fish abundance. Nature 452:835–839.

Bailey, H.C., C. Alexander, C. Digiorgio, M. Miller, S.I. Doroshov, and D.E. Hinton. 1994. The effect of agricultural discharge on striped bass (*Morone saxatilis*) in California's Sacramento-San Joaquin drainage. Ecotoxicology3:123-142.

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society, Bethesda, Maryland.

Biological Review Team. 2005. Green sturgeon (Acipenser medirostris) status review update. NOAA Fisheries. February 2005. 31 p.

Boles, G.L., and S.M. Turek. 1986. Sacramento River water quality and biology (Keswick Dam to Verona). A literature review. DWR Northern District. March 1986. 110 p.

Botsford, L.W. 2002. Ocean influences of Central Valley salmon: the rest of the story. Interagency Ecological Study Program for the San Francisco Estuary Newsletter 15(3). Summer 2002.

Boydstun, L.B. 2001. Ocean salmon fishery management. *In*: Brown, R.L., editor. Contributions to the biology of Central Valley salmonids. California Department of Fish and Game Fish Bulletin 179. p. 183–196.

Brandes, P.L. and J.S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. *In*: Brown, R.L., editor. Contributions to the biology of Central Valley salmonids. California Department of Fish and Game Fish Bulletin 179. p. 39–137.

Brannon, E.L. 1965. The influence of physical factors on the development and weight of sockeye salmon embryos and alevins. International Pacific Salmon Fisheries Commission. Progress Report No. 12. 26 p.

Brown, R. 1990. Suisun Marsh salinity control gates. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Newsletter. December 1990.

Buer, K. 1985. Sacramento River spawning gravel studies - Executive summary. Calif. Dept. of Water Resources, Northern District. Red Bluff CA. 38 p.

Buer, K. J.N. Eaves, R.G. Scott, and J.R. McMillan. 1984. Basin changes affecting salmon habitat in the Sacramento River. pp. 14-50 *In*: T.J. Hassler (ed.), Proc. Pacific Northwest stream habitat management workshop. Cooperative Fishery Research Unit, Humboldt State Univ., Arcata CA.

Buer, K., D. Forwalter, M. Kissel, and B. Stohler. 1989. The middle Sacramento River: human impacts on physical and ecological processes along a meandering river. Proceedings of the California Riparian Systems Conference, September 22-24, 1988, Davis, CA. USDA Forest Service Gen. Tech. Rep. PSW-110. 544 p.

Burgner, R.L. 1991. Life history of sockeye salmon (Oncorhychus nerka). pp. 3-117. In C. Groot and L. Margolis (Eds.). Pacific Salmon Life Histories. Univ. British Columbia Press, Vancouver.

Burmester, R. 2001. Juvenile Chinook salmon abundance. Interagency Ecological Study Program for the San Francisco Estuary Newsletter 14(2). Spring 2001.

California Department of Fish and Game. 1965. California fish and wildlife plan. Three volumes. Sacramento, CA.

California Department of Fish and Game. 1996. Status of actions to restore Central Valley spring-run Chinook salmon. A special report to the Fish and Game Commission. Inland Fisheries Division. February 1, 1996. 56 p.

California Department of Fish and Game. 1998. Status review of the spring-run Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento River drainage. Report to the Fish and Game Commission. Candidate Species Status Report 98-01. June 1998. 394 p.

California Department of Fish and Game. 2002. California Department of Fish and Game comments to the National Marine Fisheries Service regarding the green sturgeon listing. 45 p. plus tables and figures.

California Department of Fish and Game. 2010. Quantifiable biological objectives and flow criteria for aquatic and terrestrial species of concern dependent on the Delta. Draft report. September 21, 2010. 150 p.

California Department of Water Resources. 1979. Observations of Sacramento River bank erosion, 1977-78. 58 p.

California Department of Water Resources. 1996. Water quality conditions in the Sacramento – San Joaquin Delta 1970 – 1993. Sacramento, CA: California Department of Water Resources.

California Department of Water Resources. 2000. Initial Study and Negative Declaration: Year 2001 Water Purchase Agreement With Yuba County Water Agency for Support of the Environmental Water Account.

California Department of Water Resources. 2001. Initial information package relicensing of the Oroville Facilities. January 2001. FERC License Project No. 2100.

California Fish and Game Commission. 2010a. 2010-2011 Freshwater Sport Fishing Regulations.

California Fish and Game Commission. 2010b. 2010-2011 Supplemental Fishing Regulations

California Fish and Game Commission. 2010c. 2010-2011 Ocean Sport Fishing Regulations.

CH2M Hill. 1992. Environmental Endangerment Assessment. Iron Mountain Mine, Redding, CA. Environmental Protection Agency WA NO. 31-01-9N17. May 1992.

Chappell, E. 2003. Predicting juvenile Chinook salmon emigration using environmental parameters. Interagency Ecological Program for the San Francisco Estuary Newsletter 16(1). Fall 2002/Winter 2003.

Christophel, D., G. Lawley, and L. Winternitz. 1999. Prospect Island fish sampling results – some thoughts on shallow water habitat restoration. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter 12(1). Winter 1999.

Clark, G.H. 1929. Sacramento-San Joaquin salmon (*Oncorhynchus tshawytscha*) fishery of California. Calif. Fish Game Bull. 17:73.

Cohen, A. 1997. Biological invasions in the estuary. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter 10(2). Spring 1997.

Coulston, P. 1993. Clifton Court Forebay predator/predation control. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Autumn 1993.

Coulston, P. 1997. Monitoring and special study activities for 1997, Georgiana Slough acoustical barrier. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter 10(1). Winter 1997.

Cummins, K., C. Furey, A. Giorgi, S. Lindley, J. Nestler, and J. Shurts. 2008. Listen to the river: an independent review of the CVPIA Fisheries Program. Prepared for the U.S. Bureau of Reclamation and the U.S. Fish and Wildlife Service. December 2008. 51 p. plus appendices.

Dettinger, M, D. Cayan, and D. Peterson. 1995. Sierra Nevada runoff into San Francisco Bay –

why has it come earlier recently? Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Summer 1995.

Environmental Protection Agency. 1994. Water quality standards for surface waters of the Sacramento River, San Joaquin River, and San Francisco Bay and Delta of the state of California. Federal Register 59(4):810-852.

Environmental Protection Agency. 2011. Unabridged advance notice of proposed rulemaking for water quality issues in the San Francisco Bay/Sacramento – San Joaquin Delta Estuary. January 20, 2011. 83 p.

Erickson D.L., J.A. North, J.E. Hightower, J. Weber, and L. Lauck. 2002. Movement and habitat use of green sturgeon, *Acipenser medirostris*, in the Rogue River, Oregon, USA. J Appl Ichthyol 18:565–569.

Fish, M.A. 2010. A white sturgeon year-class index for the San Francisco Estuary and its relation to Delta outflow. Interagency Ecological Program for the San Francisco Estuary Newsletter 23(2). Spring 2010.

Fisher, F.W. 1994. Past and present status of Central Valley Chinook salmon. Conserv. Biol. 8:870-873.

Foss, S. 2005. Salvage of hatchery-released juvenile steelhead at the State Water Project and Central Valley Project fish facilities. Interagency Ecological Program for the San Francisco Estuary Newsletter 18(2). Spring 2005.

Fox, P. and J. Miller. 1996. Fathead minnow mortality in the Sacramento River. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Summer 1996.

Fry, D.H. 1960. King salmon spawning stocks of the California Central Valley, 1940 – 1959. California Fish and Game: 55 – 71.

Garcia, A. 1989. The impacts of squawfish predation on juvenile Chinook salmon at Red Bluff Diversion Dam and other locations in the Sacramento River. USFWS, FAO-Red Bluff. 35 p.

Gard, M. 1995. Upper Sacramento River IFIM study scoping report. U.S. Fish Wildl. Serv. 14 p.

Giddings, J., L. Hall, Jr., K. Solomon, W. Adams, D. Vogel, L. Davis, and R. Smith. 1997. An ecological risk assessment of diazinon in the Sacramento and San Joaquin River Basins. Novartis Crop Protection, Inc. Technical Report: 11/97. 289 p.

Gingras, M. 1997. Mark/recapture experiments at Clifton Court Forebay to estimate pre-screening loss to juvenile fishes: 1976 – 1993. Interagency Ecological Program for the San

Francisco Bay/Delta Estuary. Technical Report 55. September 1997. 22 p.

Gingras, M. and M. McGee. 1996. Striped bass movement as indicated by sonic tagging and implications for predator control at Clifton Court Forebay. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Spring 1996.

Grimaldo, L. and Z. Hymanson. 1999. What is the impact of the introduced Brazilian waterweed *Egeria densa* to the Delta ecosystem? Interagency Ecological Program for the San Francisco Estuary Newsletter 12(1). Winter 1999.

Grimaldo, L., C. Peregrin, and R. Miller. 2000. Examining the relative predation risks of juvenile Chinook salmon in shallow water habitat: the effect of submerged aquatic vegetation. Interagency Ecological Program for the San Francisco Estuary Newsletter 13(1). Winter 2000.

Guivetchi, K. 1990. Western Suisun Marsh Salinity Control Project. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Newsletter. December 1990.

Hall, Jr., F.A. 1977. A discussion of Sacramento squawfish predation problems at Red Bluff Diversion Dam. Memorandum to predation study files. Bay-Delta Fishery Project. California Department of Fish and Game. 14 p.

Hall, Jr., F.A. 1980. Evaluation of downstream migrant Chinook salmon, *Oncorhnchus tshawytscha*, losses in Clifton Court Forebay, Contra Costa County, California. Anad. Fish Br. Admin. Rep. 80-4, Calif. Dept. of Fish and Game, Sacramento, CA. 15 p.

Hallock, R.J. 1980. Returns from steelhead trout, *Salmo gairdneri*, released as yearlings at Coleman Hatchery and below Red Bluff Diversion Dam. California Department of Fish and Game. Anadromous Fisheries Branch Office Report. 3 p.

Hallock, R. J. 1983. An evaluation of releasing late-fall Chinook salmon, Oncorhynchus tshawytscha, in the fall at Coleman National Fish Hatchery. DFG AFB Office Report. 4 p.

Hallock, R.J. 1987. Sacramento River system salmon and steelhead problems and enhancement opportunities. A report to the California Advisory Committee on Salmon and Steelhead Trout. June 22, 1987. 92 p.

Hallock, R.J. 1989. Upper Sacramento River steelhead, Oncorhynchus mykiss, 1952-1988. September 15, 1989. A report to the U.S. Fish and Wildlife Service. 86 p.

Hallock, R.J. and W.F. Van Woert. 1959. A survey of anadromous fish losses in irrigation diversions from the Sacramento and San Joaquin Rivers. Calif. Fish and Game 45:227-296.

Hallock, R.J., W.F. Van Woert, and L. Shapovalov. 1961. An evaluation of stocking hatchery reared steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) in the Sacramento River system.

Calif. Dept. Fish and Game Bull. No. 114. 74 p.

Hallock, R. J. and F.W. Fisher. 1985. Status of winter-run Chinook salmon, Oncorhynchus tshawytscha, in the Sacramento River. AFB Office Report. 29 p.

Hanson, H.A., O.R. Smith, and P.R. Needham. 1940. An investigation of fish-salvage problems in relation to Shasta Dam. U.S. Department of Interior, Bureau of Fisheries, Special Scientific Report No. 10. 123 p. plus appendices.

Hard, J. J., M. R. Gross, M. Heino, R. Hilborn, R. G. Kope, R. Law, and J. D. Reynolds. 2008. Evolutionary consequences of fishing and their implications for salmon. Evolutionary Applications 1:388–408.

HDR/SWRI. 2007. Draft Environmental Impact Report/Environmental Impact Statement for the Proposed Lower Yuba River Accord. Prepared for the California Department of Water Resources, Yuba County Water Agency, and U.S. Bureau of Reclamation. June 2007.

Healey, M.C. and W.R. Heard. 1984. Inter- and intra-population variation in the fecundity of Chinook salmon (*Oncorhynchus tshawytscha*) and its relevance to life history theory. Can. J. Fish. Aquat. Sci. 41:476-483.

Herren, J.R. and S.S. Kawasaki. 2001. Inventory of water diversions in four geographic areas in California's Central Valley. In: Brown, R.L. (editor). Contributions to the biology of Central Valley salmonids. CDFG Fish Bulletin 179 p. 343 – 355.

Hill, K. A., and J. D. Webber. 1999. Butte Creek spring-run Chinook salmon (*Oncorhynchus tshawytscha*) juvenile outmigration and life history 1995–1998 Sacramento Valley and Sierra Region. Inland Fisheries Administrative Report No. 99-5. California Department of Fish and Game, Sacramento, CA. 46 p.

Huusko, A. and P. Hyv¨arinen. 2005. A high harvest rate induces a tendency to generation cycling in a freshwater fish population. Journal of Animal Ecology 74:525–531.

Interagency Ecological Program. 1991. Ultimate predator removal. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Newsletter. September 1991.

Interagency Ecological Program. 1992a. Striped bass. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Newsletter. Summer 1992.

Interagency Ecological Program. 1992b. Striped bass caught 8 years after tagging. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Newsletter. Autumn 1992.

Interagency Ecological Program. 1992c. Research and evaluation at Tracy Fish Collection Facility. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary

Newsletter. Autumn 1992.

Interagency Ecological Program. 1993. Clifton Court Forebay. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Winter 1993.

Interagency Ecological Program. 1995. Georgiana Slough acoustical barrier. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Winter 1995.

Interagency Ecological Program. 1996. Salmon in the Sacramento Bypass. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Spring 1996.

Johnson, R.R. 1991. Entrainment evaluation of the newly installed Red Bluff Diversion Dam downstream migrant fish protection facilities. USFWS Report No. AFF1-FRO-91-17. October 1991. 8 p. plus appendices.

Johnson, R.R. and S.J. Croci. 1994. Entrainment evaluation of the Red Bluff Diversion Dam downstream migrant fish protection facilities, May – October 1993. USFWS Report No. AFF1-FRO-94-05. March 1994. 15p.

Johnson, R.R., D.C. Weigand, F.W. Fisher. 1992. Use of Growth Data to Determine the Spatial and Temporal Distribution of Four Runs of Juvenile Chinook Salmon in the Sacramento River, California. November 1992. 18 p.

Kano, R.M. 1985. 1985 evaluation of Clifton Court Forebay losses to juvenile striped bass. Office memorandum. Bay-Delta Project files. Stockton, CA.

Kano, R.M. 1986. 1986 evaluation of Clifton Court Forebay losses to juvenile striped bass. Office memorandum. Bay-Delta Project files. Stockton, CA.

Kano, R.M. 1990. Occurrence and abundance of predator fish in Clifton Court Forebay, California. Interagency Ecological Study Program for the Sacramento – San Joaquin Estuary. Technical Report 24. FF/BIO-IATR/90-24. May 1990. 13 p.

Kelley, R. 1989. Battling the inland sea, floods, public policy, and the Sacramento Valley. University of California Press. 420 p.

Kjelson, M. 1989. Results of 1989 juvenile salmon experiments. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Newsletter. December 1989.

Kjelson, M.A., P.F. Raquel, and F.W. Fisher. 1982. Life history of fall-run juvenile Chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California. Salmon in Estuaries. pp. 393-411.

Kogut, N. 2002. Adult white and green sturgeon abundance. Interagency Ecological Study

Program for the San Francisco Estuary Newsletter 15(2). Spring 2002.

Kohlhorst, D. 2001. Population trends of green sturgeon in the San Francisco estuary. Interagency Ecological Study Program for the San Francisco Estuary Newsletter 14(4). Fall 2001.

Kreeger, K.Y. and W.J. McNeil. 1992. A literature review of factors associated with migration of juvenile salmonids. Unpublished manuscript for Direct Service Industries, Inc. October 23, 1992. 46 p.

Larry Walker Associates. 2010. A review of Delta fish population losses from pumping operations in the Sacramento – San Joaquin River Delta. Report prepared by Sacramento Regional County Sanitation District. January 2010. 26 p.

Lee, D.P. 2000. The Sacramento – San Joaquin Delta largemouth bass fishery. Interagency Ecological Study Program for the San Francisco Estuary Newsletter 13(3). Summer 2000.

Lehman, P. 1989. Discovering patterns amid chaos. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Newsletter. September 1989.

Lindley, S.T., C.B. Grimes, M.S. Mohr, W. Peterson, J. Stein, J.T. Anderson, L.W. Botsford, D.L. Bottom, C.A. Busack, T.K. Collier, J. Ferguson, J.C. Garza, A.M. Grover, D.G. Hankin, R.G. Kope, P.W. Lawson, A. Low, R.B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F.B. Schwing, J. Smith, C. Tracy, R. Webb, B.K. Wells, and T.H. Williams. 2009. What caused the Sacramento River fall Chinook collapse? July 2009. NOAA-TM-NMFS-SWFSC-447. 60 p. plus appendices.

Lisle, T.E. and R.E. Eads. 1991. Methods to measure sedimentation of spawning gravels. U.S. Forest Service. Research Note PSW-411. 7 p.

MacFarland, R.B. and E.C. Norton. 2002. Physiological ecology of juvenile Chinook salmon (Oncorhynchus tshawytscha) at the southern end of their distribution, the San Francisco Estuary and Gulf of the Farallones, California. Fishery Bulletin 100:244 – 257.

Matica, Z. and M. Nobriga. 2002. Modifications to an agricultural water diversion to permit fish entrainment sampling. Interagency Ecological Study Program for the San Francisco Estuary Newsletter 15(3). Summer 2002.

MBK Engineers. 2010. SWRCB Delta outflow criteria. October 13, 2010 presentation.

McEwan, D. R. 2001. Central valley steelhead. Contributions to the biology of Central Valley salmonids. Volume 1. (Ed. R. Brown) California Department of Fish and Game. Fish Bulletin 179. Volume 1, pp 1–45.

McEwan, D. and T.A. Jackson, T. A. 1996. Steelhead Restoration and Management Plan for California. California Department of Fish and Game. 234 p.

McGee, M. and M. Gingras. 1996. Clifton Court Forebay predator movement. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Summer 1996.

McGregor, E.A. 1922. Migrating salmon at the Redding Dam. Calif. Fish and Game 8:141-154.

McLain, J.S. and G.C. Castillo. 2009. Nearshore areas used by Chinook salmon fry, *Oncorhynchus tshawytscha*, in the northwestern Sacramento – San Joaquin Delta, California. San Francisco Estuary and Watershed Science. December 2009. 12 p.

Meehan, W. R., and T. C. Bjornn. 1991. Salmonid distributions and life histories. Pages 47-82 in W. R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication No. 19, Bethesda, Maryland.

Mills, T.J. and F. Fisher. 1994. Central Valley anadromous sport fish annual run-size, harvest, and population estimates, 1967 through 1991. California Department of Fish and Game. Inland Fisheries Division Technical Report.

Mitchell, W.T. 2010. Age, growth, and life history of steelhead rainbow trout *(Oncorhynchus mykiss)* in the Lower Yuba River, California, ICF International. March 2010.

Moffett, J.W. 1949. The first four years of king salmon maintenance below Shasta Dam, Sacramento River, California. California Fish and Game 35(2): 75 – 102.

Monismith, S., S. Simestad, R. Denton, K. Newman, W. Bennett, D. Rondorf, and K. Rose. 2008. Review of north Delta salmon out-migration study. January 23, 2008.

Moyle, P.B. 1976. Inland Fishes of California. University of California Press. 405 p.

Moyle, P. B. 2002. Inland fishes of California. 2nd edition. Davis, CA: University of California Press.

Moyle, P.B., J.E. Williams, and E.D. Wikramanayake. 1989. Fish species of special concern of California. Department of Wildlife and Fisheries Biology, University of California, Davis. October 1989. 222 p.

Moyle, P.B., R.M. Yoshiyama, J.E. Williams and E.D. Wikramanayake. 1995. Fish species of special concern in California. Second Edition. California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grand, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

National Marine Fisheries Service. 1997. NMFS Proposed Recovery Plan for the Sacramento River Winter-Run Chinook Salmon. August 1997.

National Marine Fisheries Service. 1998. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. Federal Register 63:(53) 13347-13371. March 19, 1998.

National Marine Fisheries Service. 2003. 68 FR 4433: National Marine Fisheries Service. Endangered and Threatened Wildlife and Plants: 12-Month Finding on a Petition to List North American Green Sturgeon as Threatened or Endangered Species: Proposed Rule. Federal Register 68 pages 4433-4441.

National Marine Fisheries Service. 2005. Green Sturgeon (*Acipenser medirostris*) status review update. NMFS Southwest Fish Sci Ctr, Santa Cruz, CA. 31 p.

National Marine Fisheries Service. 2006. Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon. April 7, 2006. Federal Register 71(67):17757-17766.

National Marine Fisheries Services. 2009. Draft recovery plan for the evolutionarily significant units of Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon, and the distinct population segment of Central Valley steelhead. National Marine Fisheries Service, Southwest Regional Office, Sacramento, California. October 2009.

Neave, F. 1948. Fecundity and mortality in Pacific salmon. Transactions of the Royal Society of Canada. Vol. 42(3), Sect. 5. pp. 97-105.

Needham, P.R., O.R. Smith, and H.A. Hanson. 1940. Salmon salvage problems in relation to Shasta Dam, California, and notes on the biology of the Sacramento River salmon. Trans. Am. Fish. Soc. 70:55-69.

NOAA. 2006. Endangered and Threatened Species: Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead. Federal Register 71: 834-862.

Nobriga, M. and M. Chotkowski. 2000. Recent historical evidence of centrarchid increases and tule perch decrease in the Delta. Interagency Ecological Program for the San Francisco Estuary Newsletter 13(1). Winter 2000.

Nobriga, M., M. Chotkowski, and R. Baxter. 2003. Baby steps toward a conceptual model of predation in the Delta: preliminary results from the shallow water habitat predator-prey dynamics study. Interagency Ecological Program for the San Francisco Estuary Newsletter 16(1). Fall 2002/Winter 2003.

Nobriga, M., Z. Matica, and Z. Hymanson. 2002. Assessing fish entrainment vulnerability to agricultural diversions: a comparison among native and non-native species. Interagency Ecological Study Program for the San Francisco Estuary Newsletter 15(3). Summer 2002.

Oltmann, R. 1995. Continuous flow measurements using ultrasonic velocity meters: an update. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Fall 1995.

Oltmann, R. 1996. Sediment inflow to the Delta from the Sacramento and San Joaquin Rivers. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Spring 1996.

Oltmann, R., D.H. Schoellhamer, and R.L. Dinehart. 1999. Sediment inflow to the Sacramento - San Joaquin Delta and the San Francisco Bay. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter 12(1). Winter 1999.

Pacific Fisheries Management Council. 2002. Review of 2001 ocean salmon fisheries. Portland, OR.

Phillips, J.B. 1931. Netting operations on an irrigation canal. California Fish and Game 17:45-52.

Quelvog, B.D. 1981. An inventory of selected fish screens in California. Calif. Dept. Fish and Game, Anad. Fish. Br. Admin. Rep. No. 81-5. 7 p. plus appendices.

Radtke, L.D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeon, in "Ecological Studies of the Sacramento-San Joaquin Delta, Part II", California Department of Fish and Game Bulletin 136, pp. 115 – 129.

Reisenbichler, R. R., J. D. McIntyre, and R. J. Hallock. 1981. Relations between size of Chinook salmon, *Oncorhynchus tshawytscha,* released at hatcheries and returns to hatcheries and ocean fisheries. California Fish and Game: 57-58.

Resources Agency of California. 1989. Upper Sacramento River Fisheries and Riparian Habitat Management Plan. 158 p.

Reynolds, F.L., R.L. Reavis, and J. Schuler. 1990. Central Valley salmon and steelhead restoration and enhancement plan. April 1990. Calif. Dep. Fish Game, Sacramento, CA, 115 p.

Reynolds, F.L., T.J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: A plan for action. Calif. Dep. Fish Game, Sacramento, CA, 184 p.

Ricker, W. E. 1972. Hereditary and environmental factors affecting certain salmonid populations. In Simon, R. C. and P. A. Larkin, editors, H. R. MacMillan Lectures in Fisheries: The Stock Concept in Pacific Salmon. Institute of Animal Resource Ecology, University of British Columbia. pp. 27-160.

Rooks, H. 1998. Chinook salmon passage at the Suisun Marsh salinity control gates. Interagency Ecological Program for the Sacramento – San Joaquin Estuary Newsletter 11(3). Summer 1998.

Rutter, C. 1903. Natural history of the quinnat salmon: A report of investigations in the Sacramento River, 1986 - 1901. U.S. Fish. Com., Bull. 22:65-141.

Saiki, M.K. and B. Finlayson. 1993. Contaminant problems. Abstract in Workshop of Central Valley Chinook salmon. University of California, Davis. January 4-5, 1993.

Sasaki, S. 1966. Distribution and food habits of king salmon, *Oncorhynchus tshawytscha,* and steelhead rainbow trout, *Salmo gairdnerii*, in the Sacramento-San Joaquin Delta. DFG Fish Bulletin 136. pp. 108-114.

Schaffter, R.G. 1978. An evaluation of juvenile king salmon, *Oncorhynchus tshawytscha*, loss in Clifton Court Forebay. Calif. Dept. Fish and Game Anadromous Fisheries Administrative Report 78-21.

Schaffter, R.G. 1998. Growth of largemouth bass in the Sacramento – San Joaquin Delta. Interagency Ecological Program for the Sacramento – San Joaquin Estuary Newsletter 11(3). Summer 1998.

Schaffter, R.G., P.A. Jones, J.G. Karlton. 1982. Sacramento River and tributaries bank protection and erosion control investigation: Evaluation of impacts on fisheries. Final Report. California Department of Fish and Game. U.S. Army Corps of Engineers Contract No. DACWO 5-80-C-0110. 86 p. plus appendices.

Scofield, N.B. 1913. A general report on the Chinook salmon investigation carried on during the spring and summer of 1911. Calif. Dept. Fish and Game, Fish Bull., (1): 34–41.

Scofield, N.B. 1919. Commercial fishery notes. Calif. Fish and Game 5(4): 196-197.

Scordino, J. 2010. West Coast Pinniped Program Investigations on California Sea Lion and Pacific Harbor Seal Impacts on Salmonids and Other Fishery Resources. Pacific States Marine Fisheries Commission. 102 p.

Shvidchenko, A.B., MacArthur, R.C., and B.R. Hall. Historic sedimentation in Sacramento – San Joaquin Delta. Interagency Ecological Program for the San Francisco Estuary Newsletter

17(3). Summer 2004.

Simenstad, C., J. Toft, H. Higgins, J. Cordell, M. Orr, P. Williams, L. Grimaldo, Z. Hymanson, and D. Reed. 1999. Preliminary results from the Sacramento – San Joaquin Delta breached levee wetland study (BREACH). Interagency Ecological Program for the Sacramento – San Joaquin Estuary Newsletter 12(4). Fall 1999.

Slater, D.W. 1963. Winter-run Chinook salmon in the Sacramento River, California with notes on water temperature requirements at spawning. U.S. Fish and Wildlife Service. Special Scientific Report – Fisheries No. 461. November 1963. 9 p.

Sommer, T., B. Harrell, and B. Tom. 2003. Landscape-level hydrologic variation in the Yolo Bypass: implications for river restoration. Interagency Ecological Program for the San Francisco Estuary Newsletter 16(1). Fall 2002/Winter 2003.

Sommer, T. and D. McEwan. 1995. Feather River fisheries studies. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Fall 1995.

Sommer, T., D. McEwan, and R. Brown. 2001. Factors affecting Chinook salmon spawning in the lower Feather River. *In*: Brown, R.L., editor. Contributions to the biology of Central Valley salmonids. California Department of Fish and Game Fish Bulletin 179. p. 269–297.

Sommer, T., M. Nobriga, and B. Harrell. 1998. Results of 1997 Yolo Bypass studies. Interagency Ecological Program for the Sacramento – San Joaquin Estuary Newsletter 11(1). Winter 1998.

Sommer, T., M. Nobriga, W. Harrell, W. Batham, and W.Kimmerer. 2001. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58(2):325-333

Sommer, T., M. Nobriga, B. Harrell, W. Batham, and R. Kurth. 2000. Floodplain rearing may enhance growth and survival of juvenile Chinook salmon in the Sacramento River. Interagency Ecological Program for the San Francisco Estuary Newsletter 13(3). Summer 2000.

S.P. Cramer & Associates, Inc. 1995. The status of steelhead populations in California in regards to the Endangered Species Act. Report Submitted to the National Marine Fisheries Service on behalf of the Association of California Water Agencies. 190 p.

S.P. Cramer and Associates, Inc. 1997. The status of late-fall and spring Chinook salmon in the Sacramento River basin regarding the Endangered Species Act. 111 p.

State Water Resources Control Board. 1994. Technical Report, Lower American Court Reference.

State Water Resources Control Board. 1995. Environmental Report. Appendix 1 to Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta Estuary. 95-1WR. May 1995.

State Water Resources Control Board. 2000. Yuba River Hearings.

State Water Resources Control Board. 2010. Development of flow criteria for the Sacramento – San Joaquin Delta ecosystem. Prepared pursuant to the Sacramento – San Joaquin Delta Reform Act of 2009. August 3, 2010. 178 p.

Surface Water Resources (SWRI), Inc., Jones & Stokes Associates, and Bookman-Edmonston Engineering, Inc. 2000. Aquatic and Engineering Specialists for Yuba County Water Agency. Expert Testimony on Yuba River Fisheries Issues YCWA Exhibit 19, State Water Resources Control Board Water Rights Hearing on Lower Yuba River, 2000.

Thompson, B. 1996. Recent incidents of toxity in the Delta, unexplained fish mortality at the Tracy Fish Collection Facility. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter 9(4). Autumn 1996.

Turek, S.M. 1990. Historic Sacramento River temperature data, Keswick to Butte City. California Department of Water Resources Memorandum Report. April 1990. 268 p.

Turner, G.F. 1996. Offshore Cichlids of Lake Malawi. Lauenau, Germany: Cichlid Press

U.S. Bureau of Reclamation. 1992. Biological assessment for U.S. Bureau of Reclamation long-term Central Valley Project operations criteria and plan. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, California. October 1992.

U.S. Bureau of Reclamation. 1993. Final environmental assessment and finding of no significant impact, Red Bluff Diversion Dam Pilot Pumping Plant Program. Mid-Pacific Region, Sacramento, California. August 1993. 41 p. and appendices.

U.S. Department of the Interior. 1948. Memorandum re. Comments on Preliminary Report, "Water Requirements of Anadromous Fishes," Research Department, California State Chamber of Commerce. June 17, 1948. Sacramento, California. 17 p.

U.S. Fish and Wildlife Service. 1993. Northern Central Valley Fishery Resource Office Annual Report, 1993. 29 p.

U.S. Fish and Wildlife Service. 1995. Working paper: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volume 2. May 9, 1995. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

U.S. Fish and Wildlife Service. 1997. Revised draft Restoration Plan for the Anadromous Fish Restoration Program. A plan to increase natural production of anadromous fish in the Central Valley of California. May 30, 1997. 112 p. plus appendices.

van den Berghe, E.P., and M.R. Gross. 1984. Female size and nest depth in coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 41: 204-206.

Van Eenennaam, J.P., J. Linares-Casenave, X. Deng, and S.I Doroshov. 2005. Effect of incubation temperature on green sturgeon embryos, *Acipenser medirostris*. *Environmental Biology of Fishes,*72, 145-154.

Vigg, S. 1988. Functional response of northern squawfish predation to salmonid prey density in McNary tailrace, Columbia River. Pages 174-207 In T.P. Poe and B.E. Rieman (editors). Predation by resident fish on juvenile salmonids in John Day Reservoir. Volume 1, Final Report of Research 1983-1986. Bonneville Power Authority.

Vigg, S., T.P. Poe, L.A. Pendergast, and H.C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

Vincik, R. and F.H. Bajjaliya. 2008. Timing, composition, and abundance of juvenile salmonid emigration in the Sacramento River near Knights Landing, October 2002 – July 2003. Calif. Dept. Fish Game, Habitat Conservation Division, Native Anadromous Fish and Watershed Branch, Stream Evaluation Program. 29 p.

Vogel, D.A. 1982. Evaluation of the 1981-82 operation of the Tehama-Colusa Fish Facilities. U.S. Fish and Wildlife Service Report. Fisheries Assistance Office. January 28, 1982. 24 p.

Vogel, D.A. 1983. Evaluation of the Tehama-Colusa Fish Facilities. Cal-Neva Wildlife Transactions. pp. 20-25

Vogel, D.A. 1984. Minutes of the Sacramento River steelhead management meeting. February 8, 1984. U.S. Fish and Wildlife Service. 6 p.

Vogel, D.A. 1989. Tehama-Colusa Canal Diversion and Fishery Problems Study. Final Report. U.S. Fish and Wildlife Service Report No. AFF/FAO-89-06. April 1989. 33 p. with appendices.

Vogel, D.A. 1990. Important biological considerations of the proposed Shasta Dam water temperature control device. Congressional briefing paper. October 1990. 9 p.

Vogel, D.A. 1993a. Preliminary assessment of streambed substrate at principal anadromous salmonid spawning areas in Little River, California. March 1993. Vogel Environmental Services. 36 p.

Vogel, D.A. 1993b. Chinook Salmon Rearing in the Central Valley. Abstract from presentation given at the Central Valley Chinook Salmon Workshop, University of California, Davis. January 4-5, 1993. 2 p.

Vogel, D.A. 1994. Progress report on riverbed surveys associated with the Diestelhorst Bridge Project. Vogel Environmental Services. August 26, 1994.

Vogel, D.A. 1995a. Technical memorandum on the results of a November 1995 riverbed survey of the Sacramento River in the vicinity of the South Bonnyview Bridge. Natural Resource Scientists, Inc. December 1, 1995.

Vogel, D.A. 1995b. Losses of young anadromous salmonids at water diversions on the Sacramento and Mokelumne Rivers. Contract report to the USFWS and USBR for the Central Valley Improvement Act. Vogel Environmental Services. 36 p.

Vogel, D.A. 1998. Preliminary assessment of streambed substrate for salmon spawning in Stony Creek, California. Natural Resource Scientists, Inc. Report prepared for the Orland Unit Water Users and Tehama-Colusa Canal Authority. February 1998. 15 p.

Vogel, D.A. 2000. Technical memorandum on the results of a November 2000 riverbed survey of the Sacramento River in the vicinity of Deschutes Bridge. Natural Resource Scientists, Inc. December 29, 2000.

Vogel, D.A. 2001. Juvenile Chinook salmon radio-telemetry study in the northern Sacramento-San Joaquin Delta, January – February 2000. Contract report for the U.S. Fish and Wildlife Service. Natural Resource Scientists, Inc. May 2001. 34 p. plus figures and appendices.

Vogel, D.A. 2002. Juvenile Chinook salmon radio-telemetry study in the southern Sacramento-San Joaquin Delta, December 2000 – January 2001. Contract report for the U.S. Fish and Wildlife Service. Natural Resource Scientists, Inc. June 2002. 27 p. plus figures and appendices.

Vogel, D.A. 2003a. Assessment of anadromous salmonid habitat in the Lower Bear River, California. Unpublished report prepared for South Sutter Water District. Natural Resource Scientists, Inc. December 2003. 33 p. plus appendices.

Vogel, D.A. 2003b. Technical memorandum on the results of an October 2003 salmon spawning habitat survey in the Sacramento River near the North Street (Airport Road) Bridge, Anderson, California. Natural Resource Scientists, Inc. November 10, 2003.

Vogel, D.A. 2004. Juvenile Chinook salmon radio-telemetry studies in the northern and central Sacramento-San Joaquin Delta, 2002 – 2003, Final Report. Contract report for CALFED, administered by the National Fish and Wildlife Foundation. Natural Resource Scientists, Inc.

January 2004. 188 p.

Vogel, D.A. 2007a. Technical memorandum on the results of a June 2007 riverbed survey of the Sacramento River in the vicinity of Jellys Ferry Bridge. Natural Resource Scientists, Inc. July 5, 2007.

Vogel, D.A. 2007b. Technical memorandum to participating agencies in the 2007 Vernalis Adaptive Management Program concerning high fish mortality near Stockton, California. Natural Resource Scientists, Inc. May 20, 2007. 5 p.

Vogel, D.A. 2008a. Biological evaluations of the fish screens at the Glenn-Colusa Irrigation District's Sacramento River pump station, 2002 – 2007. Final Report prepared for the multi-agency Technical Oversight Committee. Natural Resource Scientists, Inc. April 2008. 48 p.

Vogel, D.A. 2008b. Surveys of water diversions in the Sacramento River - 2008. Report prepared for the Anadromous Fish Screen Program, U.S. Bureau of Reclamation and U.S. Fish and Wildlife Service. Natural Resource Scientists, Inc. December 2008. 14 p. plus 27 GB database.

Vogel, D.A. 2008c. Pilot study to evaluate acoustic-tagged juvenile Chinook salmon smolt migration in the northern Sacramento – San Joaquin Delta, 2006 – 2007. Report prepared for the California Department of Water Resources. Natural Resource Scientists, Inc. March 2008. 43 p.

Vogel, D.A. 2009. Progress report for the Natomas Cross Canal fish sampling program, March 17 – July 6, 2009. Natural Resource Scientists, Inc.

Vogel, D.A. 2010a. A synthesis of 22 telemetry studies to evaluate Chinook salmon smolt migration and mortality in California's Sacramento – San Joaquin Delta. Bay-Delta Science Conference, Sacramento, CA. September 27 - 29, 2010.

Vogel, D.A. 2010b. Evaluation of acoustic-tagged juvenile Chinook salmon movements in the Sacramento – San Joaquin Delta during the 2009 Vernalis Adaptive Management Program. Final Report. Natural Resource Scientists, Inc. March 2010. 63 p.

Vogel, D.A. 2010c. Technical memorandum to the Vernalis Adaptive Management Program Biology Committee on 2008 striped bass tagging. Natural Resource Scientists, Inc. March 26, 2010. 11 p.

Vogel, D.A. 2011. Evaluation of fish entrainment in seven unscreened Sacramento River diversions, 2010. Report prepared for the Anadromous Fish Screen Program, CALFED Ecosystem Restoration Program, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, NOAA Fisheries, and the California Department of Fish and Game. Natural Resource Scientists, Inc. February 2011. 77 p. plus appendices.

Vogel, D.A. and K.R. Marine. 1991. Guide to Upper Sacramento River Chinook Salmon Life History. Prepared for the U.S. Bureau of Reclamation, Central Valley Project. CH2M Hill. July 1991. 55 p. with appendices.

Vogel, D.A., K.R. Marine, and J.G. Smith. 1988. Fish Passage Action Program for Red Bluff Diversion Dam. Final Report of Fisheries Investigations. U.S. Fish and Wildlife Service Report No. FR1/FAO-88-19. 77 p. plus appendices.

Vogel, D.A., K.R. Marine and J.G. Smith. 1990. A summary of evaluations of upstream and downstream anadromous salmonid passage at Red Bluff Diversion Dam on the Sacramento River, California, U.S.A. Paper presented at the *International Symposium on Fishways '90 in Gifu, Japan.* Proceedings pp. 275-281. October 8-10, 1990.

Vogel, D.A. and G. Taylor. 1987. Survey of the Chinook Salmon Spawning Substrate in the Sacramento River from the Highway 273 Bridge to Keswick Dam, July-August, 1987. Contract Report for the Federal Energy Regulatory Commission Request for Information Concerning the Proposed Lake Redding Hydroelectric Project (FERC No. 2828). 13 p.

Vondracek, B. and P.B. Moyle. 1983. Squawfish predation at Red Bluff Diversion Dam. Contract report for the California Department of Water Resources. 34 p.

Ward, P.D. 1989. A review and evaluation of the losses of migrant juvenile Chinook salmon at the Glenn-Colusa Irrigation District. California Department of Fish and Game, Glenn-Colusa Fish Screen. Unpublished office report. 35 p. and six appendices.

Wernette, F. 1995. Suisun Marsh diversion screening program. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Fall 1995.

Wickett, W.P. 1954. The oxygen supply to salmon eggs in spawning beds. J. Fish. Res. Bd. Can. Vol. 11(6):933-953.

Winternitz, L. P.Brandes, R.Baxter, and C.Armor. 1995. Real-time monitoring program, salmon evaluation. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter. Summer 1995.

Wullschleger, J. 1994. Estimating winter run survival with late-fall run fish. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Newsletter. Spring 1994.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical abundance and decline of Chinook salmon in the central valley region of California. North American Journal of Fisheries Management. 18(3):487–521.

Exhibit A

Sacramento River, San Joaquin River, and Delta technical reports authored or co-authored by Dave Vogel

(Sequential Listing)

Vogel, D.A. 2011. Evaluation of fish entrainment in seven unscreened Sacramento River diversions, 2010. Report prepared for the Anadromous Fish Screen Program, CALFED Ecosystem Restoration Program, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, NOAA Fisheries, and the California Department of Fish and Game. Natural Resource Scientists, Inc. February 2011. 77 p. plus appendices.

Vogel, D.A. 2010. Evaluation of acoustic-tagged juvenile Chinook salmon movements in the Sacramento – San Joaquin Delta during the 2009 Vernalis Adaptive Management Program. Final Report. Natural Resource Scientists, Inc. March 2010. 63 p.

Vogel, D.A. 2010. Technical memorandum to the Vernalis Adaptive Management Program Biology Committee on 2008 striped bass tagging. Natural Resource Scientists, Inc. March 26, 2010. 11 p.

Vogel, D.A. 2010. Evaluation of fish entrainment in three unscreened Sacramento River diversions, 2009. Report to the Anadromous Fish Screen Program, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service. Natural Resource Scientists, Inc. March 2010. 40 p. plus appendices.

Vogel, D.A. 2009. Concept for a temporary behavioral fish barrier at the head of Old River. Proposal to the California Department of Water Resources. January 5, 2009. Natural Resource Scientists, Inc. 6 p.

Vogel, D.A. 2008. Surveys of water diversions in the Sacramento River - 2008. Report prepared for the Anadromous Fish Screen Program, U.S. Bureau of Reclamation and U.S. Fish and Wildlife Service. Natural Resource Scientists, Inc. December 2008. 14 p. plus 27 GB database.

Vogel, D.A. 2008. Evaluation of unscreened diversions, 2007 – 2008. Report prepared for the Anadromous Fish Screen Program, U.S. Bureau of Reclamation and U.S. Fish and Wildlife Service. Natural Resource Scientists, Inc. December 2008. 38 p. plus six appendices.

Vogel, D.A. 2008. Biological evaluations of the fish screens at the Glenn-Colusa Irrigation District's Sacramento River pump station, 2002 – 2007. Final Report prepared for the multi-agency Technical Oversight Committee. Natural Resource Scientists, Inc. April 2008. 48 p.

Vogel, D.A. 2008. Evaluation of adult sturgeon migration at the Glenn-Colusa Irrigation District gradient facility on the Sacramento River. Final Report prepared for the multi-agency Technical Oversight Committee.. Natural Resource Scientists, Inc. April 2008. 33 p.

Vogel, D.A. 2008. Pilot study to evaluate acoustic-tagged juvenile Chinook salmon smolt migration in the northern Sacramento – San Joaquin Delta, 2006 – 2007. Report prepared for the California Department of Water Resources. Natural Resource Scientists, Inc. March 2008. 43 p.

Vogel, D.A. 2007. A feasibility investigation of reintroduction of anadromous salmonids above Crocker-Huffman Dam on the Merced River. Report prepared for the U.S. Fish and Wildlife Service Anadromous Fish Restoration Program. Natural Resource Scientists, Inc. December 2007. 110 p. plus appendices.

Vogel, D.A. 2007. 2006 biological evaluation of the fish screens at the Glenn-Colusa Irrigation District's Sacramento River pump station. Report prepared for the multi-agency Technical Oversight Committee. Natural Resource Scientists, Inc. June 2007. 24 p.

Vogel, D.A. 2007. Technical memorandum to participating agencies in the 2007 Vernalis Adaptive Management Program concerning high fish mortality near Stockton, California. Natural Resource Scientists, Inc. May 20, 2007. 5 p.

Vogel, D.A. 2006. 2006 Vernalis Adaptive Management Program pilot study to monitor the migration of juvenile Chinook salmon using acoustic telemetry. Report to the Vernalis Adaptive Management Program Biology Committee. Natural Resource Scientists, Inc. November 2006.

Vogel, D.A. 2006. 2005 biological evaluation of the fish screens at the Glenn-Colusa Irrigation District's Sacramento River pump station. Report prepared for the multi-agency Technical Oversight Committee. Natural Resource Scientists, Inc. May 2006. 40 p.

Vogel, D.A. 2006. Evaluation of acoustic telemetry equipment for monitoring juvenile Chinook salmon. Report prepared for the California Department of Water Resources. Natural Resource Scientists, Inc. March 2006. 56 p.

Vogel, D.A. 2005. Assessment of adult anadromous salmonid migration barriers and holding habitats in the Upper Yuba River, Technical Appendix. Report prepared for the CALFED Upper Yuba River Study Program. 34 p.

Vogel, D.A. 2005. The effects of Delta hydrodynamic conditions on San Joaquin River juvenile salmon. Natural Resource Scientists, Inc. Report submitted to the California State Water Resources Control Board. May 2005. 18 p.

Vogel, D.A. 2005. Fishery Resources Chapter for the Western Tehama County Watershed Assessment. Natural Resource Scientists, Inc. Prepared for VESTRA and Tehama County. 57 p.

Vogel, D.A. 2005. 2004 biological evaluation of the fish screens at the Glenn-Colusa Irrigation District's Sacramento River pump station. Report prepared for the multi-agency Technical Oversight Committee. May 2005. Natural Resource Scientists, Inc. 24 p.

Vogel, D.A. 2005. Evaluation of adult sturgeon migration at the Glenn-Colusa Irrigation District gradient facility on the Sacramento River during 2003. Report prepared for the multi-agency Technical Oversight Committee. May 2005. Natural Resource Scientists, Inc. 14 p.

Vogel, D.A. 2005. 2003 biological evaluation of the fish screens at the Glenn-Colusa Irrigation District's Sacramento River pump station. Report prepared for the multi-agency Technical Oversight Committee. January 2005. Natural Resource Scientists, Inc. 37 p.

Vogel, D.A. 2004. Juvenile Chinook salmon radio-telemetry studies in the northern and central Sacramento-San Joaquin Delta, 2002 – 2003, Final Report. Contract report for CALFED, administered by the National Fish and Wildlife Foundation. Natural Resource Scientists, Inc. January 2004. 188 p.

Wilkinson, C., R. Churchwell, D. Vogel. 2004. Yolo Bypass Experimental Fish Passage Project, 2003-2004 Interim Report. California Department of Water Resources, Division of Environmental Services, Fish Facilities Section. 19 p.

Vogel, D.A. 2003. Merced River Water Temperature Feasibility Investigation: Reconnaissance Report. Contract report prepared for the U.S. Fish and Wildlife Service Anadromous Fish Restoration Program. Natural Resource Scientists, Inc., Red Bluff, CA. December 2003. 89 p.

Vogel, D.A. 2003. Evaluation of a proposal for hydraulic salmonid egg deposition. Report prepared for the U.S. Bureau of Reclamation. Natural Resource Scientists, Inc. October 2003. 36 p.

Vogel, D.A. 2003. Assessment of anadromous salmonid habitat in the Lower Bear River, California. Unpublished report prepared for South Sutter Water District. Natural Resource Scientists, Inc. December 2003. 33 p. plus appendices.

Vogel, D.A. 2003. 2002 biological evaluation of the fish screens and gradient facility at the Glenn-Colusa Irrigation District's Sacramento River pump station. Report prepared for the multi-agency Technical Oversight Committee. Natural Resource Scientists, Inc. October 2003. 27 p.

Vogel, D.A. 2003. Fish monitoring in the vicinity of the Glenn-Colusa Irrigation District Sacramento River gradient facility, 1998 – 2001 (pre- and post-construction). Report prepared for the multi-agency Technical Oversight Committee. Natural Resource Scientists, Inc. February 2003. 45 p. plus appendices.

Vogel, D.A. 2002. Juvenile Chinook salmon radio-telemetry study in the southern Sacramento-San Joaquin Delta, December 2000 – January 2001. Contract report for the U.S. Fish and Wildlife Service. Natural Resource Scientists, Inc. June 2002. 27 p. plus figures and appendices.

Vogel, D.A. and K.R. Marine. 2001. Assessment of salmon spawning gravel characteristics and quality, 1995 – 1997, Lower Mokelumne River Fisheries Monitoring Program. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. June 2001. 35 p. plus appendices.

Vogel, D.A. 2001. Juvenile Chinook salmon radio-telemetry study in the northern Sacramento-San Joaquin Delta, January – February 2000. Contract report for the U.S. Fish and Wildlife Service. Natural Resource Scientists, Inc. May 2001. 34 p. plus figures and appendices.

Vogel, D.A. and K.R. Marine. 2000. Lower Mokelumne River Fisheries Monitoring Program, Downstream migration monitoring at Woodbridge Dam during December 1999 through July 2000. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. November 2000. 41 p. plus appendices.

Marine, K.R. and D.A. Vogel. 2000. Lower Mokelumne River Fisheries Monitoring Program, Upstream migration monitoring at Woodbridge Dam during August 1999 through March 2000. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. September 2000. 48 p. plus appendices.

Vogel, D.A. 2000. Fish monitoring in the vicinity of the future Glenn-Colusa Irrigation District gradient facility on the Sacramento River, 1998 - 1999. Report prepared for the multi-agency Technical Oversight Committee. Natural Resource Scientists, Inc. September 2000. 29 p. plus appendices.

Vogel, D.A. and K.R. Marine. 2000. Lower Mokelumne River Fisheries Monitoring Program, Downstream migration monitoring at Woodbridge Dam during December 1998 through July 1999. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. March 2000. 38 p. plus appendices.

Marine, K.R. and D.A. Vogel. 1999. Lower Mokelumne River Fisheries Monitoring Program, Upstream migration monitoring at Woodbridge Dam during August 1998 through March 1999. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. December1999. 48 p. plus appendices.

Vogel, D.A. and K.R. Marine. 1999. Lower Mokelumne River Fisheries Monitoring Program, Evaluation of the downstream migration of juvenile salmon and steelhead in the lower Mokelumne River and the Sacramento - San Joaquin Delta (December 1997 through July 1998. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. September 1999. 43 p. plus appendices.

Marine, K.R. and D.A. Vogel. 1999. Lower Mokelumne River Fisheries Monitoring Program, Monitoring of the upstream migration of Chinook salmon and steelhead during September 1997 through February 1998. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. February 1999. 44 p. plus appendices.

Vogel, D.A. and K.R. Marine. 1999. Lower Mokelumne River Fisheries Monitoring Program, Evaluation of the downstream migration of juvenile salmon and steelhead in the lower Mokelumne River and the Sacramento - San Joaquin Delta (January through July 1997. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. February 1999. 44 p. plus appendices.

Marine, K.R. and D.A. Vogel. 1999. Lower Mokelumne River Fisheries Monitoring Program, Monitoring of the upstream migration of Chinook salmon and steelhead during September through December 1996. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. October 1998. 44 p. plus appendices.

Vogel, D.A. and K.R. Marine. 1998. Lower Mokelumne River Fisheries Monitoring Program, Evaluation of the downstream migration of juvenile salmon and steelhead in the lower Mokelumne River and the Sacramento - San Joaquin Delta (January through July 1996. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. October 1998. 43 p. plus appendices.

Vogel, D.A. 1998. History and status of the lower Mokelumne River fishery resource. Report prepared for East Bay Municipal Utility District and submitted to the California State Water Resources Control Board. June 1998. 46 p.

Marine, K.R. and D.A. Vogel. 1998. Lower Mokelumne River Fisheries Monitoring Program, Monitoring of the upstream migration of Chinook salmon and steelhead during September through December 1995. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. April 1998. 47 p. plus appendices.

Vogel, D.A. 1998. Riverine habitat monitoring data in the Glenn-Colusa Irrigation District's oxbow bypass channel on the Sacramento River. Report prepared for the multi-agency Technical Oversight Committee. Natural Resource Scientists, Inc. 55 p.

Vogel, D.A. and K.R. Marine. 1998. Lower Mokelumne River Fisheries Monitoring Program, Evaluation of the downstream migration of juvenile salmon and steelhead in the lower Mokelumne River and the Sacramento - San Joaquin Delta (January through July 1995. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. April 1998. 55 p. plus appendices.

Vogel, D.A. 1998. Preliminary assessment of streambed substrate for salmon spawning in Stony Creek, California. Natural Resource Scientists, Inc. Report prepared for the Orland Unit Water Users and Tehama-Colusa Canal Authority. February 1998. 15 p.

Vogel, D.A. and K.R. Marine. 1997. Fish passage and stress effects on juvenile Chinook salmon physiology and predator avoidance abilities. Natural Resource Scientists, Inc. February 1997. 32 p. plus appendices.

Giddings, J., L. Hall, Jr., K. Solomon, W. Adams, D. Vogel, L. Davis, and R. Smith. 1997. An ecological risk assessment of diazinon in the Sacramento and San Joaquin River basins. Novartis Crop Protection, Inc. Technical

Report 11/97. Greensboro, North Carolina. 289 p.

Marine, K.R. and D.A. Vogel. 1996. Lower Mokelumne River Fisheries Monitoring Program, Monitoring of the upstream migration of Chinook salmon and steelhead during October through December 1994. Technical Report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District, Oakland, California. November 1996. 58 p. plus appendices.

Vogel, D.A. and K.R. Marine. 1996. Lower Mokelumne River Fisheries Monitoring Program, Evaluation of the downstream migration of juvenile salmon and steelhead in the lower Mokelumne River and the Sacramento - San Joaquin Delta (January through July 1994. Technical Report prepared by Vogel Environmental Services for East Bay Municipal Utility District, Oakland, California. July 1996. 66 p. plus appendices.

Vogel, D.A. and K.R. Marine. 1995. A technical memorandum on 1995 predation evaluations near the GCID Sacramento River pump station. Natural Resource Scientists, Inc. Prepared for Glenn-Colusa Irrigation District, Willows, California. December 1995. 17 p.

Vogel, D.A. and K.R. Marine. 1995. 1995 evaluation of juvenile Chinook salmon transport timing in the vicinity of the new fish screens at the Glenn-Colusa Irrigation District's Sacramento River pump station. Natural Resource Scientists, Inc. Prepared for Glenn-Colusa Irrigation District, Willows, California. November 1995. 34 p.

Vogel, D.A. and K.R. Marine. 1995. 1994 biological evaluation of the new fish screens at the Glenn-Colusa Irrigation District's Sacramento River pump station. Natural Resource Scientists, Inc. February 1995. 77 p. plus appendices.

Vogel, D.A. 1995. Losses of young anadromous salmonids at water diversions on the Sacramento and Mokelumne rivers. Report prepared for the U.S. Fish and Wildlife Service Anadromous Fish Restoration Program. January 1995. 34 p.

Marine, K.R. and D.A. Vogel. 1994. Lower Mokelumne River Fisheries Monitoring Program, Monitoring of the upstream spawning migration of Chinook salmon and steelhead during October through December 1993 and monitoring of the emigration of the 1993 fall release of yearling Chinook salmon from Mokelumne River Fish Installation during October 1993 through February 1994. Technical Report prepared by Vogel Environmental Services for East Bay Municipal Utility District, Oakland, California. December 1994. 49 p. plus appendices.

Vogel, D.A. 1994. Considerations on the use of fish survival indices as a tool to develop fish and wildlife standards in the Sacramento - San Joaquin Delta. Testimony presented to the California State Water Resources Control Board. Natural Resource Scientists, Inc. July 14, 1994. 16 p.

Vogel, D.A. and K.R. Marine. 1994. Lower Mokelumne River Fisheries Monitoring Program, Evaluation of the downstream migration of juvenile salmon and steelhead in the lower Mokelumne River and the Sacramento - San Joaquin Delta (January through July 1993. Technical Report prepared by Vogel Environmental Services for East Bay Municipal Utility District, Oakland, California. April 1994. 59 p. plus appendices.

Vogel, D.A. 1993. Need for updating fish protection facilities for anadromous and resident stocks in the West Coast of North America. Proceedings of the American Fisheries Society Bioengineering Symposium, Portland, Oregon. August 30 - September 3, 1993. 6 p.

Marine, K.R. and D.A. Vogel. 1993. Lower Mokelumne River Fisheries Monitoring Program, Monitoring of the upstream spawning migration of Chinook salmon and steelhead during October through December 1992. Technical Report prepared by Vogel Environmental Services for East Bay Municipal Utility District, Oakland, California. June 1993. 40 p. plus appendices.

Vogel, D.A. 1992. Resolving Environmental Issues in the Environmental Age. Chapter in *Achieving Consensus on Water Policy in California.* Edmund G. "Pat" Brown Institute of Public Affairs, California State University, Los Angeles. p. 137-147.

Vogel, D.A. and K.R. Marine. 1992. An assessment of the appraisal study of options for improving fish passage at Red Bluff Diversion Dam. Report prepared for the Tehama-Colusa Canal Authority. Vogel Environmental Services. 29 p.

Vogel, D.A. 1992. Assessment of the fish passage facilities at Lake Lodi in the Mokelumne River. Report prepared for East Bay Municipal Utility District, Oakland, California. Vogel Environmental Services. 42 p.

Vogel, D.A. 1991. The Human Side of Fisheries Science. Chapter in *California's Salmon and Steelhead: Perspectives on an Imperiled Resource.* University of California Press. p. 124-134.

Vogel, D.A. and K.R. Marine. 1991. Guide to Upper Sacramento River Chinook Salmon Life History. Report prepared for the U.S. Bureau of Reclamation, Central Valley Project. July 1991. 55 p. with appendices.

Vogel, D.A. and several co-authors. 1991. Assessment of options for excluding adult salmon from entry into the Colusa Basin Drain. Report prepared for Reclamation District 2047. CH2M Hill. September 1991. 19 p.

Vogel, D.A. 1990. Important biological considerations of the proposed Shasta Dam water temperature control device. Congressional briefing paper. October 1990. 9 p.

Vogel, D.A., K.R. Marine and J.G. Smith. 1990. A summary of evaluations of upstream and downstream anadromous salmonid passage at Red Bluff Diversion Dam on the Sacramento River, California, U.S.A. Paper presented at the *International Symposium on Fishways '90 in Gifu, Japan.* Proceedings p. 275-281. October 8-10, 1990.

Vogel, D.A. 1989. Tehama-Colusa Canal Diversion and Fishery Problems Study. Final Report. U.S. Fish and Wildlife Service Technical Report No. AFF/FAO-89-6. April 1989. 33 p. plus appendices.

Vogel, D.A. 1989. Sacramento River salmon restoration. Sacramento Valley Landowners Magazine. Pp. 10 – 13.

Vogel, D.A., K.R. Marine and J.G. Smith. 1988. Fish passage action program for Red Bluff Diversion Dam: Final report on fishery investigations. U.S. Fish and Wildlife Service Report No. FR1/FAO-88-19. October 1988. 77 p. plus appendices.

Vogel, D.A. 1987. Tehama-Colusa Canal Diversion and Fishery Problems Study. U.S. Fish and Wildlife Service Technical Report No. FR1/FAO-87-9.

Vogel, D.A. and G. Taylor. 1987. Survey of the Chinook salmon spawning substrate in the Sacramento River from the Highway 273 bridge to Keswick Dam, July – August 1987. U.S. Fish and Wildlife Service. Joint report by the Fisheries Assistance Office and the Division of Ecological Services Office. 13 p.

Vogel, D.A. 1987. Estimation of the 1986 spring Chinook salmon run in Mill Creek, California. U.S. Fish and Wildlife Service. Fisheries Assistance Office. Report No. FR1/FAO-87-12. May 1987. 9 p.

Vogel, D.A. 1987. Estimation of the 1986 spring Chinook salmon run in Deer Creek, California. U.S. Fish and Wildlife Service. Fisheries Assistance Office. Report No. FR1/FAO-87-3. January 1987. 10 p.

Vogel, D.A., K.R. Marine, and J.G. Smith. 1987. Fish passage action program for Red Bluff Diversion Dam. Annual progress report. March 1987. U.S. Fish and Wildlife Service Report No. FR1/FAO-87-6. 56 p. plus

appendices.

Vogel, D.A. 1985. Fish passage action program for Red Bluff Diversion Dam. Annual progress report. October 1985. USFWS Report No. FR1/FAO-86-5. 53 p. plus appendices.

Vogel, D.A. 1984. Data on daily entrainment for fry and juvenile Chinook salmon into the Tehama-Colusa (Dual-Purpose) and Corning Canals, California, January 1982 through December 1983. March 1984. U.S. Fish and Wildlife Service Report No. FR1/FAO-84-1. 27 p. plus appendices.

Vogel, D.A. 1984. Fish passage action program for Red Bluff Diversion Dam. Annual progress report. December 1984. U.S. Fish and Wildlife Service Report No. FR1/FAO-85-4. 72 p. plus appendices.

Vogel, D.A. 1984. Evaluation of the 1982-83 operation of the Tehama-Colusa Fish Facilities. July 1984. U.S. Fish and Wildlife Service Report No. FR1/FAO-84-2. 9 p.

Vogel, D.A. 1983. Evaluation of the Tehama-Colusa Fish Facilities. Cal-Neva Wildlife Transactions 1983: 20 – 25.

Vogel, D.A. 1982. Evaluation of the 1981-82 operation of the Tehama-Colusa Fish Facilities. U.S. Fish and Wildlife Service Report. Fisheries Assistance Office. January 28, 1982. 24 p.

Vogel, D.A. 1982. Preferred spawning velocities, depths, and substrates for fall Chinook salmon in Battle Creek, California. U.S. Fish and Wildlife Service, Fisheries Assistance Office. November 18, 1982. 8 p.

Hallock, R.J., D.A. Vogel, R.R. Reisenbichler. 1982. The effect of Red Bluff Diversion Dam on the migration of adult Chinook salmon, *Oncorhynchus tshawytscha*, as indicated by radio-tagged fish. California Department of Fish and Game, Anadromous Fisheries Branch, Administrative Report No. 82-8. 47 p.

Vogel, D.A. and K.M. Clemens. 1982. An evaluation of the contribution of Chinook salmon produced at the Tehama-Colusa Fish Facilities to the ocean fisheries and upper Sacramento River escapement (brood years 1973 – 1977). U.S. Fish and Wildlife Service Report. September 27, 1982. 7 p.

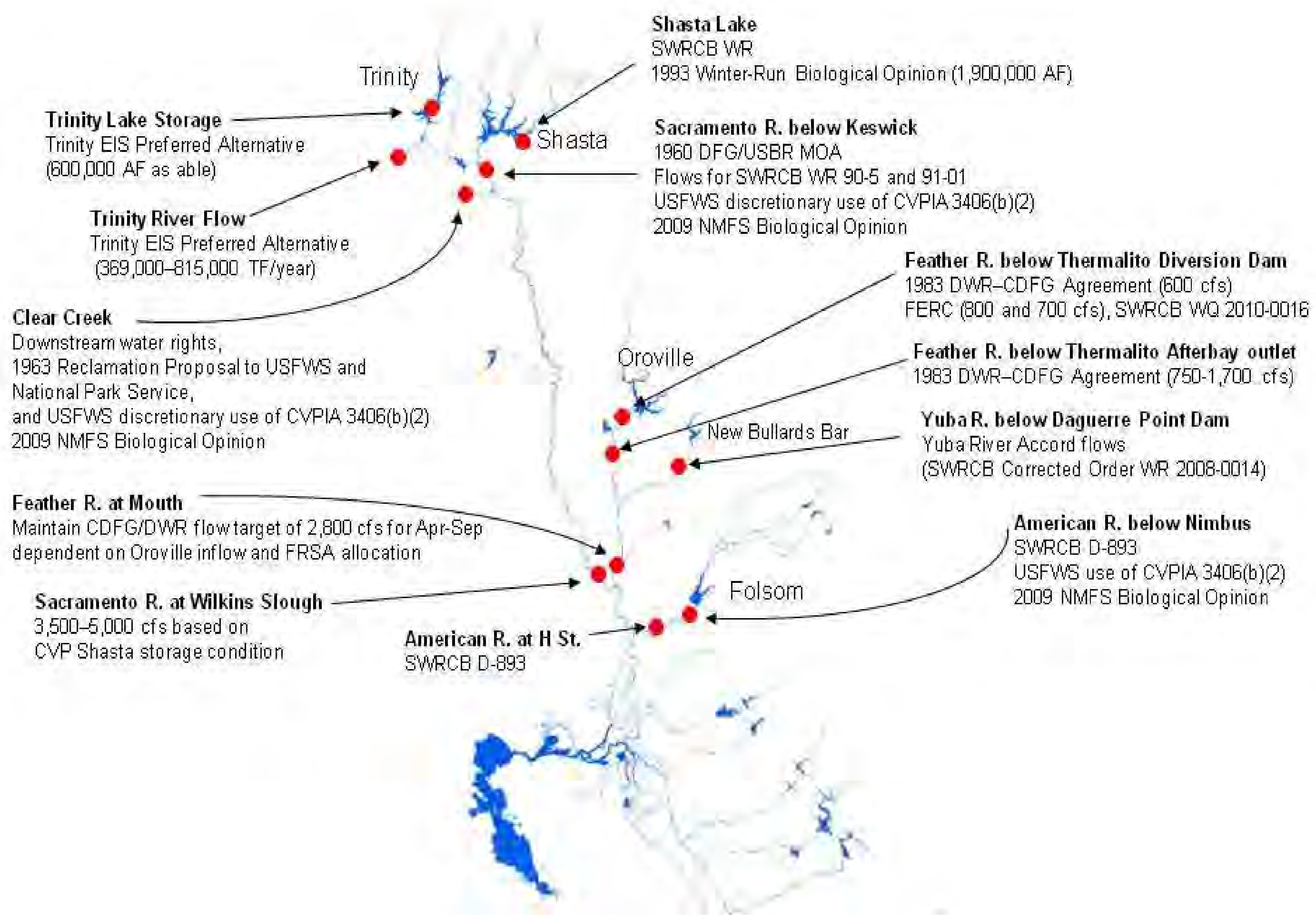
Johnson, S.I. and D.A. Vogel. 1981. Tehama-Colusa Fish Facilities Operational Plan. U.S. Fish and Wildlife Service Report. 27 p.

EXHIBIT 4

Instream Flow Requirements in the
Sacramento River Hydrologic Region
September 2011

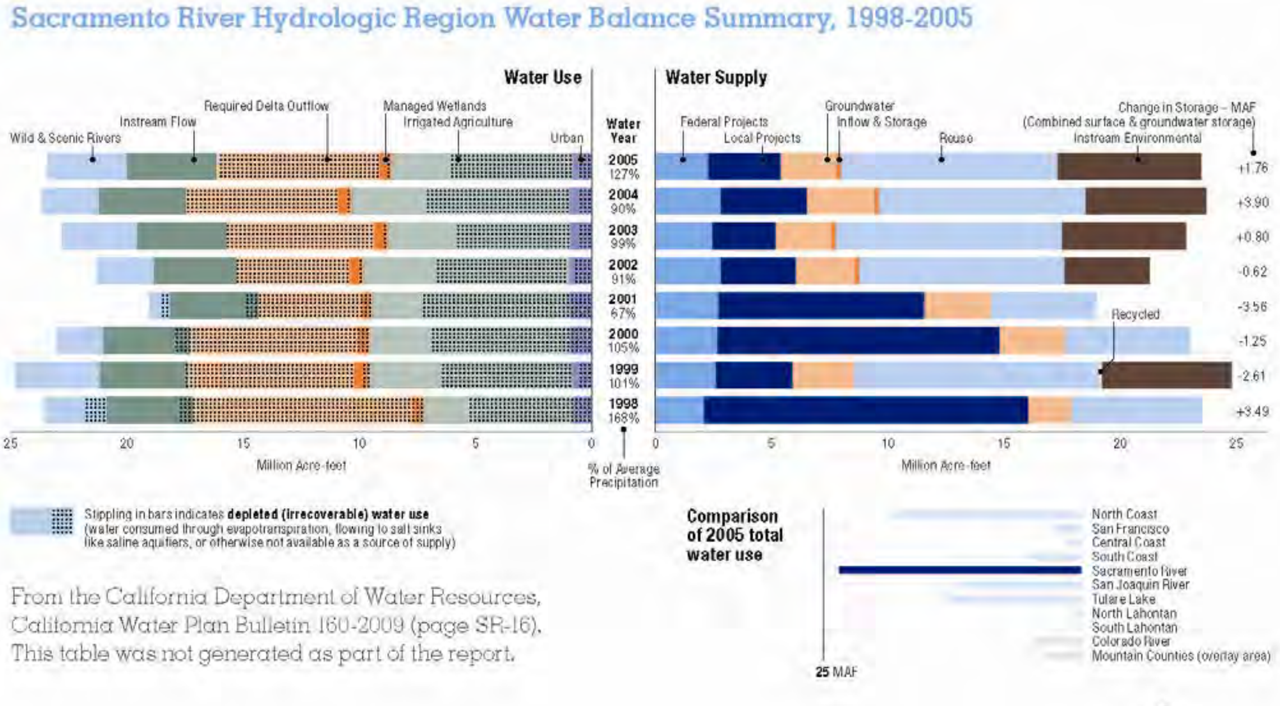
This briefing paper demonstrates the existing instream flow requirements for the major rivers and streams in the Sacramento River hydrologic region. This includes requirements in State Water Resources Control Board (SWRCB) decisions, biological opinions, streamflow agreements, and other processes. New processes to develop different flow requirements should be aware of, and take into account, these existing flow requirements.

Existing Flow Requirements - Sacramento Valley Hydrologic Region



Regional Water Balance

The following water balance, prepared by the Department of Water Resources as part of the California Water Plan (Bulletin 160-2009), shows a significant part of water in this region is dedicated to instream flows and required Delta outflow.


Sacramento River Hydrologic Region Water Balance Summary, 1998-2005

From the California Department of Water Resources, California Water Plan Bulletin 160-2009 (page SR-16). This table was not generated as part of the report.

Upper Sacramento River

1. 1960 MOA between Reclamation and DFG

An April 5, 1960, Memorandum of Agreement (MOA) between Reclamation and the DFG originally established flow objectives in the Sacramento River for the protection and preservation of fish and wildlife resources. The agreement provided for minimum releases into the natural channel of the Sacramento River at Keswick Dam for normal and critically dry years (Table 1, below). Since October 1981, Keswick Dam has operated based on a minimum release of 3,250 cfs for normal years from September 1 through the end of February, in accordance with the MOA. This release schedule was included in Order 90-05 (described below), which maintains a minimum release of 3,250 cfs at Keswick Dam and Red Bluff Diversion Dam (RBDD) from September through the end of February in all water years, except critically dry years.

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

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

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

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

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

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

3. June 4, 2009 NMFS Biological Opinion

The National Marine Fisheries Service's (NMFS) June 4, 2009, Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (NMFS BiOp) contains numerous terms and conditions addressing instream flows on the Upper Sacramento River.

Table 1 below, as excerpted from the NMFS BiOp (at page 254), identifies the aforementioned MOA and SWRCB order requirements, and Reclamation's proposed flow objectives below Keswick that were analyzed in the NMFS BiOp.

Table 1: Minimum flow requirements and objectives (cfs) on the Sacramento River below Keswick Dam

Water year type	MOA	WR 90-5	MOA and WR 90-5	Proposed Flow Objectives below Keswick
Period	Normal	Normal	Critically dry	All
January 1 - February 28(29)	2600	3250	2000	3250
March 1 - March 31	2300	2300	2300	3250
April 1 - April 30	2300	2300	2300	---*
May 1 - August 31	2300	2300	2300	---*
September 1 - September 30	3900	3250	2800	---*
October 1 - November 30	3900	3250	2800	3250
December 1 - December 31	2600	3250	2000	3250
Note: * No regulation.				

The flow related components of the NMFS BiOp related to the Sacramento River Basin are detailed in the Reasonable and Prudent Alternatives (RPA) section of BiOp at pages 587 through 611. The RPA Actions include flow requirements on Clear Creek; release requirements from Whiskeytown Dam for temperature management; cold water pool management of Shasta Reservoir; development of recommended minimum flows at Wilkins Slough; and restoration of floodplain habitat in the lower Sacramento River basin for protection of certain listed species. A selection of the more specific flow-related requirements are described below.

Clear Creek Operations

RPA Action I.1.1 - Clear Creek Spring Attraction Flows

Reclamation shall annually conduct at least two pulse flows in Clear Creek in May and June of at least 600 cfs for at least three days for each pulse, to attract adult spring-run holding in the Sacramento River main stem. This may be done in conjunction with channel-maintenance flows (Action I.1.2).

RPA Action I.1.2. – Clear Creek Channel Maintenance Flows

Reclamation shall re-operate Whiskeytown Glory Hole spills during the winter and spring to produce channel maintenance flows of a minimum of 3,250 cfs mean daily spill from Whiskeytown for one day, to occur seven times in a ten-year period, unless flood control operations provide similar releases. Re-operation of Whiskeytown Dam should be implemented with other project facilities as described in the EWP Pilot Program (Reclamation 2008d).

RPA Action I.1.5. – Clear Creek Thermal Stress Reduction

Reclamation shall manage Whiskeytown releases to meet a daily water temperature of:

(1) 60 deg. F at the Igo gage from June 1 through September 15; and

(2) 56 deg. F at the Igo gage from September 15 to October 31.

Reclamation, in coordination with NMFS, will assess improvements to modeling water temperatures in Clear Creek and identify a schedule for making improvements.

RPA Action I.1.6. - Adaptively Manage to Habitat Suitability/IFIM Study Results on Clear Creek

Reclamation shall operate Whiskeytown Reservoir as described in the Project Description with the modifications described in Action I.1 until September 30, 2012, or until 6 months after current Clear Creek salmonids habitat suitability (*e.g.*, IFIM) studies are completed, whichever occurs later.

When the salmonid habitat suitability studies are completed, Reclamation will, in conjunction with the Clear Creek Technical Working Group (CCTWG), assess whether Clear Creek flows shall be further adapted to reduce adverse impacts on spring-run and CV steelhead, and report their findings and proposed operational flows to NMFS within 6 months of completion of the studies. NMFS will review this report and determine whether the proposed operational flows are sufficient to avoid jeopardizing spring-run and CV steelhead or adversely modifying their critical habitat.

Reclamation shall implement the flows on receipt of NMFS' written concurrence. If NMFS does not concur, NMFS will provide notice of the insufficiencies and alternative flow recommendations. Within 30 days of receipt of non-concurrence by NMFS, Reclamation shall convene the CCTWG to address NMFS' concerns. Reclamation shall implement flows deemed sufficient by NMFS in the next calendar year.

<u>Shasta Operations</u>

RPA Action Suite I.2 – Shasta Operations

This suite of actions is designed to ensure that Reclamation uses maximum discretion to reduce adverse impacts of the projects to winter-run and spring-run in the Sacramento River by maintaining sufficient carryover storage and optimizing use of the cold water pool.

RPA Action I.2.1 – Performance Measures

The following long-term performance measures shall be attained. Reclamation shall track performance and report to NMFS at least every 5 years. If there is significant deviation from these performance measures over a 10-year period, measured as a running average, which is not explained by hydrological cycle factors (*e.g.*, extended drought), then Reclamation shall reinitiate consultation with NMFS.

Performance measures for end-of-season ("EOS") carryover storage at Shasta Reservoir:

- 87 percent of years: Minimum EOS storage of 2.2 MAF
- 82 percent of years: Minimum EOS storage of 2.2 MAF and end-of-April storage of 3.8 MAF in following year (to maintain potential to meet Balls Ferry compliance point)
- 40 percent of years: Minimum EOS storage 3.2 MAF (to maintain potential to meet Jelly's Ferry compliance point in following year)

Measured as a 10-year running average, performance measures for temperature compliance points during summer season shall be:

- Meet Clear Creek Compliance point 95 percent of time
- Meet Balls Ferry Compliance point 85 percent of time
- Meet Jelly's Ferry Compliance point 40 percent of time
- Meet Bend Bridge Compliance point 15 percent of time

RPA Actions I.2.2 through I.2.4 – Keswick Release Schedules

Depending on EOS carryover storage and hydrology, Reclamation is mandated to develop and implement Keswick release schedules, and reduce deliveries and exports, as detailed in RPA Actions I.2.2.A through I.2.2C, I.2.3.A through I.2.3.C, and I.2.4. (See NMFS BiOp at pp. 593-603.)

Required Technical Teams for Adaptive Management

The NMFS BiOp requires actions by various Fisheries and Operations Technical Teams whose function is to make recommendations for adjusting operations to meet contractual obligations for water delivery and minimize adverse effects on listed anadromous fish species. The two teams on the Upper Sacramento River are the SRTTG and the CCTWG. Each group must gather and analyze information, and make recommendations, regarding adjustments to water operations within the range of flexibility prescribed in the implementation procedures for a specific action in their particular geographic area.

4. *Wilkins Slough Navigation Flow Requirements Under Federal Law*

The NMFS BiOp requires the development of certain recommendations regarding the Wilkins Slough navigation flow requirements. Reclamation's compliance with the Wilkins Slough 5,000 cfs navigation flow standard, however, is not discretionary.

In this regard, Congress initially authorized the construction of certain facilities for the Central Valley Project ("CVP") under the Rivers and Harbors Act of 1935 (the "1935 Act"). (49 Stat. 1028, 1038). The 1935 Act mandated in relevant part that "the following works of improvement of rivers . . . are hereby adopted and authorized . . . in accordance with the plans recommended in the respective reports hereinafter designated and subject to the conditions set forth in such documents . . . Sacramento River, California; Rivers and Harbors Committee Document Numbered 35, Seventy-third Congress . . . ." (50 Stat. 1028, 1038.) As such, the 1935 Act incorporates by reference, and expressly requires the implementation of, the recommendations of the Rivers and Harbors Committee Document Number 35. This document is a 1934 report from the Corps' Chief Engineer recommending to Congress that Kennett Dam (predecessor to Shasta Dam) "shall be operated so as to provide a minimum flow of 5,000 cubic feet per second between Chico Landing and Sacramento." (*See* Central Valley Project Documents, Part I, 544, 548 [Committee Doc. 35, 73rd Cong.].)

Congress re-authorized the CVP under the Rivers and Harbors Act of 1937 (the "1937 Act"). (50 Stat. 844, 850.)[1] This re-authorization mandated in relevant part that "the $12,000,000 recommended for expenditure for a part of the Central Valley project, California, in accordance with the plans set forth in Rivers and Harbors Committee Document Numbered 35, Seventy-third Congress, and adopted and authorized by the provisions of section 1 of the Act of August 30, 1935 (49 Stat. 1028, at 1038) . . . shall, when appropriated, be available for expenditure in accordance with the said plans of the Secretary of Interior instead of the Secretary of War." (50 Stat. 844, 850.) As such, the 1937 Act also incorporates by reference, and expressly requires the implementation of, the recommended minimum flow of 5,000 cfs between Chico Landing and Sacramento. There has been no subsequent action by Congress that has "discontinued" or otherwise changed this minimum navigation flow requirement.

The 1937 Act also mandates that CVP "dams and reservoirs *shall* be used, *first*, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses; and, third, for power." (50 Stat. 844, 850, emphasis added; *see also United States v. SWRCB* (1986) 182 Cal.App.3d 82, 135.) In 1992, Congress explicitly amended this hierarchy of use by enacting sections 3406(a) and (b) of the Central Valley Project Improvement Act (Pub. L. No. 102-575 (1992)), which make protection of non-ESA listed fish and wildlife co-equal priorities with irrigation. Even with this amendment, however, Reclamation's first priority remains river regulation, navigation and flood control.

On the Sacramento River, all major diversions have positive barrier flat-plate fish screens installed that provide protection to listed fishery species. These screens have been designed with an approach velocity of 0.33 ft/s as required by NMFS and the Department of Fish and Game. During design, the screens, velocities, and diversion rates were based upon the Wilkins Slough Navigational Flow requirement of 5,000 cfs since this requirement under federal law was controlling.

The NMFS BiOp states that flows could be reduced to 3,250 cfs, which is lower than the Wilkins Slough flow requirement. If the Bureau of Reclamation reduced flows below the Wilkins Slough control point requirement and depending on the diversion rate, some screens may not meet the velocity criteria as designed. The agencies should coordinate with the Sacramento River diverters to develop contingency plans and wells as a coordinated operations plan that would benefit the Sacramento River system for fisheries and water users.

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[1] *See also Stockton East Water District, et al. v. United States*, 583 F.3d 1344, 1349 (Fed. Cir. 2009) [citing to the 1935 and 1937 Acts as Congress' initial authorization and reauthorization of the CVP].

Lower American River

The American River provides important fish and wildlife habitat, a high-quality water source, a critical floodway, and a spectacular regional recreational parkway. The Bureau of Reclamation (Reclamation) operates Folsom and Nimbus dams to provide flood control and water for irrigation, municipal and industrial uses, hydroelectric power, recreation, water quality, and the protection of aquatic resources.

In April of 2000, a diverse group of over 40 local business and agricultural leaders, citizen groups, environmentalists, water managers and local governments ended decades of conflict by signing the Water Forum Agreement (WFA). The foundational elements of the WFA are two coequal objectives: to provide a reliable safe water supply for the region and to preserve fishery, wildlife, recreational, and aesthetic values of the lower American River.

Working in cooperation with Reclamation, California Department of Fish and Game, National Marine Fisheries Service, Fish and Wildlife Service, the Water Forum developed the Flow Management Standard (FMS) as an alternative to D-893 (the current instream flow requirements on the lower American River). The FMS is intended to improve the condition of aquatic resources in the lower American River, particularly fall-run Chinook salmon and steelhead. In addition, the FMS benefits other fish species, the aquatic environment and the riparian ecosystem of the lower American River Corridor. Designed to achieve these benefits over a wide range of hydrologic conditions, the FMS provides a forum through which biologic and ecologic factors are considered in the river management process, and provides for the analysis of hydrologic and biologic information collected though the monitoring and evaluation component.

The lower American River FMS is designed to allocate flow releases from Folsom and Nimbus dams in consideration of variable hydrology and coldwater pool availability in Folsom Reservoir. The FMS includes: (1) minimum flow requirements; (2) water temperature objectives; (3) implementation criteria; (4) an agency group to address river management and operational actions (the American River Group); and (5) a monitoring and evaluation component.

1. Minimum Flow Requirements

The minimum flow requirements prescribe the flows in the lower American River water to meet fishery needs throughout the entire water year. These minimum flow requirements include minimum release requirements (MRR) measured downstream of Nimbus Dam, and downstream flow requirements (250 cfs from January through mid-September and 500 cfs from mid-September through December) between Nimbus Dam and the mouth of the lower American River. The prescribed flows are minimums only and do not preclude Reclamation from making higher releases.

The MRR varies from 800 to 2,000 cfs throughout the year in response to the hydrology of the Sacramento and American River basins and a set of prescriptive and discretionary adjustments. As such, the specified MRR is higher in wet years and lower in dry years. These adjustments are made in response to specific conditions related to the need for spawning flow progressions, fish protection, and reservoir water conservation. The resultant MRR varies throughout the season as shown in Table 1.

Table 1. Seasonal Variation in the Minimum Release Requirement

Time Period	MRR Range (cfs)	Index	Relevance of Index
October	800 to 1,500	Four Reservoir Index (FRI)	Indicates the amount of upstream storage available during the fall and winter months
November and December	800 to 2,000	FRI	
January and February	800 to 1,750	Sacramento River Index (SRI)	Indicates current multi-basin water availability
March through Labor Day	800 to 1,750	Folsom Inflow Index (IFII)	Forecasts water availability for the American River Basin for the remainder of the current water year
Post-Labor Day through September	800 to 1,500	IFII	

The FMS also includes exceptions to the MRR during extreme dry conditions, including:

- **Conference Years:** Occur when the projected March through November unimpaired inflow to Folsom Reservoir is less than 400,000 AF. A minimum flow of 190 cfs is required downstream of the H Street Bridge.
- **Off-ramp Criteria:** Triggered if Folsom Reservoir storage is forecasted to fall below 200,000 AF in the succeeding 12 months. In this case, downstream flow requirements rather than MRR become the minimum flow requirement throughout the lower American River.

2. Water Temperature Objectives

The water temperature objectives of the FMS have been developed to allocate the available lower American River cold water resources for juvenile steelhead rearing in summer, and fall-run Chinook salmon spawning in fall. These objectives are met through use of an Annual Operations Forecast (Operations Forecast) and Annual Water Temperature Management Plan (Temperature Plan).

The Operations Forecast will be prepared by May 1 of each year to describe forecasted American River operations, including flows and water temperatures for the next 12 months, with implementation of the Minimum Flow Requirements and Water Temperature Objectives.

The Temperature Plan will be developed by May 1 of each year to describe how Reclamation will meet the following water temperature objectives for the lower American River:

- 65ºF or less from May 15 through October at Watt Avenue for steelhead juvenile rearing. This objective may be relaxed to 68ºF if Temperature Plan analysis indicates that lower temperature targets will prematurely exhaust the available cold water.

- ☐ 60ºF or less as early in October as possible at Hazel Avenue for Chinook salmon spawning and egg incubation.

3. Implementation Criteria

Implementation criteria serve as a tool to determine the conditions by which the FMS Minimum Flow Requirements may be implemented, and to define the method of measuring compliance with the FMS Minimum Flow Requirements. The implementation criteria that are applied for decision-making purposes regarding operational adjustments affecting lower American River flows and water temperatures address the following: (1) end-of-month Folsom Reservoir storage, particularly during May and September; (2) Nimbus Dam releases and flows at the mouth of the lower American River measured over a 5-day averaging period; (3) water conservation adjustments; (4) fish protection adjustments; and (5) other considerations.

4. Lower American River Group

The Lower American River Group (ARG) is an advisory group consisting of agency representatives convened regularly by Reclamation. Through the regularly scheduled ARG meetings, which are open to the public, the ARG provides information to the public and formulates CVP operational recommendations for the protection of fisheries and other in-stream resources consistent with the FMS.

5. Monitoring and Evaluation

Monitoring and evaluation of physical and biological factors are included in the FMS to provide information to support operational decisions and to evaluate operational effects on the aquatic resources of the lower American River including river hydrology, water temperature, salmonid population and downstream movement.

Current Status

Sacramento County recently adopted a revised American River Parkway Plan which includes specific policies related to implementing water flows protective of the lower American River ecosystem. The Parkway Plan serves as a guide for other local, state and federal agencies with authority within the American River Parkway under the Wild and Scenic Rivers Act and the Urban American River Parkway Preservation Act. Sacramento County, through the Water Forum, is in the process of preparing a draft environmental impact report to institute the FMS consistent with the American River Parkway Plan and the coequal goals of the Water Forum Agreement by entering into an operations agreement with Reclamation or by seeking to modify Reclamation’s Folsom Dam water right permit through a petition to the SWRCB, or both.

Reclamation has been operating the Folsom dam in accordance with the minimum release requirements of the FMS since 2006. In 2009, the National Marine Fisheries Service (NMFS) included the FMS flow, operational criteria, American River Group, and monitoring requirements in the Reasonable and Prudent Alternatives of the Biological Opinion (BO) for operating the CVP. The NMFS BO also called for an iterative temperature management planning process that is consistent with the water temperature objectives of the FMS.

Yuba River

In 2008, the State Water Resources Control Board (the SWRCB) adopted streamflow requirements and related measures proposed by Yuba County Water Agency (YCWA) that implemented the Yuba River Accord Fisheries Agreement that YCWA developed with the Department of Fish and Game (DFG), the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS) and several conservation groups. The Accord and the SWRCB's related order – Corrected Order WR 2008-14 – resolved 20 years of disputes concerning the Yuba River's streamflows. The Accord streamflow requirements, as implemented by the SWRCB, are depicted on Exhibit A. The SWRCB adopted Corrected Order WR 2008-14 based on a $6 million environmental impact report that YCWA certified and that was not challenged in court. The Yuba River Accord is summarized below and additional information is available on YCWA's Web site at http://www.ycwa.com/projects/detail/8.

Disputes concerning the Yuba River's streamflows began in 1988 and continued through a 14-day SWRCB hearing in 1992, a 13-day SWRCB hearing in 2000 and a three-day SWRCB hearing in 2003. In 2003, the SWRCB adopted Revised Water Right Decision 1644 (RD-1644) and many lawsuits, including one by YCWA, were filed to challenge RD-1644.

As an alternative to litigating these disputes to a conclusion, YCWA, DFG, NMFS, USFWS and environmental groups engaged in a collaborative, science-based process to identify and prioritize the key stressors on salmon and steelhead in the lower Yuba River and then develop streamflow requirements that would address these stressors. The resulting Yuba Accord Fisheries Agreement sets new, substantially-higher streamflow requirements that allocate more water to fishery benefits than RD-1644 would have required. Specifically, the Fisheries Agreement's streamflow schedules include up to more than 174,000 acre-feet of water annually, and more than 100,000 acre-feet in the springtime of about 60% of all years, to fishery benefits than RD-1644 would have committed. The Fisheries Agreement allocates these fishery streamflows in a manner that enables YCWA to deliver approximately 350,000 acre-feet or more of water a year for consumptive use in Yuba County and to transfer water to downstream water users, including Delta-export agencies, for irrigation, municipal and environmental uses.

The Fisheries Agreement is only one of four agreements that make up the Yuba River Accord. The other agreements are: (1) a Conjunctive Use Agreement with local Yuba County water suppliers; (2) a Water Transfer Agreement with the state Department of Water Resources (DWR); and (3) an agreement with PG&E to allow modified operations at YCWA's New Bullards Bar Reservoir. Under the Conjunctive Use Agreement, Yuba County water suppliers agreed to pump up to 30,000 acre-feet of groundwater to substitute for surface water deliveries in certain dry years to provide water allocated by the Fisheries Agreement for fishery benefits. Also under the Conjunctive Use Agreement, YCWA agreed to provide funding from its Accord transfer proceeds to assist water suppliers in pumping the necessary groundwater and to monitor local groundwater conditions to ensure that pumping under the Accord does not cause overdraft. Under the Water Transfer Agreement, YCWA agreed to transfer at least 60,000 acre-feet per year of water to the Environmental Water Account (and successor programs) and potentially 140,000 acre-feet of water in drier years to DWR. In addition to assisting local Yuba County water suppliers in implementing conjunctive use, YCWA has used Accord transfer proceeds as contributions to setback-levee projects and other flood risk management projects.

The Accord Fisheries Agreement contains several unique elements in addition to the new streamflow requirements depicted in Exhibit A. That Agreement establishes a River Management Team (RMT), which includes representatives of YCWA, DFG, NMFS, USFWS, PG&E and conservation groups. The RMT has the ability to modify flows at certain times for fishery benefits. The RMT also is responsible for allocating 50% of the volume of any supplemental surface water transfer by YCWA and up to 20% of the streamflows enabled by implementation of the Accord Conjunctive Use Agreement. The RMT oversees a monitoring and evaluation program that is tasked with determining the efficacy of the Fisheries Agreement's streamflows. That Agreement also establishes a cap on irrigation diversions in extremely dry (1-in-100) "conference years" at about 70% of annual irrigation demands.

Consistent with the Accord agreements, the SWRCB's Corrected Order WR 2008-14 approved water-right permit terms under which, in conference years, YCWA would operate its project to maintain the minimum streamflows required by a 1965 streamflow agreement between YCWA and DFG, but without certain reductions authorized by that agreement and subject to supplemental flow release requirements developed by the RMT's Planning Group under the Fisheries Agreement and approved by the SWRCB's Deputy Director for Water Rights. Under Corrected Order WR 2008-14, if the Planning Group does not make any streamflow recommendations in a conference year by April 1 or if no streamflow requirements are in place by April 11 of such a year, then YCWA must comply with streamflow requirements ordered by the SWRCB after a hearing.

Finally, in operating its facilities, YCWA must comply with the requirements of its existing license no. 2246 from the Federal Energy Regulatory Commission (FERC). Those FERC license requirements, however, typically are dwarfed by the Accord Fisheries Agreement's streamflow requirements.

The Yuba River Accord has been recognized as a landmark achievement in collaborative water management to achieve water supply reliability and habitat protection. For example, the Accord received the 2008 ACWA Theodore Roosevelt Environmental Award for Excellence in Conservation and Natural Resources Management, the 2009 National Hydropower Association Award for Outstanding Stewards of America's Waters and the 2009 Governor's Environmental and Economic Leadership Award.

Feather River

On December 15, 2010, the SWRCB adopted, as Order WQ 2010-0016, a water quality certification for the Oroville Facilities, FERC # 2100, for the relicensing of the Oroville project by DWR. The water quality certification contains instream-flow and temperature-control requirements for the Feather River's reaches downstream of DWR's Oroville Dam.

In general, the streamflow requirements adopted by the SWRCB in the certification are as follows.

For the Low Flow Channel – which is the reach between DWR's Fish Barrier Dam and the outlet of the Thermalito afterbay – the certification requires that DWR release into that Channel 800 cfs from September 9 to March 31 of each water year to accommodate spawning anadromous fish and 700 cfs the remainder of the time, with both standards subject to possible revision as recommended by resource agencies under a settlement agreement signed by parties to DWR's relicensing proceeding. The SWRCB's Deputy Director for Water Rights would have to approve changes from the indicated streamflows for the Low Flow Channel.

For the High Flow Channel – which is the reach between the Thermalito Afterbay's outlet and the Feather River's confluence with the Sacramento River – the certification applies the following instream-flow requirements, provided that they, along with project operations, are not projected to cause Oroville Reservoir to be drawn below elevation 733 feet (approximately 1,500,000 acre-feet of storage):

Preceding April through July unimpaired runoff	Minimum Flow in HFC October-February	Minimum Flow in HFC March	Minimum Flow in HFC April-September
Percent of Normal			
55% or greater	1,700 cfs	1,700 cfs	1,000 cfs
Less than 55%	1,200 cfs	1,000 cfs	1,000 cfs

Under the certification, if applying these requirements would be projected to cause Oroville Reservoir to be drawn below elevation 733 feet, then the minimum streamflows in the High Flow Channel could be reduced by the same percentage as State Water Project deliveries for agricultural use, provided that streamflows would not ever be reduced more than 25 percent below the requirements. In addition, if the highest one-hour streamflow between October 15 and November 30 were to exceed 2,500 cfs because of project operations and not a flood flow, then DWR is required to maintain a minimum flow within 500 cfs of the peak flow.

The certification also contains complex terms that require DWR to operate the Oroville project to meet temperature standards in the Low Flow Channel and the High Flow Channel.

For the Low Flow Channel at the Robinson Riffle, the certification sets the following temperature standards: (1) October 1-April 30, 56 degrees F; (2) May 1-15, 56-63 degrees F (as a transition); (3) May 16-August 31, 63 degrees F; (4) September 1-8, 63-58 degrees F (as a transition); and (5) September 9-30, 58 degrees F. If DWR were to demonstrate that it cannot meet these requirements with its current facilities, then the certification would require DWR to submit an interim operations plan to the SWRCB and, within three years of the renewed FERC license's issuance, submit a long-term facility-modification and operations plan to the SWRCB. If after implementing the facility modifications, DWR were to demonstrate that it still cannot meet the above temperature standards, then DWR would be required to propose alternate temperature standards that would provide "reasonable protection of the COLD beneficial use." Upon the approval of the SWRCB's Deputy Director for Water Rights, DWR would be required to operate to the alternate standards.

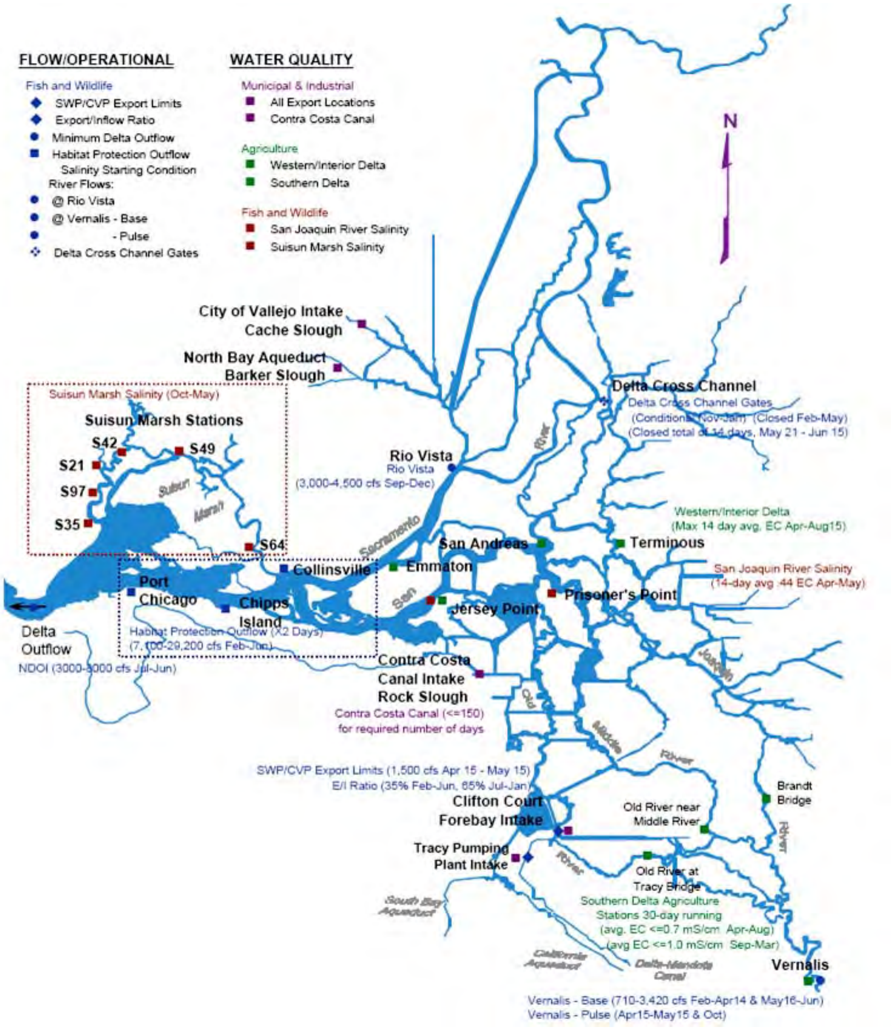
For the High Flow Channel, DWR is required to operate the project "to protect the COLD beneficial use in [that Channel], as measured in the Feather River at the downstream Project Boundary, to the extent reasonably achieveable." Within one year of the renewed FERC license's issuance, DWR would be required to submit an operations plan for the period before facility modifications, which plan would be required to include proposed interim temperature standards and interim measures to reduce temperatures. Within three years of the renewed FERC license's issuance, DWR would be required to submit a long-term facility modification and operations plan, which plan would have to include proposed temperature standards to take effect within 10 years of the renewed license's issuance.

Bay-Delta Standards

The following map shows the existing Bay-Delta standards in SWRCB Decision 1641. Water supplies in the Sacramento Valley are operated to meet these standards.

In 2002, the USBR, DWR, USFWS, DFG, various export water users, and various Sacramento Valley water users approved the Sacramento Valley Water Management Agreement (SVWMA), which established a framework to meet water supply, water quality, and environmental needs in the areas of origin, the Delta, and in export areas. The SVWMA provides that, pursuant to specified terms and conditions being met, certain upstream Sacramento Valley water users will take actions to make available up to 185,000 acre-feet of water that would otherwise not be available in the Sacramento River during the period June 1 through October 31 of each year.

Notably, the SWRCB facilitated the SVWMA parties' negotiation and execution of the SVWMA, by issuing its Orders WR 2001-05 and WR 2002-12, which stayed and ultimately dismissed Phase 8 of the Bay-Delta Water Rights Hearing related to SWRCB Decision 1641.



D-1641
Bay-Delta
Standards
Stations

EXHIBIT A
Yuba Accord Streamflows, Approved by SWRCB in Corrected Order WR 2008-14

MARYSVILLE GAGE (CFS)

Schedule	OCT		NOV	DEC	JAN	FEB	MAR	APR		MAY		JUN		JUL	AUG	SEP	Total Annual Volume (AF)
	1-15	16-31	1-30	1-31	1-31	1-29	1-31	1-15	16-30	1-15	16-31	1-15	16-30	1-31	1-31	1-30	
1	500	500	500	500	500	500	700	1000	1000	2000	2000	1500	1500	700	600	500	574,200
2	500	500	500	500	500	500	700	700	800	1000	1000	800	500	500	500	500	429,066
3	500	500	500	500	500	500	500	700	700	900	900	500	500	500	500	500	398,722
4	400	400	500	500	500	500	500	600	900	900	600	400	400	400	400	400	361,944
5	400	400	500	500	500	500	500	500	600	600	400	400	400	400	400	400	334,818
6	350	350	350	350	350	350	350	350	500	500	400	300	150	150	150	350	232,155

* Indicated flows represent average volumes for the specified time period. Actual flows may vary from the indicated flows according to established criteria.
* Indicated Schedule 6 flows do not include an additional 30 TAF available from groundwater substitution to be allocated according to established criteria

SMARTVILLE GAGE (CFS)

Schedule	OCT		NOV	DEC	JAN	FEB	MAR	APR		MAY		JUN		JUL	AUG	SEP	Total Annual Volume (AF)
	1-15	16-31	1-30	1-31	1-31	1-29	1-31	1-15	16-30	1-15	16-31	1-15	16-30	1-31	1-31	1-30	
A	700	700	700	700	700	700	700	700	-	-	-	-	-	-	-	700	-
B	600	600	600	550	550	550	550	600	-	-	-	-	-	-	-	500	-

* Schedule A used with Schedules 1, 2, 3 and 4 at Marysville.
* Schedule B used with Schedules 5 and 6 at Marysville.

EXHIBIT 5

MBK ENGINEERS
Water Resources • Flood Control • Water Rights

M E M O R A N D U M

DATE:	December 15, 2011
TO:	Northern California Water Association
FROM:	Walter Bourez
SUBJECT:	Relating Delta Smelt Index to X2 Position, Delta Flows, and Water Use

INTRODUCTION

There has recently been much interest in requiring higher instream flows through the Sacramento-San Joaquin River Delta (Delta) in an attempt to reverse the continuing decline of a number of fish species that reside in or migrate through the Delta. Last year, for instance, reports issued by the State Water Resources Control Board (SWRCB) and the California Department of Fish & Game (DFG) stated that additional flows in the form of increased Delta outflows would be needed to meet the needs of both pelagic and salmonid species. More recently, the United States Environmental Protection Agency (USEPA) issued an Advance Notice of Proposed Rulemaking, which also suggested that higher instream flows through the Delta may be necessary. These reports rely on the theory that, by increasing instream flows and restoring a more natural hydrograph, habitat conditions for the fish species in question will improve and, as a result, fish populations will also improve.

Examination of the data used in each of these reports, however, shows that there is little, if any, scientific basis for the claim that additional flows will enhance declining fish populations. Key findings are:

1. The data used to support the claim that additional flows will enhance fish populations compares a wetter period (1956-1987) with a drier period (1988-2003). This invalid comparison of periods with very different hydrology is a fundamental flaw in the claim that increasing flows through the Delta will result in increasing fish populations.

2. Moreover, the constantly changing nature of the operations of the federal Central Valley Project (CVP) and the State Water Project (SWP) during the period from 1988-2003, as well as the fact that Delta outflow requirements increased during that period, make it difficult to conclude that a lack of flows is responsible for the decline in Delta fisheries.

3. A comparison of Delta fish population with water use in the Sacramento Valley shows that there appears to be no relationship between that water use and fish populations.

Taken together, all of these factors suggest that the decline in Delta fisheries is the result of factors other than flow.

Both the SWRCB and the DFG reports advocate modifying instream flows in the Delta and its tributaries so as to more closely mimic the natural hydrograph (i.e. streamflows occurring prior to 1850). A “natural hydrograph” means that hydrology will mimic the variability that occurred prior to the construction of the CVP and SWP. This variability included both wet and dry years. Examination of the data discussed above, however, indicates that both reports are – in fact – advocating not a natural hydrograph but, rather, that the Delta and its tributaries be operated so that every year mimics a wet or above normal year. If the fundamental concept behind the “natural hydrograph” claim is correct, then it is likely that it is just as harmful to fish species for every year to be a wet year as it would be if every year were a dry year.

Lastly, examination of the hydrologic data for the Delta leads to the strong conclusion that hydrology is not destiny. The continuing decline in fish populations, notwithstanding continuing regulatory adjustments to project operations through increasing Delta outflow requirements, strongly suggest that there are other factors at play. Specifically, as described in depth by Dave Vogel in his April 2011 report entitled *Insights into the Problems, Progress and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration*, it appears that predation (particularly by non-native species) and habitat degradation in the Delta is likely a major problem for Sacramento River basin anadromous fisheries. In addition, there may be alternative ocean harvest methods that could increase the reproductive capacity of Sacramento River basin anadromous fisheries. The data presented in this report make it clear; however, that increasing Delta outflow by means of X2 is not likely to reverse population declines in anadromous fisheries.

COMPARING HYDROLOGIC PERIODS DURING SPRING PERIODS

The SWRCB Delta Flow Report (at pages 104-106) compares average net Delta outflow for the January through June period from 1956-2009. The report then concludes that the “step-decline in the abundance X2 relationship that occurred after 1987 for many of these species . . . leads to uncertainty regarding the future response of these species to elevated flows.” (p. 107). Notwithstanding this caution, the report concludes that such elevated flows “are necessary to protect public trust resources and that the current flow regime has harmed native species and benefited non-native species.” (p. 108). Figure 1, below, contains “Figure 14, Net Delta Outflow Exceedance Plot – January through June” from page 106 of the SWRCB August 3, 2010 report titled: *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem*, prepared pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009. The line representing “Actual” flow for the 1956-1987 period is above the line representing the 1988-2009 period, indicating flow during the 1956-1987 period was greater. Average net Delta outflow during the 1988-2009 period was approximately 5,000 cfs less than during the 1956-87 period, which means that during the 1956-87 period there was approximately an additional 1.7 million acre-feet of net Delta outflow (5,000 cfs x 1.98 af/cfs x 180 days) than during the 1988-2009 period.

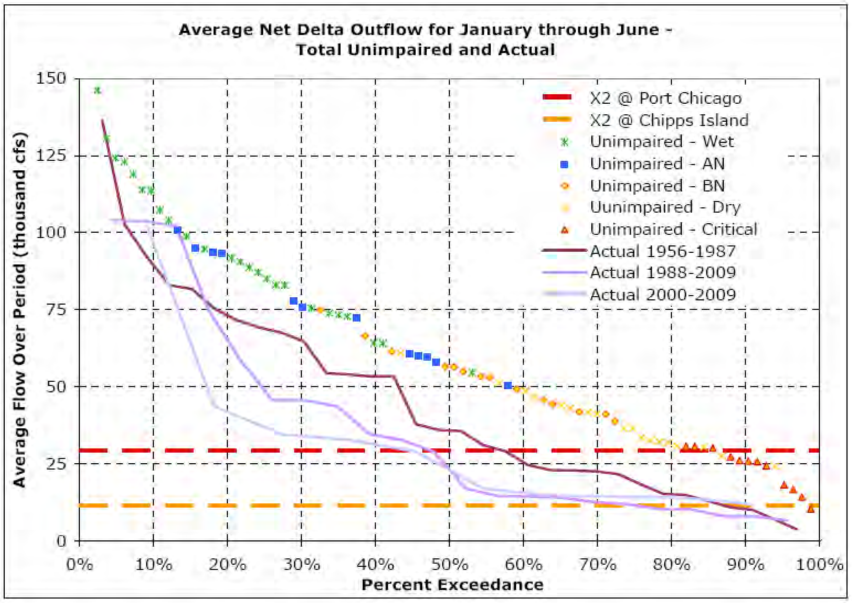


Figure 1 - Net Delta Outflow Exceedance Plot from SWRCB Report Page 106

Figure 2 shows probabilities of exceedance of historical ("actual") average Delta outflow for the DAYFLOW period of record (1930-2008) during January through June and the average Delta outflow for the periods 1930-1955, 1956-1987, 1988-2009, and 2000-2009. As in Figure 1, the 1988-2009 period is substantially drier than the 1956-1987 period.

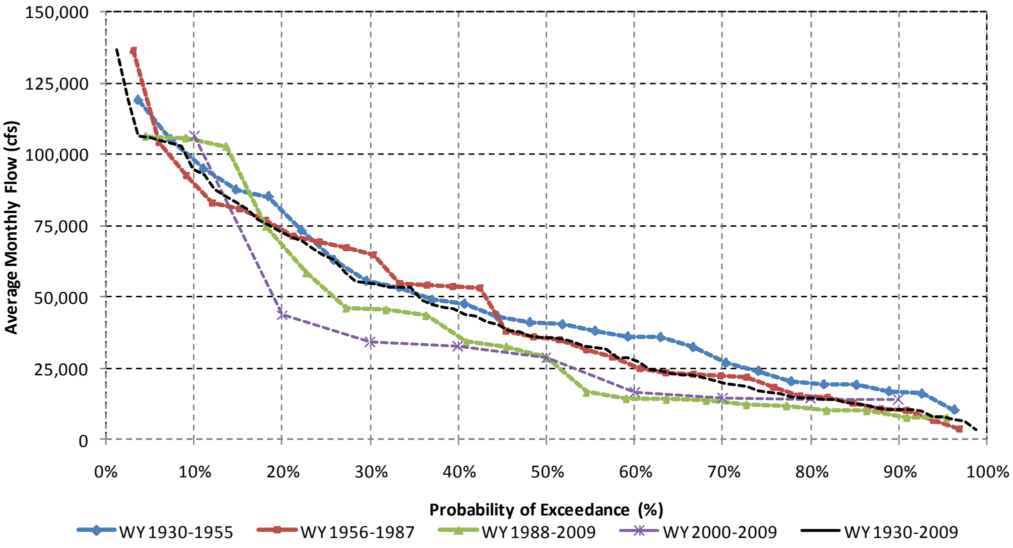


Figure 2 – Average January - June Historical Net Delta Outflow from 1930 - 2009

Figure 3 shows, for the January-June period, probabilities of exceedance of average unimpaired Delta outflow for the 1930-2003 period of record and the average unimpaired Delta outflow for those months during the component periods 1930-1955, 1956-1987 and 1988-2003. Unimpaired flow is runoff that would have occurred had water flow remained unaltered in rivers and streams instead of stored in reservoirs, imported, exported, or diverted. The data is a measure of the total water supply available for all uses after removing the impacts of most upstream alterations as they occurred over the years;

therefore, all variation in this data is due to natural causes. Although DWR has estimated unimpaired Delta outflow for the period of 1922-2003, this comparison uses the period after 1930 to be as consistent as possible with the DAYFLOW period.

Comparison of unimpaired flow for these various periods demonstrates variations due to hydrology alone, without human influence. Differences in the exceedance plots between the 1956-1987 and the 1988-2003 are solely due to natural variation in hydrology and cannot be attributed to project operations or water use.

As can be seen in the unimpaired flow chart in Figure 3, the 1956-1987 period was wetter than the average for the entire 1930-2003 period and was also generally wetter than the post-1988 period. On average, unimpaired Delta outflow during the January to June period during 1956-1987 seems generally to have been about 4,300 cfs greater than average January to June Delta Outflow during the period from 1988-2003. This means that, for the January-June period under unimpaired conditions, an average of about 1.5 million acre-feet more water would have flowed out of the Delta during the 1956-1987 period than during the 1988-2003 period. A flow difference of this magnitude can change X2 location and influence any conclusions based on this data. **Thus, the decline in the abundance-X2 relationship that occurred since 1987 is probably due, in significant part, to the fact that this period was substantially drier than the 1956-1987 period.**

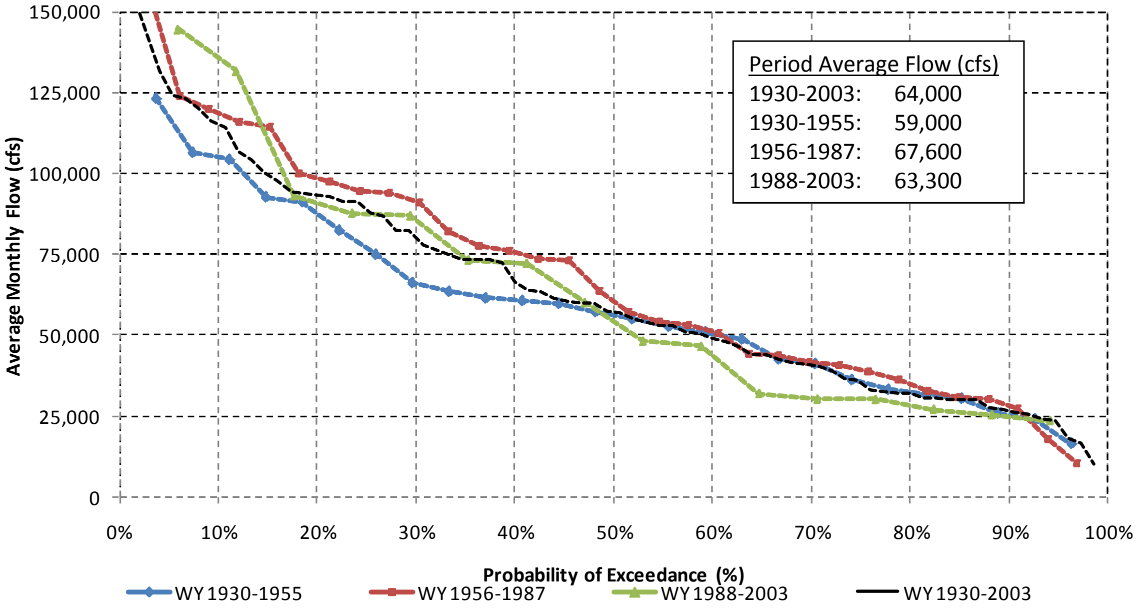


Figure 3 – Average January – June Unimpaired Net Delta Outflow from 1930 - 2003

COMPARING HYDROLOGIC PERIODS DURING FALL PERIODS

In discussing the proposed fall X2 action, the SWRCB Delta Flow report states that "the average position of X2 during fall has moved upstream, resulting in a corresponding reduction in the amount and location of suitable abiotic habitat." (p. 108). The report then refers to a period since 1987 and particularly since 2000 during which the fall X2 has moved upstream. (p. 109). The report continues by using data from 1960-2010 (report Figure 15) and data from 1956-2008 (report Figures 16-18). (pp. 110-112).

Again, these data seem largely to reflect the contrast between a relatively wet period from 1956-1987 and the relatively drier period since 1988. Figures 4, 5, and 6, below, compare average unimpaired Delta outflow for September, October and November, respectively. In each of those months, the period from 1956-1987 was substantially wetter than the long-term average (1930-2003) and very much wetter than the period from 1988 to 2003. Again, unimpaired flow is used for this comparison to demonstrate the differences due to hydrology alone, without human influence.

The purpose of these charts is to illustrate the importance of using representative periods when comparing fish abundance. Only if two periods being compared have the same hydrology can one attribute the increase or decline in abundance to factors other than hydrology (e.g., changes in exports, introduced species, etc.).

From a policy perspective, these data cast significant doubt on the efficacy of a proposed fall X2 action. Implementation of the fall X2 action is based on the concept that there have been man-made changes in project operations (perhaps to increase exports) since 1987 and that part of the suite of actions needed to restore Delta fisheries is the reversal of those changes. However, if the upstream movement of X2 during the fall since 1987 is largely a reflection of drier hydrology during the post-1987 period and if the goal of Delta restoration efforts is to replicate "natural" conditions to the extent feasible, then "fixing" natural hydrology may be a well-intentioned, but counter-productive, action that diverts attention from the actual causes of declining Delta smelt populations, such as invasive species or other ecosystem stressors of the type identified in the Vogel report referred to earlier. Attempting to impose historical wet-year hydrology on the Delta and its tributaries in all years also could severely reduce the amount of cold water available to support the needs of salmon and steelhead in Delta tributaries at important times of the year.

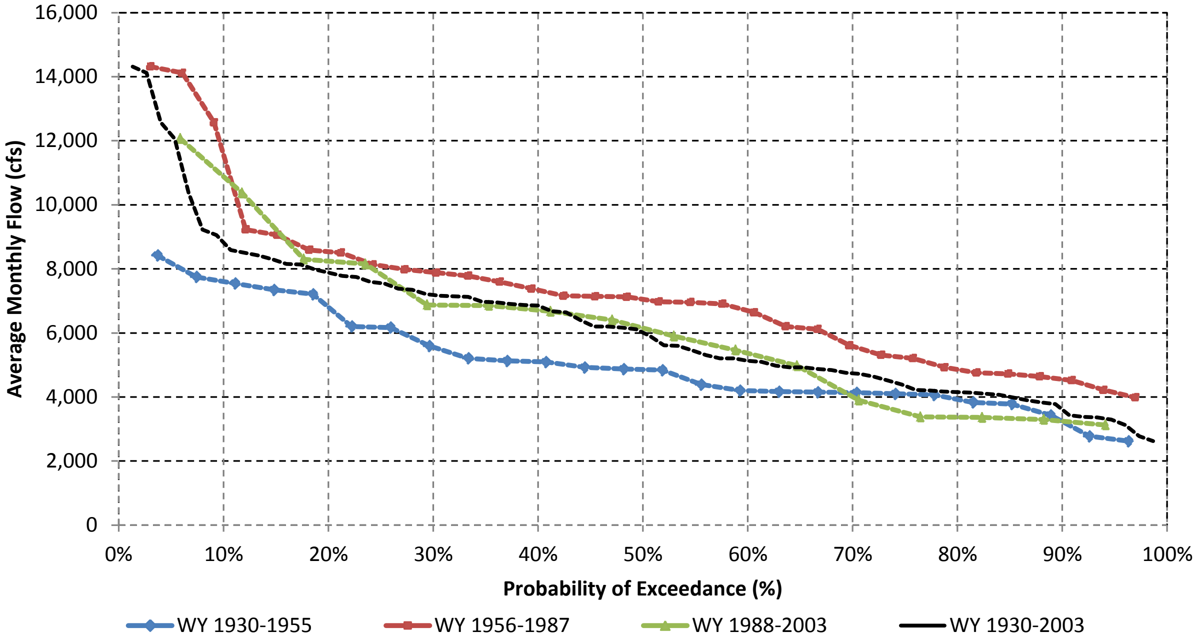


Figure 4 - Average September Unimpaired Net Delta Outflow from 1930 – 2003

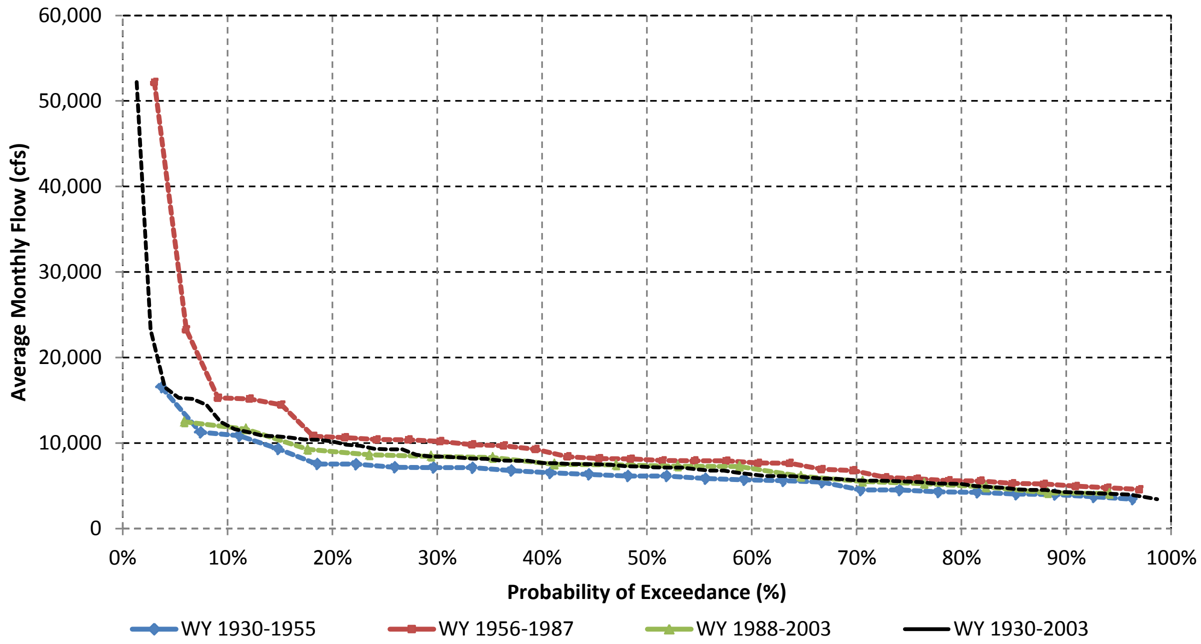


Figure 5 - Average October Unimpaired Net Delta Outflow from 1930 - 2003

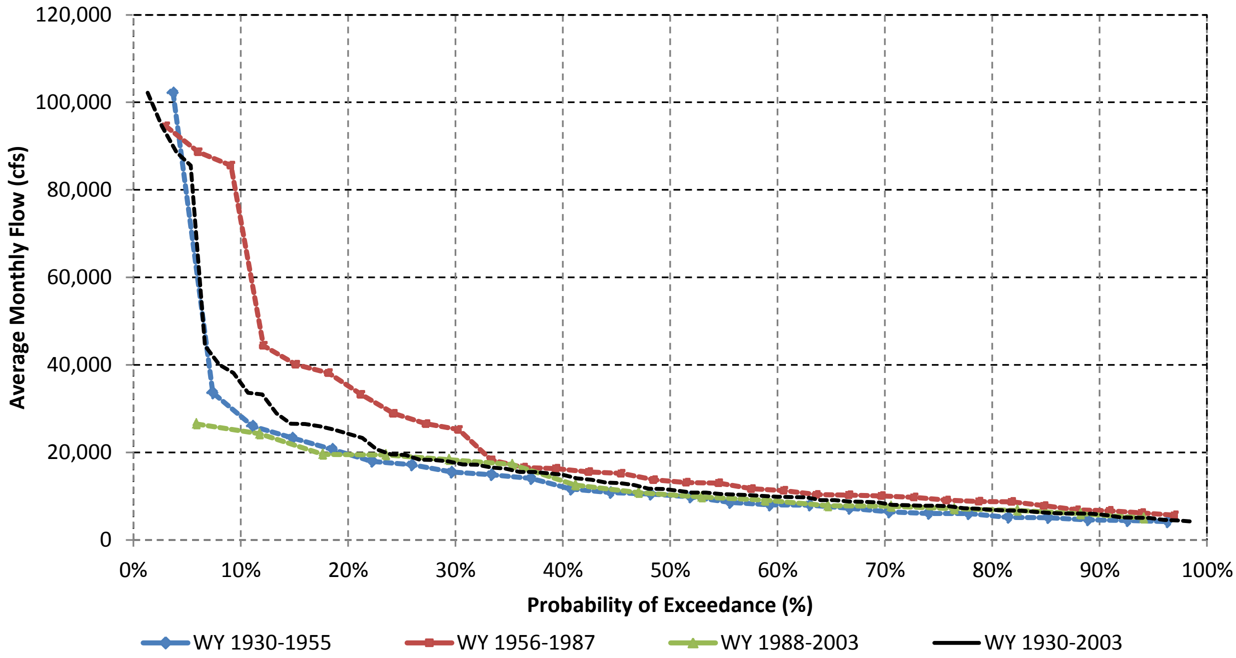


Figure 6 - Average November Unimpaired Net Delta Outflow from 1930 - 2003

The USEPA's Advanced Notice of Proposed Rulemaking ("ANPR") concludes that the "low salinity zone in the fall has moved upstream, especially after 2000." (p. 53). This statement is almost identical to the statement in the SWRCB's 2010 Delta Flow Report and is subject to the same criticism: it compares a wetter period (1956-1987) with a drier period (1988-2008) and attempts to draw conclusions regarding the status of delta smelt without acknowledging that the species is likely to do more poorly in a drier period. Similarly, the ANPR states there has been a "dramatic decline in the variability of the location (and therefore the extent) of low salinity habitat." (p. 53). The ANPR also states "In the late 1990's, the median areal extent of this low salinity estuarine habitat was about 9000 hectares in the fall; since 2000, that habitat declined by about 78 percent."(p.52). This statement compares a few very wet years in the late 1990's to a drier period that contains a mix of year types, including several very dry years, to conclude there has been a 78 percent decrease in habitat. The decline is in part due to hydrology, but may also be due to changes in regulatory standards. The increased Delta outflow requirements in the spring contained in SWRCB D-1641 have mandated increased reservoir releases during the spring months and lower upstream reservoir storage during the summer and fall period. This reduction in upstream reservoir storage has resulted in decreased reservoir releases during fall months, which in turn has resulted in X2 moving upstream in the fall. **In other words, the ANPR is correct to note that the location of X2 during the fall has moved upstream since the year 2000; the ANPR, however, fails to understand and acknowledge that the cause of that upstream movement is the requirement for increased spring Delta outflow contained in D 1641 as well as dry conditions throughout California. The lesson here is that it is important to recognize that measures to benefit one life stage or one species can have unintended effects on other life stages or other species.**

Figure 7, below, contains the average X2 location during the months of September, October, and November for the period of 1930 – 2008. The average X2 location presented in the ANPR's Figure E on page 54 displays X2 locations for the period from 1967 – 2008. Figure E implicitly uses the late 1960's and early 1970's as the baseline against which to evaluate subsequent changes in X2 locations, and concludes that X2 has moved substantially upstream over time. However, as can been seen in Figure 7, analyzing X2 position for the entire period of record (1930-2008) leads to a different a conclusion. The periods before and after the 1967-1975 period are drier, therefore this period should not be used as a baseline from which to draw conclusions. The entire period of record should be used to better understand how the system has changed. In the earlier period from 1930 to the early 1940's, before the Projects began operation, X2 position during the fall was farther upstream. When the Projects began operation, releases were made to satisfy instream flow requirements and Delta requirements causing Fall X2 to move downstream. The "natural" position for X2 during fall months is farther upstream than has occurred since the Projects began operations and releasing water to comply with environmental flow requirements. Because the delta smelt index is not available prior to 1967 it is not possible to determine if there is a relationship between fall X2 and the delta smelt index.

The consequence of these errors is that many of the effects that both the SWRCB's 2010 Delta Flow report and the USEPA's Advanced Notice of Proposed Rulemaking have attributed to reduced Delta outflows are, to a substantial extent, actually reflections of the variations in the natural hydrology of the Delta watershed since the late 1980's. It is not clear what is actually causing that change in hydrology or whether it will continue. What is clear is that the pre-1987/post-1987 comparison that has been used to justify both proposals for increased Delta outflows during the springtime and the proposed fall X2 action is a comparison between a relatively wet period and a relatively dry period.

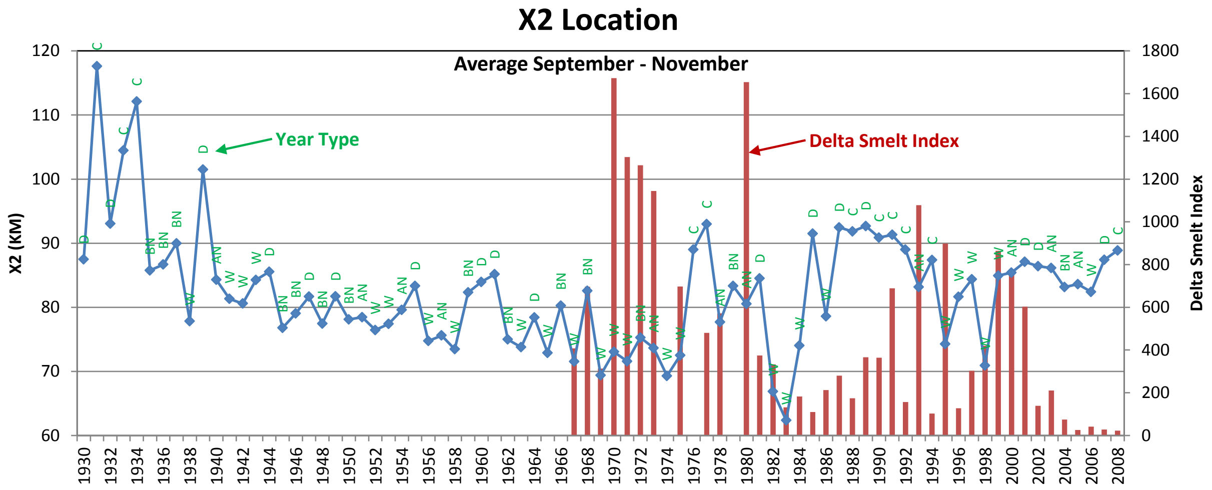


Figure 7 – Average September Through November X2 Location and Delta Smelt Index

CHANGES IN SACRAMENTO BASIN FLOWS AND DIVERSIONS DURING THIS PERIOD

Figure 8 shows Sacramento Valley irrigated acreage and combined annual diversions of water by the eight largest Sacramento River Settlement Contractors (SRSCs) for the period 1964 to 2008. Together, these eight diversions comprise about 90 percent of total settlement contract diversions in the Sacramento River Basin. These data indicate, that despite hydrologic variability, irrigated acreage has not increased and diversions by the SRSCs, while fairly consistent from year to year, have declined slightly over the past twenty to thirty years. This decline is probably due to changes in cropping mix, increased irrigation efficiency, and cultural practices.

Figure 9 contains a chart of historical diversions and consumptive use produced by the state’s 2007-2008 Delta Vision Task Force. The data on the bottom of the bar chart is labeled “Estimated Sacramento Valley agricultural consumptive use of applied water + urban demand.” This chart shows that upstream water use has been fairly constant over the past 40+ years.

Figure 10 shows the historical Delta smelt index from 1967 to present, Sacramento Valley irrigated area, and annual diversions by the Sacramento River Settlement Contractors. During the period between 1967 and 1980, the Delta smelt index varied significantly. During the 1980’s, the Delta smelt index was largely stable, but relatively low. During the 1990’s, the Delta smelt index was quite variable, but with little relation to hydrology. Since 2002, the Delta smelt index has been very low. This variability presents a clear contrast with Sacramento Valley irrigated area and diversions by the Sacramento River Settlement Contractors, which – as noted above – have been fairly consistent over the 40+ year period.

In summary, the available data indicate that the populations of the fish species that have been the focus of Delta restoration and recovery efforts for the past fifty years have been quite variable. There may be some relationship for some species to hydrology (e.g., the very low levels of Delta smelt during the 1976-77 drought) but those relationships are, at best, unclear. What is clear is that there does not appear to be a relationship between populations of Delta smelt and Sacramento Valley irrigated area or diversions by the Sacramento River Settlement Contractors, which were quite consistent over that period.

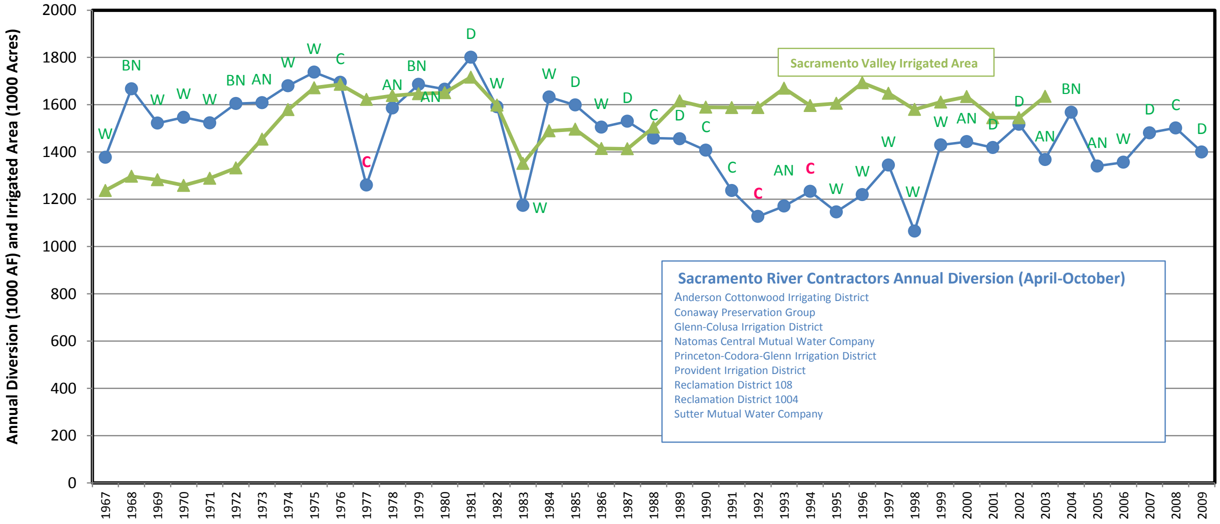


Figure 8 – Sacramento Valley Irrigated Area and Annual CVP Settlement Contract Diversions

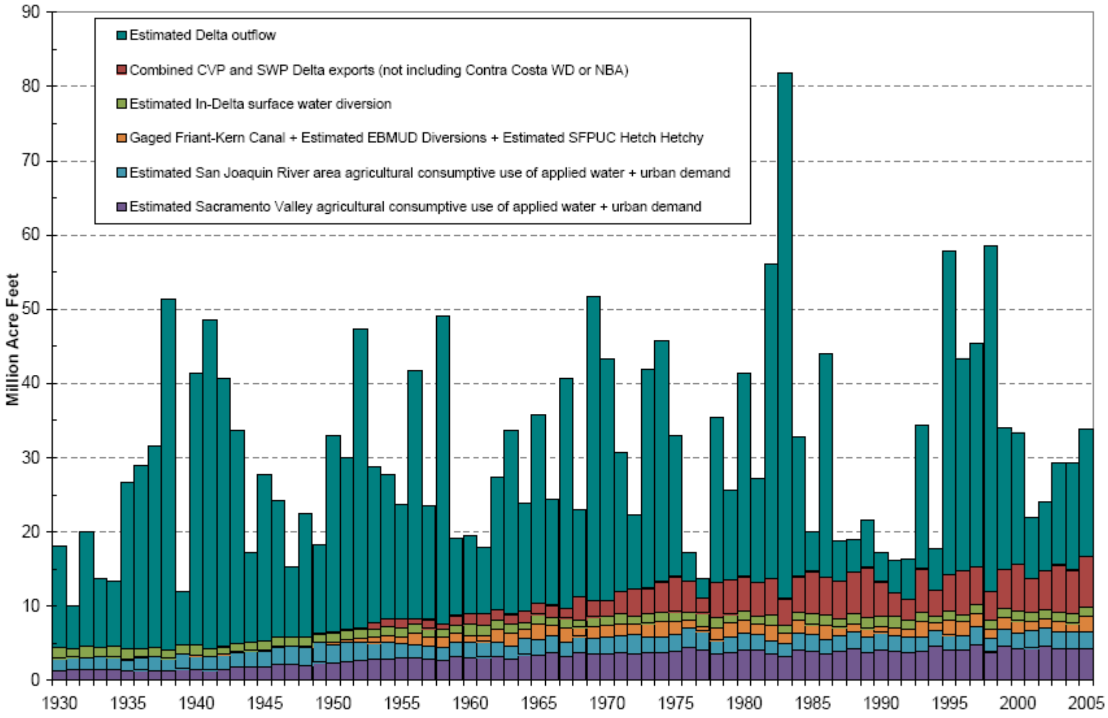


Figure 9 –Delta Vision "Revised Figure 7b – Historic Diversion from the Delta"

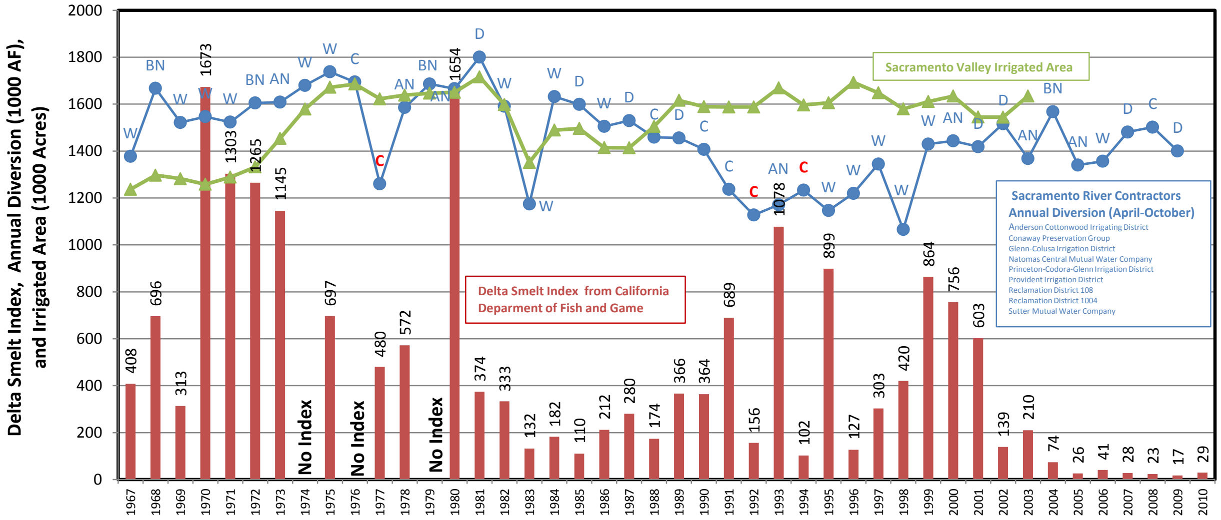


Figure 10 – Sacramento Valley Irrigated Area, Annual CVP Settlement Contract Diversions, and Delta Smelt Index